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Archives of Neurosurgery: The Scientific Home of Neurosurgery. The Creation of the Unique Diamond-open Access Journal in Neurosurgery with an Author-friendly Advisory Peer-reviewing and Publishing Policy Within Reach of Everyone in the World… Born from the Ashes of a World-Chaos

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Stars, the neurons of God …

José Alberto Israel Romero Rangel

Born from the Ashes …

Archives of Neurosurgery was born from the ashes of several chaotic events around the world in many fields. From the scientific readership standpoint, we were in the middle of a revolution in scientific divulgation. At this point, new schemas for knowledge sharing started to popularize (open-access and free-access) as a response to the overwhelming efficiency of cybernetic code-breakers for unlocking pay-for-reading scientific papers, the most recognized entity SciHub [1]. Concerning the healthcare research field, it was more evident that knowledge generation was driven by economic profit rather than an authentic medical need for knowledge [2–5]. As a result, medical research guides medical care to a culture of expensive individualized treatment to benefit a capitalist system that few people can afford and that not necessarily correlates with better outcomes [6,7]. Farther than that, medical care that does not fill these characteristics is considered suboptimal if not unethical [8], even when the vast majority of the world's population is not in reach of that kind of healthcare, representing an ethics crisis in medical praxis. From the scientific publishing aspect, we are convinced from years and years of research that effective publishing is increasingly more a matter of what relationships researchers have than what they have to say or transmit [9–11]. Therefore, the scientific research community is markedly perceived as elitist by many physicians; on the other hand, most physicians do not have the proper training to perform their research studies or the skills to communicate their results effectively [9–11]. It is also true that many physicians and researchers who lack edge technology or belong to low or middle-income countries do not have the financial or background support to provide the utmost quality research [9–11]. Publishing should be more a matter of what people have to say rather than the lack of support or an adverse background; the results physicians provide in their communities with the available

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resources they have are the key factors in delivering medicine effectively and developing useful clinical knowledge. Simultaneously, several efforts have made publishing available to many but hardly not for everyone [9,12,13]. To turn research into the reach of everyone, we need new ways of mind-thinking about the publishing and peer-review process, a concept we will explain further in the paragraphs below, and that provides the core of Archives of Neurosurgery. The next chaotic event is an aspirational issue for medical research collaborators. Publishing is regarded as a medium to access higher circles among medical communities or to have increased recognition among peers; meanwhile, others use it to start a political career, to leader assignments inside an institution, among many other proper goals in a person's lifespan [12,14]. Nevertheless, none of these reasons obey the authentic need to discover knowledge which is why motor of science. The divulgation of research under these motives is mainly performed not for the patients' benefit but the researcher's own. From the academic teaching point of view, there is a current crisis of disrespect between formed neurosurgeons and young neurosurgeons or trainees in both directions [15–19]. Adding for this situation, the student body seems to rebel against "the military tutorship style" imposed by mentors in the neurosurgery residence programs to fight for their human rights; unfortunately, this fight is not infrequently confused with anarchy [18,19]. This war of egos reflects in papers, too, where students consider themselves used by professors as a workforce for paper production, and professors consider they owe this workload as they benefit from coauthoring renowned neurosurgeons [18,19]. Few call this situation by its proper name "cooperation"; probably the only aspect done effectively among scientists - joint efforts for the benefit of knowledge; never before has research sharing skills been so important as they are nowadays. That drives us to the final but not least important aspect of the time in which Archives of Neurosurgery was born, the heart of the COVID-19 pandemic. At this point, the whole world fell into a full-aspect crisis, from the very center in each's one universe named home, with family members falling sick or dying, up to the magnificent concept of humanity being at risk of survival [20–24]. Not once but many times, we continue being afraid that this could end humanity as we know it. As a result, this phenomenon made us aware of our fragility, which we considered overcome by being the most developed species on our planet. The scientific community made a complete mind-thinking change as abrupt as the hypervariable section of the COVID-19 [25]. We broke rigid scientific rules that provided the ethics committee a bureaucratic spirit that most of the time took the development of proper research a delay of ten years; when for industry, things are developed, used, and then proven. These phenomena made us break these rules in an emergency to have an effective vaccine to survive as a species [25]. In such a manner, it worked that we reached not one but many vaccines with different action mechanisms in a multi-interdisciplinary intercontinental effort [26]. Nowadays, COVID-19 seems to be under control [27], but we are not safe; other viruses have started crowding and coming to our species [28–30]. There seems that from the passing of years, pandemics have shortened the "in-between" periods, probably directly related to the human mass distribution, interconnection, and world devastation we have done as species [30], as well as questionable research on the virus cross-species transmission [31]. Not to be sufficient, soon after the pandemic had reached a plateau, world potency nations increased their military tensions and changed our reality continuously and deeply again [32].

As a result of these phenomena, Archives of Neurosurgery was born with a single objective, to bring top-class neurosurgical research in reach of every physician in the world. We compromise with this extreme effort to provide core knowledge in the most authentic and unique Diamond Open-Access Journal (totally free) in neurosurgery (Table 1). designed to benefit patients everywhere, regardless of their economic status, country's infrastructure, or physicians' scientific background. Therefore our revolutionary mind-thinking change is to serve as an advisory journal that provides the needed methodological, statistical, and reporting guidance that requires most neurosurgeons to provide high-quality research and publishing.

1. The project

Archives of Neurosurgery is auspicated by the Mexican Society of Neurological Surgery, which has a lifelong history of desiring to have a World-class scientific journal. The SMCN was founded in 1954 [33]; it has had 37 presidents and represents a community of more than 1285 neurosurgeons, growing to provide healthcare to more than 126,014,024 [34] inhabitants. In our country, we have over 16 Neurosurgical training centers located inside the highest-level facilities inside the three-tier infrastructure healthcare. Throughout history, many World-Class Neurosurgeons have emerged from our country since the specialty started in the

Table 1. Top 10 global journals in neurosurgery as compared to Archives of Neurosurgery, highlighting Archives of Neurosurgery as the unique Diamond Open-Access journal in Neurosurgery and the only one with an Author Friendly Concept with advice on Methods, Guidelines adherence, Statistics, English Edition and Graphics on a single-blind peer-review with certified reviewers [61–70].

Rank	Journal	Country	H-Index	Publisher	SJR 2019 [43]	Impact Factor [43]	Quality	Scheme	Peer-Reviewing Process	Author Support
1	Spine	United States	266	Lippincot Williams and Wilkins Ltd.	1.386	2.735	Q1 Journal	Subscription Gold-OA 4,400 USD [33]	Double-Blind	None
2	Journal of Neurosurgery	United States	219	American Association of Neurological Surgeons	1.413	3.541	Q1 Journal	Subscription Gold-OA 3,000 USD [34]	Double Blind	None
3	Journal of Neurology, Neurosurgery and Psychiatry	United Kingdom	216	BMJ Publishing Group	2.922	7.413	Q1 Journal	Subscription Gold-OA 3,600 GBP [35]	Double-Blind	None
4	Neurosurgery	United States	207	Lippincot Williams and Wilkins Ltd.	1.324	2.646	Q1 Journal	Subscription Gold-OA 4,250 USD [36]	Double-Blind	None
5	Journal of Neurotrauma	United States	156	Mary Ann Liebert Inc.	1.374	4.667	Q1 Journal	Subscription Gold-OA 4,000 USD [37]	Single-Blind	None
6	European Spine Journal	Germany	145	Springer Verlag	1.231	2.186	Q1 Journal	Subscription Gold-OA 4,190 USD [38]	Double-Blind	None
7	The Spine Journal	United States	115	Elsevier	1.572	3.423	Q1 Journal	Subscription Gold-OA 3,920 USD [39]	Double-Blind	None
8	Journal of Neurosurgery: Spine	United States	106	American Association of Neurological Surgeons	1.394	2.797	Q1 Journal	Subscription Gold-OA 3,000 USD [40]	Double-Blind	None
9	Neurosurgical Focus	United States	102	American Association of Neurological Surgeons	1.298	3.367	Q1 Journal	Gold-OA 3000 USD [41]	Double-Blind	None
10	World Neurosurgery	United States	101	Elsevier	0.695	1.862	Q1 Journal	Subscription Gold-OA 3,530 USD [42]	Single-Blind	None
To be Ranked	Archives of Neurosurgery	Mexico	To be Ranked	Mexican Society of Neurological Surgery empowered by Digital Commons/ Elsevier	To be Ranked	To be Ranked	To be Ranked	Diamond Open-Access Totally Free for authors and readers	Single-Blind by Certified Reviewers	Author Friendly Concept Full support for free on Methods Guidelines adherence Statistics English Edition And Graphics

General Hospital of Mexico in 1937 [35]. In 2019, the society elected Dr. José Antonio Soriano Sánchez (H index of 6 [36]) as President of the Mexican Society of Neurological Surgery for the biennium 2019–2021. He has a personality with a profound sense of self-determination in fulfilling every project he starts. He is also an international leader in neurosurgery and a renowned pioneer in the field of Minimally Invasive Spine Surgery [37], whose main objective of his direction was to concrete the journal project, making it a reality. Simultaneously, the first author, José Alberto Israel Romero Rangel, was in the middle of his research carrier and was at the core of the scientific publishing process as a researcher and reviewer for multiple international journals (more than 161 reviews in 12 international Journals and 16 publications in 2022 in 5 international Journals H-Index of 4 [36,38]), which permitted him to discover the barriers to publishing and the voids in the reviewing process. With this knowledge in mind, he formulated a project with innovative ideas that could theoretically be included in a new journal under a different publishing and managing schema. Once designed, he later offered this project to the president of our society Dr. Soriano, who, after reviewing and adding with advisory, agreed to assign to Dr. Romero the task of fulfilling the making of the journal and directing the project under his supervision. Finally but not least important, both decided to select Dr. Fiacro Jímenez Ponce as the Editor in chief of the Journal because of having the highest H-Index (26 and 56 documents [36]) among Mexican Neurosurgeons at that time and having a recognized research reputation for his long-life history in research; including own research, collaborations, and directing research courses in many important institutions in Mexico [39]. The inclusion of Dr. Fiacro assured the best practices in publishing for a World Top-Class Journal. Dr. Fiacro agreed with joy and provided his expertise as a senior researcher with continuous guidance on ethics and academic surveillance. In this way, we undertook the project as founders under the following figures Dr. Soriano Sánchez José Antonio as ANS Founder and Founder Directive Editor, Dr. Fiacro Jiménez Ponce as ANS Founder and Editor-in-Chief Founder, and Dr. José Alberto Israel Romero Rangel as ANS Founder and Managing Editor Founder [40]. The project was centered on a world-class journal and directed with the assistance of digital commons, a service the SMCN contracted with Elsevier (R) that provides the infrastructure to deliver an independent scientific journal by the hand of the number 1 publisher in medicine. This aid would help us match our goal to be indexed and recognized as a world-class journal. To meet this goal, we were convinced that our publications should be English centered, with other secondary language options in the future. The name was selected as inclusive and non-discriminating as to represent every neurosurgeon worldwide and to resemble the importance of neurosurgery in the historical development of medicine (given that trephination was the first documented surgical procedure in medicine). As a result of both factors, we selected Archives of Neurosurgery, an original and pragmatic name never used before to date [41]. The first author designed the logo draft (Fig. 1) as a coat of arms (to operate and research) and style validation, appropriateness, and approval by the directive editor after the selective professional edition, suggestions, visual improvement, and final edition by the creative commons team [42]. It includes several elements; the first, the "Logo" is formed by "the journal name" outside the circle [42]. The second, "The book," represents scientific knowledge in neurosurgery. The third, "The circle with the name inside," represents the neurosurgical community around the world. The fourth, the "ANS" letters, represent the abbreviated form of the journal's name [42]. The left and right images around ANS letters represent two key instruments in the surgical praxis of every neurosurgeon around the world, the Malice bipolar and the Hudson Tree, providing a common language for all of us [42]. The name - "Archives of Neurosurgery" - appeals to the historical value of research that fosters the great achievements and knowledge development in the neurosurgical praxis as a contribution to humanity [42]. Blue and White (light gray) colors represent the colors of the Mexican Society of Neurosurgical Surgery [42]. They represent the joint efforts of the global neurosurgical research community and the knowledge that guides our praxis. With this idea in mind, we proposed the project to the Assembly of the Mexican Society of Neurological Surgery, which unanimously accepted it on the February assembly

Fig. 1. Archives of Neurosurgery Logo. Design and original draft by José Alberto Israel Romero Rangel; style validation, appropriateness and approval by José Antonio Soriano Sánchez; professional edition, suggestions and final edition by Digital Commons design team [42].

of 2020 to start working on its finances and implementation.

2. The journal's structure and its contribution to scientific divulgation from now on

The journal's main editorial structure has two slopes. First, we respect history and take advantage of current knowledge on managing a journal, so we take the best of the current journals. The Second is our authenticity in a new concept for the reviewing process, the Author-friendly advisory journal, which highlights the importance of the scientific core of the paper and helps the author improve the quality of research and reporting to provide world-class quality research. In the first aspect, we were inspired by some neurosurgical journals by the practical requirements of the manuscript typesetting format for submission. From other general medicine journals, we agreed that all papers must follow reporting guidelines at best. And from interdisciplinary journals, we added focusing on methodology, not results. For the second aspect of our journal, we decided to solve the scientific barriers that many neurosurgeons have. Archives of Neurosurgery is the a Diamond Open-Access Journal in neurosurgery available since 2020 [43]; which means that it is totally free, no cost for authors on publishing nor for readers and no subscription needed [44], with all of our papers published under a Creative Commons license 4.0 CCBY with an option for non-commercial distribution and any other varieties of the CC 4.0 license [45]. Furthermore, our journal offers an English-language edition for free, which is another service that no other journal offers at a free cost. Our reviewers are certified by Elsevier's Research Academy [46]; we instruct them with our policy to identify the scientific value of the papers and help authors take the best out of them by advising on methods, statistics, and reporting. Once the paper is accepted, the editorial team provides an English-language edition and provides the authors with the pre-print proof to ensure that no meaningful changes were made to the document. Also, the editorial team can assist or guide the final version's figures or tables presentation. Finally, unlike many journals, we do not ask the authors for copyright transfer of their research efforts because we consider this practice unethical; we only keep publishing and reprint rights. Therefore we are proud to say that this is the first journal in neurosurgery that offers these advantages betting for the entire distribution of knowledge.

With these tools, we aim to break the barriers to publishing in neurosurgery, the main one, the self-imposed barrier to joining the world of publishing. With our journal, you only need something important to say, and we help you say it best so that all the world hears every word you say. Archives of Neurosurgery was born from the ashes of Chaos through the full human effort and financial support of the Mexican Society of Neurological Surgery to become worldwide: The Scientific Home of Neurosurgery (Archives of Neurosurgery motto).

3. Archives of Neurosurgery up today

Archives of Neurosurgery officially launched its journal site on May 1st, 2020 [43], just two months after the starting of the pandemic in Mexico on February 28th. It received the first submission on May 22nd, 2020, by Dr. Diego Mendez Rosito et al. from Mexico, along with two other submissions, including one international submission by A. Campero et Al. We received 33 submissions in the first year [47], including eight of international precedence, within which some were published in the first volume and Issue brought online on April 20th, 2021, but officially launched on a formal presential meeting on May 1st, 2021 at the Club 51 ® installations in Mexico City [48]. By then, only ten days from the online upload, we already had readers in North America, South America, Europe, Africa, and Asia [47], precisely one year from its foundation after a year of work in the middle of the pandemic. We reached all five continents within the first month of the launch with a steady increase in our readership, with over one thousand readers in just four months. Up to a day at two issues of the first volume, with 20 papers online within all levels of evidence, and at one year and three months of its launch, we have reached 6417 downloads from 507 institutions in 137 countries across the world [49]. We have had submissions from several countries and almost all the continents (except Antarctica) Kenia accounting for Africa; Germany; Italy and United Kingdom for Europe; USA, Mexico, Colombia, and Brazil for America; and Russia and India for Asia (Fig. 2).

First Issue was filled with plenty of rich aspects including a most relevant editorial related to research as the focus to a neurosurgical praxis standards of medical care [50]; a COVID-19 guideline developed by joint effort of the subsections of the Mexican Society of Neurological Surgery for stratifying management on neurosurgical patients [51]; a most successful paper on traumatic peroneal nerve injuries having up to date 2617 downloads by Rodriguez Aceves et al. [49,52]; a validation of a distress thermometer for brain tumors in the

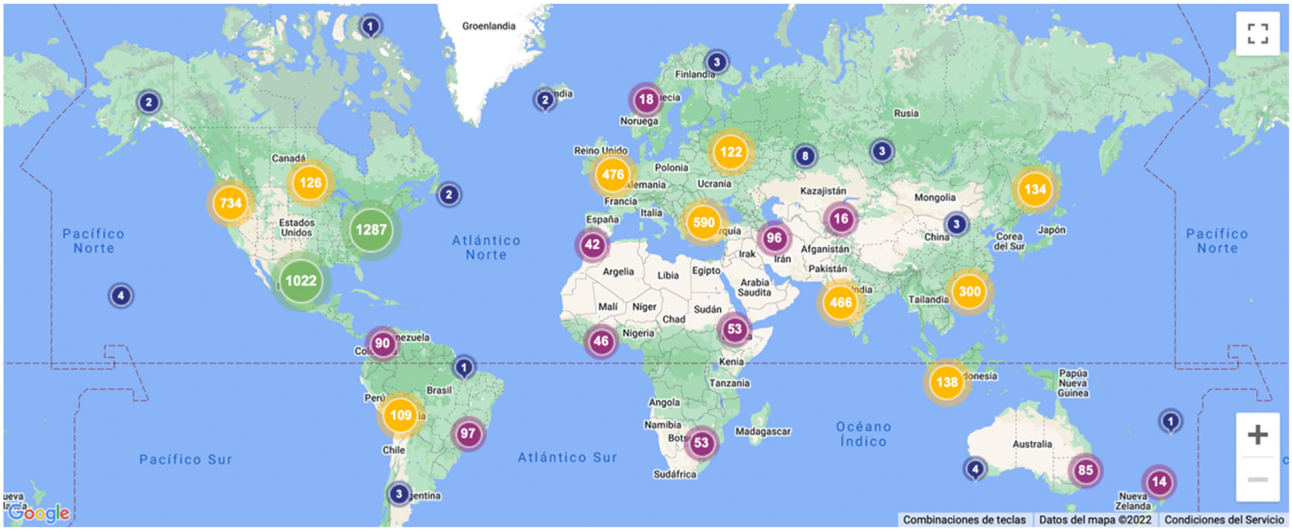

Fig. 2. Archives of Neurosurgery Worldwide readership as of Digital Commons Dashboard (powered by Google Maps ®) since its Launch in May 1st, 2020 up-to-date [71,72].

Mexican population [53]; an anatomical classification of the supreameatal tubercle for posterior fossa skull base surgery [54]; an educational vignette on the sellar barriers concepts [55]; a cohort comparison on two endovascular techniques [56]; a paper on anatomical and technical aspects on endoscope assisted surgery for posterior fossa [57], and a new minimally invasive surgical procedure (MINTED Technique) for Chiari disease that reunites the advantages of the historically described procedures and adds specific patients goals without disrupting posterior tension band [58] that merited the Coverage of the Journal (Fig. 3) [59] and a special invited commentary by one of the Worldwide Leaders in Neurosurgery and Spine Surgery, Atul Goehl who describe a completely different approach to Chiari disease aiming to fusion without decompression [60] based on his long-life research library of up to 725 papers, having an H index of 48 [36].

There is jet more to say about Archives of Neurosurgery, such as that our readership is most significant outside of Mexico, with the United States of America being the number 1 reader [49]. Most of our readers belong to the commercial industry, education, and governments. Therefore, it is to highlight among our top readers the Dow Jones & Company, Merit Network Inc, Mayo Foundation for Medical Education and Research, The Massachusetts General Hospital, King's College London, West Virginia University, and Rush University Medical Center, Alberta Health Services, among others [49]. Finally, we have incorporated trends in publishing, such as visual abstracts since the beginning of the journal's history, and surgical demonstrative videos are coming as authors start to submit them. We have also developed two workshops to teach authors the skills for fast paper production with prolific terminal proficiency. As we have described, we

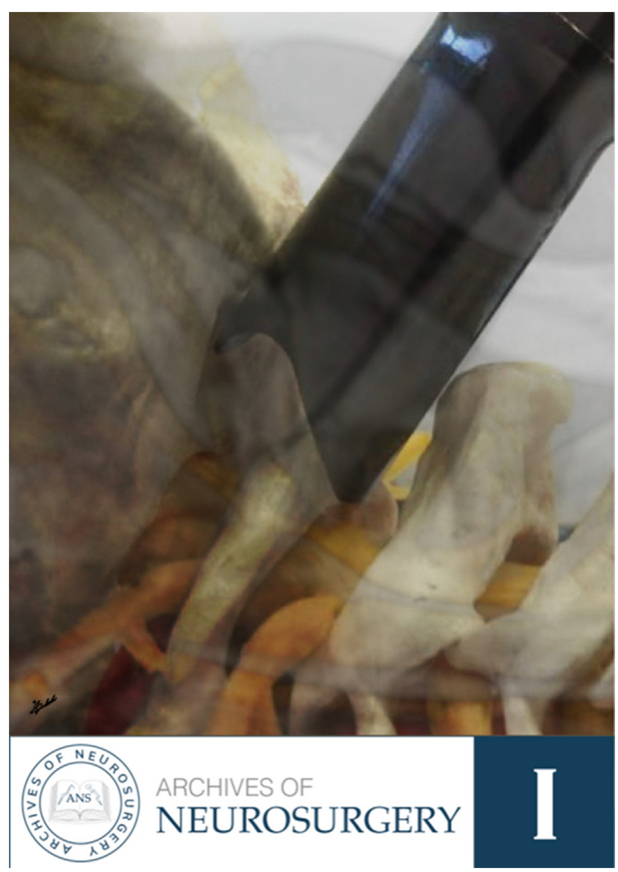

Fig. 3. Cover Page of the first Issue of the Journal [59].

have top-class neurosurgeons, reviewers, and authors on our committee. However, also we consider that every neurosurgeon has the same potential. Therefore, our objective is to provide them with the same visibility and research quality so that no distinctions are made when referring to our neurosurgical community.

Conflict of interest

We have no conflict of interest.

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High-Grade AVM. Educational Vignette and Clinical Cases

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Abstract

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Visual Abstract

Keywords

Arteriovenous malformation, high-grade, Spetzler-Martin classification, surgery, multimodal treatment

Authors

Marcos Devanir Silva da Costa, Marcelo Augusto Acosta Goiri, Daniela Coelho, Juan Alberto Paz Archila, Talita Helena Martins Sarti, and Feres Chaddad-Neto

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High-grade AVM. Educational Vignette and Clinical Cases

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Abstract

The arteriovenous malformation (AVM) is a vascular malformation characterized by fistulas between arteries and veins forming a nidus, without interposition of capillary vessels and of which early draining vein is identified at the digital angiography. Potential reports of its existence date from the second century AD. Spetzler and Martin (S-M) proposed a classification considering three features and Lawton then added new predictors. A maximum of 10 score can be achieved by applying the modified S-M grade system. This classification guides decision-making and the possible choice of the multimodal treatment (surgery, radiosurgery and embolization). We discuss historical, pathological, clinical and therapeutic characteristics of the condition. Much emphasis was placed on the AVM classified as grade III, once it requires multimodal therapy. Surgical technique and anatomical nuances are well described in the text and we also report cases to demonstrate our approach to the patients with AVM.

Keywords: Arteriovenous malformation, High-grade, Spetzler-Martin classification, Surgery, Multimodal treatment

1. Background

Antyllus (2nd century AD), Albucasis (10th century AD), and Vidus Vidius (17th century AD) were potentially the first to report arteriovenous malformations (AVMs). However, it was only in the 18th century that William Hunter described abnormal direct communications between arteries and veins. He also observed that applying pressure in the fistula region decreased the caliber of the peripheral vessels, probably due to a reduction in the recruitment of flow caused by the AVM. In the following century, Stanley (1853) and Warren (1837) performed postmortem dissections and demonstrated this pathology's direct communication between arteries and veins. Wernher (1876) characterized the fistulous features of the disease by removing the nidus from an AVM and observing a decrease in the caliber of afferent and efferent vessels [1].

However, the terminology used during this period was highly variable, showing some confusion regarding the characterization of AVMs. We included words like aneurysmal varix, anastomotic aneurysms, arterial angiomas, plexiform angiomas, arterial varix, serpentine aneurysms, and racemose aneurysms. In the early 20th century, Dandy published eight surgical cases where no patient survived attempting an AVM surgical removal. Furthermore, Cushing stated that the reports of attempted surgical treatment in AVM patients showed the futility of the surgical approach and the extreme risk of brain injury it posed [1,2].

In 1966, McCormick formalized the classification of vascular malformations, encompassing AVMs, cavernomas, telangiectasias, and venous angiomas. McCormick's article emphasized the confusion regarding the definition of vascular malformations, considering that there were descriptions of approximately 70 different types of these malformations. Therefore, he contributed significantly by allocating all previous reports in the four new

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subtypes he presented. Other definitions, however, were still under discussion as authors such as Kernohan considered the malformations to be true neoplasms, believing that many AVMs did not show strictly static behavior [3]. All of this historical evolution ultimately led to the current definition of an AVM—a congenital pathology presenting fistulas between arteries and veins forming a nidus, where angiography shows an early draining vein and no interposition of capillary vessels. As a result of this absence of capillary vessels interposition, there is low pressure and the high arterial flow inside the AVM.

In 1986, Spetzler and Martin published a study that classified AVMs using a simple and practical approach to predict surgical risk. According to this classification, three parameters are the main predictors of surgical risk: AVM size, venous drainage type, and eloquence of the anatomical region of the AVM. Each parameter partially contributes to the overall score that ranges from 1 to 5, [4].

Angiography helps in establishing the venous drainage of an AVM. Deep drainage occurs when the AVM drains into internal cerebral veins, basal veins of Rosenthal, or precentral cerebellar veins. In the posterior fossa, drainage is superficial when hemispheric veins drain directly into the tentorial or transverse sinus [4].

According to the original classification, AVMS are eloquent if present in the following locations: the primary sensory-motor area, language area, hypothalamus, thalamus, internal capsule, brainstem, cerebellar peduncles, or cerebellar nuclei [4].

This classification has a maximum of 5 points; however, Spetzler and Martin also characterized a 6-point AVM; it indicates an inoperable AVM, for example, one involving the brainstem [4].

In their article, Spetzler and Martin showed that 0% of grade I, 5% of grade II, 16% of grade III, 27% of grade IV, and 31% of grade V AVMs showed postoperative deficits [4].

The Spetzler and Martin (S-M) grading scale has been used for decision-making in AVMs treatment due to its ability to predict surgical risk. Brain AVMs grades I and II have low morbidity related to surgical treatment, whereas grades IV and V are associated with high-risk postoperative morbidity [5].

Since then, many authors have attempted to improve the scale used to classify brain AVMs, and Spetzler and Ponce readjusted the original classification into three groups. They concluded that group A (grades I and II of the S-M scale) needed surgical treatment. Group B (grade III of S-M) required a combination of surgery, embolization, and radiosurgery. Finally, group C (grades IV and V of S-M) benefit from a conservative approach. This final group includes high-grade AVMs, which are the topic of our chapter [6].

Lawton then proposed an adaptation to the S-M scale to simplify decision-making, adding three new predictors: age, stratified into three different groups (children younger than 20 years, young adults aged 20–40 years, and adults older than 40 years), where the first age group receives 1 point and an additional 1 point to both others; the presence of bleeding in the AVM, where bleeding absence presents the most significant risk and adds 1 point; and lastly the characteristics of the nidus, namely whether it is compact or diffuse, with a diffuse nidus presenting a more significant risk and adding 1 point. This new scale has a maximum total of 10 points and maintains the simplicity of the previous S-M scale. A validation study of this supplementary scale evaluated the clinical outcome of patients from four major vascular neurosurgery centers; it concluded that a cutoff value of less than or equal to 6 points indicated low surgical risk. Patients with a score equal to or below 6 demonstrated a surgical risk between 0 and 24%, while those above 6 had 39–63% surgical risk. However, the authors stated that this scale should not replace each patient's evaluation and guide decision-making [7].

The two examples we described above were attempts to adapt the S-M classification, but there are still several critics, especially concerning grade III AVMs. However, these classifications helped systematize AVMs and simplify the communication between neurosurgeons, neurologists, and neuroradiologists. It is simple, can be applied while the patient is in bed, and includes objective relevant criteria to determine surgical morbidity and mortality. Nevertheless, we also believe that, for mathematical reasons, grade III of this classification is not a homogeneous group. It can include both an AVM of 3–6 cm with deep drainage, occurring, for example, in the temporal lobe, and a small AVM of less than 3 cm with deep drainage located in an eloquent area. Therefore, we have reclassified grade III as follow [8].

III A. Superficial AVMs with superficial venous drainage and a size of 3–6 cm, located in non-eloquent areas.

III B. AVMs with deep venous drainage and a size of less than 3 cm, in the limbic lobe, corpus callosum, and para-olfactory and para-terminal gyri.

III C. AVMs with deep venous drainage and a size of less than 3 cm, located in the insular lobe.

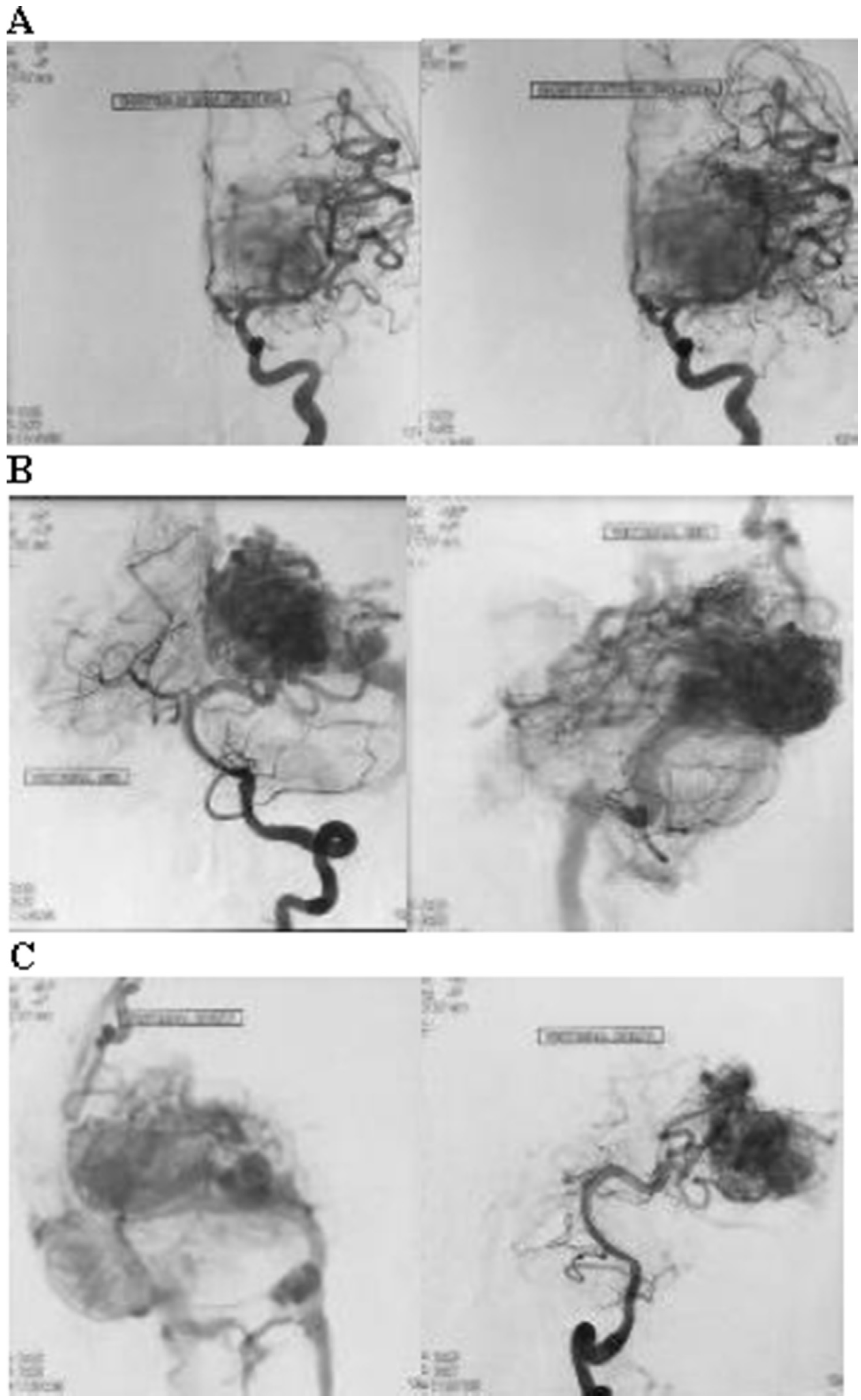

*Fig. 1. Digital angiography demonstrating the AVM supply. **A.** Left side angiogram showing cortical branches of the middle cerebral artery. **B.** Left side vertebral angiogram confirming the AVM is also fed by terminal branches of the left posterior cerebral artery. **C.** Oblique left side view showing drainage through the left transverse sinus and tributaries to the vein of Galen (C).*

Besides being considered small AVM in eloquent areas, grades III B and III C are classified separately due to their different vascular supply. Mesial temporal lobe AVM, for instance, receives supply from the anterior choroidal artery, the posterior cerebral artery and its branches, the perforators arteries of the internal carotid artery, and the M1 segment of the middle cerebral artery. Thus, grade B lesions can benefit from surgical treatment using refined microsurgical techniques. At cross-purpose, surgically excision of lesions in the insular lobe is too difficult. The insula receives blood supply predominantly from the M2 segment of the middle cerebral artery. Most insular arteries are short and supply the insular cortex and extreme capsule, whereas 10% are medium-sized and feed claustrum and external capsule [9]. About 3–5% of the branches reach the corona radiata; hence, long insular-arteries occlusion can result in the same symptoms as lenticulostriate arteries infarction [10].

2. Clinical condition

Most brain AVMs are clinically asymptomatic but, with the greater availability of imaging tests such as magnetic resonance image (MRI), the incidental diagnosis of this condition has become more common. When these lesions start causing symptoms, this is mainly due to parenchymal or subarachnoid bleeding. Prospective studies have shown that the incidences of bleeding and non-bleeding AVMs are 0.5 and 0.6–0.8 per 100,000 individuals per year, respectively [9]. Bleeding-related symptoms include sudden loss of consciousness, sudden severe headache, nausea, and vomiting [11]. As in all intracranial hemorrhages, there is damage to the brain tissue at the site of the bleeding, which can result in motor, sensory, language, or behavioral sequelae.

Another frequent clinical presentation of brain AVMs is the occurrence of seizures, which is the initial symptom experienced by 20–29% of patients. It is more frequent in male patients, patients with cortical AVMs, especially in the frontal and temporal lobes, AVMs with superficial drainage, AVMs in the middle cerebral artery region (MCA), multiple AVMs, or AVMs bigger than 6 cm. Epileptic seizures are predominantly focal or focal with impaired awareness. Focal seizures tend to evolve into bilateral tonic-clonic seizures [12].

Other symptoms associated with AVMs have been described:

- headache, occurring in approximately 6–14% of patients, primarily women (58%), presenting as mainly unilateral migraine attacks, with or without aura [13].
- progressive focal neurological deficit, occurring in 6–12% of patients, presumably due to a flow-related steal syndrome in the arteries adjacent to the AVM-nourishing arteries [13].

An interesting fact that neurosurgeons must consider is that many AVMs, although not presenting focal neurological signs or symptoms, can give neurocognitive deficits in certain situations. A recent study conducted at the São Paulo Medical School showed that up to 71.3% of patients with

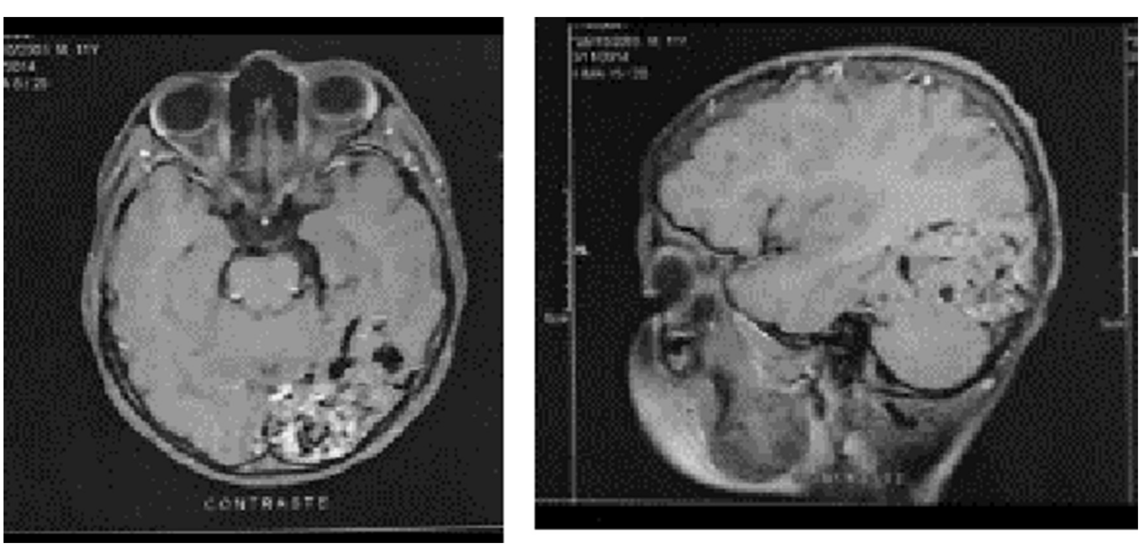

Fig. 2. MRI showing left occipital AVM situated in the lingual gyrus and visual cortex.

bleeding or non-bleeding AVMs without neurological deficits presented alterations in at least one of the eight cognitive domains studied. This data is essential both in postoperative follow-up since the great majority of patients present neurocognitive deficits and to assist in the indication of surgery given the current trend of conservative treatment for non-bleeding AVMs [14].

3. Physical examination and imaging

A physical examination is crucial to determine a patient's condition. In extreme cases of bleeding AVMs, the patient presents signs and symptoms of intracranial hypertension, which should be promptly recognized and managed using a neurointensive approach. Most patients who present with bleeding maintain a level of consciousness and compensation of the intracranial pressure, allowing investigation with imaging tests.

The first imaging test utilized in suspected meningeal syndrome or stroke is cranial computed tomography scan (CT scan); it is a fast, practical, and widely available test that can detect blood in the acute phase. It does, however, have a drawback in that it exposes an individual to radiation. CT scan can show signs of arteriovenous malformation in cases of intraparenchymal bleeding. MR angiography is a noninvasive exam that can provide more detail than cranial tomography and does not expose the individual to ionizing radiation. This imaging test can provide a static image of the vessels that form the nidus and provide more anatomical details on the topography of the lesion, thus providing information on one of the elements of the S-M grading scale previously mentioned. In addition, other unique resonance modalities can provide further information on the anatomical details of such malformations.

Tractography, for example, can show the relationship of the internal capsule with AVMs close to the primary motor area. Furthermore, functional resonance can help anatomically map speech in cases of AVMs close to the language area.

Digital subtraction angiography (DSA) is the gold standard exam for diagnosing an AVM. It is performed by injecting the carotid arteries and the two vertebral arteries and is the only exam able to show the dynamic behavior of an AVM. Angiography allows several factors to be determined: characteristics of the venous drainage, type of flow (high, medium, or low), presence or absence of intranidal aneurysms, nourishing arteries, involvement of the vertebrobasilar system, configuration of the nidus (compact or diffuse), and recruitment of perforating

A

B

C

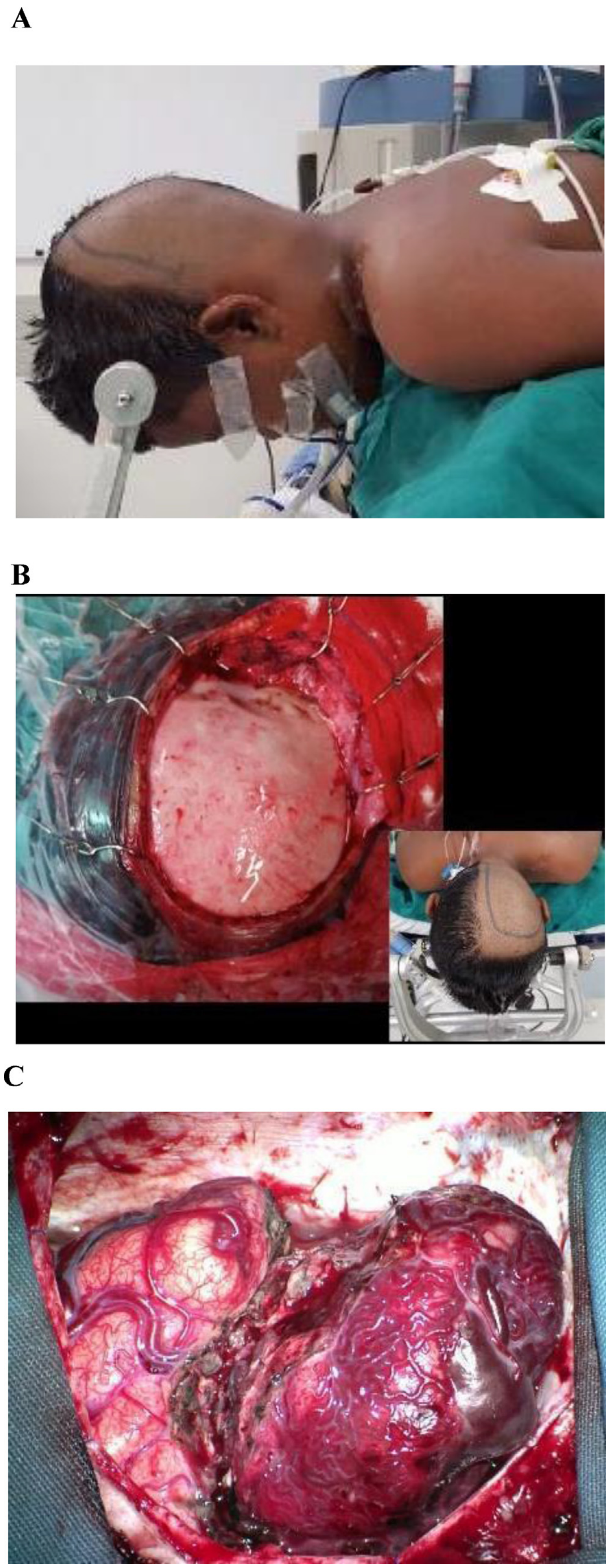

*Fig. 3. **A.** The was positioned prone and the head fixed with a skull clamp. **B.** An inverted horseshoe incision was performed, and a parieto-occipital craniotomy was performed to expose the AVM. **C.** MIcrosurgical view of the lesion in the left occipital lobe.*

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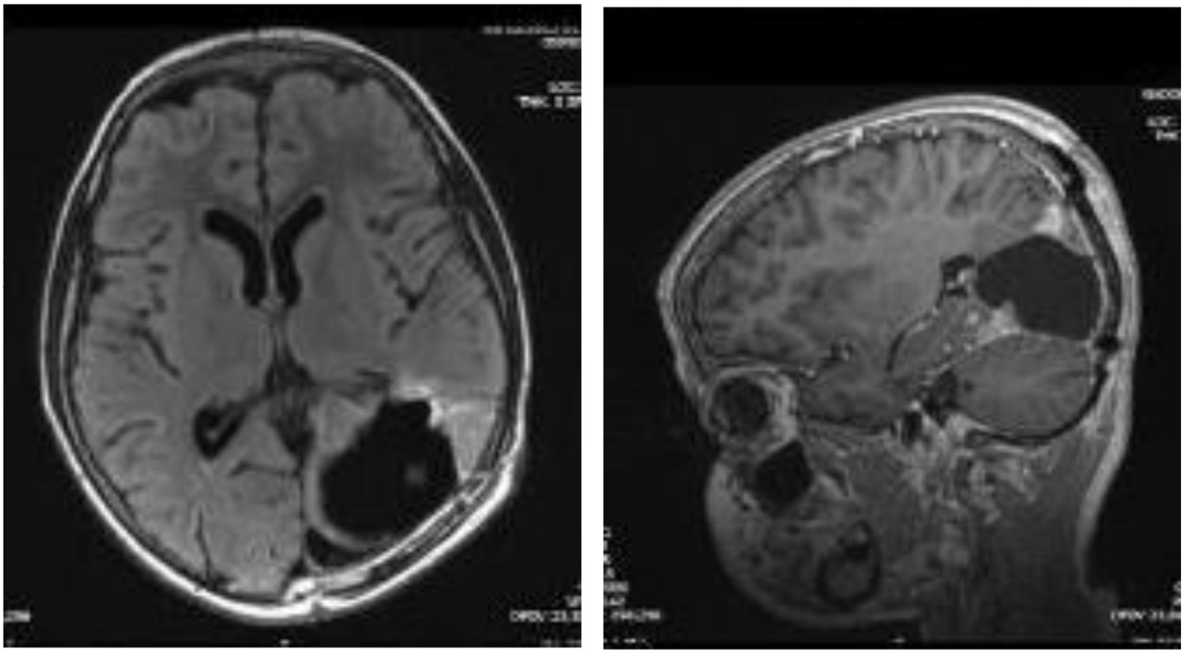
A



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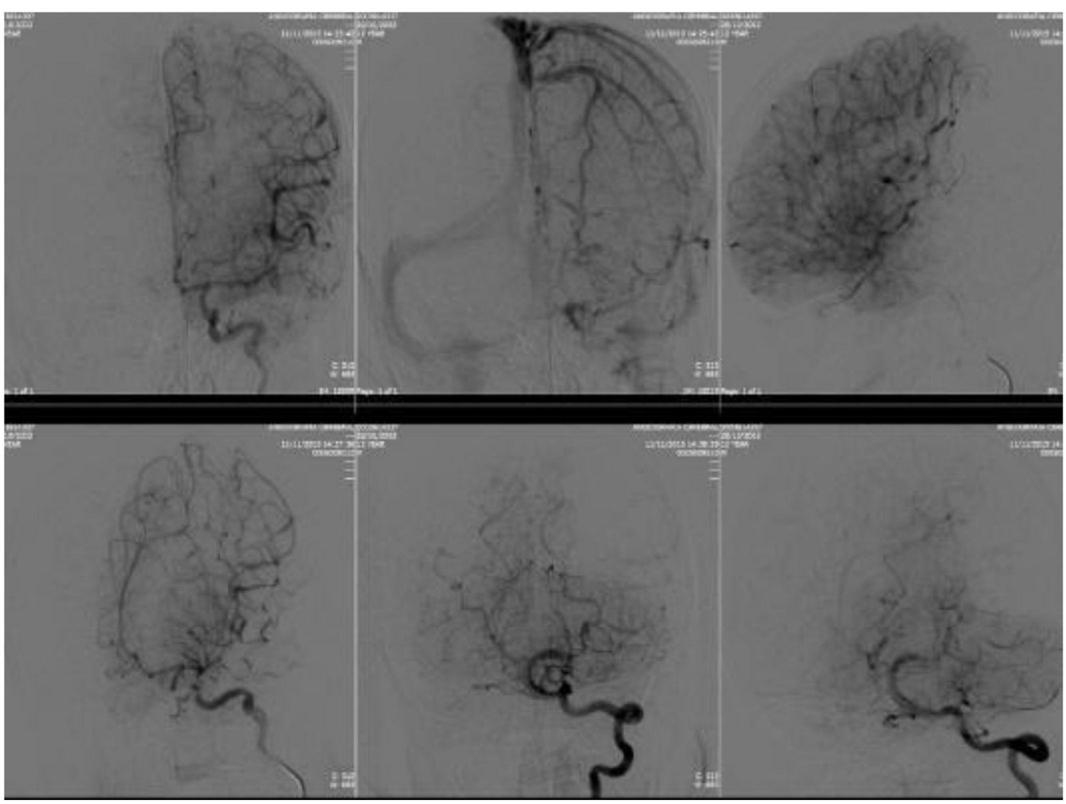

Fig. 4. Postoperative MRI (A) and angiography (B) showed complete resection of the AVM.

arteries and choroidal arteries. Although the S-M classification does not primarily consider them, these are all relevant factors when deciding treatment strategies.

4. Differential diagnosis

The primary differential diagnoses of AVMs are hereditary hemorrhagic telangiectasias, Rendu-Osler-Weber syndrome, Wyburn-Mason Syndrome, Divry Van Bogaert angiomatosis, and proliferative angiopathy [15]. The latter is the most difficult to distinguish from more than 6 cm AVMs, causing significant confusion and misdiagnosis. There are, however, some key elements that differentiate AVMs from proliferative angiopathies. Angiopathies present a lobar or even hemispheric nidus, are associated with numerous equal contributions of nourishing arteries, some of which are transdural, absent dominant feeders, small drainage veins, capillary-angioectasia, and exhibit brain tissue interspersed in the malformation [16].

5. Treatment options

There is much debate regarding the treatment of AVMs, and thus, it is necessary to remember the natural history of these diseases. The annual risk of bleeding for brain AVM is 3%, but depending on the features of the malformation, it can vary from 1% to 33%. The risk of bleeding increases by 2-fold if there is exclusively deep drainage, 3-fold in cases with a

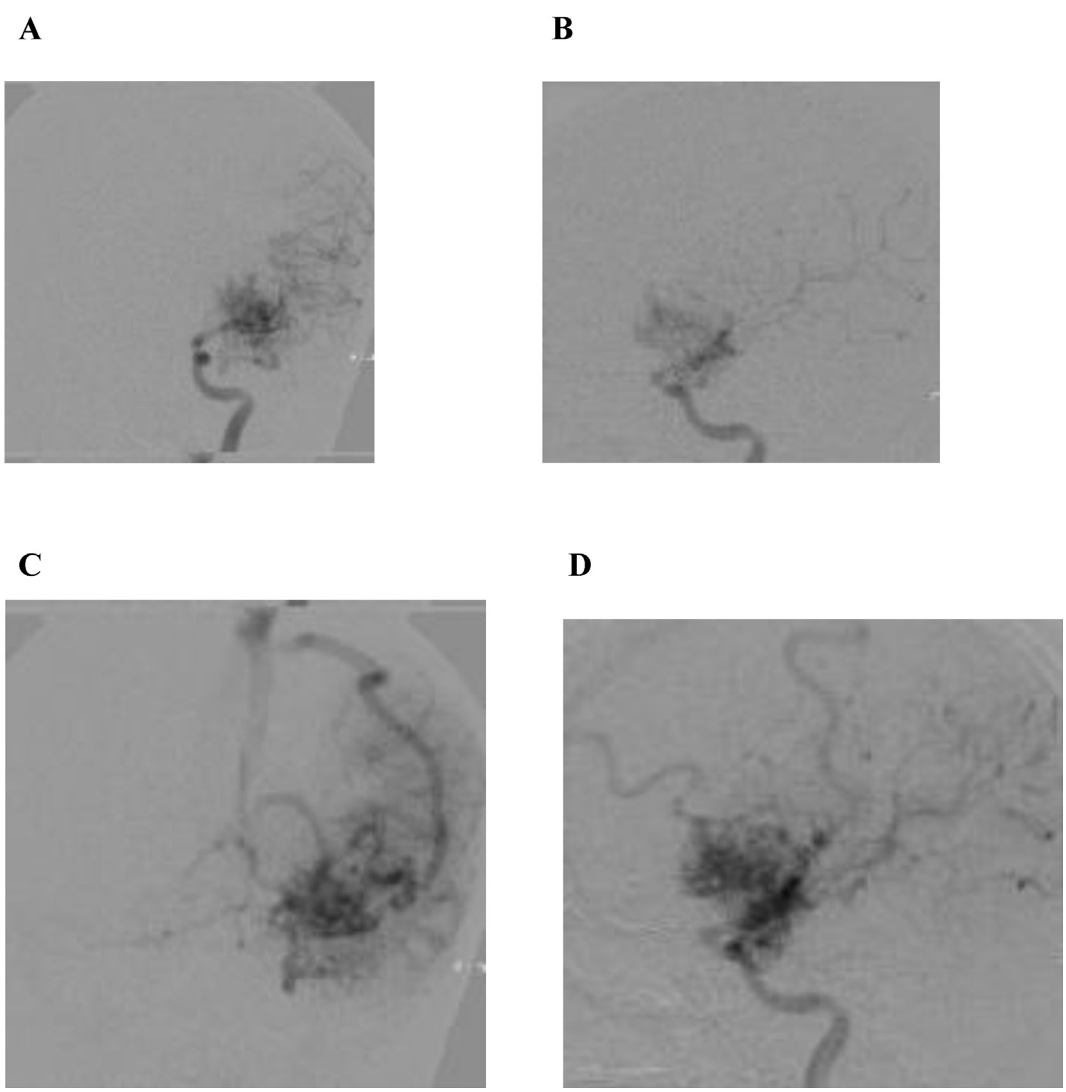

Fig. 5. Digital angiography shows AVM-related vessels. A. Antero-posterior view of the left carotid angiogram demonstrates that the lesion is supplied by M1 arteries laterally and perforating arteries medially. B. Lateral view of the left carotid angiogram showing the left posterior communicating artery feeding the AVM. C and D shows that the superficial veins drain the AVM to the superior sagittal sinus and the deep Sylvian vein drains to the deep venous system.

history of previous bleeding episodes, and 4-fold if the malformation is located deep or in the brainstem. Based on several models, patients with none of these risk factors have a very low risk of cerebral hemorrhage (<1% per year), patients with one have a low risk (3–5% per year), patients with two have an average risk (8–15% per year), and patients with all three have a high risk (>30% per year) [17].

Other anatomical features associated with bleeding include flow-related aneurysms in an artery that nourishes the AVM and restriction of AVM venous drainage. Venous drainage restriction occurs by the narrowing or occlusion of one or more of the significant drainage veins of the AVM. Consequently, this is associated with increased bleeding risk in malformations with only one drainage vein [17].

The clinical consequences of cerebral hemorrhages in AVMs depend on the extent of the injury to adjacent brain structures. Damage to regions of the brain that control motor, sensory, visual and language functions (termed “eloquent” areas of the cortex), damage to deep white matter and basal ganglia structures, and secondary elevations of intracranial pressure are all associated with a poor clinical outcome [17].

Conservative treatment is the standard approach for high-grade AVMs, namely grades IV and V. Endovascular “palliative” treatment serves for cases with bleeding and, for example, intra-nidus aneurysms that present a greater risk of future bleeding, where embolization is mandatory. Another potential treatment is radiosurgery, usually performed in AVMs up to 3 cm; however, the patient remains at risk of bleeding until definitive exclusion of the malformation, which occurs three years following the treatment. Regarding surgery, high-grade AVMs are divided into large superficial AVMs (>6 cm) in eloquent areas and large AVMs or medium-sized deep AVMs. Deep drainage AVMs locate primarily in eloquent regions such as the thalamus or basal nuclei.

Concerning the first group, it is necessary to understand two aspects. First, a large AVM in an eloquent area will require preoperative embolization to reduce the flow inside the nidus. In addition, it is necessary to investigate the eloquence of the region in which the AVM locates. Due to the congenital nature of this disease, functional displacement caused by the malformation should play a role, namely its ability to steal flow, and it is important not to misinterpret the eloquence of the surrounding tissue. In these cases, a major problem associated with postoperative deficits is transit vessels that irrigate functional areas that cross the margins of the malformation, leading to confusion.

Preoperative planning is vital in the second group, which includes deep AVMs. In AVMs of the basal nuclei, embolization can reduce the malformation to permit radiosurgery. It is essential in these cases to embolize deep feeder arteries, given that it is very common to find nourishing choroidal arteries in this group of AVMs [18–20]. Rates of complete resection by microsurgery for deep AVMs are lower than for other regions, which reflects posture that prioritizes the neurological outcome [21].

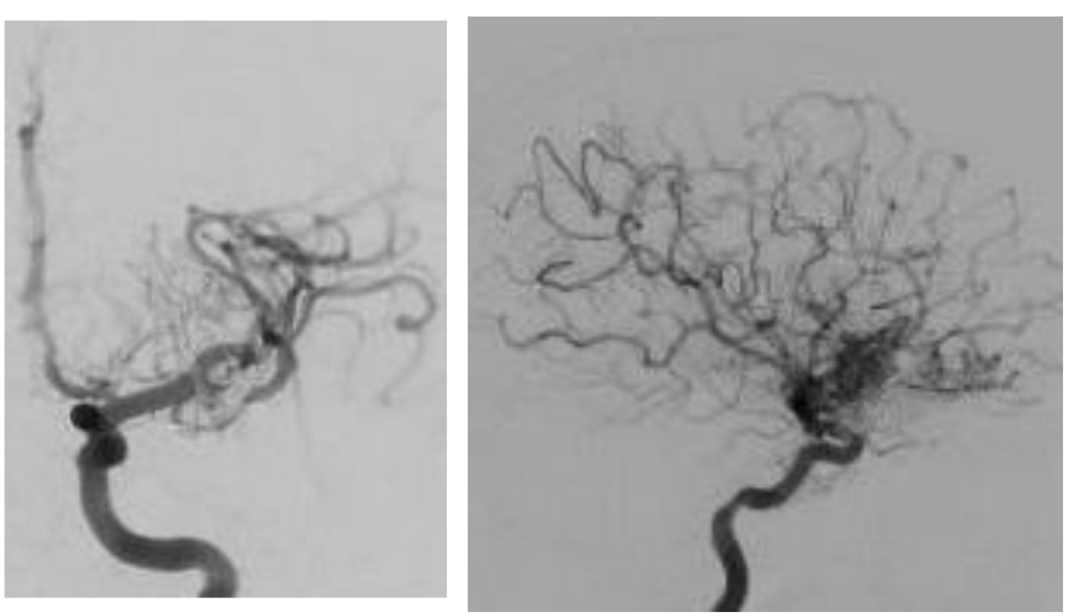

Fig. 6. DSA demonstrated that the AVM became more diffused post embolization and recruited several perforating arteries.

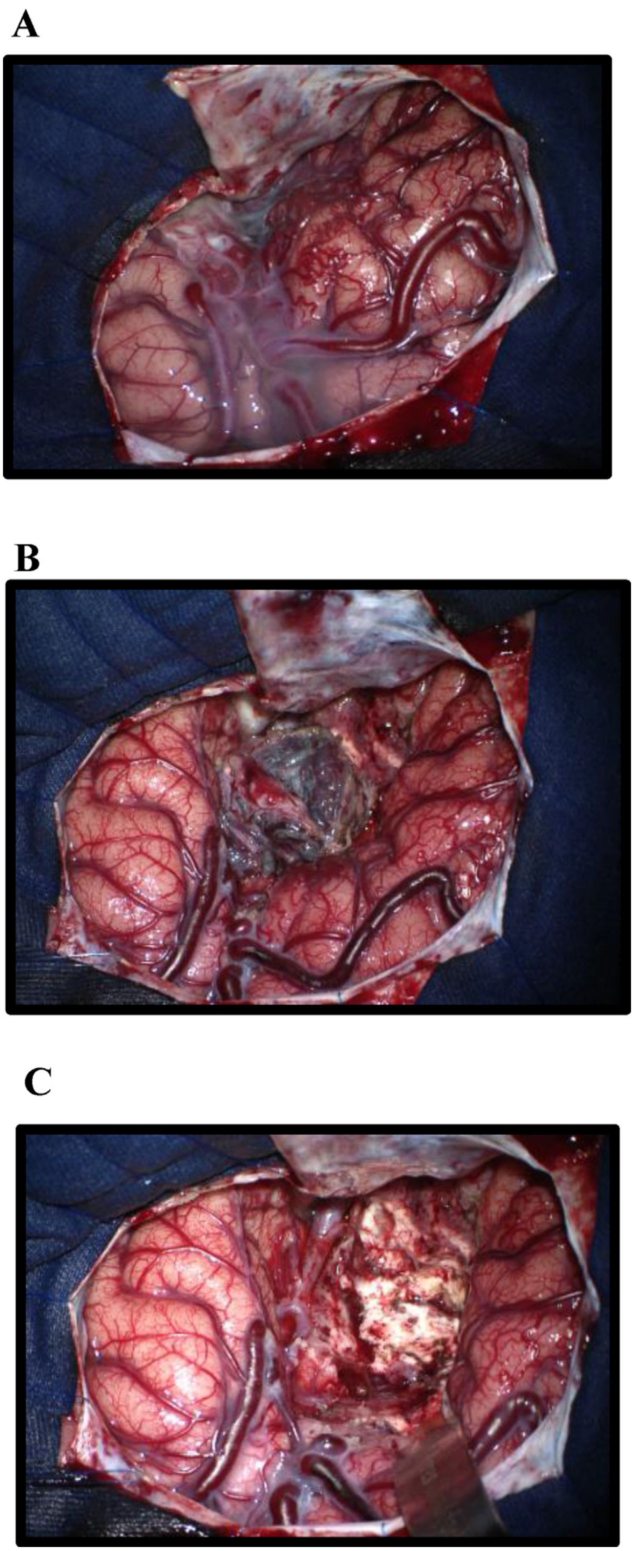

Fig. 7. ***A.*** *Intraoperative view showing diffuse vessels composing the AVM.* ***B.*** *Microsurgical dissection revealed the AVM post embolization with Onyx®.* ***C.*** *Complete AVM resection.*

Based on the AVM location, multiple surgical approaches are available. Transylvian-transinsular approaches can reach insular and most basal ganglia lesions. The supracarotid-infrafrontal approach serves for basal ganglia AVM. Caudate nucleus AVMs suites best, while thalamus and insula regions carry a significant neurological deficit risk with any treatment modality. Proximity to the critical areas makes surgical resection challenging, and many neurosurgeons choose radiosurgery or observation. However, deep AVM has increased radiosurgery side effects and lower obliteration rates than surgery. Transcallosal anterior and posterior ipsilateral approaches expose different thalamic regions. Transfrontal, transparietal, and transtemporal approaches may be useful when a hematoma creates a non-anatomical corridor from the brain surface to the AVM [21].

We present three cases below to illustrate this "philosophy." In short, the surgeon must plan the access and microsurgical access to the AVM. Then, the interventional neuroradiologist helps select nourishing arteries to embolize for flow reduction during surgery.

6. Surgical technique

A surgical approach must follow some basic principles, starting with a craniotomy that should be broad enough to expose the nidus, nourishing arteries, and drainage veins of the AVM. The opening of the dura mater should also be wide and initiated from the drainage veins, which can help determine the correct location of the nidus. When there is doubt, the drainage vein is the safest parameter to identify the nidus of the lesion.

Dissecting the nourishing arteries help expose the nidus while avoiding mobilization of the drainage veins. Coagulation of the nourishing arteries aims to reduce blood flow early. If there is doubt whether a vessel is an artery or a drainage vein, it is possible to clamp the vessel while observing its electrophysiological potentials temporarily. Occluding the correct artery requires observing the color change of the venous blood, which should become darker. Suppose there is clotting or inadvertent occlusion of the drainage vein. In that case, there can be a local hemorrhage or cerebral edema, so it is essential to determine the correct sequence of the surgical approach.

After reducing the arterial flow, circumferential dissection of the AVM should occur. In this step, the main objective is to maintain a uniform depth around the nidus while remaining outside the AVM pial plane. Therefore, the presence of excessive bleeding may suggest invasion of the nidus, whereas the absence of bleeding may indicate that the dissection site is too distant.

After this circumferential dissection, the entire AVM is apart from the brain, and only the drainage veins remain. Surgeons should separate the veins from the AVM as proximally as possible. The final stage of the procedure is the review of the remaining surgical cavity. The presence of bleeding may indicate that there are still remnants of the brain AVM [22–25].

7. Case 1

An 11-year-old boy has a history of chronic holocranial headache during the last five years, associated with visual loss during the episodes. The DSA and MRI revealed an extensive arteriovenous malformation (AVM), measuring 3 cm × 3 cm x 5,5 cm, with its principal feeders from the terminal branches of the left posterior cerebral artery, and also from cortical branches of the middle cerebral artery, draining to the left transverse sinus and tributaries to the vein of Galen (Fig. 1). The AVM also takes the blood flow from the middle cerebral artery through the posterior communicating artery. The MRI reveals that the AVM locates in the left occipital lobe (Fig. 2).

With the details described above, the AVM, in this case, might be classified as grade IV. The patient presented paroxysmal visual loss, representing a visual seizure; therefore, we chose microsurgical resection. He was positioned prone, and we made an inverted horseshoe incision. Then, we performed a wide craniotomy to get the best visualization of the AVM, its feeding arteries, and drainage veins (Fig. 3). The postoperative images showed the complete resection of the AVM and no residual lesion (Fig. 4). Also, the cerebrovascular

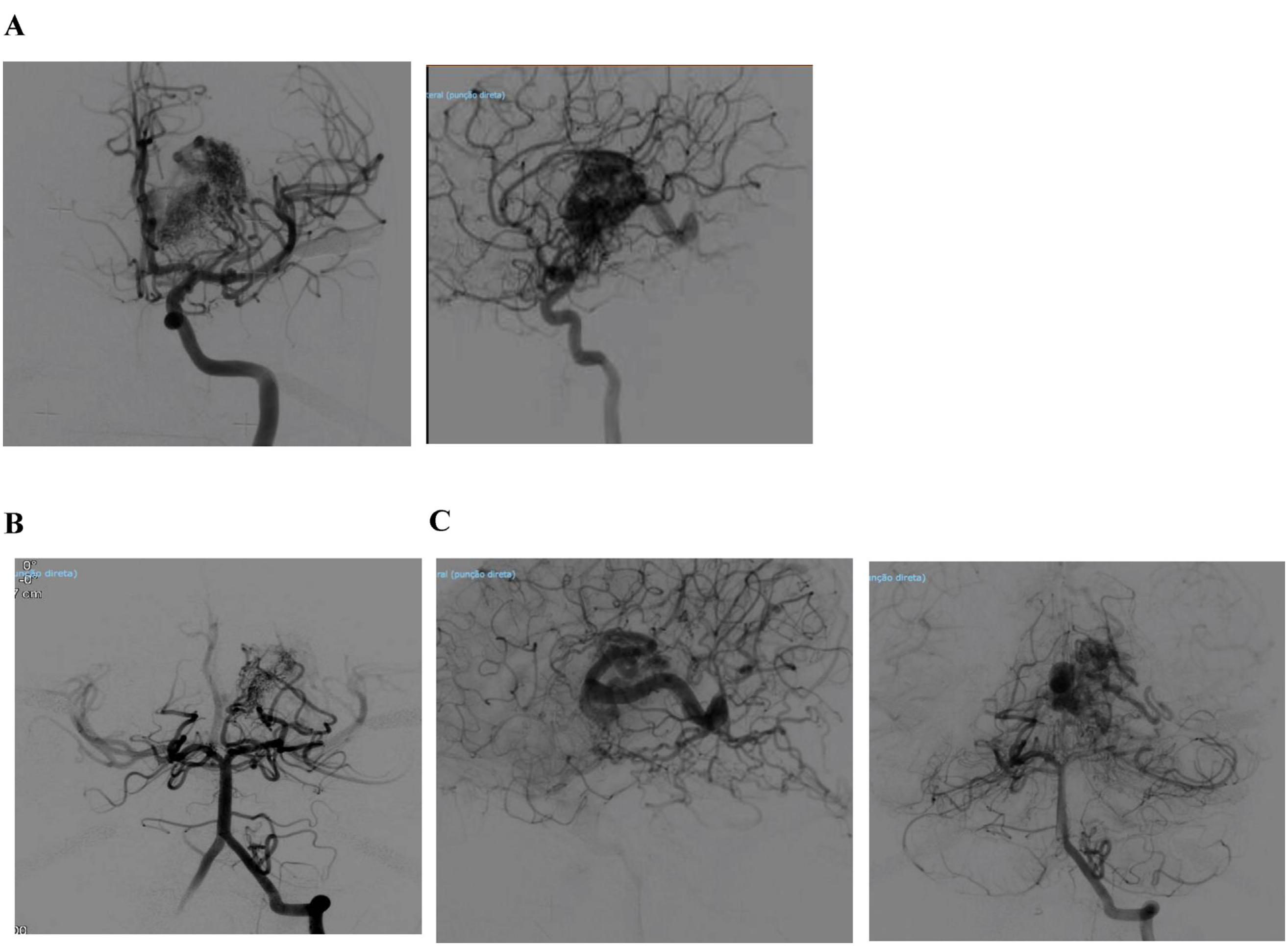

Fig. 8. A. AVM is fed by the perforating arteries of the segment M1, A1, and the anterior choroidal artery. B. The left thalamo-perforating arteries and lateral posterior choroidal arteries also contribute to the arterial supply. C. Venous drainage from the thalamostriate vein to Galen's vein.

flow returned to normal, with no postoperative complications.

8. Case 2

An 8-year-old girl had an absence seizure two years ago. Her neurological exam was normal. However, after the clinical investigation, the images revealed a large left fronto-opercular (Broca area) AVM, measuring 3.5 cm × 3.5 cm x 4 cm. The DSA showed a circumscribed nidus fed by cortical M1 arteries laterally, perforating arteries medially, and lastly from the vertebrobasilar circulation through the left posterior communicating artery. Superficial veins made the drainage of the AVM to the superior sagittal sinus.

We embolized with Onyx® the superficial and temporal parts of the AVM. The resulting AVM became more diffused and recruited several perforating arteries (Fig. 6), which raises the risk of rupture. The neurosurgical team performed the surgery. We made a left pterional craniotomy and entirely removed the AVM (Fig. 7). The DSA

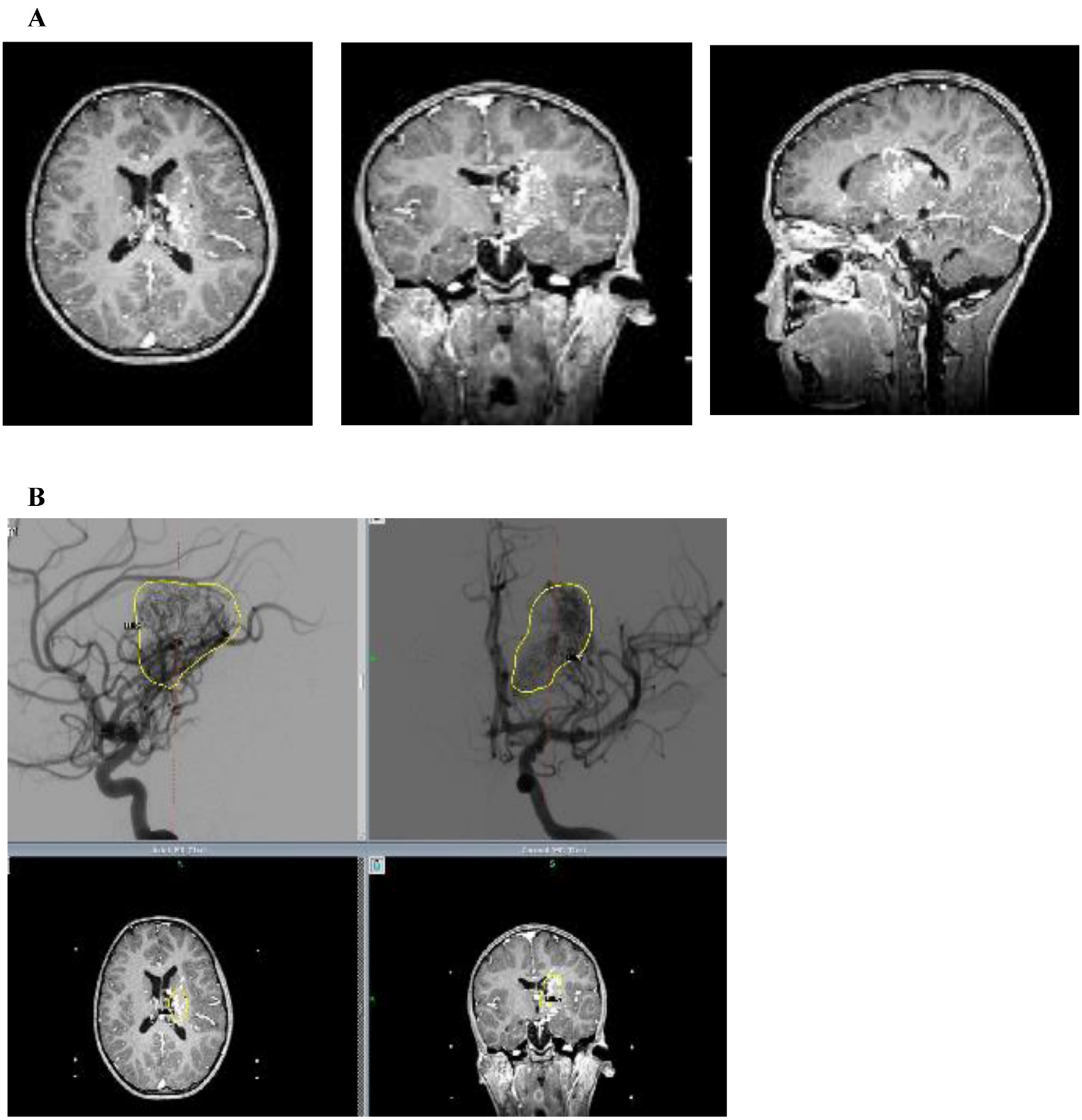

*Fig. 9. **A.** T1 MRI contrasted-enhanced image with the AVM in the thalamus, basal ganglia, and left lateral ventricle region. **B.** Radiosurgery planning showing the nidus area.*

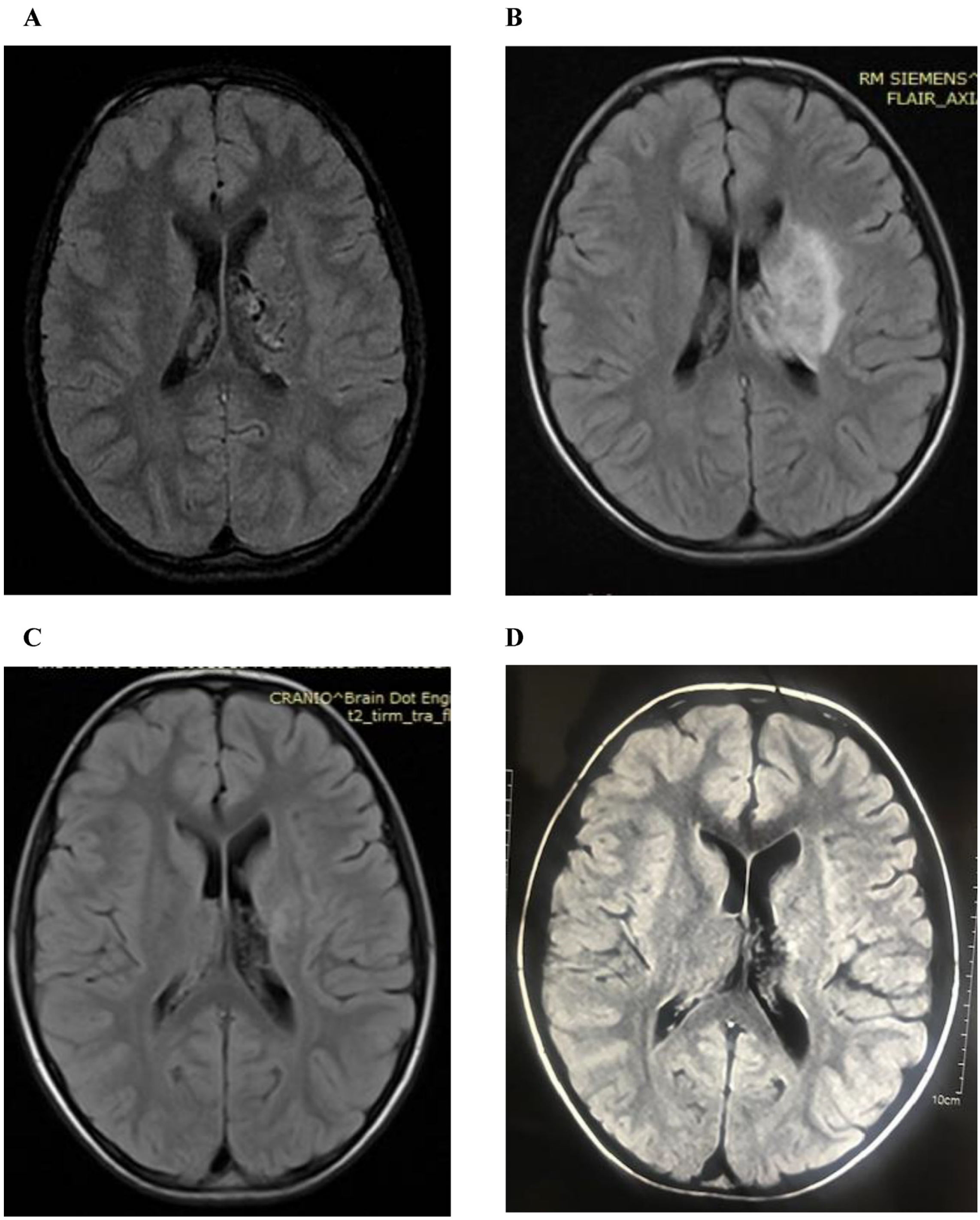

*Fig. 10. Flair MRI image demonstrating a decrease of the AVM size. **A.** Pre radiosurgery. **B.** Six months after the radiosurgery. **C.** One year after the radiosurgery. **D.** Two years after the radiosurgery.*

showed complete exclusion of the AVM and restitution of the cerebral blood flow to normal. She had no postoperative complications.

9. Case 3

A 7-years-old boy presented a sudden left hemiparesis and motor aphasia associated with a decreased level of consciousness. The DSA and MRI (Figs. 8 and 9A) revealed the presence of a deep AVM in the region of the thalamus, basal ganglia, and the left lateral ventricle. The perforating arteries of segment M1, A1, the anterior choroidal artery, left thalamus perforating arteries, and lateral posterior choroidal arteries fed the

AVM. The AVM is diffuse, with 3cm of diameter, and the venous drainage from the thalamostriate vein to Galen's vein and deep veins to the deep venous system (Fig. 5).

We considered this AVM a grade IV involving an eloquent area; therefore, we chose endovascular treatment to reduce flow directed to the nidus.

Then, we conducted radiosurgery (Fig. 9B) due to the depth of the AVM and the difficulty of surgery. It consisted of a Gamma Knife single-dose prescription of 15 Gy at the isodense of 50% for a nidus volume of 7.67 ccs.

The post radiosurgery exam showed a decrease in the AVM size one year and two years after the procedure (Fig. 10).

10. Intraoperative anesthesia-related considerations

Mechanisms of brain injury can be resultant of both surgery and anesthesia. Anesthesia-induced damage may result from blood pressure dysregulation, hypoxemia, hypoosmolarity, and hyperglycemia. Anesthesia management includes all these factors. Non-pharmacological brain protection may be reached by: diuretic/osmotherapy, euvolemia, optimal cerebral perfusion pressure, isotonicity, euglycemia, careful temperature monitoring, and avoidance of hyperthermia [18].

In the case of brain AVMs, intracranial compliance may be lower, thus avoiding cerebral vasodilators is reasonable. Except for these anesthetic agents, the choice is guided primarily by other coexisting conditions.

In respect of blood pressure, induced hypotension is helpful during surgery, especially when the surgeon is dealing with deep feeding arteries, which hemostasis may be difficult to obtain [26].

11. Complications

The most common complication is bleeding, which can occur intraoperatively due to nidal lesions or postoperative. Postoperative bleeding has two leading causes. Firstly, incomplete resection of the AVM and the residual vessels can lead to bleeding due to its patency. Alternatively, bleeding can also result from the breakthrough phenomenon caused by a failure in the auto-regulation of the adjacent arteries at the AVM site, given its altered intraluminal pressures due to proximity to the fistulous connections [8]. Our service routinely uses two approaches to minimize the risk of these two causes of bleeding. Firstly, an angiographic control is performed before hospital discharge, thus avoiding the discharge of a patient with residual nidus. Secondly, the patient is sedated for 24–72h in a controlled systemic hypotension regime (mean blood pressure of 65 mmHg) to avoid the break in the auto-regulation mechanism. The wake-up process should occur while blood pressure control is maintained, and when the patient is fully awake, withdrawal of hypotensive drugs is mandatory.

The second most common complication is cauterization of passage branches or venous infarction. Other complications include cerebral edema, seizures, hydrocephalus, and infections, mainly due to ischemia, bleeding, or prolonged surgical time [27].

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Manuscript 1040

Microendoscopic Versus Open discectomy for the Treatment of Extruded Lumbar Disc Herniation: A Comparative Cohort Study

Juan Guapo Mendoza

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See next page for additional authors

Microendoscopic Versus Open discectomy for the Treatment of Extruded Lumbar Disc Herniation: A Comparative Cohort Study

Abstract

Background: Lumbosciatica syndrome affects millions of people worldwide, usually caused by a herniated disc. Most patients with extruded herniated discs are highly symptomatic, and they respond better to surgical treatment. Several studies have tried to compare the efficacy and benefits of microendoscopic discectomy (MED) and open discectomy (OD).

Objective: The objective of this study was to compare the results and complications of our MED experience versus standard OD in patients with lumbar disc extrusion.

Material and methods: We included patients from 18 to 60 years with radicular pain syndrome and single-level extruded disc herniation between January 2015 and December 2020. We grouped into two prospective cohorts to undergo MED and OD. We assessed pain scores (VAS) and functional outcomes (ODI) and followed them over 12 months.

Results: We found a statistically significant difference in VAS score difference and ODI score difference in the first postoperative evaluations, less operative time, less intraoperative bleeding, fewer days of hospital stay, and less time of return to work in favor of the MED group.

Conclusion: Although relief of symptoms was faster among patients with the radicular syndrome in the MED group, this study demonstrated that the MED technique did not result in better overall 1-year functional outcomes than OD; however, in young working-age patients, it is essential to return to work as soon as possible. Our results showed a faster return to work in the MED group.

Visual Abstract

Keywords

Extruded disc, Microendoscopic discectomy, Open Discectomy

Authors

Juan Guapo Mendoza, Antonio Guapo Mendoza, Juan Arturo Muciño Mercado, Sonia Melisa Juarez, Arturo Gonzalez, and Vianney Guapo Ortiz

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ORIGINAL RESEARCH - SPINE

“ Microendoscopic Versus Open Discectomy for the Treatment of Extruded Lumbar Disc Herniation: A Comparative Cohort Study”

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Abstract

Background: **Lumbosacral radicular syndrome affects millions of people worldwide and is usually caused by a herniated disc. Most patients with extruded herniated discs are highly symptomatic, and they respond better to surgical treatment. Before, several studies have tried to compare the efficacy and benefits of microendoscopic discectomy (MED) and open discectomy (OD).**

Objective: **The objective of this study was to compare the results and complications of our MED experience versus standard OD in patients diagnosed with lumbar disc extrusion.**

Material and methods: **We included patients from 18 to 60 years with radicular pain syndrome and single-level extruded disc herniation between January 2015 and December 2020. We grouped into two prospective cohorts to undergo MED and OD. Pain score and functional outcomes were assessed and followed over 12 months.**

Results: **We found a statistically significant difference in VAS score difference and ODI score difference in the first postoperative evaluations, less operative time, less intraoperative bleeding, fewer days of hospital stay, and less time of return to work in favor of the MED group.**

Conclusion: **Although relief of symptoms was faster among patients with the radicular syndrome who were treated with MED, this study demonstrated that the MED technique did not result in a better overall 1-year functional outcomes than OD, however in young working-age patients, it is essential to return to work as soon as possible. Our results showed a faster return to work in the MED group.**

Keywords: Extruded disc, Microendoscopic discectomy, Open discectomy

1. Background

The lumbosciatica syndrome affects millions of people worldwide, caused mainly by a herniated disc [1]. Surgical treatment is indicated in patients who do not respond favorably to conservative treatment [2], mainly in extruded herniated discs that are highly symptomatic [3].

Micro endoscopic discectomy (MED) and Open microdiscectomy (OMD) are the two main surgical techniques for herniated discs [4]. However, the choice between micro or standard open discectomy (OD) probably depends more on the surgeon's experience and available resources than on scientific efficacy evidence [5].

Although all percutaneous techniques have reported high success rates, no study has shown superiority over the open microdiscectomy (with or without an operating microscope), which is still considered the gold standard for comparison [6, 7].

We compared two cohorts of patients with herniated discs to determine whether microendoscopic discectomy produces better clinical outcomes and less surgical trauma than open surgery.

The objective of this study was to compare the results and complications of our MED experience

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versus standard OD in patients diagnosed with lumbar disc extrusion.

2. Patients and methods

A convenience sample included patients aged 18 to 60 with radicular pain syndrome and a single level extruded disc herniation between January 2015 and December 2020. We separated them into the Micro-endoscopic discectomy MED and open discectomy OD groups. In addition, we included patients who had persistent radiculopathy (despite at least six weeks of conservative therapy) or with severe disability (ODI greater than 41%) and MRI with lumbar extruded disc herniation in all its variants according to the Lumbar disc nomenclature version 2.0 [8].

Based on their medical history and imaging studies, we excluded those patients with spinal canal stenosis, previous lumbar surgery, morbid obesity, instability, neuropathy, drug dependency, or known psychological disorders to avoid bias in postoperative evolution.

We grouped consecutive patients admitted to the spine clinic of two private hospitals and one public hospital with the criteria mentioned above. The patients from in private hospitals (Celaya's Medical-Surgical Center, Angeles of León Hospital) were operated on with the microendoscopic discectomy technique, and those who were admitted to a public hospital (General Hospital of Zone 4 of the Mexican Institute of Social Security) were operated with standard open discectomy technique. The surgical team was the same in private hospitals (MED). However, in public Hospitals (OD), the principal author operated with a different nursing team according to the hospital's role in all cases.

Abbreviations

MED	microendoscopic discectomy
ODI	Oswestry Disability Index
VAS	Visual Analog Scale
OD	Open discectomy

As extruded herniated discs cause significant neural compression, the symptoms are great, which causes substantial disability (Fig. 1). The included patients underwent surgery if they had a severe disability (ODI greater than 41%) or did not improve with non-steroidal anti-inflammatory drugs, muscle relaxants, and physical therapy.

We assessed pain scores and functional outcomes using a visual analog scale (VAS, 0–10) and the Oswestry Disability Index (0–100%). These measures were applied preoperatively, at 24 h, after a week, a month, three months, six months, and 12 months. Intraoperative and postoperative complications, bleeding, surgical time, body mass index, hospital stay, and return to work data were assessed by clinical charts and operation records. We compared the two groups using the Student's t-test, the Wilcoxon rank-sum test, Fisher's exact test, or the Pearson Chi-squared test as appropriate.

2.1. Statistical analysis

We expressed descriptive statistics as mean, standard deviation, and frequency. We used Student's t-test, Wilcoxon rank-sum test, and the Pearson Chi-squared test for intergroup comparisons. We evaluated data within a 95% confidence interval and at a significance level of $p < .05$. We

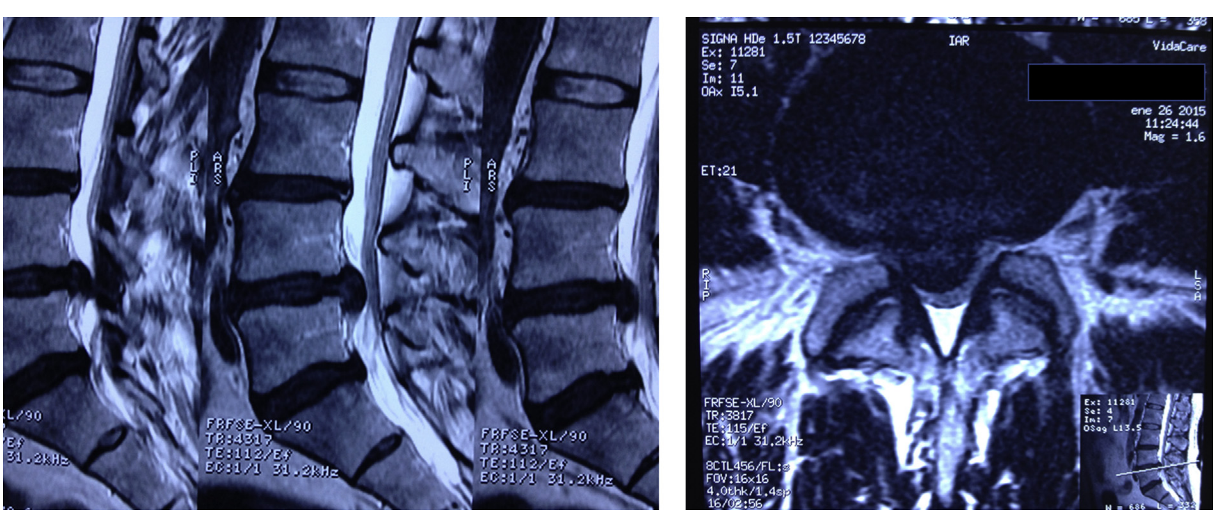

Fig. 1. This figure shows sagittal and axial T2 Magnetic resonance (MR) imaging of a classic extruded disc herniation, displacing neural structures.

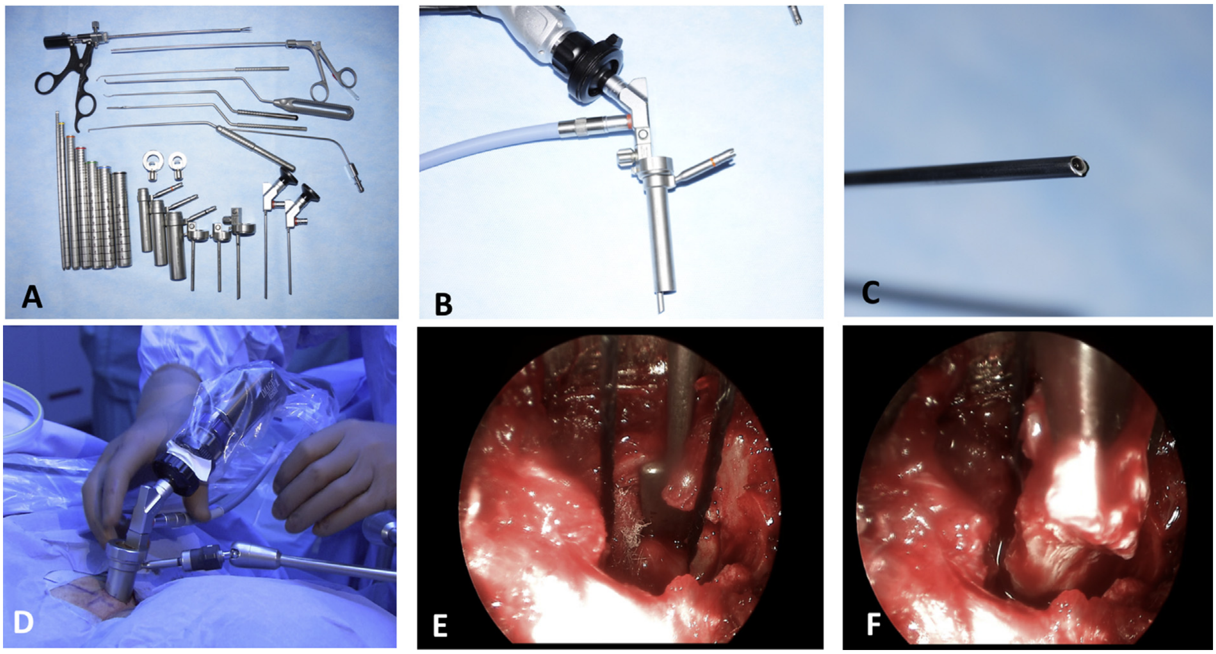

Fig. 2. A. EasyGo system for MED. B. The working sheath of an outer diameter of 15 mm. C. 30° Hopkins optic for a full endoscopic view. D. MED bimanual surgical technique. E. Endoscopic view of the lateral edge of the dural sac and the nerve root retracted medially. F. Removing the extruded disc.

analyzed data using the Statistical Package for the Social Sciences (SPSS) version 25.

2.2. Surgical techniques

2.2.1. Microendoscopic group

We performed MED with the patient under general anesthesia and in a prone position. We used the Easy GO Storz (Gaab-Oertel) system (Fig. 2A) [9]. We used image intensification to identify the initial incision point; we inserted a 15 mm tubular retractor over the sequential dilators over a guidewire directed to the superior lamina of the desired level. We performed the surgical procedure through a working sheath of an outer diameter of 15 mm (Fig. 2B). We used a 30° Hopkins optic for a full endoscopic view (Fig. 2C). We fixed the optic to the working sheath and subsequently fixed it to the surgical table via a standard endoscope holder. We performed the endoscopic procedure under a bimanual surgical technique (Fig. 2D). We performed a partial resection of the interlaminar ligament after laminotomy. We limited the excision of the Ligamentum flavum enough to see the lateral edge of the dural sac and the nerve root and retract them both medially (Fig. 2E), then performed the discectomy. In almost all cases, we found the large extrusion directly under the ligamentum flavum (Fig. 2F).

2.3. Open surgery group

Based on the fluoroscopic view, we made a 4−6 cm skin incision in the midline above the affected level without an operating microscope. First, we incised the lumbar fascia using cutting diathermy. Then, we stripped the paraspinal muscles of the spinous processes, exposing the lamina with the facet joints as lateral limits. Next, we retracted muscles laterally using the Taylor spinal retractor. Finally, we performed a hemilaminectomy using a Kerrison's Rongeur to locate and remove the disc material.

3. Results

3.1. Participants

In the 3 study hospitals, we collected information on 236 patients; we included 202 in the study; we excluded 34 as they refused surgery (26 in the MED group and 8 in the OD group). Of the patients who refused surgery in the MED group, 19 were due to a change in treatment surgeon and seven because the patient preferred to continue with conservative treatment indefinitely. The eight patients who refused surgery in the OD group were because patients preferred to continue with conservative treatment. All patients included in the study had at least 12 months of follow-up after surgery.

3.2. Demographic and clinical characteristics

We grouped o121 men (59.9%) and 81 women (40.1%) with a single level extruded disc herniation into the MED group (n = 89), and OD group (n = 113).

The mean age of patients was 35.77 ± 8.1 years (range, 18–56 years), with a mean body mass index of 29.76 ± 3.2 (range, 19.2–38.0). The most affected level was L5 to S1 in 103 patients (51%).

There was no statistically significant difference between the MED and OD groups concerning age, gender, body mass index, and level of herniation.

This study obtained the MED group from two private hospitals, which present the primary demographic and outcome data homogeneity (Table 1).

3.3. Outcome after surgery

The mean ± SD operative time was 40.55 ± 8.58 min for MED and 72.38 ± 12.10 min for OD. Intraoperative bleeding was 54.66 ± 29.42 ml in MED and 133.58 ± 36.02 ml in OD. Hospital stay was 1.10 ± 0.33 days in MED and 1.51 ± 0.87 days in OD. Return to work was 17.19 ± 9.46 days for MED and 39.42 ± 16.56 days for OD. With the statistical difference in favor of MED, less operative time, less intraoperative bleeding, fewer days of hospital stay, and less time of return to work, P values from paired t-test (P < .05) in all these variables.

Preoperative and postoperative data were available for outcome analysis for all the patients. The preoperative VAS score means ± SD was 7.52 ± 0.97 for MED and 7.61 ± 0.82 for OD. We analyzed the difference between postoperative and preoperative VAS, finding that 24 hrs VAS versus Preoperative VAS was −6.15 ± 1.06 for MED and −5.50 ± 1.01 in OD. We found a statistically significant difference in VAS scores between the two groups (P < .05). One-week VAS versus Preoperative VAS was −6.60 ± 1.08 for MED and −6.16 ± 1.00 in OD, with a statistically significant difference (P < .004), one-month VAS versus Preoperative VAS was −6.95 ± 1.08 for MED and −6.53 ± 0.09 in OD, with statistically significant difference (P < .005). There was no statistically significant difference at 3, 6, and 12 months. The difference between VAS at three months versus Preoperative VAS was −7.19 ± 1.03 for MED and −6.92 ± 0.93 in OD (P < .056). The difference between VAS at six months versus Preoperative was −7.33 ± 0.98 for MED and −7.20 ± 0.98 in OD (P < .34). Furthermore, at 12 months versus Preoperative, VAS was −7.44 ± 1.03 for MED and −7.32 ± 0.99 in OD (P < .38) (Fig. 3).

*Table 1. * P-value corresponds to private hospitals (MED) comparison. T-test for numerical data and a chi-square test for categorical data.*

Patient demographics and outcomes per hospital

Mean ± SD range, N(%)

	OPEN DISCECTOMY (OD)	MICROENDOSCOPIC DISCECTOMY(MED)		
	General Hospital of Zone 4	Celaya´s Surgical Medical Center	Angeles of Leon Hospital	P *
N	*113*	*77*	*12*	
Age	36.47 ± 8.97	35.08 ± 7.15	33.67 ± 5.74	0.15
Gender				
Male	68(60.2%)	46(59.7%)	7(58.3%)	0.99
Female	45(39.8%)	31(40.3%)	5(41.7%)	0.99
Herniation Level				
L5-S1	60 (53.1%)	35(45.5%)	8(66.7%)	
L4-L5	48(42.5%)	36(46.8%)	4(33.3%)	
L3-L4	4(3.5%)	5(6.5%)	0	
L2-L3	1(0.9%)	1(1.3%)	0	
Visual Analogue Scale				
VAS Preop	7.61±.082	7.53±0.99	7.42±0.90	0.68
VAS 24Hrs	2.11±.072	1.31±0.87	1.67±0.65	0.11
VAS 1Week	1.44±0.66	0.88±0.62	1.08±0.66	0.34
VAS 1Month	1.08±0.58	0.52±0.59	0.83±0.57	0.10
VAS 3Month	0.69±0.53	0.29±0.45	0.58±0.51	0.08
VAS 6Month	0.41±0.51	0.16±0.36	0.33±0.49	0.25
VAS 12Mont	0.28±0.49	0.04±0.19	0.25±0.45	0.13
Oswestry Disability Index				
ODI Preop	73.57±6.63	71.65±9.01	73.42±5.66	0.37
ODI 24Hrs	16.90±8.14	10.90±4.57	11.67±2.46	0.39
ODI 1Week	10.35±5.91	5.84±3.88	5.92±2.90	0.94
ODI 1Month	6.82±5.30	3.19±3.71	4.42±2.61	0.17
ODI 3Month	4.56±3.88	1.83±2.82	3.33±2.46	0.07
ODI 6Month	2.58±3.12	0.91±1.51	1.50±1.93	0.32
ODI 12Mont	1.41±2.66	0.32±0.97	0.83±1.58	0.30

* P-value corresponds to private hospitals (MED) comparison. T-test for numerical data and a chi-square test for categorical data.

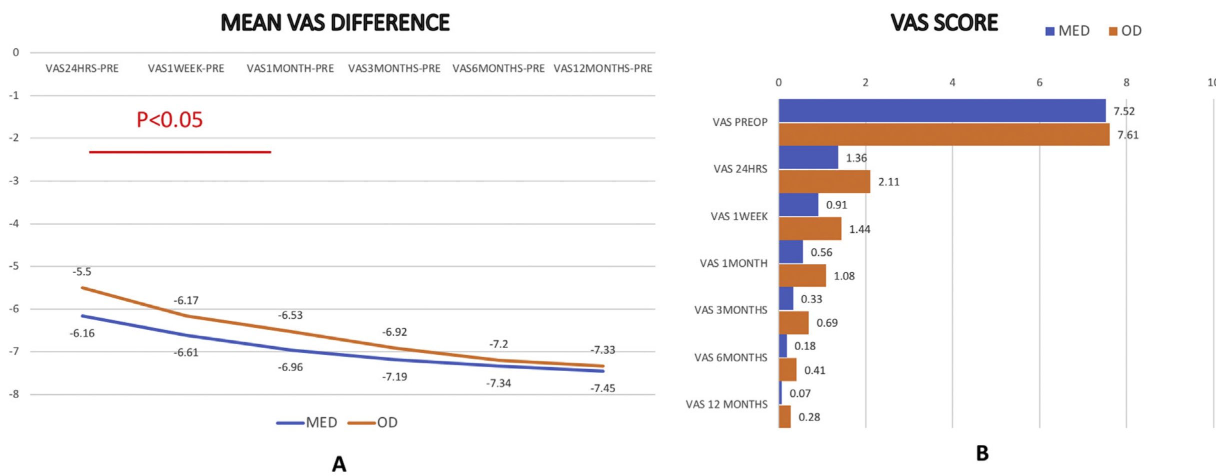

Fig. 3. A. The mean VAS difference is expressed as a negative number. It corresponds to the decrease in the mean VAS score from the initial preoperative value to the postoperative pain mean score at 24Hrs, 1Week, month, three months, six months, and the final review at 12 months. Note that the first three results showed a statistically significant difference in favor of the MED group. B. Shows the absolute values of the preoperative and postoperative averages in MED and OD groups.

We also analyzed the difference between the postoperative and preoperative ODI scores with the following findings. The difference between 24 hrs ODI versus Preoperative was −60.88 ± 8.79 for MED and −56.66 ± 11.30 in OD; there was a statistically significant difference between the two groups ($P < .004$). One week ODI versus Preoperative was −66.03 ± 9.23 for MED and −63.21 ± 9.26 in OD, with a statistically significant difference ($P < .03$). We did not find statistically significant differences when analyzing the difference ODI scores at 1, 3, 6, and 12 months. The one-month ODI versus Preoperative was −68.52 ± 8.91 for MED and −66.74 ± 8.69 in OD ($P < .15$). The three-month ODI versus Preoperative was −69.85 ± 8.57 for MED and −69.00 ± 7.59 for OD ($P < .46$). The six-month ODI versus Preoperative ODI was −70.89 ± 8.40 for MED and −70.99 ± 7.06 in OD ($P < .03$). The twelve-month ODI versus Preoperative ODI was −71.49 ± 8.56 for MED and −72.15 ± 6.88 in OD ($P < .55$) (Fig. 4).

3.4. Complications and reoperations

The most frequent intraoperative complication was incidental durotomy, which occurred in 5 patients (5.6%) of the MED group and five (4.4%) of the OD group. The other intraoperative

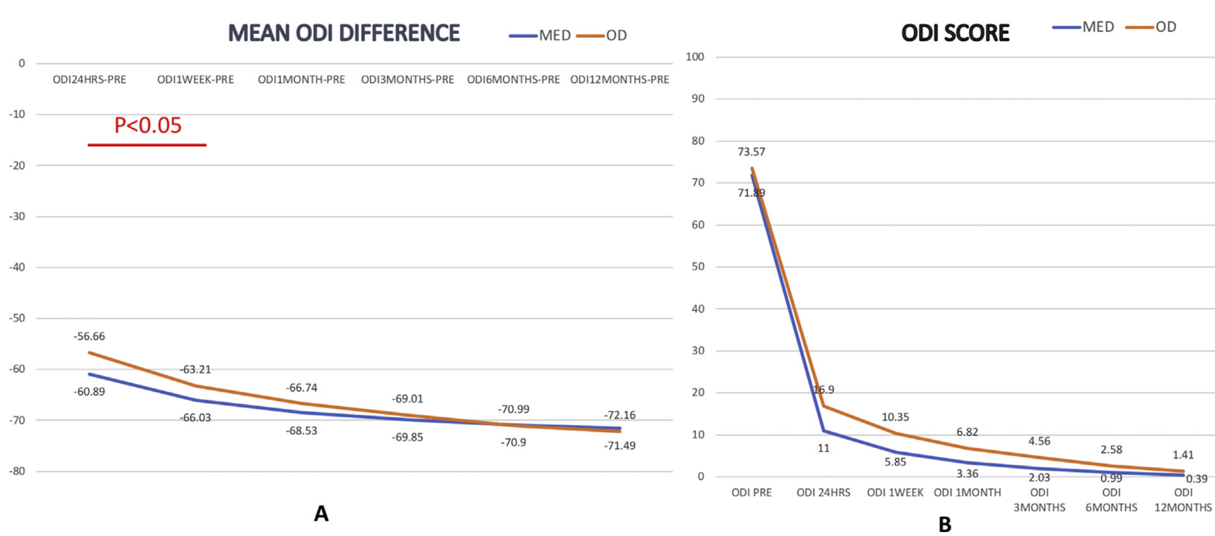

*Fig. 4. A. Line graph demonstrating the comparative results of the mean ODI difference (postoperative mean-preoperative mean). A statistically significant difference was found in favor of the MED group in ODI24 hrs-ODI PRE and ODI 1WEEK-ODI PRE. B. Shows the absolute values of the preoperative and postoperative averages in MED and OD groups. *Negative Values represent decrease of the ODI score.*

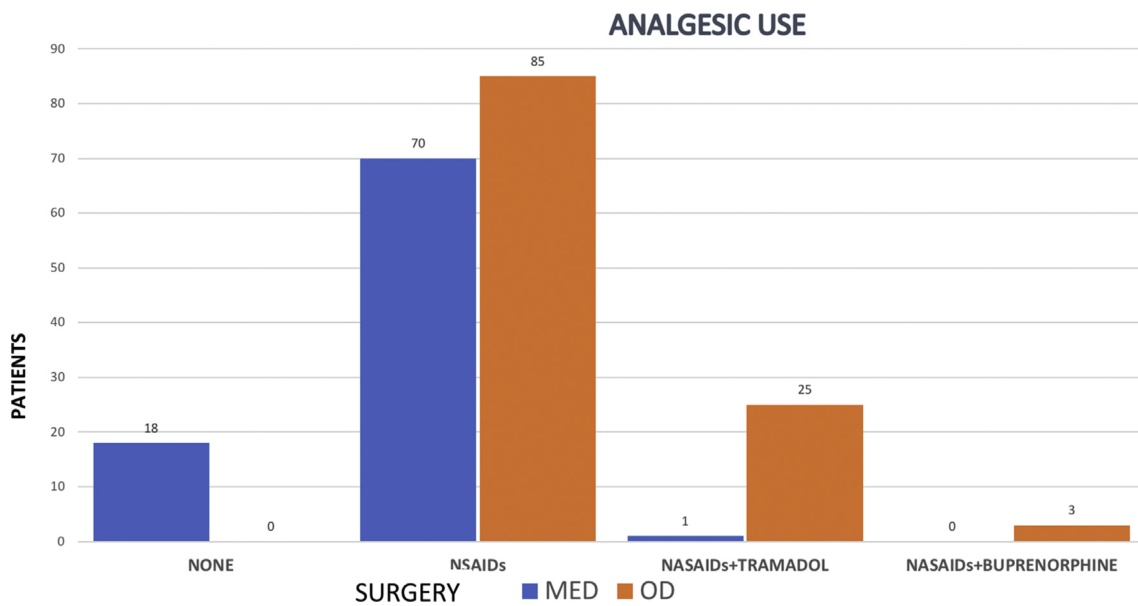

Fig. 5. The use of postoperative analgesics is shown in both groups studied. We found a statistically significant difference for less use of analgesics in the MED group (P < .001).

complication was bleeding greater than 250 ml in the OD group.

In the MED group, five dural leaks occurred; we controlled all of them using gel foam and an absorbable fibrin sealant patch alone. In addition, we observed no long-term sequelae, delayed leaks, fluid collections, or pseudomeningocele. In the OD group, we observed five dural leaks; we repaired one using a 5-0 monofilament suture, and in four cases, we used gel foam and an absorbable fibrin sealant patch. There was no postoperative fistula in three of the five cases. However, postoperative cerebrospinal fluid leakage occurred in 2 cases of the OD group and was treated with lumbar drainage without reoperation.

The postoperative complications in the MED group were spondylodiscitis in 1 case, requiring oral antibiotic therapy for six weeks, and severe postoperative pain in 1 case requiring reoperation due to residual disc. In the OD group, we observed seven postoperative complications. Postoperative cerebrospinal fluid fistula in 2 patients treated with lumbar drainage. Postoperative motor or sensory affection in 3 cases; in all cases, the symptoms were transients and resolved in less than a week. Furthermore, severe postoperative pain in 2 patients; 1 patient required reoperation, and one patient resolved with anti-inflammatory treatment. We found three reoperations, two patients (1.76%) in the OD group and one patient (1.12%) in the MED group. There were no significant differences between the study groups regarding complications and reoperations.

3.5. Postoperative analgesic use

In the MED group of the total number of patients studied (89), 18 (20.2%) did not require the use of analgesics due to the significant decrease in pain after surgery, 70 (78.6%) used NSAIDs, 1 (1.1%) NSAIDs + Tramadol and none required the use of potent opioids. In the OD group (113 patients), they all needed some pain reliever: 85 (75.2%) used NSAIDs, 25 (22.1%) NSAIDs + Tramadol and, 3 (2.6%) used buprenorphine. We found a statistically significant difference for less use of analgesics in the MED group (P < .001) (Fig. 5).

4. Discussion

Some authors have described the potential benefits of the Micro endoscopic Discectomy (MED) technique, including less muscle damage [10, 11, 12], rapid pain relief [13, 14], and less retraction of the nerve root [15], and faster postoperative recovery [16, 17]. There are still few published studies comparing MED and OD outcomes [18–26], and even fewer studies are evaluating patients with extruded disc herniations [22, 27, 28].

The prospective studies for large (extruded) contained and uncontained lumbar disc herniations of Hussein et al. [27], and Schizas et al. [22] concluded that there were no statistical differences between the MED and OD results in terms of outcome.

In our study, we observed statistically significant differences when comparing the results in pain reduction (VAS) and functional status improvement

(ODI) in the initial postoperative period. In favor of the MED group, we obtained a statistically significant improvement ($P < .05$) in the difference between the postoperative and preoperative VAS scores at 24 h, one week, and one month. The VAS differences at 3, 6, and 12 months were not statistically significant.

The difference between postoperative and preoperative ODI scores in our study had statistically significant differences at 24 h and a week in favor of the MED group compared to the OD group. We found no differences between the two groups at 1, 3, 6, and 12 months.

These data indicate that the MED technique used is more efficient for decompressing the nerve root with minor tissue damage than the OD technique; however, the evolution continues its course, and in the long-term outcomes, evaluations are similar.

Wu et al. [16], in a prospective study of 873 cases operated on with MED compared with a control group, did not find significant differences in pain between the two groups. However, the MED group experienced minor bleeding during surgery.

Righesso et al. [21], in a randomized controlled trial comparing MED and OD, found statistically significant differences in the size of the incision, length of hospital stay, with a better result for the MED group, and operative time was lower in OD group.

In our study, we found a significant statistical difference ($P < .05$) in favor of MED with less operative time (40.55 8.58 min), less intraoperative bleeding (54.66 29.42 ml), fewer days of hospital stay (1.10 0.33 days), and less time of return to work (17.199.46 days).

Hussein et al. [27] did not report severe complications in both groups concerning complications and reoperations. However, dural tears were the most frequent complication found in 6 patients (6.6%) in the MED group and five patients (5.6%) in the OD group. 2 patients (2.1%) in the MED group, and three patients (3.3%) in the OD group required reoperation.

We also found incidental durotomy as the most frequent intraoperative complication, which occurred in 5 patients (5.6%) of the MED group and five (4.4%) of the OD group. Other intraoperative complications were spondylodiscitis in 1 case and severe postoperative pain in 1 patient in the MED group. In the OD group, we observed seven postoperative complications: Postoperative cerebrospinal fluid fistula in 2 cases (treated with lumbar drainage) and postoperative motor or sensory affection in 3 cases. In addition, we found a total of 3 reoperations, two patients (1.76%) in the OD group and one patient (1.12%) in the MED group. There were no significant differences between the study groups regarding complications and reoperations.

We analyzed the postoperative analgesic use, and we found in the MED group of the total number of patients studied (89), 18 (20.2%) did not require the use of analgesics due to the significant decrease in pain after surgery, and 71 (79.7%) used some analgesic. In the OD group (113 patients), they all required some pain reliever. We found a statistically significant difference for less use of analgesics in the MED group ($P < .001$). Our results are similar to those reported by Hussein et al. [27], who found 21 patients (22.1%) in the MED group compared with 66 patients (73.3%) in the control group who received NSAIDs during their hospital stay.

This study had several characteristics that may limit the generalization of its findings. First, patients assigned to the OD did not have the option of undergoing the MED technique since they were operated on in a public hospital without this resource. In addition, the nursing team was different according to the rules of a public hospital. That is important because the outcomes can be influenced by human staff. Second, the time until recovery was determined based on examinations performed only at fixed predefined time points during follow-up; however, both treatment groups were affected in the same way. Finally, this was not a prospective, randomized, concurrently conducted study, and this introduces a potential for bias and confounding, which may explain the differences found.

5. Conclusion

Although relief of symptoms was faster among patients treated with MED than those with OD, this study demonstrated that the MED technique did not result in better overall 1-year functional outcomes than OD. However, it is essential to return young working-age patients to work as soon as possible. Our results showed a faster return to work in the MED group.

Other differences found, such as shorter operating time, less bleeding, and less analgesic use in favor of the MED group, have little clinical difference in practice.

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Conflict of interest

The authors declare no relevant conflicts of interest in this study.

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Misdiagnosis between coccygeal dislocation fracture and lumbosacral disc herniation

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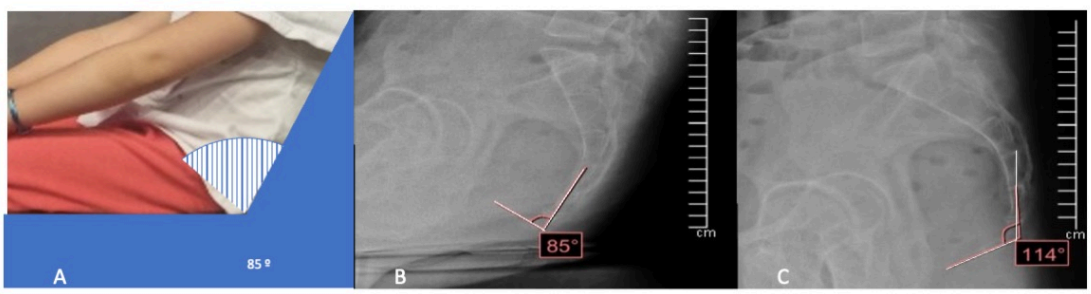
Misdiagnosis between coccygeal dislocation fracture and lumbosacral disc herniation

Abstract

INTRODUCTION: Coccydynia is the condition of disabling pain in the coccyx that occurs when sitting or moving to a standing position. Due to a lack of knowledge by spine specialists, many patients suffer for years without adequate treatment. We highlight the relevance of diagnosing and treating coccygodynia correctly to avoid lumbosacral pathology overestimation. METHODS: We present a series of patients with painful coccygeal segment syndrome associated with different lumbar alterations who underwent coccygectomy from 1996 to 2021 in our spine clinic. We describe VAS and MacNab scores and complication rates. We used Student-T-Test for statistical analysis. RESULTS: We included 40 patients, 36 women and four men, mean age of 41.75 years old. Twenty-one patients were idiopathic, six were because of labor, and 13 cases were due to trauma. We also included the data of 6 patients who simultaneously underwent coccygectomy and spine surgery. The results on the VAS scale 15 days after coccygeal surgery showed a significant improvement from a preoperative 9.63 (SD 0.54) to 1.6 (SD 0.71), with further improvement at four months to 0.50 (SD 0.71). Thirty-five patients were excellent, three good, one fair, and one poor regarding the Macnab scale. There was an infection in 3 patients (7.5%), totally improving with antibiotics and daily wound cleaning; 9 (22.5%) had superficial and partial wound dehiscence. CONCLUSIONS: We suggest making a differential diagnosis of coccydynia in all patients with lumbosacral pathology. Patients improve significantly after coccygectomy, although infection and wound dehiscence are the main complications.

Visual Abstract



Keywords

Coccydynia, Coccygectomy, Macnab, Dynamic plain films, Coccygeal palpation, Misdiagnosis, disc hernial differencial diagnosis

Authors

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Misdiagnosis between Coccygeal Dislocation Fracture and Lumbosacral Disc Herniation

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Abstract

Introduction: **Coccydynia is the condition of disabling pain in the coccyx that occurs when sitting or moving to a standing position. Due to a lack of knowledge by spine specialists, many patients suffer for years without adequate treatment. We highlight the relevance of diagnosing and treating coccygodynia correctly to avoid lumbosacral pathology overestimation.**

Methods: **We present a series of patients with painful coccygeal segment syndrome associated with different lumbar alterations who underwent coccygectomy from 1996 to 2021 in our spine clinic. We describe VAS and MacNab scores and complication rates. We used student-t-test for statistical analysis.**

Results: **We included 40 patients, 36 women and four men, mean age of 41.75 years old. Twenty-one patients were idiopathic, six were because of labor, and 13 cases were due to trauma. We also included the data of 6 patients who simultaneously underwent coccygectomy and spine surgery. The results on the VAS scale 15 days after coccygeal surgery showed a significant improvement from a preoperative 9.63 (SD 0.54) to 1.6 (SD 0.71), with further improvement at four months to 0.50 (SD 0.71). Thirty-five patients were excellent, three good, one fair, and one poor regarding the Macnab scale. There was an infection in 3 patients (7.5%), totally improving with antibiotics and daily wound cleaning; 9 (22.5%) had superficial and partial wound dehiscence.**

Conclusions: **We suggest making a differential diagnosis of coccydynia in all patients with lumbosacral pathology. Patients improve significantly after coccygectomy, although infection and wound dehiscence are the main complications.**

Keywords: Coccydynia, Coccygectomy, Macnab, Dynamic plain films, Coccygeal palpation, Misdiagnosis, Disc hernial differencial diagnosis

1. Introduction

Coccydynia, first described by Simpson in 1859, is the condition of disabling pain in the coccyx that occurs when sitting or moving to a standing position [1]. The pain may irradiate to the sacrum, lumbar spine, or laterally to the buttocks. Rarely do patients present with rectal pain or associated radicular symptoms. One-third of patients have associated back pain, contributing to misdiagnosis [1–5]. Due to a lack of knowledge of this condition by spine specialists, many patients may suffer for years without adequate treatment [5–8]. 13 patients presented a diagnosis of lumbar pathology (sciatic compression syndrome and low back pain), and ten patients had even undergone lumbosacral spine surgery. None of the cases that had previously undergone lumbar surgery had any improvement in VAS or the Macnab scale (see Table 1).

Additionally, most neurosurgeons and orthopedic surgeons are uncomfortable treating coccydynia due to a lack of surgical training in this topic.

Table 1. This table shows the most relevant demographic data of the sample expressed as means, standard deviations (SD), frequency, and 95% confidence intervals (CI).

Variable	Mean (SD)	Frequency	95% CI
Age (years)	41.75 (27.47)	NA	±4.85
Gender	NA	36 women /4 men	NA
Evolution (months)	24.24 (27.48)	NA	±8.78
VAS	9.63 (0.54)	NA	±0.29

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Fortunately, the skills to diagnose and surgically treat chronic refractory coccydynia are easily acquired. Diagnosis is based on history and physical examination, supplemented by radiologic imaging findings. The etiology and intensity of symptoms may result from severe trauma, repetitive injuries, post-partum issues, local tumors, disc degeneration, and can also be idiopathic [1]. However, the most frequent cause is coccygeal dislocation fracture, but as it resembles lumbosacral pathology, many patients undergo surgery without improvement. Nevertheless, its diagnosis is simple since all patients have pain on digital coccygeal palpation (ideally with the index finger), and most present instability of the coccyx in dynamic radiographs.

We highlight the relevance of diagnosing and treating coccygodynia correctly to avoid lumbosacral pathology overestimation.

2. Material and methods

We present a series of patients with painful coccygeal segment syndrome associated with different lumbar alterations who underwent coccygectomy from 1996 to 2021 in our spine clinic. Patients were included in this series if they presented chronic or acute pain of the sacrococcygeal portion, considerable pain on sitting for over 30 minutes, and intensified pain when getting up from the seated position. Despite meeting these criteria, we excluded those cases that did not meet a follow-up period of at least two weeks. The cabinet studies confirming this diagnosis were already described by Franco P. Cerabona in 2003 [9] and consist of plain films on lateral standing and lateral sitting. Most of them show fracture or displacement of the coccyx, as shown in Fig. 1.

We explored all patients who suffered from coccydynia through coccygeal palpation and dynamic radiographs on standing and sitting positions; for this last one, we asked the patients to remain with the back in moderate extension.

We used the following surgical technique in all the patients [9]. It consisted of a longitudinal midline incision exposing the dorsal part of the terminal sacrum and extending to the painful coccygeal segment; subperiosteal dissection was essential. We used electrocautery on the dorsal surface and cautiously when dissecting ventrally. Excision began in the disc space with sharp dissection, and then a small periosteal elevator proceeded. We grasped the proximal part of the coccyx with gauze or Kocher forceps and proceeded with dissection in a cranial to caudal direction. It is unnecessary to remove the terminal segment unless it is too prominent; we prefer using hemostatic agents instead of cautery to avoid injury to the rectum. We incorporated the terminal coccyx on the periosteal closure to eliminate dead space and apply tension to the anococcygeal and sacrococcygeal ligaments. Drainage is usually not needed. We performed skin closure with subcuticular sutures and an occlusive dressing [9].

We quantified the Visual Analog Pain Scale (VAS) at 15 days and four months and the Macnab scale at four months to quantify performance after surgery.

We used Student's t-test for results statistical analysis and descriptive statistics for demographic data. Finally, we respected patient confidentiality in evaluating these data.

3. Results

We included 40 patients, 36 women and four men, with a mean age of 41.75 (SD ± 27.47) years, who underwent surgery by coccygectomy. The mean time of pain duration was 24.24 (SD ± 27.48) months with a range of 0.5–96 months. The etiology for 21 patients was idiopathic, six were because of labor, and 13 cases were due to trauma. Two patients had diabetes mellitus, and two others had hypertension. All the patients had coccydynia, and 75% (30 patients) reported low back pain with irradiation to the pelvic limbs. In the files, 13 patients presented a diagnosis of lumbar pathology (sciatic compression syndrome and low back pain), and ten patients had even undergone lumbosacral spine surgery. None of the cases that had previously undergone lumbar

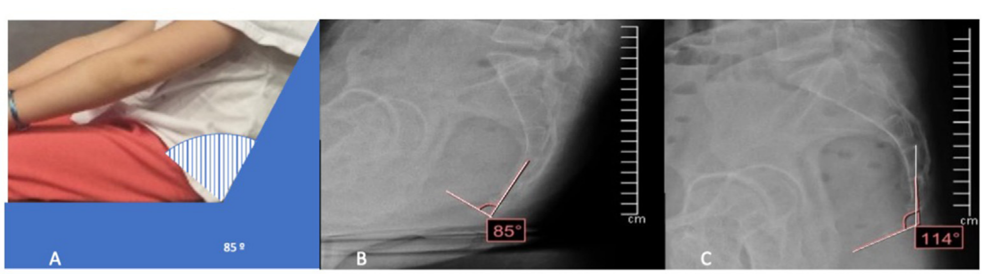

Fig. 1. The 85° posture is seen when seated. This condition changes to 114° when standing.

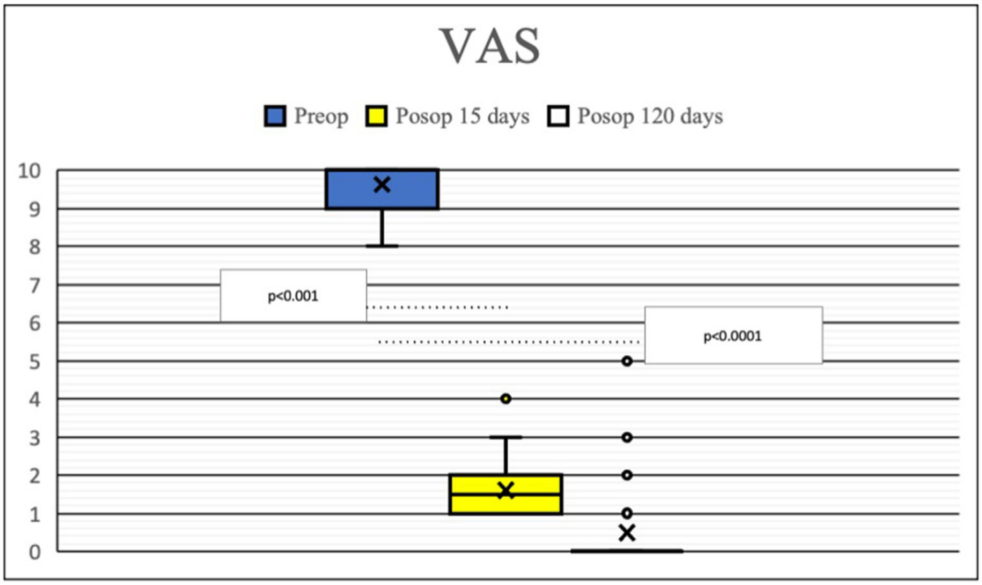

Fig. 2. This graph shows the changes in the VAS score before and after treatment. A statistically significant change is observed at both 15 ($p < 0.001$) and 120 days ($p < 0.0001$) applying a paired t-student test.

surgery had any improvement in VAS or the Macnab scale. In this study, we also included the data of 6 patients who underwent coccygectomy and spine surgery simultaneously.

The results on the VAS scale 15 days after coccygeal surgery had a significant improvement from a preoperative 9.63 (SD 0.54) to 1.6 (SD 0.71) with a $p < 0.001$ (Fig. 2). Four months later, there was further improvement on the VAS scale with 0.50 (SD 0.71). Regarding the Macnab scale, the results were 35 patients excellent, three good, one fair, and one poor. There were infection data in 3 patients (7.5%), totally improving with antibiotics and daily wound cleaning; 9 (22.5%) had superficial and partial wound dehiscence. There was no relation between complications and comorbidities.

4. Discussion

This work shows 40 cases, of which 32.5% were mistaken as lumbosacral pathology, and 25% operated on the lumbar spine while having coccygeal pathology. Spine surgeons have forgotten that a coccygeal disease can produce low back pain or sciatica data. To properly diagnose coccydynia, we need to consider two key elements:

a) Clinical examination, finding above all, pain provoked by digital palpation of the coccyx, ideally with the index finger, as a pathognomonic sign of the disease.
b) Dynamic radiographs of the coccyx on lateral standing and lateral sitting.

The data of this study show a statistically significant reduction ($P < 0.001$) in pain on the VAS scale (Delta −8.03) as well as excellent results on the Macnab scale.

Coccygeal dislocation fracture is a cause of pain that is mistaken for lumbosacral pathology; it is rarely diagnosed if there is no evident history of direct trauma to the coccyx. However, many patients undergo surgery because of disc herniation or spondylolisthesis; obviously, they do not improve because the pathology is at the coccyx. Therefore, the differential diagnosis of sciatica or low back pain should include coccygeal pathology. In addition, surgeons should test for pain on digital coccygeal palpation and perform dynamic radiographs in case of doubt since, in most cases, these show the instability of the coccyx.

Coccygeal surgery significantly improves the patient's symptoms, as shown by the Macnab scale and the visual analog scale (VAS). However, the most frequent complication is infection and dehiscence of the wound. We have tried to avoid it with different incisions, transverse or parasagittal, and even so, these complications have persisted. We even think that endoscopic surgery would be a good option. Although it is a sample with few patients, this study emphasizes the clinical importance of making a correct differential diagnosis in lumbosacral and coccygeal pathology. Other authors have reported coccyx surgeries mainly in traumatic pathology or coccygectomies in tumors of the pelvis, sacrum, or metastases. Others have reported coccyx surgery to prevent or improve decubitus bed sores, but few studies make a differential diagnosis between spinal pathology and coccygeal pathology.

5. Conclusions

We suggest making a differential diagnosis of coccydynia in all patients with lumbosacral pathology. Patients improve significantly after coccygectomy, although infection and wound dehiscence are the main complications.

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Conflict of interest

We have no conflict of interest nor any financial relationship to disclose.

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