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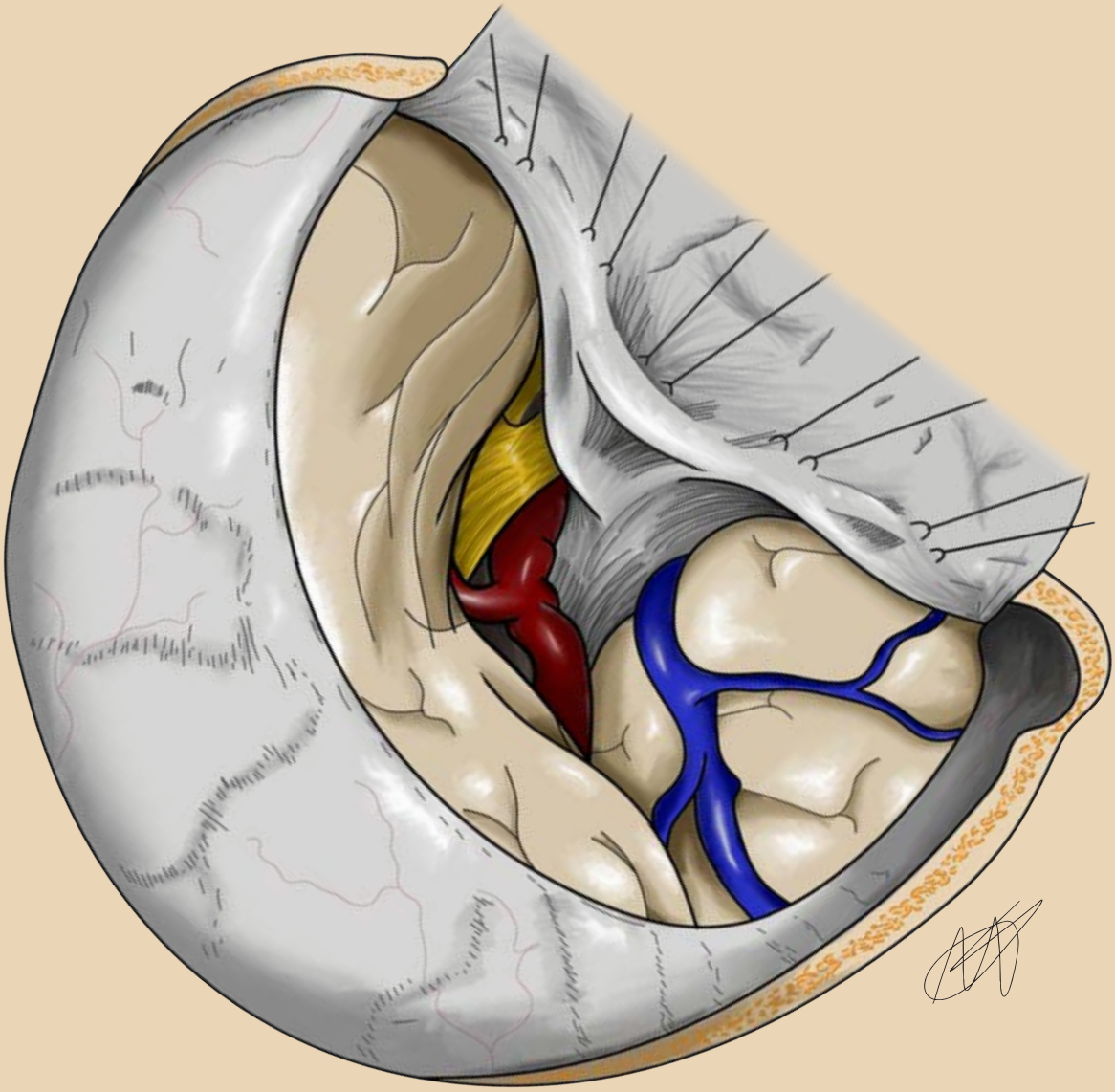

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Submissions must follow the limits and specific requirements outlined on the table below, according to their section.

Section	Abstract	Text sections	Text length	Tables & Figures	References (max)
Original article	structured not exceeding 200 words	introduction, methods, results, discussion, conclusion and references	4000 words	10	75
Review (preferably systematic review)	non-structured not exceeding 200 words	introduction, method, results, discussion, conclusion and references	4000 words	10	75
Case Report (preferably with systematic review)	non-structured not exceeding 200 words	introduction (with brief literature review), clinical case presentation, discussion, final comments and references	3500 words	8	45
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Clinical Images	non-structured not exceeding 200 words	no requirement	1500 words	5	30
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NUMBER OF AUTHORS

The number of authors should be proportional to the complexity and scientific nature of the submitted manuscript. In general, case reports and technical notes are recommended to include between 3 and 6 authors; case series between 4 and 8 authors; and original articles between 5 and 10 authors. Multicenter studies, complex prospective investigations, research involving advanced statistical analysis, innovative technologies, or multidisciplinary collaboration may justify a higher number of authors. All authors must fully meet internationally accepted authorship criteria, including substantial contribution to the conception of the study, data collection or analysis, drafting or critical revision of the manuscript, final approval of the submitted version, and full intellectual responsibility for the published content. The inclusion of authors without effective scientific contribution is strongly discouraged.

Section	Authors (max)
Original article	5-10
Review (preferably systematic review)	5-8
Case Report (preferably with systematic review)	3-6
Case series (preferably with systematic review)	4-8
Brief Note	3-5
Clinical Images	3-5
Letter to the editor	3
Multicenter studies, complex prospective investigations, research involving advanced statistical analysis, innovative technologies, or multidisciplinary collaboration	Justify more authors

INTRODUCTION

In the Introduction section we state the motivation for the work presented in the manuscript. Its contents could be:

1) context (to orient readers who are less familiar with the topic and to establish the importance of the manuscript),
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Patient's clinical data in comprehensive account of the presenting features, with medical, and social, family history, if needed are presented. All crucial investigations to the management of decisions should be discussed. Images of the case: Choose appropriate images being aware of removing any detail that can identify the patient. If relevant, describe the treatment or surgery. Outcomes and follow up are described elsewhere.

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In Materials and Methods section, the technical specifications and quantities and source or method of preparation are described. Attention to the use only scientific names of drugs; inclusion of the manufacturer in brackets when describing equipment. Discuss statistical methods if needed.

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In Results section, the results of the paper are presented in logical order, using tables and graphs as necessary. Remember that results must be presented and then explained. The results are explained showing how they help to answer the research questions (already cited in the Introduction section).

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Units of measurements should follow the primary language used (Portuguese/Spanish or English).

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Abbreviatons should follow the first mention of the term in the manuscript. The list of abbreviations is waived.

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Footnotes are used only in Tables/Boxes.

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Although the use of color is permitted, it is important that authors (or professionals hired for editing) make an effort to ensure that the use of color does not impair understanding for readers with some form of visual impairment. We recommend consulting the following resources before preparing figures or tables using colors:

How to make scientific figures accessible to readers with color-blindness (https://www.ascb.org/science-news/how-to-make-scientific-figures-accessible-to-readers-with color-blindness/) (2019, Science News,The American Society for Cell Biology).

Wong, B. Points of view: Color blindness. Nat Methods 8, 441 (2011). https://doi.org/10.1038/nmeth.1618 (https://doi.org/10.1038/nmeth.1618).

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Graphs, photographs, diagrams, illustrations, and similar content should be referred to as figures (e.g., Figure 1, Figure 2, Figures 1, 2, 5-7) in ascending order according to their appearance in the text. Authors are strongly advised to adhere to the guidelines specified in the ‘Use of Colors’ and ‘Preparation and Manipulation of Figures’ sections below, in line with the International Committee of Medical Journal Editors (ICMJE) (https://www.icmje.org/recommendations/browse/manuscript-preparation/preparing for-submission.html#i) recommendations.

When using arrows, symbols, letters, or numbers to highlight specific parts of the figures, authors must clearly describe their purpose in the corresponding figure caption. Additionally, in compliance with privacy concerns and ICMJE recommendations for the protection of research participants (https://www.icmje.org/recommendations/browse/roles-and-responsibilities/protection-of-research participants.html), images containing photographs of people must ensure that individuals cannot be identified unless their explicit permission for publication has been obtained. This ensures the protection of individual privacy and aligns with ethical standards in scholarly publication.

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RECOMMENDED MINIMUM IMAGE SIZES

Between 2500 and 5000 pixels in width: For full page width images or panels.
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When preparing your images, be careful when using filters or other types of editing to include highlights, etc. Images should not be manipulated or adjusted excessively in a way that could lead to misinterpretation of the information.

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Digital Images and Misconduct (https://www.councilscienceeditors.org/resource library/editorial-policies/white-paper-on-publication-ethics/3-4-digital-images-and misconduct/). (Council of Science Editors, White Paper on Publication Ethics).

Preparing a Manuscript for Submission to a Medical Journal > Illustrations (Figures) (http://www.icmje.org/recommendations/browse/manuscript-preparation/preparing-for submission.html#i). (International Committee of Medical Journal Editors).

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Never build tables using spaces or tabs. Tables and Boxes must be created using the text editor built-in table creation tool and follow the following guidelines:

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Captions should be explanatory, starting with the identification in bold (Table 1, Table 2, Tables 1, 2, 5-7, etc.), followed by a period and descriptive text. Explanation about acronyms or other information must be done using symbols (*, ‡, §, ǂ, #, ¢, £, etc.), letters, numbers, etc., and be inserted in the footer of the table.

Every table must include an indication of the source and citations whenever relevant, and authors are responsible for obtaining the correct authorization for use (or adaptation of data) from other sources, as appropriate, directly from the copyright owner.

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In the text, cite references in consecutive order using Arabic numerals (1,2,3...) in superscripT 1,2,3. Ensure that each citation corresponds accurately to a numbered reference in the references list (in citation order). This system allows readers to locate the source easily in the references list.

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Cover Letter: A letter introducing your manuscript, its importance, and confirming its originality. Author Statements: Ensure that all required declarations and statements are provided according to their respective policies.

Main Manuscript: The complete manuscript prepared according to the journal's formatting and structuring requirements. Note: This file MUST NOT have any author data, and MUST HAVE the titles in English/Portuguese, English/Spanish, Spanish/Portuguese

References and Citations: Ensure that all sources referenced in their work are cited accurately and formatted correctly.

Original Figures: High-resolution images (if applicable), each submitted as a separate file. Tables: Make sure your tables are editable and designed using your text editor table tool. Disclosure Forms: Completed forms disclosing any potential conflicts of interest for all authors. License Agreement: A signed agreement form from all authors, granting necessary publishing rights to the journal.

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Revision Comments File: (If submitting a revised version) A document addressing reviewers' and editors' comments from previous submission rounds.

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The title page is a critical component of your submission and should include the following information, organized clearly and in order:

Submission Type (in English): Indicate the manuscript type as per JBNc section policies. Institutional Affiliation: Provide the name of the institution where the study was conducted, including city and country.

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The cover letter should introduce your manuscript and explain its importance to the field of neurosurgery. It must include a declaration that the work is original, has not been published elsewhere, and is not under consideration by any other journal. The letter should briefly outline the major findings of your study and how they contribute to the existing knowledge. Additionally, any potential conflicts of interest or important points not covered in the manuscript or in other submission files should be disclosed. The cover letter is also an opportunity to suggest preferred or opposed reviewers and to provide any other information that may assist the editorial process.

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Contents

Original

Review

Case Report

Functional Disability Thirty Days After Stroke: a retrospective cross-sectional study in a northeastern setting

Incapacidade Funcional Trinta Dias Após Acidente Vascular Cerebral: estudo transversal retrospectivo em cenário nordestino

Fernanda Gomes de Magalhães Soares Pinheiro[1]
Daniela Andrade Lima[1]
Lucas dos Santos de Souza[1]
Eduesley Santana Santos[2]
Marcirene Santos de Mendonça[1]
Camila Farias de Rezende[2]
Adriano Souza Tavares[3]
Caio Lopes Pinheiro de Paula[3]
Carolina Santos Souza Tavares[4]

ABSTRACT

Introduction: *Functional sequelae resulting from stroke represents one of the main causes of disability worldwide, severely impacting the autonomy and quality of life of survivors.* **Objective:** *To evaluate the factors associated with functional disability of patients 30 days after an acute stroke event.* **Methods:** *This retrospective cross-sectional study analyzed 66 patient records from individuals with stroke treated at a reference public hospital in the state of Sergipe, Brazil, between August 2022 and January 2023. Data were gathered through medical chart reviews and telephone interviews. Variables included age, sex, marital status, education level, place of residence, Glasgow Coma Scale (GCS) score, modified Rankin Scale (mRS) score, and Charlson Comorbidity Index (CCI). Statistical tests comprised Shapiro-Wilk, Levene, chi-square, Fisher's exact, and Mann-Whitney, with a significant level of 5%.* **Results:** *Participants were stratified into Group 1 (G1; n=14), without functional disability, and Group 2 (G2; n=52), with functional disability. Individuals with disability were older (65.7 vs. 57 years; p=0.022), predominantly female and widowed/single (p=0.003), exhibited higher CCI scores (5.5 vs. 3.0; p<0.001), and had lower GCS scores (p=0.015).* **Conclusion:** *Functional disability was associated with older age, female sex, marital status, GCS score and comorbidities.*

Keywords: *Stroke; International classification of functioning, disability and health; Post-stroke functionality; Epidemiology*

RESUMO

Introdução: *Sequelas funcionais decorrentes do Acidente Vascular Cerebral (AVC) representam uma das principais causas de incapacidade, com impacto na autonomia e qualidade de vida dos sobreviventes.* **Objetivo:** *Avaliar os fatores associados à incapacidade funcional de pacientes 30 dias após evento agudo de AVC.* **Método:** *Estudo transversal retrospectivo, baseado em 66 registros de pacientes com AVC, atendidos em hospital público de referência no Estado de Sergipe, entre agosto de 2022 e janeiro de 2023. Os dados foram coletados por consulta de prontuários e entrevista telefônica. As variáveis incluíram idade, sexo, estado civil, escolaridade, localidade, Escala de Coma de Glasgow (ECG), Escala de Rankin modificada (mRS) e Índice de Comorbidade de Charlson (ICC). Os testes estatísticos foram Shapiro-Wilk, Levene, Qui-quadrado, Exato de Fisher e Mann-Whitney, com 5% de significância.* **Resultados:** *Os participantes foram estratificados em Grupo 1 (G1), sem incapacidade funcional (n=14), e Grupo 2 (G2), com incapacidade funcional (n=52). Indivíduos com incapacidade eram mais velhos (65,7 vs. 57 anos; p=0,022), predominantemente mulheres e viúvos/solteiros (p=0,003), com maior ICC (5,5 vs. 3,0; p<0,001) e menores escores na ECG (p=0,015).* **Conclusão:** *A incapacidade funcional foi associada à idade, sexo feminino, estado civil, pontuação na ECG, e comorbidades.*

Palavras-Chave: *Acidente vascular cerebral; Classificação internacional de funcionalidade, incapacidade e saúde; Epidemiologia*

[1]Universidade Federal de Sergipe, Lagarto, SE, Brasil.
[2]Universidade Federal de Sergipe, Aracaju, SE, Brasil.
[3]Hospital de Urgências de Sergipe, Aracaju, SE, Brasil.
[4]Laboratório de Patologia Investigativa, Aracaju, SE, Brasil.

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INTRODUCTION

Stroke is one of the main causes of morbidity, mortality and functional disability in the world, and is an acute neurological event resulting from the interruption of cerebral blood flow, either by arterial occlusion (ischemic stroke) or vascular rupture (hemorrhagic stroke)[1]. The clinical consequences of stroke go beyond the acute event, with a significant impact on functionality and quality of life, especially among the older people and individuals with multiple risk factors[2]. The severity of post-stroke neurological repercussions is associated with the presence of comorbidities such as systemic arterial hypertension, diabetes mellitus, dyslipidemia, atrial fibrillation, obesity and smoking, in addition to sociodemographic factors such as gender and advanced age[3]. Evidence indicates that approximately 30% of affected individuals develop severe functional disabilities, requiring continuous assistance for activities of daily living (ADLs)[4]. Functionality, according to the International Classification of Functioning, Disability and Health (ICF), results from the interaction between health conditions, environmental factors and personal factors[5]. In the context of stroke, the loss of functionality is directly related to motor, cognitive and sensory changes, interfering with the ability to perform ADLs autonomously[6].

Several scales have been used to measure the degree of functional impairment, with the modified Rankin Scale (mRS) widely used for its sensitivity in assessing global functional limitation and clinical prognosis[7]. Studies show that individuals with higher scores on the mRS tend to have a lower capacity for social reintegration, reduced quality of life and greater dependence on formal and informal caregivers[8,9].

Functional recovery after stroke depends, among other factors, on early intervention and adherence to multidisciplinary rehabilitation programs[10]. However, structural, geographic and socioeconomic obstacles, such as a shortage of specialized centers, logistical barriers and long queues in the health system, hinder equitable access to rehabilitation care, particularly in regions with lower service density, such as Northeastern Brazil[11,12].

Despite the relevance of the topic, there are few national studies that explore the association between sociodemographic, clinical and functional factors in the first 30 days after a stroke, especially in subnational settings such as the state of Sergipe. Understanding such associations is essential to support early interventions and rehabilitation strategies adapted to the population profile.

This study was to evaluate factors associated with functional disability in patients 30 days after an acute stroke event.

METHODS

Study design, setting and participants

This is a cross-sectional, retrospective and documentary study, derived from an umbrella project entitled "Temporal and geographic course of patients affected by stroke in hospitals in Sergipe", conducted based on the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines.

The study was carried out in a large public hospital, a reference in acute neurological care in the state of Sergipe, Brazil. Data collection covered the period between August 2022 and January 2023. Patients aged 18 years or older, with a confirmed diagnosis of stroke (ischemic or hemorrhagic), through computed tomography and clinical neurological evaluation, residing in the territory of Sergipe were included.

Cases with death prior to the monitoring interview, patients initially treated in private institutions, records in which the diagnosis of stroke was ruled out during hospitalization, and those who could not be contacted after five telephone attempts within the 30-day interval were excluded.

Ethical aspects

The study was approved by the Research Ethics Committee of Faculdade Estácio de Sergipe – Estácio Fase (CAAE: 57341822.9.0000.8079; opinion number 2,830,187), in accordance with Resolution 466/2012 of the National Health Council and the General Law on the Protection of Personal Data (Law number 13,709/2018). Since this is a retrospective documentary study, there was no requirement for an Informed Consent Form (ICF). However, the confidentiality of the data was ensured through the signing of the Commitment and Confidentiality Form by the researchers involved.

Variables, instruments and procedures

The variables included sociodemographic data (age, sex, marital status, education, place of residence), clinical data (type of stroke, need for hospitalization, type of treatment, comorbidities) and

functional data. Neurological status was assessed using the Glasgow Coma Scale (GCS), post-stroke functionality using the modified Rankin Scale (mRS), and comorbid burden using the Charlson Comorbidity Index (CCI), validated as a predictor of mortality within 10 years.

The GCS, widely used in emergency practice, scores the patient's neurological response on a scale of 3 to 15, with lower scores indicating greater neurological severity[13,14]. The mRS classifies the degree of functional dependence into seven levels, from 0 (no symptoms) to 6 (death), and is a prognostic marker validated in neurological rehabilitation studies[15]. The CCI quantifies the burden of comorbidities based on 19 clinical conditions, each weighted by its impact on mortality, with their sum correlated with clinical severity[16].

The collection was conducted by a trained team consisting of a master nurse, two nursing students and a PhD professor. The data were extracted from structured spreadsheets in Google Drive containing clinical and 30-day monitoring information, with cross-checking between reviewers and final validation by a third evaluator, with the aim of mitigating recording biases.

Statistical analysis

Statistical analyses were performed using JASP software (version 9.1.0)[17]. The distribution of continuous variables was verified by the Shapiro-Wilk test. Homogeneity of variances was assessed using the Levene test[18]. For comparison between groups (with and without functional disability), the Mann-Whitney test was used for continuous variables and the Chi-square or Fisher's exact tests for categorical variables, as appropriate[19,20]. The significance level adopted was 5% ($p < 0.05$).

RESULTS

The initial sample consisted of 91 hospital records of patients with a confirmed diagnosis of stroke. After applying the eligibility criteria, 25 records were excluded, resulting in a final sample of 66 patients.

Participants were stratified into two groups: Group 1 (G1) composed of individuals without functional disability (n = 14), and Group 2 (G2), composed of patients with functional disability (n = 52), as assessed by the modified Rankin Scale. Table 1 illustrates the patient inclusion flow.

Sociodemographic characteristics

The median age was significantly higher in G2 (65.7 years; IQR: 55.0–75.0) compared to G1 (57.0 years; IQR: 54.3–60.5; p = 0.022).

Table 1. Sociodemographic characterization of patients with and without functional disability after stroke.

Variables	Group 1 (n=14) (without disability)	Group 2 (n=52) (with disability)	p-value
Age	57.0 (54.3-60.5)	65.7 (55.0 -75.0)	**0.022**
Gender			
Male	10 (71.4)	20 (38.5)	0.057
Female	4 (28.6)	32 (61.5)	
Marital status			
Married/stable union	13 (92.9)	23 (44.2)	**0.003**
Widowed/single	1 (7.1)	29 (55.8)	
Education			
Without education	4 (28.6)	16 (30.8)	1.000
With education	10 (71.4)	36 (69.3)	
Place of residence			
Capital	8 (57.1)	22 (42.3)	0.492 I
Countryside	6 (42.9)	30 (57.7)	

A higher proportion of female patients was observed in G2 (61.5%) in contrast to G1, where males predominated (71.4%), although this difference did not reach statistical significance (p = 0.057).

Marital status differed significantly between the groups: 92.9% of patients in G1 were married or in a stable union, while in G2, widowers or singles predominated (57.7%; p = 0.003). Education level and place of residence (capital vs. countryside) did not show statistical differences between the groups, although a higher concentration of patients with disability was observed in the countryside (57.7%).

Clinical and functional characteristics

The comorbid burden, measured by the Charlson Comorbidity Index, was significantly higher in G2 (median: 5.5; IQR: 4.0–7.0) compared to G1 (median: 3.0; IQR: 2.25–3.75; p < 0.001), indicating greater clinical complexity among individuals with functional disability as seen in Table 2.

Although ischemic stroke predominated in both groups (G1: 78.6%; G2: 84.6%), this difference was not statistically significant (p = 0.599). The need for hospitalization was more frequent among patients in G2 (11.5%), while no patient in G1 required hospitalization (p = 0.082).

Regarding the type of treatment, the clinical approach was predominant in both groups, with a slightly higher proportion of thrombolysis in G1 (14.3% vs. 5.8%) and two cases of neurosurgery exclusively in G2.

In the assessment of the level of consciousness at admission, all patients in G1 had a mild score on the Glasgow Coma Scale (GCS), while in G2 there was a higher proportion of moderate (21.2%) and severe (3.8%) cases, with a statistically significant difference (p = 0.030).

Finally, functional limitation was significantly more prevalent in G2 (98.0%) compared to G1 (42.8%; p < 0.001), evidencing the functional impact of stroke in patients with greater clinical and demographic risk factors.

Table 2. Clinical and functional characteristics of patients with and without functional disability after stroke.

Variables	Group 1 (n=14) (without disability)	Grupo 2 (n=52) (with disability)	p-valor
Charlson score			
With adjustment	3.0 (2.25-3.75)	5.5 (4.0-7.0)	<0.0001
Type of stroke			
Ischemic	11 (78.6)	44 (84.6)	0.599*
Hemorrhagic	3 (21.4)	8 (15.4)	*
Hospitalization			
Yes	0	6 (11.5)	0.082
No	14 (100.0)	46 (88.5)	
Type of Treatment			
Clinical	12 (85.7)	47 (90.4)	0.445**
Thrombolysis	2 (14.3)	3 (5.8)	
Neurosurgery	0	2 (3.8)	
Glasgow Coma Scale			
Mild	14 (100.0)	39 (75.0)	0.030
Moderate	0	11 (21.2)	
Severe	0	2 (3.8)	
Functionality			
With limitation	6 (42.8)	51 (98.0)	<.001*
Without limitation	8 (57.2)	1 (2.0)	

*Fisher's exact test. *Chi-square test of independence. *Mann-Whitney U test. *Fisher's exact test (Likelihood Ratio), and Fisher's exact test (Likelihood Ratio).

DISCUSSION

The findings of this study indicate that functional disability thirty days after a stroke is strongly associated with demographic, clinical, and neurological factors. These findings corroborate the international and national literature, while also offering a relevant contribution by describing this association in a population from the Brazilian Northeast, a region frequently underrepresented in hospital-based epidemiological studies.

Advanced age was one of the most consistent predictors of functional limitation, as widely described in previous studies. Aging is associated not only with a higher prevalence of stroke, but also with worse functional outcomes due to reduced physiological reserve and the accumulated presence of chronic comorbidities[21]. The predominance of women among patients with disability is also consistent with studies that indicate a worse functional prognosis among women, especially after menopause, due to the loss of the vasoprotective effect of estrogen hormones[22]. In addition, women have specific biological and physiological factors. Changes in endogenous hormone levels, the use of exogenous hormone therapies, as well as hemodynamic and vascular changes resulting from pregnancy, the peripartum period and gestational complications, directly influence the risk of developing cerebrovascular events. These particularities give women a distinct vulnerability profile throughout the different phases of life[23]. Marital status also emerged as an important functional determinant. Married individuals or those in a stable union had lower rates of disability, which suggests that the social and emotional support offered by the spouse may have a protective effect on post-stroke recovery. Longitudinal studies indicate that patients with consistent family support have greater adherence to treatment, better engagement in rehabilitation, and lower rates of institutionalization[24,25]. Furthermore, the lack of social support may contribute to delays in seeking care, as evidenced in studies that identified a longer time between the onset of symptoms and hospital care among single individuals or those living alone[26].

Regarding comorbidity burden, patients with functional disability presented significantly higher scores on the Charlson Comorbidity Index (CCI), indicating greater clinical complexity. This association has already been described in emergency settings, in which high scores on the CCI correlate with greater clinical severity, prolonged hospitalization, and increased in-hospital mortality[27]. Specific comorbidities such as atrial fibrillation, arterial hypertension, diabetes mellitus, and structural heart disease contribute synergistically to the risk of stroke and worse functional outcomes, especially when multiple conditions coexist[28,29].

Another relevant fact concerns the geographic distribution of patients. Individuals living in the countryside of the state had a higher prevalence of functional disability. This finding may reflect inequalities in access to emergency and neuroimaging services, which are essential for early diagnosis and eligibility for therapies such as venous thrombolysis. In the context of Sergipe, studies indicate that the median time between the onset of symptoms and specialized care exceeds eight hours, exceeding the recommended therapeutic window for neuroprotective interventions[30]. The literature indicates that delay in care is among the main modifiable factors associated with greater severity of sequelae [31].

The Glasgow Coma Scale (GCS), administered at hospital admission, also proved to be a reliable indicator of functional prognosis. It was observed that patients with lower scores were more likely to have disability, a result consistent with studies that indicate an inverse correlation between the GCS and the modified Rankin Scale in post-stroke monitoring[32]. The GCS, by estimating the level of consciousness, reflects the extent of neurological injury and, consequently, the capacity for initial functional recovery.

In addition, the functionality data revealed that, even among individuals without complete functional limitation (G1), approximately 42.8% had some degree of limitation in activities of daily living. This reinforces the notion that functional recovery is a continuous process and that the absence of severe disability does not imply full social reintegration or autonomy. Studies indicate that motor, cognitive and emotional limitations persist in a considerable proportion of survivors, even months after the acute event[33,34].

Finally, it is worth highlighting that functional dependence after stroke has implications that are not only clinical, but also economic and psychosocial, directly affecting caregivers, the family network and public health systems. Early rehabilitation programs, health education and public policies aimed at equitable access to specialized care are fundamental strategies to reduce the functional impact of stroke, especially in regions with structural vulnerabilities.

CONCLUSION

This study showed that functional disability thirty days after stroke is associated with multiple interdependent factors, including advanced age, female gender, lack of marital support, greater comorbidity, worse level of consciousness at admission and residence in less urbanized areas.

These results reinforce the complexity of the functional recovery process in the subacute period after stroke and indicate the need for rehabilitation strategies that consider not only clinical aspects, but also social and contextual determinants. Early functional risk stratification, combined with the implementation of public policies that expand access to specialized care, especially in peripheral regions, is essential to mitigate the impact of short-term disability.

In addition, the findings contribute to the body of evidence on early prognostic factors in stroke and may support the design of care protocols that are more sensitive to regional and demographic inequalities.

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CORRESPONDING AUTHOR

Fernanda Gomes de Magalhães Soares Pinheiro, PhD
Associate Professor
Universidade Federal de Sergipe
Lagarto, Sergipe, Brasil.
E-mail: fernandagmsoares@gmail.com

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Extended Transforaminal Microdiscectomy with Partial Rib Resection for Thoracic Disc Herniation

Microdiscectomía Transforaminal Extendida con Resección Parcial de Costilla para Hernia Discal Torácica

Buse Sarigul[1]
Ferhat Harman[2]
Mesut Yilmaz[3]
Gonca Gül Öndüç[1]
Sedat Dalbayrak[3]

ABSTRACT

Introduction: *Thoracic disc herniation (TDH) is rare but potentially debilitating, particularly when centrally located and calcified, presenting significant surgical challenges due to spinal cord injury risk. Various approaches have limitations including restricted exposure or increased complications.* **Objective:** *To present the operative technique and clinical experience with extended transforaminal microdiscectomy (TFMD) with rib removal for median-located TDH.* **Methods:** *14 patients with midline TDH underwent extended TFMD with partial rib resection. Preoperative and postoperative (10th day, 6th month) assessments included Visual Analogue Scale (VAS), Oswestry Disability Index (ODI), and radiological measurements of segmental kyphotic and thoracic kyphosis angles (T2-T12).* **Results:** *Mean follow-up was 17.78 months. Female/male ratio 4:10; mean age 50.5 years. All TDHs were midline; 10 were calcified. Mean operative time 131.54 minutes; mean hospital stay 1.5 days. Two patients had intraoperative dural tears; one had postoperative atelectasis. VAS and ODI scores improved significantly. Kyphotic angles showed no statistically significant changes.* **Conclusion:** *Extended TFMD with rib resection is a feasible, safe technique for midline-located TDH, providing adequate surgical corridor with low neural injury risk.*

Keywords: *Thoracic disc herniation; Transforaminal microdiscectomy; Extended transforaminal approach*

RESUMEN

Introducción: *La hernia discal torácica (HDT) es rara pero potencialmente incapacitante, particularmente cuando se localiza centralmente y está calcificada, presentando desafíos quirúrgicos significativos debido al riesgo de lesión medular. Varios abordajes presentan limitaciones, incluyendo exposición restringida o aumento de complicaciones.* **Objetivo:** *Presentar la técnica operatoria y experiencia clínica con microdiscectomía transforaminal extendida (MTFE) con resección de costilla para HDT localizada medialmente.* **Método:** *14 pacientes con HDT mediana fueron sometidos a MTFE extendida con resección parcial de costilla. Las evaluaciones preoperatoria y postoperatoria (10º día, 6º mes) incluyeron Escala Visual Analógica (EVA), Índice de Discapacidad de Oswestry (ODI) y mediciones radiológicas de los ángulos cifóticos segmentarios y de la cifosis torácica (T2-T12).* **Resultados:** *Seguimiento medio de 17,78 meses. Razón femenino/masculino 4:10; edad media 50,5 años. Todas las HDT fueron medianas; 10 fueron calcificadas. Tiempo operatorio medio 131,54 minutos; estancia hospitalaria media 1,5 días. Dos pacientes presentaron desgarros durales intraoperatorios; uno tuvo atelectasia postoperatoria. Las puntuaciones EVA y ODI mejoraron significativamente. Los ángulos cifóticos no mostraron cambios estadísticamente significativos.* **Conclusión:** *MTFE extendida con resección de costilla es una técnica viable y segura para HDT localizada medialmente, proporcionando corredor quirúrgico adecuado con bajo riesgo de lesión neural.*

Palabras Clave: *Hernia discal torácica; Microdiscectomía transforaminal; Abordaje transforaminal extendido*

[1]Department of Neurosurgery, Umraniye Education and Research Hospital, Istanbul, Turkey.
[2]Department of Neurosurgery, Marmara University Hospital, Istanbul, Turkey.
[3]Department of Neurosurgery, Medicana Atasehir Hospital, Istanbul, Turkey.

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INTRODUCTION

Thoracic disc herniation (TDH) is a rare pathology which compromises 0.25-1% of all disc herniations[1]. TDHs are calcified in 30-70% of patients at presentation, and 5 to 10% of calcified TDHs have an intradural extension[1,2]. They may be median or laterally located. 37% of the TDHs are asymptomatic[3]. Stillerman et al.[2] classified TDH based on the symptoms and the response of these symptoms to surgical intervention. In their case series, the most common symptoms were back pain and myelopathy. Less common symptoms were bladder dysfunction, sensory impairment, and motor deficits.

Surgical management of TDHs pose a challenge due to the unique anatomy of the thoracic spine and the risk of neurological impairment. Surgical approach depends mostly on the disc level, disc location in the spinal canal (median, paramedian, far lateral), risk stratification of the patient and the surgeon's preference and experience[4]. The main goal of the surgery is to maintain a sufficient decompression of the neural structures while avoiding any further damage to the spinal cord[5].

Transforaminal approach to TDH is suggested to provide a safe corridor for the removal of TDHs avoiding the risk of neural injury. Both endoscopic and microscopic techniques are described. Transforaminal microdiscectomy (TFMD) was introduced as an alternative surgical treatment of median-located TDHs[6]. We have modified this technique with an addition of partial rib removal to increase the surgical exposure and ease the removal of the TDH without any retraction of the spinal cord especially when the disc is calcified. In this paper, we describe the TFMD with partial rib removal for TDHs and present the surgical outcomes of 14 patients.

MATERIALS AND METHODS

Patient evaluation

The ethical approvement for this study was obtained from Healthcare Sciences University Umraniye Education and Research Hospital Ethical Committee on December 2024. Written informed consent form was signed by all the participants. Patients diagnosed with TDH who were operated with extended TFMD with partial rib resection were included in this study. The surgery was performed for patients with a thoracic disc herniation with/without calcification, located in the midline. Informed consent was obtained from all of the patients prior to surgery. Age, gender, symptoms at admission, preoperative neurological status were recorded. MRI and the CT scan of the thoracic spine were obtained in all patients prior to surgery. CT scans were repeated on the 10th day and MRI scans were repeated on the 6th month follow-up. The intervertebral disc level, location of the disc in the spinal canal, presence of calcification, segmental kyphosis and thoracic kyphosis angles were evaluated in the radiological scans. Segmental kyphosis was measured as the angle between a line parallel to the superior endplate of the upper vertebra and a line parallel to the inferior endplate of the lower vertebra. Thoracic kyphosis was measured as the angle between a line parallel to the superior endplate of the T2 vertebra and a line parallel to the inferior endplate of the T12 vertebra. VAS and ODI scores were evaluated preoperatively, on postoperative 10th day and 6th month (Table 1).

Operative technique

The patient is intubated under general anesthesia and given a prone position after neuromonitoring probes are inserted. Motor evoked potentials (MEP) and somatosensory evoked potentials (SSEP) are monitored throughout the surgery. After sterile cleansing and covering of the surgical site, an anteroposterior fluoroscopy is obtained to locate the level of the pathology. The skin is cut either in a L-shaped or linear incision 3-4 cm lateral to the midline, depending on the anatomical ease of visualization, from the side with the symptom, laterality or spinal cord compression dominancy. The subcutaneous tissues are dissected to reach the rib to be cut. 5-6 cm of the rib was cut with a rib shear and removed to expose the facet joint (Figure 1). The superior articular process of the facet joint is drilled for exposure of the nerve root cranially, the pedicle caudally, and the spinal cord and the disc space medially. The dorsal parts of the inferior end plate

Table 1. Preoperative and postoperative VAS and ODI scores of the patients.

	VAS Score	ODI score
Preoperative	7.42±2.20	46.15±2.51
Postop 10th day	2.11±2.91	31.39±3.61
Postop 6th month	1.25±2.15	13.50±1.48

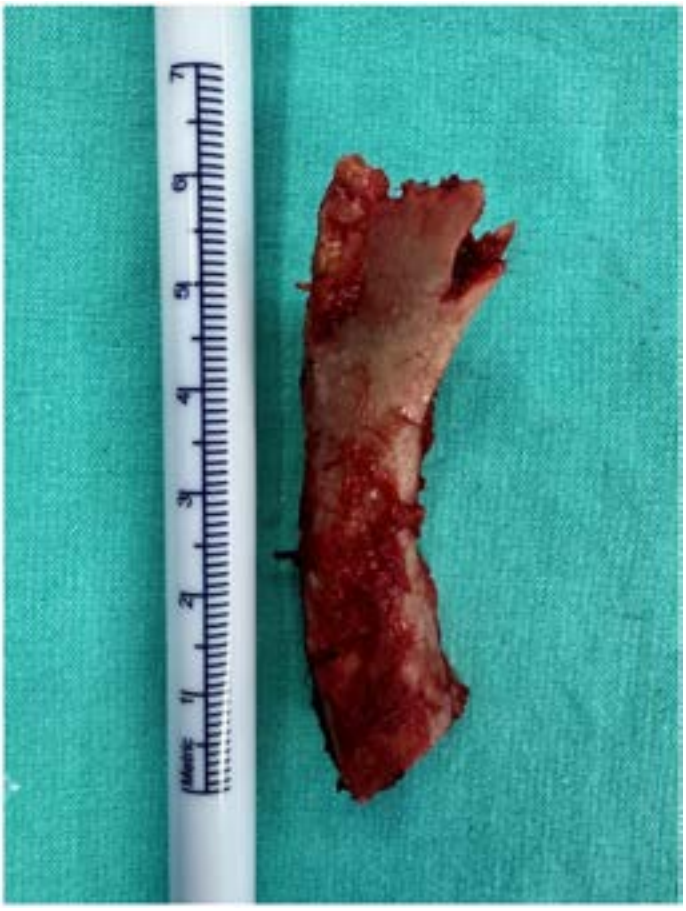

Figure 1. Partial rib removal. The rib is cut 5-6 cm lateral to the costotransverse joint and dissected from the surrounding tissues to increase the surgical exposure.

of the superior vertebral body and the superior end plate of the inferior vertebral body adjacent to the disc are also removed for safe removal of the herniated disc. The intervertebral disk space is cut with a blade and the TDH is removed with a pituitary rongeur in soft, non-calcified discs. A drill is used for removing the calcified portion of TDHs. Hemostasis is performed in the surgical site via Surgicel®. The remaining portion of the facet joint is decorticated and the extracted costal bone is placed vertically lateral to the facet joint for fusion. The layers are closed anatomically.

Statistical analysis

Statistical analysis was performed via SPSS 17.0 program for Windows. The mean and standard deviations of all the data were calculated. A student T-test was utilized for comparing the preoperative and postoperative clinical and radiological parameters.

RESULTS

Fourteen patients underwent TFMD with partial rib removal between June 2020 and February 2024 (Table 2). The average age of the patients was 50.5 (range: 37-68). 10 patients were male and 4 were female. The mean follow-up was 17.78 months (range:7-38 months). The most prominent symptom at admission was axial pain, 3 patients had bilateral paraparesis and 1 patient had monoparesis in neurological examination. The most common levels of TDH were T10-11 (6/14), followed by T9-10 (3/14), T7-8 (3/14) and T8-9 (2/14). All of the TDHs were median located and the herniation was calcified in 10 of them. None of the TDHs had intradural extension.

The mean operation duration was 131.54 minutes. The mean length of stay in hospital was 1.5 days (range:1-3). During the surgery, two patients (patient #3 and 13) had a dural tear. In both patients, the tear was sutured primarily and a fibrin glue was used. Patients did not have a postoperative fistula and cerebrospinal fluid leak. Another patient (patient #6) had mild dyspnea on postoperative day 1. An anteroposterior chest X-ray was performed and mild pulmonary atelectasis was observed in the left lung. The patient was well after medical treatment.

The clinical scores improved in all the patients postoperatively. The mean VAS and ODI scores were 7.42±2.20 and 46.15±2.51 preoperatively, respectively. Postoperative 10th day VAS and ODI scores were 2.11±2.91($p<0.05$) and 31.39±3.61 ($p<0.05$) respectively. On postoperative 6th month, the VAS score was 1.25±2.15 ($p<0.05$) and ODI score was 13.50±1.48 ($p<0.05$). The difference between preoperative and postoperative segmental kyphotic angle and thoracic kyphosis angle were statistically insignificant (Table 3).

Illustrative Case #1

A 37-year old male patient admitted with back pain (VAS 6/10) and weakness, numbness and stiffness in both legs for 3 months. Neurological examination revealed paraparesis with muscle strength of 3/5 in the left leg and 4/5 in the right leg. The deep tendon reflexes were hyperactive and Babinski sign was unresponsive bilaterally. The spinal MRI scan revealed a calcified, median located TDH at the T8-T9 vertebral segment with significant compression of the spinal

Table 2. The demographic information of the patients included in the study.

	Age/ gender	Symptom	Neurological status	TDH level	Calcification	Peroperative complication	Additional notes
1	37M	back pain, weakness in legs	Bilateral paraparesis	T8-9	+	-	
2	53M	Axial pain	N/A	T9-10	+	-	Pathology revealed tumoral calcinosis
3	59F	Axial pain, numbness in legs	N/A	T7-8	+	Dural tear	
4	49M	Axial pain	N/A	T10-11	-	-	
5	36M	muscle weakness in legs, difficulty walking	Bilateral paraparesis	T9-10	+	-	
6	63M	Numbness in left leg	N/A	T7-8	+	Pulmonary contusion	
7	49M	Axial pain	N/A	T10-11	-	-	
8	38F	Axial pain, difficulty walking	N/A	T10-11	+	-	
9	61F	Difficulty walking, numbness in legs	Bilateral paraparesis	T7-8	+	-	
10	59M	Axial pain	N/A	T10-11	-	-	
11	33M	Axial pain	N/A	T9-10	-	-	
12	48M	weakness & numbness in left leg	Paresis in left leg	T10-11	+	-	
13	68M	Axial pain, difficulty walking	N/A	T8-9	+	Dural tear	
14	54F	Axial pain	N/A	T10-11	+	-	

N/A: not applied

Table 3. Preoperative and postoperative segmental and kyphotic angles and thoracic kyphosis angles.

	Segmental kyphosis	Thoracic kyphosis
Preoperative	9.14±4.23	42.63±7.19
Postop 6th month	9.88±5.17	43.51±5.30

cord. Preoperative segmental kyphosis was 12.10^0 and the thoracal kyphosis was 45.29^0.

The patient underwent an extended TFMD with partial rib resection from the right side. The surgical images are presented in Figure 2. Neuromonitoring showed improvement in MEP and SEP signals after the removal of the disc. The patient was immobilized on 24th hour with a thoracolumbar brace and discharged. There were no complications. He underwent physical therapy postoperatively and had no neurological deficits on the 12th month follow-up. The segmental kyphotic angle was 10.55^0 and the thoracic kyphosis was 44.05^0 on 6th month follow-up.

Illustrative Case #2

A 53-year old male patient admitted with a complaint of pain on the right side of his back for 6 months. He had no neurological impairment. A calcified median located lesion was observed dorsal to the T9-T10 intervertebral disc space causing significant compression of the spinal canal (Figure 3). The preoperative segmental kyphosis was 7.6^0 and thoracic kyphosis was 43.9^0.

The patient underwent an extended TFMD with partial rib resection from the right side. However, as the disc space was exposed, a soft

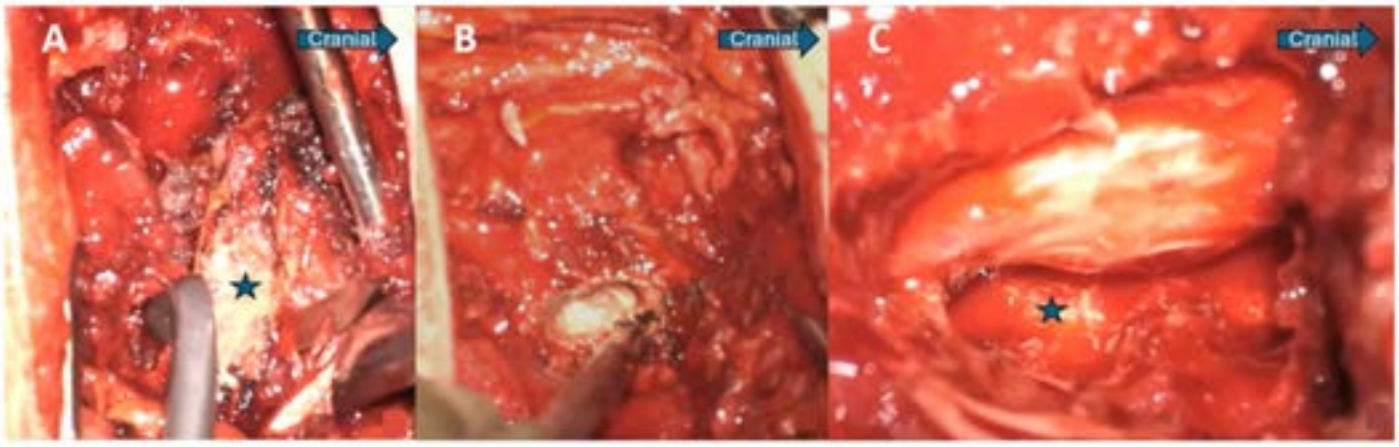

Figure 2. Intraoperative images from the operation of patient #2. **A.** The rib was cut 5-6 cm lateral to the costovertebral joint with a rib shear after dissecting from the pleura. The star depicts the removed rib. **B.** Following the removal of the rib, the lateral face of the facet joint is removed with a high-speed drill. **C.** The intervertebral disc is exposed. Borders are the spinal cord superiorly, the nerve root cranially, the pedicle caudally. The star depicts the disc space.

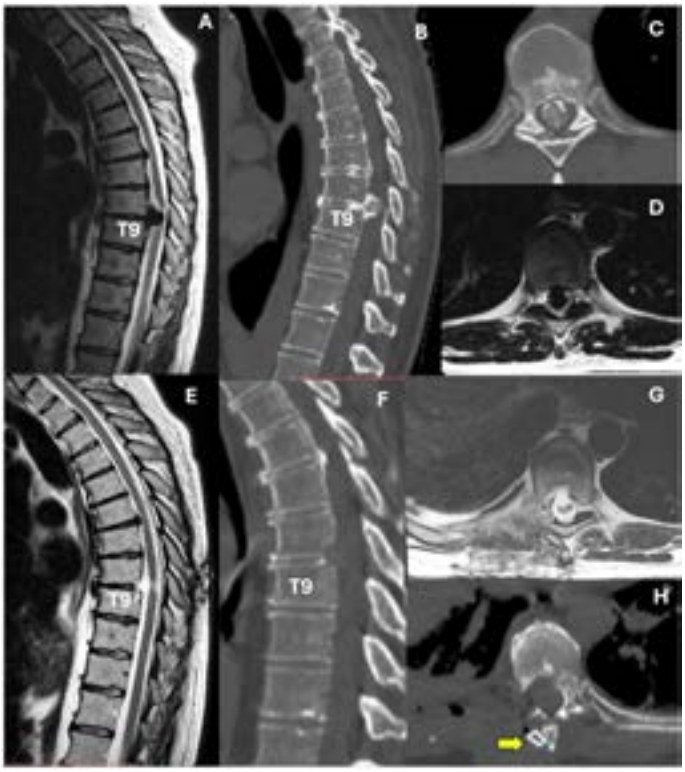

Figure 3. A-H. Preoperative and postoperative MRI and CT scans of Patient #1. The yellow arrow depicts the removed bone replaced dorsal to the facet for fusion.

and yellow-colored lesion was observed. The lesion was removed and the spinal cord was decompressed. The histopathological examination of the lesion revealed a tumoral calcinosis. The patient did not have any perioperative complications. The segmental kyphotic angle was 6.8^0 and the thoracal kyphosis angle was 43.6^0 on 6th month follow-up (Figure 4).

DISCUSSION

TDHs are rare, however, may cause significant neurological impairment. The anatomical and biomechanical structure of the thoracic spine makes the surgical treatment of this pathology challenging, therefore, many surgical approaches including transthoracic approaches[7], costotransversectomy[8], lateral extracavitary approach[9], transpedicular and transfacet pedicle-sparing approaches[10,11], thoracoscopic approach[12], endoscopic and microscopic transforaminal approaches[6] have been defined[3]. The most important factor to be considered when choosing the surgical approach is to minimize spinal cord retraction, thus avoid neurological impairment[13]. Posterolateral approaches may be preferred for paracentral or lateral disc herniations, while anterolateral approaches are suggested for central located TDHs in general for better surgical exposure and avoiding neurological damage. TFMD with partial rib resection also provides a good visualization of the disc herniation without any spinal cord retraction. The angle of the microscope is positioned oblique to be nearly parallel to the disc space and the disc space is directly visualized after drilling of the facet partially.

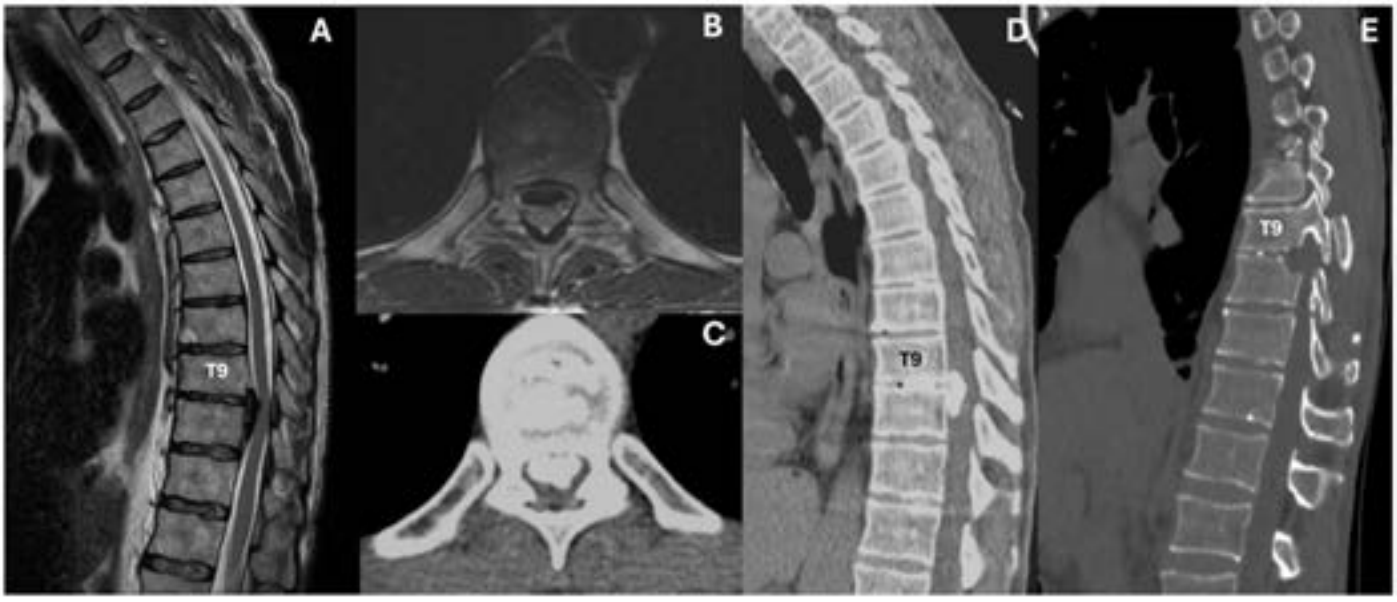

Figure 4. A-E. Preoperative and postoperative MRI and CT scans of Patient #2.

Anterior approaches provide an adequate ventral exposure of the spinal cord and creates a safe surgical corridor. Even though anterior and anterolateral approaches are suggested for central located median disc herniations, the pulmonary complications associated with these techniques are high. Thoracoscopy and mini-open thoracotomy have been suggested as minimal invasive approaches, however, the complication rates are not reduced with these techniques[14]. The most common pulmonary complications are atelectasis, pneumonia, pleural effusion and pulmonary embolism. Fessler et al.[15] reported pleural effusion by CSF-pleural fistula following transthoracic discectomy. In our technique we cut the rib approximately 5-6 cm lateral to the disc space and dissected the soft tissue surrounding the costotransverse joint to open a surgical corridor through the Cambin triangle. We did not use a double lumen intubation tube in any of our patients. 2 patients had minimal asymptomatic contusions postoperatively, which improved in an average of 3 days with medical treatment.

Costotransversectomy with various modifications have been used in the surgical treatment of TDH. Most of these approaches were described for the removal of a lateral located herniation and consisted of ipsilateral hemilaminectomy/hemilaminotomy and facetectomy. This technique was initially described for obtaining an oblique exposure to the vertebral body of the thoracic spine[16,17] and modified in various studies for pathologies of the spinal canal including a cause of trauma, disc herniation and tumor[18-20]. Hamburger et al.[21] described a costotransversectomy technique including the removal of hemilamina, facet joint and a portion of the pedicle down to the level of the posterior longitudinal ligament. In the technique that we are describing, a lateral transforaminal approach is adopted to reach the ventral spinal cord without removal of the lamina. The pedicle and the facet joint are drilled laterally to obtain a safe corridor. Moreover, as the final exposure provides an oblique view after rib resection, the median part of the spinal canal may be safely reached.

Calcification of TDHs is not an uncommon entity, moreover, calcified discs may be associated with intradural extension which may lead to postoperative CSF fistula[13]. Ayhan et al.[22] performed a transthoracic approach for centrally located calcified discs in 27 patients. Stabilization was performed in all cases and improvement of myelopathy symptoms were observed in 90% of the patients. Oltulu et al.[4] compared the complications in anterior and posterior approaches for TDHs and found a lower rate of neurological injury for calcified central TDH with anterior approach. The overall major complication rate was also higher with the posterior group (33% for posterior, 5.9% for anterior), and minor complication rate was high in the anterior group (38.2% for anterior, 22.2% for posterior)[4]. All of the patients in our series had a calcified disc herniation located in the midline, and none of them had an intradural extension. After exposure of the surgical site is completed, even though the disc bulging may be palpated with a dissector we performed another fluoroscopy for confirmation of the disc space. We utilized a high-speed drill

to remove the calcified portion of the herniation and also used pituitary rongeurs when applicable.

Transforaminal approach is also a feasible technique in endoscopic surgery for TDHs. Sheikh et al.[3] performed endoscopic minimal invasive microdiscectomy in central located soft discs and lateral-located discs. They suggested that this technique avoids significant muscle and ligament dissection, minimizes retraction of anatomical structures, reduces the extent of bone resection, minimizes blood loss and avoids iatrogenic instability[3]. However, they suggested performing a thoracoscopic approach for centrally located calcified discs. Choi et al.[23] reported on 14 patients that underwent transforaminal endoscopic thoracic microdiscectomy with sedation and local anesthesia and reported significant improvement in VAS and ODI scores. In another study, 92 patients were operated via transforaminal endoscopic thoracic microdiscectomy for symptomatic soft TDH. The mean follow-up was 38.4 months and the patients showed improvement in VAS and ODI scores. The reported complications were transient motor deficit, lower extremity paresthesia and symptomatic recurrent herniation[24]. Transforaminal approach provides a direct approach to the intervertebral disc space without spinal cord retraction. For this reason, it may be used easily in central located disc herniations. Even though endoscopy avoids significant muscle dissection, microscopic approach has the advantage of 3D visualization of the surgical site.

There are several limitations to our study. This is a retrospective study consisting of only 14 patients, further studies with larger patient groups are necessary to evaluate the short and long term outcomes of the technique more accurately. Secondly, the surgical management of TDHs is very challenging and advanced recognition of the anatomy of this area, especially the paraspinal region, is fundamental when performing this technique. In our opinion, this technique is very feasible in centrally located calcified discs with a wide exposure of the surgical site, thus reduction of the neurological injury risk.

CONCLUSION

TFMD combined with partial rib resection provides a wide and safe surgical corridor for reaching centrally located calcified and non-calcified discs. This technique allows for a surgical exposure nearly as much as an anterolateral approach, moreover, does not carry the high risk of pulmonary complications. The clinical and radiological outcomes of patients who underwent TFMD with partial rib resection are favorable at 6 months follow-up.

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CORRESPONDING AUTHOR

Buse Sarigul, MD, Neurosurgeon
Umraniye Education and Research Hospital
Department of Neurosurgery
Istanbul, Turkey
E-mail: busesarigul90@hotmail.com

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CRediT

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CURITIBA | PR

Factors Associated with Clinical Outcomes in Patients Undergoing Elective and Emergency Neurosurgery for Tumor Resection

Fatores Associados com o Desfecho Clínico de Pacientes Submetidos a Neurocirurgia Eletiva e de Emergência para Ressecção Tumoral

Alex Seabra[1]
Camille Giordana Riva[2]
Eduarda Antonelli do Carmo[3]
Gabriella Frattari de Araújo Rondon Borges[4]
Rosa Maria Elias[5]

ABSTRACT

Introduction: *Brain tumor neurosurgery has high morbidity and mortality, especially in emergencies. Factors linked to outcomes remain poorly described in real-world settings.* **Objectives:** *To assess associations between sociodemographic/clinical factors and outcomes in elective and emergency brain tumor neurosurgery.* **Methods:** *Cross-sectional study using DATASUS/SIH-SUS data (2013-2022). Statistical analysis included Mantel-Haenszel chi-square, PR and 95% CI.* **Results:** *Among 138 hospitalizations, most were emergencies. Stays >10 days were associated with higher mortality (PR=4.7; p=0.0049).* **Conclusion:** *Longer hospitalization increased mortality risk after brain tumor neurosurgery. Optimizing perioperative care may improve outcomes.*

Keywords: *Neurosurgery; Epidemiology; Outcome assessment, health care*

RESUMO

Introdução: *A neurocirurgia de tumores cerebrais apresenta elevada morbidade e mortalidade, especialmente em situações de emergência. Os fatores associados aos desfechos permanecem pouco descritos em cenários do mundo real.* **Objetivos:** *Avaliar as associações entre fatores sociodemográficos/clínicos e desfechos na neurocirurgia de tumores cerebrais eletiva e de emergência. Métodos: Estudo transversal utilizando dados do DATASUS/SIH-SUS (2013-2022). A análise estatística incluiu qui-quadrado de Mantel-Haenszel, razão de prevalência e intervalo de confiança de 95%.* **Resultados:** *Entre 138 internações, a maioria foi de emergência. Internações superiores a 10 dias associaram-se a maior mortalidade (RP=4,7; p=0,0049).* **Conclusão:** *O prolongamento da hospitalização aumentou o risco de mortalidade após neurocirurgia de tumores cerebrais. A otimização do cuidado perioperatório pode melhorar os desfechos.*

Palavras-Chave: *Neurocirurgia; Epidemiologia; Avaliação de desfechos em saúde*

[1]Faculdade de Medicina, UNIC Beira Rio, Cuiabá, MT, Brazil.

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INTRODUCTION

The incidence of central nervous system (CNS) neoplasms has been progressively increasing worldwide, with an estimated 175,000 new cases annually. In Brazil, primary brain tumors represent the seventh leading cause of cancer-related death, with approximately 11,000 new cases expected between 2020 and 2022. In the state of Mato Grosso, an estimated 140 new cases were reported in 2020[1,2].

Risk factors associated with CNS tumors include age, sex, exposure to ionizing radiation, and genetic predisposition. The management of these tumors is multidisciplinary and depends on histological type, size, and anatomical location, involving surgical resection, radiotherapy, chemotherapy, and targeted therapies [3,4,5].

The epidemiological profile of patients undergoing neurosurgical procedures for brain tumor resection is influenced by regional and healthcare system characteristics. Primary tumors are more frequently observed in adults aged 40 to 64 years, while secondary tumors are more prevalent among older individuals. Among primary tumors, gliomas, meningiomas, and pituitary adenomas are the most common, whereas metastases from lung, breast, and melanoma represent the main secondary lesions[3,4,5].

Neurosurgical procedures in neuro-oncology are associated with a substantial risk of both neurological and systemic complications, even in elective settings [6,7]. Emergency procedures and prolonged hospitalizations may further increase morbidity and mortality. Postoperative neurological complications include decreased level of consciousness, intracranial hemorrhage, hemiparesis, seizures, and the need for reoperation [8,9]. Additionally, systemic complications such as respiratory failure, infections, and hemodynamic instability may contribute to worse clinical outcomes.

Despite the clinical relevance of these factors, data on determinants of outcomes in patients undergoing neurosurgery for brain tumor resection, particularly in real-world settings using population-based data, remain limited.

Therefore, this study aimed to evaluate the association between sociodemographic and clinical factors and outcomes in patients undergoing elective and emergency neurosurgery for brain tumor resection.

METHODS

This was an observational, analytical, cross-sectional study using secondary data from the Hospital Information System of the Brazilian Unified Health System (SIH/SUS), accessed via the DwWeb platform of the Mato Grosso State Health Department (SES-MT).

The study population included patients of all age groups who underwent neurosurgical procedures for malignant brain neoplasms (ICD-10 code C71) between 2013 and 2022. Records with incomplete or missing data for key variables were excluded from the analysis.

Variables were categorized into three groups: sociodemographic (sex, age group, and place of residence), healthcare-related variables (type of care—public or private—and nature of admission—elective or emergency), and clinical variables (length of hospital stay, need for intensive care unit admission, and outcome—discharge, ongoing hospitalization, or death).

As the data were publicly available and anonymized, ethical approval was waived in accordance with Resolution No. 510/2016.

Statistical analysis was performed using Epi Info version 7.2 (Centers for Disease Control and Prevention, Atlanta, USA). Associations between independent variables and mortality were assessed using the Mantel-Haenszel chi-square test. Prevalence ratios (PR) and their respective 95% confidence intervals (95% CI) were calculated. A two-sided p-value <0.05 was considered statistically significant.

RESULTS

A total of 138 hospitalizations were included in the analysis. Most patients were male (55.1%) and aged ≥50 years (66.7%). Intermunicipal transfer occurred in the majority of cases (71%).

Regarding healthcare characteristics, most procedures were performed in the private sector (98.6%) and were classified as emergency admissions (72.5%). Elective procedures accounted for 27.5% of cases.

Table 1. Distribution of deaths and non-deaths with selected variables.

Variables	Total (n=138)	Death (n=13)	No Death (n=125)
Sex – Male	76 (55.1)	9 (69.2)	67 (53.6)
Sex – Female	62 (44.9)	4 (30.8)	58 (46.4)
Age 18-49	39 (33.3)	2 (15.4)	45 (36.0)
Age ≥50	78 (66.7)	11 (84.6)	80 (64.0)
Residence – Cuiabá	37	4 (30.8)	33 (26.4)
Residence – Country side	—	9 (69.2)	92 (73.6)
Regime – Private	136 (98.6)	13 (100)	123 (98.4)
Regime – Public	2 (1.4)	0	2 (1.6)
Character – Emergency	100 (72.5)	5 (38.5)	33 (26.4)
Character – Elective	38 (27.5)	8 (61.5)	92 (73.6)
Length of stay <10 days	93 (67.4)	4 (30.8)	89 (71.2)
Length of stay ≥10 days	45 (32.6)	9 (69.2)	36 (28.8)
ICU – Yes	124 (89.9)	12 (92.3)	112 (89.6)
ICU – No	14 (10.1)	1 (7.7)	12 (10.4)

Table 2. Bivariate analysis of mortality according to length of stay and ICU requirement.

Characteristics	Death	No Death	PR	95% CI	p-value
Length of stay ≥10 days	9 (20.0)	36 (80.0)	4.65	1.51-14.2	0.003
Length of stay <10 days	4 (4.3)	89 (95.7)	1	-	-
ICU – Yes	12 (9.68)	112 (90.32)	1.35	0.19-9.65	0.7591
ICU – No	1 (7.14)	13 (92.86)	1	-	-

The majority of hospitalizations lasted less than 10 days (67.4%), and most patients required admission to the intensive care unit (89.9%). The overall mortality rate was 9.4% (13/138).

In the bivariate analysis, hospital stay ≥10 days was significantly associated with increased mortality (PR=4.65; 95% CI: 1.51-14.2; p=0.003). In contrast, ICU admission was not significantly associated with mortality (PR=1.35; 95% CI: 0.19-6.65; p=0.759).

No statistically significant associations were observed between mortality and sex, age group, residence, or type of admission (Table 1).

Hospital stays of 10 days or more were associated with a mortality rate of 30.8%. Mortality was higher among men (69.2%) compared to women (30.8%). Patients from rural areas had slightly higher mortality than those from Cuiabá, suggesting that proximity to healthcare services may improve outcomes. ICU admission was frequent among patients who died; however, this variable was not statistically associated with mortality (Table 2).

DISCUSSION

This study evaluated factors associated with mortality in patients undergoing neurosurgery for brain tumor resection. The main finding was that hospital stay ≥10 days was significantly associated with increased mortality. In contrast, no statistically significant associations were observed between mortality and sociodemographic variables, ICU admission, or type of admission.

The association between prolonged hospital stay and increased mortality should be interpreted with caution. This finding may be influenced by reverse causality, as patients with greater clinical severity are more likely to require extended hospitalization and are inherently at higher risk of death. Therefore, length of stay may act as a proxy marker of disease severity rather than an independent risk factor.

Although not statistically significant, higher mortality was observed among male patients and those aged ≥50 years, which is consistent with previous studies suggesting increased vulnerability in these groups. Similarly, patients from outside the capital showed higher mortality proportions, possibly reflecting disparities in access to specialized healthcare services and delays in treatment [10,11].

Emergency procedures were more frequent in the sample and showed a higher proportion of deaths compared to elective surgeries, which is consistent with the literature indicating that urgent interventions are often associated with worse clinical conditions and increased perioperative risk [10,11]. However, this association was not statistically significant in the present study.

Neurosurgical procedures for brain tumors are known to be associated with a high risk of complications. Previous studies have reported postoperative neurological complications such as cerebral edema, hemorrhage, seizures, and the need for reoperation, as well as systemic complications including infections and respiratory failure. These factors may contribute to increased morbidity and mortality, particularly in more severe cases [6,7,8,9].

This study has limitations inherent to the use of secondary data, including potential underreporting and lack of detailed clinical information, such as tumor histology, staging, and severity at admission. Additionally, the cross-sectional design limits the ability to establish causal relationships between variables and outcomes.

CONCLUSION

Clinical outcomes in patients undergoing neurosurgery for brain tumor resection were mainly associated with length of hospital stay. Prolonged hospitalization (≥10 days) was significantly associated with increased mortality, likely reflecting greater clinical severity.

No statistically significant associations were observed between mortality and sociodemographic variables, ICU admission, or type of admission.

These findings highlight the importance of optimizing perioperative care and early clinical management to potentially reduce adverse outcomes.

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CORRESPONDING AUTHOR

Gabriella Frattari de Araújo Rondon Borges, MS
Medical student
UNIC Beira Rio
Faculdade de Medicina
Cuiabá, Mato Grosso, Brazil
E-mail: gabriellafrattari@gmail.com

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Development and Internal Validation of a Clinical Prediction Model for In-hospital Mortality in Pediatric Neurosurgery Patients: a retrospective cohort study

Desenvolvimento e Validação Interna de um Modelo de Predição Clínica para Mortalidade Intra-hospitalar em Pacientes Pediátricos de Neurocirurgia: um estudo de coorte retrospectivo

Gabriela Teodora de Souza Sanches[1]
Renato Leite Barros Filho[1]
Cintia Horta Rezende[2]

ABSTRACT

Introduction: *Pediatric neurosurgery patients represent a highly vulnerable population with significant mortality risks, particularly in resource-constrained environments lacking tailored prognostic tools.* **Objective:** *To develop and internally validate a clinical prediction model for in-hospital mortality in pediatric neurosurgical patients at a major Brazilian trauma center.* **Methods:** *A retrospective cohort study was conducted with 188 pediatric patients undergoing cranial neurosurgery at Hospital João XXIII between January 2020 and June 2025. Predictor variables significantly associated with mortality ($p < 0.05$) were included in a discriminant analysis. Model performance was thoroughly evaluated using accuracy, sensitivity, specificity, and the area under the receiver operating characteristic curve (AUC-ROC).* **Results:** *Lower Glasgow Coma Scale scores at admission, thoracic trauma, abdominal trauma, and congenital etiology were significantly associated with mortality. The developed model achieved 93.1% accuracy and 97.0% specificity, demonstrating excellent discriminatory ability (AUC = 0.910; 95% CI: 0.846–0.975; $p < 0.001$).* **Conclusion:** *The model shows robust discriminatory power for predicting mortality in pediatric neurosurgery. While high specificity reliably identifies low-risk patients, its lower sensitivity highlights the need for further refinement and external validation before widespread clinical implementation.*

Keywords: *Hospital mortality; Predictive learning models; Neurosurgery*

RESUMO

Introdução: *Pacientes pediátricos submetidos a procedimentos neurocirúrgicos representam uma população vulnerável com riscos significativos de mortalidade, sobretudo em cenários com recursos limitados e escassez de ferramentas prognósticas estruturadas.* **Objetivo:** *Desenvolver e validar internamente um modelo de predição clínica para mortalidade hospitalar em pacientes pediátricos de neurocirurgia em um grande centro de trauma brasileiro.* **Métodos:** *Estudo de coorte retrospectivo analisando 188 pacientes pediátricos submetidos a neurocirurgia craniana no Hospital João XXIII (janeiro de 2020 a junho de 2025). Variáveis preditoras associadas estatisticamente à mortalidade ($p < 0,05$) foram selecionadas para análise discriminante. O desempenho estatístico foi avaliado por meio de acurácia, sensibilidade, especificidade e AUC-ROC.* **Resultados:** *Escala de Coma de Glasgow reduzida na admissão, trauma torácico, trauma abdominal e etiologia congênita correlacionaram-se significativamente com o desfecho de óbito. O modelo preditivo alcançou acurácia de 93,1% e especificidade de 97,0%, exibindo excelente capacidade discriminatória (AUC = 0,910; IC 95%: 0,846–0,975; $p < 0,001$).* **Conclusão:** *O modelo demonstra excelente poder discriminatório para predição de mortalidade em neurocirurgia pediátrica. A elevada especificidade confere confiabilidade na identificação de pacientes de baixo risco; todavia, a sensibilidade limitada demanda refinamento e validação externa antes de sua incorporação definitiva na prática clínica.*

Palavras-Chave: *Mortalidade hospitalar; Modelos de aprendizagem Preditiva; Neurocirurgia*

[1]Universidade Federal de Minas Gerais – UFMG, Belo Horizonte, MG, Brazil.
[2]Hospital João XXIII, Fundação Hospitalar do Estado de Minas Gerais – FHEMIG, Belo Horizonte, MG, Brazil.

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INTRODUCTION

It is well established in literature the high risks suffered by patients who undergo pediatric surgery, who face life-threatening conditions requiring urgent care and may have significant comorbidities, such as prematurity. On a fairly regular basis, particular issues related to communication, vascular access, sedation, complications due to cerebrospinal fluid diversion and brain tumors present themselves as comorbidities and are magnified even more in the context of neurosurgical procedures[1-5]. A prospective, two-year study at the Hospital for Sick Children in Toronto analyzed 1082 consecutive pediatric neurosurgical procedures. The research, led by Drake et al.[6], found that 16.4% of these procedures resulted in a complication. Highlighting the severity of these outcomes, the study further revealed that 64% of these adverse events required a repeat surgical intervention.

Even though the pediatric population represents a uniquely vulnerable group, primarily because their nervous systems are still in a critical phase of development, a significant gap persists in the clinical research on their specific outcomes[7]. This underrepresentation in scientific literature is aggravated in developing countries, such as Brazil[8]. The intersection of this vulnerable pediatric patient population and a resource-constrained environment underscores a critical challenge, which leaves surgeons with an insufficient evidence base to guide their priorities in medical care, especially to the most delicate patients[9,10]. Addressing this disparity becomes a moral imperative, in order to assure a step closer to global health equity.

Initiatives addressing this gap are therefore of fundamental importance. Predictive models become in this context a great strategy to guide clinical decision-making and help physicians prioritize care. Despite prognostic predictions based on medical records being widely used across medicine[11,12], their application in pediatric neurosurgery[13] remains neglected. This disparity is acutely worsened in low-income countries, which suffer from a scarcity of validated assessment tools[14,15]. A comprehensive study by the Global Neurosurgery Initiative found that although low- and middle-income countries account for 82% of the neurosurgical disease volume, only 56% of the world's neurosurgeons are distributed in these regions[13]. This workforce overload amounts to justify the development of simple, clinical data-based predictive models to assist physicians in triage and efficient decision-making and better direct the medical care in this scenario.

Therefore, the main goal of this retrospective study was to develop and internally validate a clinical predictive model of intra-hospital mortality in pediatric patients who underwent neurosurgical treatment on a reference unit.

METHOD

Study design and population

A retrospective cohort study was conducted at Hospital João XXIII, a major trauma and tertiary care reference center. The study was based on the analysis of electronic medical records of all pediatric patients who underwent neurosurgical treatment between January 2020 and June 2025. This study was approved by the Research Ethics Committee of the Fundação Hospitalar do Estado de Minas Gerais (FHEMIG) under opinion number 7.523.445 (CAAE: 87862325.5.0000.5119). A waiver for the Informed Consent Form was granted as the study involves the retrospective analysis of existing medical records.

Data collection and variables

This study utilized data collected retrospectively from the hospital's electronic medical records. Predictor variables were selected based on their established clinical relevance for prognostication in neurosurgery. The primary outcome variable was in-hospital mortality, defined as death from any cause during the hospitalization period.

Inclusion and exclusion criteria were applied during data collection. The inclusion criterion was age under 19 years at the time of the neurosurgical procedure. Exclusion criteria were: (1) procedures exclusively involving spinal neurosurgery, to ensure a homogeneous study population, as cranial pathologies present distinct risk factors and outcomes that could confound the predictive model; and (2) patients with incomplete medical records for the primary outcome or key predictor variables.

The collected data included: demographic information (age, sex); admission details (etiology, date of admission, surgical timing); clinical assessments (GSC scores at admission and discharge, preoperative computed tomography [CT] scan findings); interventions (specific surgical procedures, use of intracranial pressure [ICP] monitoring); and outcomes (length of ICU stay,

complications). A complete list and detailed description of all variables collected is available in the Supplementary Material (Table 1).

Statistical analysis

The initial dataset extracted from electronic medical records (EMRs) consisted of raw, unstructured medical reviews for key variables, including mechanism of injury, surgical procedures, and associated traumas. These fields contained a high degree of variability in terminology, spelling, and level of detail, making them unsuitable for direct statistical analysis. To create a standardized and analyzable dataset, a systematic variable engineering protocol was developed and applied.

First, the raw free-text entries were manually reviewed and systematically grouped into standardized, mutually exclusive categories based on their clinical definitions. This process was applied as follows:

- For Mechanism of Injury, seven distinct etiologies were defined: Fall-related Trauma, Traffic Accident Trauma, Firearm-related Trauma, Vascular/Tumoral Pathology, Infectious/Inflammatory Pathology, Congenital/Developmental Conditions, and Other/Not Informed.
- For Surgical Procedures, descriptions were condensed into six primary groups: Drainage (of hematomas or abscesses), Craniotomy/Cranioplasty, Shunt-related Procedures (including external and internal shunts), Procedure Revision, Intracranial Pressure (ICP) Monitoring, and Other/Not Informed.
- For Associated Traumas, injuries were classified by anatomical location and type, including Cranial Fracture, Facial Fracture, Spine Fracture, Long Bone Fracture, Thoracic Trauma, and Abdominal Trauma.
- For postoperative Complications, events were grouped into seven types: Infectious, Neurological (e.g., seizures, intracranial hypertension), Respiratory, Hemorrhagic, CSF Fistula-related, Device-related, and Other/Not Informed.

Following this categorization, the dataset was transformed using one-hot-encoding. Each category was converted into a distinct binary (dummy) variable, where a value of '1' indicated the presence of the characteristic for a given patient and '0' indicated its absence. The classification was executed using rule-based text parsing with a predefined list of keywords for each category. For instance, any entry in the raw 'Mechanism of Injury' field containing terms such as 'hydrocephalus,' 'aneurysm,' or 'malformation' was coded as '1' in the new mecanismo_Condições_Congênitas_Desenvolvimento binary variable. The complete codebook detailing all classification rules and their corresponding keywords is available in the Table 2.

Table 1. Baseline Characteristics of the Study Population.

Characteristic	N	Mean	Standard Deviation	Range
Continuous Variables				
Age (years)	182	8.63	6.719	18
Admission GCS	150	10.03	4.792	12
Discharge GCS	124	14.39	1.752	12
ICU Stay (days)	167	54.75	190.127	1830
Categorical Variables	**N**	**Frequency (%)**		
Thoracic Trauma (Yes)	188	11 (5.9%)		
Abdominal Trauma (Yes)	188	1 (0.5%)		
Surgery (Laparotomy)	188	1 (0.5%)		
Etiology (Congenital)	188	1 (0.5%)		
ICP Monitoring (Yes)	188	48 (25.5%)		

Abbreviations: GCS = Glasgow Coma Scale; ICU = Intensive Care Unit; N = Number of patients.

Table 2. Bivariate Analysis of Factors Associated with Mortality.

Characteristic	Survivors (N=172)	Deceased (N=16)	p-value
Continuous Variables (Mean ± SD)			
Age (years)	8.62 ± 6.74	8.73 ± 6.70	0.952
Admission GCS	10.59 ± 4.57	3.58 ± 1.17	< 0.001
Categorical Variables (n, %)			
Thoracic Trauma (Yes)	6 (3.5%)	5 (31.3%)	< 0.001
Abdominal Trauma (Yes)	0 (0%)	1 (6.3%)	0.001
Surgery (Laparotomy)	0 (0%)	1 (6.3%)	0.001
Etiology (Congenital)	0 (0%)	1 (6.3%)	0.001
ICP Monitoring (Yes)	40 (23.3%)	8 (50.0%)	0.019
Surgery (Decompressive Craniectomy)	22 (12.8%)	5 (31.3%)	0.044

Abbreviations: GCS = Glasgow Coma Scale; SD = Standard Deviation; ICP = Intracranial Pressure.

Concurrently, numerical variables such as age and GSC were cleaned and standardized. Across the entire final dataset, any missing or non-applicable values were uniformly coded as -1 and subsequently defined as a discrete missing value within the statistical software to ensure their exclusion from all analyses.

Descriptive and bivariate analysis

Descriptive statistics were used to summarize the final, processed sample characteristics. Continuous variables were presented as means and standard deviations (SD), while the engineered binary variables were presented as frequencies and percentages (n, %). Bivariate analysis was then conducted to identify factors associated with mortality. The Independent-Samples T-Test was used to compare the means of continuous variables between the survivor and deceased groups. Pearson's Chi-Square test, or Fisher's Exact Test when appropriate, was used to assess the association between the binary categorical variables and mortality.

Predictive model development

The predictive model was developed upon the guidelines published on the BMJ[16], through the performance of a direct-entry discriminant analysis. The outcome variable was mortality (coded as 0 = survival, 1 = death). Predictor variables that demonstrated a significant association in the bivariate analysis ($p<0.05$) were included as independent variables in the model. The model's performance was evaluated based on its overall classification accuracy, sensitivity, specificity, and the Area Under the Receiver Operating Characteristic (ROC) Curve.

For all statistical tests, a p-value of less than 0.05 was considered statistically significant. All analyses were performed using IBM SPSS Statistics, Version 21.0.

RESULTS

Sample characteristics

The final sample consisted of 188 pediatric patients who underwent neurosurgical treatment. The demographic and clinical characteristics of the study population are summarized in Table 1. Of the 182 patients with available age data, the mean age was 8.63 years (SD = 6.72). The mean GSC score on admission for the entire cohort was 10.03 (SD = 4.79).

Bivariate analysis: factors associated with mortality

The results of the bivariate analysis comparing the survivor and deceased groups are presented in Table 2. Several variables were found to be significantly associated with in-hospital mortality. The mean admission GCS score was substantially lower in the deceased group (3.58 ± 1.17) compared to the survivor group (10.59 ± 4.57, $p < 0.001$). In contrast, age was not significantly different between the two groups ($p = 0.952$).

The presence of thoracic trauma ($p < 0.001$), abdominal trauma ($p = 0.001$), a congenital etiology ($p = 0.001$), and the performance

of a laparotomy (p = 0.001) were all significantly associated with a higher risk of mortality.

Multivariate predictive model for mortality

A direct-entry discriminant analysis was performed to develop a predictive model for mortality using the variables that were significant in the bivariate analysis. The analysis yielded a statistically significant model (Wilks' Lambda = 0.716, p < 0.001). The unstandardized linear discriminant function to calculate the mortality risk score (D) is presented in Equation 1, with the corresponding coefficients detailed in Table 3.

$$\begin{aligned} D = {} & 1.215 - (0.010 \times Age) - \\ & (0.131 \times AdmissionGCS) - \\ & (0.148 \times Decompressive\ Craniectomy) + \\ & (5.892 \times Laparotomy) + \\ & (1.054 \times Thoracic\ Trauma) + \\ & (6.848 \times Congenital\ Etiology) + \\ & (0.213 \times ICP\ Monitoring) \end{aligned} \quad (1)$$

The model's performance in classifying patients is summarized in the classification matrix (Table 4). The overall accuracy of the model was 93.1%. The model correctly classified 97.0% of survivors (specificity) but only 45.5% of non-survivors (sensitivity).

The model's discriminatory ability was assessed using a Receiver Operating Characteristic (ROC) curve analysis (Figure 1). The Area Under the ROC Curve (AUC) was 0.910 (95% CI: 0.846–0.975, p < 0.001), indicating excellent discrimination between the survivor and deceased groups.

DISCUSSION

Main findings

In this study, we developed a clinical prediction model for in-hospital mortality in pediatric neurosurgery patients who underwent cranium procedures. The model was based upon 7 clinical variables of easy reach at the patient's admission. Despite its low sensibility in identifying the patients that progressed to death, an exceptional discrimination capacity between patients with good or bad prognosis was noticed.

As predicted, lower GCS was found to be a determinant variable to predict in-hospital mortality in neurosurgical patients. A Chinese study reporting a regression analysis of 161 patients also stated that the GCS value has a strong correlation to higher mortality rates, ensuring that lower scores are related to a bad prognosis[17]. Furthermore, another study also constructed and externally validated prognostic models that combined age, motor score, and pupillary reactivity for 6-month outcomes following traumatic brain injury, although without age restrictions, and obtained an area under the receiver operating characteristic curve (AUC) between 0.66 and 0.84 at cross-validation[18].

As previously stated by Watanabe et al.[19], the association of extracranial injuries in patients who suffered severe head injury can significantly worsen their outcomes. The presence of systemic trauma was a strong prognostic factor for mortality with an adjusted odds ratio of 2.30[19]. Therefore, the inclusion

Table 3. Coefficients of the Discriminant Function.

Variable	Unstandardized Coefficient (β)
Age	-0.010
Admission GCS	-0.131
Surgery (Decompressive Craniectomy)	-0.148
Surgery (Laparotomy)	5.892
Thoracic Trauma	1.054
Etiology (Congenital)	6.848
ICP Monitoring (Yes)	0.213
(Constant)	1.215

Abbreviations: GCS = Glasgow Coma Scale; ICP = Intracranial Pressure.

Table 4. The Model's performance.

	Predicted: Survival	Predicted: Death	Total
Actual: Survival	129 (True Negative)	4 (False Positive)	133
Actual: Death	6 (False Negative)	5 (True Positive)	11
Total	135	9	144

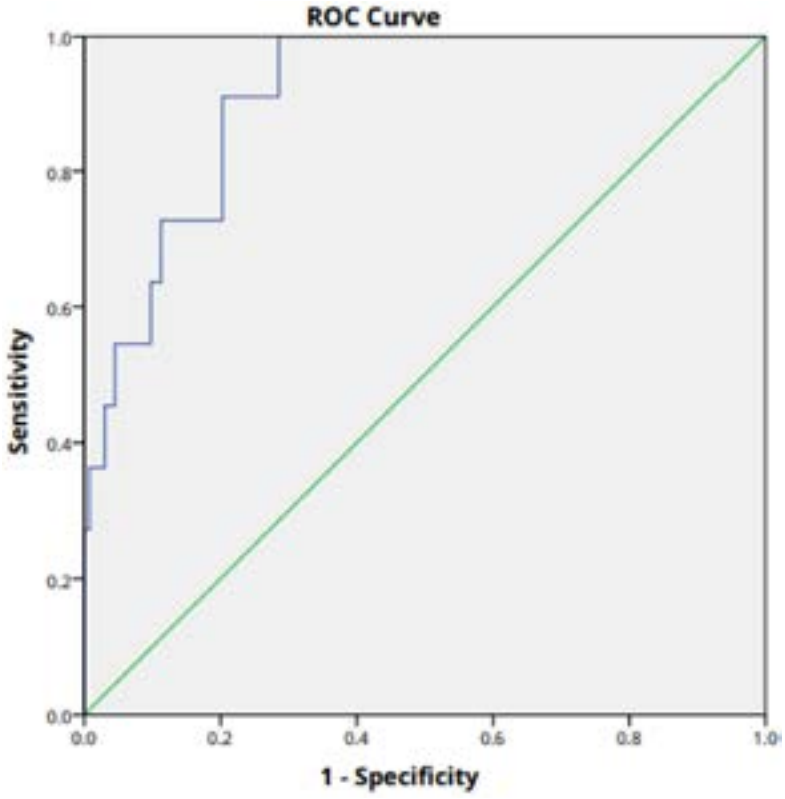

Figure 1. Receiver Operating Characteristic (ROC) curve of the clinical prediction model for in-hospital mortality. The curve illustrates the model's performance in distinguishing between survivors and non-survivors, achieving an Area Under the Curve (AUC) of 0.910 (95% CI: 0.846–0.975, $p < 0.001$), which indicates excellent discriminatory power.

of thoracic and abdominal trauma and the necessity for a laparotomy procedure in our model highlights that, even in critical neurosurgical patients, the outcomes are not only determined by cerebral lesion, but also because of the systemic impacts of a trauma.

Furthermore, recent research[20-23] underscores that a congenital etiology is a notable predictor of mortality in individuals undergoing neurosurgical procedures. This finding suggests that the inherent complexities and fragile health status of patients born with neurological conditions contribute to a higher risk of adverse outcomes, and given the prevalence of these disorders in the pediatric population, our model represents a strong asset for their particularities.

Strengths and limitations

The main strengths of this study are the development of a specific model destined to evaluate the pediatric neurosurgical population, often misrepresented in the current clinical research, with the data from the largest reference trauma center in Latin America. Alongside, the use of routine variables collected upon the patients admission represents a great step upon the reparation of inequalities of care conditions in lower-income countries, such as Brazil, as the model can be widely diffused and easily applied in daily practice.

This study also has limitations that must be recognized. Firstly, as this research has been developed upon the data from only one center, the generalization of the results can be limited to other units given the demographic discrepancies that can be faced. Additionally, the sample of patients that progressed to death was limited, which, although reflecting directly on the quality of the service, was a barrier to furnish a model with a low sensibility, limiting the use to evaluate the higher risk patients.

Clinical implications

The primary clinical utility of this predictive model stems from its excellent specificity of 97.0%. This positions it as a powerful rule-out tool for in-hospital mortality. In a clinical setting, a pediatric patient who receives a low-risk score from this model can be identified with a high degree of certainty as having a very strong chance of survival. This information has tangible benefits, particularly in the resource-constrained environments highlighted by the study. For clinicians, it can help manage bed allocation by identifying patients who may be safely moved from a high-dependency intensive care unit to a step-down unit, thus freeing critical resources for more severe cases. Furthermore, it provides an objective basis for communicating prognosis to anxious families, offering data-driven reassurance in a highly stressful situation.

Beyond resource management, the model serves as an important adjunctive tool for clinical triage and decision-making. In a high-volume tertiary care center, where physician workload can be overwhelming, such a tool can help stratify patients upon admission or post-operatively. While the model's score would not replace clinical judgment, it can rapidly flag patients at the lowest end of the risk spectrum, allowing medical staff to prioritize their attention and intensive monitoring efforts on patients with higher-risk scores or more complex clinical presentations. This quantitative risk assessment, based on simple clinical data, adds a layer of objectivity to the initial patient assessment, complementing established indicators like the admission Glasgow Coma Scale score.

However, the model's most significant limitation—its low sensitivity of 45.5%—must dictate how it is applied clinically. This figure indicates that the model fails to identify more than half of the patients who will ultimately die. Consequently, it must never be used to create a false sense of security or to "rule-in" mortality. A high score should be seen as a serious red flag, but a low score cannot be interpreted as a definitive guarantee of a positive outcome. The model's value is therefore not in definitively identifying all high-risk patients, but rather in reliably confirming those who are at a very low risk, allowing for a more efficient and confident allocation of clinical care and attention.

Future directions

A primary focus for future research should be on enhancing the model's performance, particularly its low sensitivity of 45.5%. Although the model effectively identifies low-risk patients, its inability to flag more than half of the patients who will not survive is a significant limitation. This could be addressed by incorporating a wider array of predictor variables, such as specific laboratory values, more detailed findings from imaging scans, or intraoperative data. Furthermore, employing more advanced machine learning techniques, beyond the discriminant analysis used in this study, might uncover more complex patterns and improve the model's ability to correctly identify these high-risk individuals.

Before the model can be recommended for wider clinical use, it must undergo rigorous validation to ensure its generalizability. The current study performed an internal validation, meaning the model was tested on the same population from which it was developed at Hospital João XXIII. The critical next step is external validation, which involves testing the model's accuracy on a new dataset of patients from a different hospital or region. Additionally, conducting a prospective study, where the model is applied to patients in real-time as they are admitted, would provide a higher level of evidence for its practical utility, moving beyond the limitations of the current retrospective design.

Finally, the scope of this research could be expanded to provide even greater clinical insight. The current model was specifically designed to predict a single outcome: in-hospital mortality. Future work could focus on developing similar predictive tools for other crucial outcomes, such as the risk of specific postoperative complications, long-term neurological function, or the likelihood of requiring repeat surgeries. Another valuable direction would be to develop a dedicated model for the pediatric spinal neurosurgery population, which was intentionally excluded from this study to maintain a homogeneous sample but represents another group that could benefit from risk stratification tools.

CONCLUSION

We developed a model with excellent discriminatory ability for predicting mortality in pediatric neurosurgery. While promising for identifying low-risk patients, its low sensitivity requires external validation and refinement before it can be considered for clinical use.

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CORRESPONDING AUTHOR

Gabriela Teodora de Souza Sanches, MS
Medical student
Universidade Federal de Minas Gerais – UFMG
Medical School
Belo Horizonte, Minas Gerais, Brazil
E-mail: gabi.teodoraa@gmail.com

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Institution: *Hospital João XXIII.*

CrediT

Gabriela Teodora de Souza Sanches: Conceptualization, Methodology, Formal analysis, Software, Investigation, Data curation, Writing – Original Draft, Visualization, Validation, Writing – Review & Editing, Project administration. Renato Leite Barros Filho: Conceptualization, Methodology, Formal analysis, Software, Investigation, Data curation, Writing – Original Draft, Visualization, Validation, Writing – Review & Editing, Project administration. Cintia Horta Rezende: Conceptualization, Validation, Writing – Review & Editing, Project administration, Resources, Supervision.


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Clinicopathological Profile, Management and Outcomes of Surgical Intracranial Infections in a Nigerian Tertiary Hospital

Perfil Clinicopatológico, Gerenciamento e Desfechos de Infecções Intracranianas Cirúrgicas em um Hospital Terciário Nigeriano

Olukorede Olabanji Adekunle[1]
Timothy Olugbenga Odebode[1]
Nurudeen Abiola Adeleke[1]
Olakunle Michael Adegboye[1]
Oghenevwoke Isaiah Enaworu[1]
Hakeem Ayinde Yeqeen[1]
Akingbade Adebayo Akin-Dosumu[1]
Stanley Onyeka Nnara[1]
Gbenga Timothy Oyegbami[1]

ABSTRACT

Introduction: *Intracranial infections remain critical neurosurgical challenges with high morbidity. Early diagnosis and prompt surgical intervention are essential for favorable outcomes.* **Objective:** *To review clinicopathological profiles, management, and outcomes of intracranial infections in a Nigerian hospital.* **Methods:** *This 6-year retrospective study analyzed patients managed surgically using descriptive and inferential statistics.* **Results:** *Thirty-two patients were included (male: female 3:1; aged 3 months–73 years; median: 19.5years). Peak incidence: 0–20 years. Sources were identified in 20 (62.5%) patients while 12 (37.5%) were cryptogenic. Symptoms included headache (24.6%), fever (18.4%), seizures (14.9%), and altered sensorium (14.9%). Forty-three lesions were treated: cerebral abscesses (41.9%), subdural empyemas (16.3%), and epidural abscesses (14.0%) predominated. The frontal (43.8%) and parietal (31.3%) lobes were most affected; 43.8% involved the left hemisphere. Burr-hole drainage (71.9%) was the commonest intervention. Volumes: 10–220 mL (median: 40mls). Five patients had culture-positive collections (60% Escherichia coli). At two months, outcome was favorable in 25 (78.1%) patients and unfavorable in 7 (21.9%). Complications (n=20) included surgical site infections (45%), mortalities (25%), and recurrences (15%). Admission Glasgow Coma Scale (GCS) score significantly predicted outcome (p=0.016).* **Conclusion:** *Whereas intracranial infections are still a major challenge in neurosurgery, higher admission GCS scores predict favorable prognosis.*

Keywords: *Intracranial infections; Cryptogenic; Cerebral abscess; Subdural empyema; Burr-hole*

RESUMO

Introdução: *Infecções intracranianas permanecem desafios neurocirúrgicos críticos com alta morbidade. Diagnóstico precoce e intervenção cirúrgica imediata são essenciais para desfechos favoráveis.* **Objetivo:** *Revisar perfis clinicopatológicos, manejo e desfechos de infecções intracranianas em um hospital nigeriano.* **Métodos:** *Este estudo retrospectivo de 6 anos analisou pacientes manejados cirurgicamente utilizando estatística descritiva e inferencial.* **Resultados:** *Trinta e dois pacientes incluídos (homem: mulher 3:1; idade 3 meses–73 anos; mediana: 19.5 anos). Pico incidência: 0–20 anos. Fontes identificadas em 20 (62.5%) pacientes; 12 (37.5%) criptogênicas. Sintomas: cefaleia (24.6%), febre (18.4%), convulsões (14.9%) e sensório alterado (14.9%). Quarenta e três lesões tratadas: abscessos cerebrais (41.9%), empiemas subdurais (16.3%) e abscessos epidurais (14.0%) predominaram. Lobos frontal (43.8%) e parietal (31.3%) mais afetados; 43.8% envolveram hemisfério esquerdo. Drenagem por orifício-trépano (71.9%) foi intervenção comum. Volumes: 10–220 mL (mediana: 40mls). Cinco pacientes com culturas positivas (60% Escherichia coli). Em dois meses, desfecho favorável em 25 (78.1%) pacientes e desfavorável em 7 (21.9%). Complicações (n=20): infecções sítio cirúrgico (45%), mortalidades (25%) e recorrências (15%). Escala Coma Glasgow (GCS) admissão previu significativamente desfecho (p=0.016).* **Conclusão:** *Embora infecções intracranianas sejam grande desafio na neurocirurgia, maiores escores GCS admissão predizem prognóstico favorável.*

Palavras-Chave: *Infecções intracranianas; Criptogênica; Abscesso cerebral; Empiema subdural; Orifício-trépano*

[1]Division of Neurosurgery, Department of Surgery, University of Ilorin Teaching Hospital, Ilorin, Kwara State, Nigeria.

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INTRODUCTION

Intracranial infections are uncommon but serious neurosurgical conditions that can arise primarily in a previously healthy intracranial cavity or secondarily following trauma, cranial surgery, or contiguous and systemic infections[1-3]. Despite advances in surgical techniques, infection control, and antimicrobial therapy, these infections remain a major source of morbidity and mortality in neurosurgery[4].

Intracranial infections include brain and epidural abscesses, subdural empyemas, Pott's puffy tumor, ventriculitis, and pyoventricle[5]. They can result from direct inoculation following trauma or surgery, contiguous spread from paranasal sinuses or mastoid air cells, or hematogenous spread from distant foci such as the lungs or abdomen[6].

The incidence of intracranial infections is rising due to increased penetrating head injuries, wider use of intracranial devices (e.g., external ventricular drains, shunts, and ICP monitors), expanding neurosurgical practice, and higher prevalence of systemic infections capable of hematogenous seeding[1,3,7,8].

Clinical manifestations vary widely, from fever, headache, vomiting, and seizures to focal neurological deficits or altered consciousness[9]. Presentations may be indolent or fulminant. Neuroimaging, particularly contrast-enhanced CT or MRI, is essential for diagnosis, lesion characterization, surgical planning, and prognostication[10]. Prompt recognition and early surgical intervention combined with appropriate antimicrobial therapy are critical to prevent permanent neurological deficits and improve survival[11-14].

This study aims to describe the spectrum of surgically managed intracranial infections at a Nigerian tertiary center, highlighting clinical features, etiologies, neuroimaging findings, surgical strategies, and outcomes.

MATERIALS AND METHODS

This retrospective study reviewed all patients surgically managed for intracranial infections at the University of Ilorin Teaching Hospital between July 2019 and June 2025. Data were extracted from the neurosurgery division operating register and patients' case folders obtained from the Medical Records Department using a pre-designed proforma.

Thirty-eight patients underwent surgery during the study period; complete data were available for 32 patients. Collected variables included demographics, clinical presentation, identified etiologies and risk factors, neuroimaging and laboratory findings (including microbiology), surgical procedures, and outcomes.

Data analysis was performed using IBM SPSS Statistics version 22. Descriptive statistics included means, medians, standard deviations, and frequencies. Continuous variables were compared using independent samples t-tests or Mann-Whitney U tests as appropriate. Logistic regression was performed to identify predictors of outcome, with p-values <0.05 considered statistically significant.

RESULTS

Sociodemographic characteristics

A total of 32 patients were included in the study, comprising 24 males (75%) and 8 females (25%), yielding a male-to-female ratio of 3:1 (Figure 1). Patient ages ranged from 3 months to 73 years. The age distribution was skewed (Kolmogorov–Smirnov test, $p = 0.001$), with a median of 19.5 years and a mean of 27.03 ± 22.00 years. Male patients (median 20 years, mean rank 17.27) were older than females (median 16 years, mean rank 14.19), though this difference was not statistically significant (Mann–Whitney $U = 77.5$, $p = 0.420$; Table 1, Figure 2). The highest incidence of intracranial infections occurred in the 0–20-year age group (n = 18, 56.3%) (Table 1, Figure 2).

Suspected or identified aetiology

An identifiable source of infection was found in 20 patients (62.5%), while 12 patients (37.5%) had cryptogenic infections. Contiguous spread was the most common etiology (n = 9, 28.1%), followed by trauma (n = 7, 21.9%) and post-cranial surgery (n = 4, 12.5%) (Figure 3).

Table 1. Comparison of age ranks by gender.

Gender	N	Mean Rank	Sum of Ranks
Male	24	17.27	414.50
Female	8	14.19	113.50
Total	32		

Mann–Whitney U = 77.500, P = 0.420.

Table 2. Laterality of lesions.

Side	Frequency	Percent
Right	9	28.1
Left	14	43.8
Midline	2	6.3
Bilateral	7	21.9
Total	32	100.0

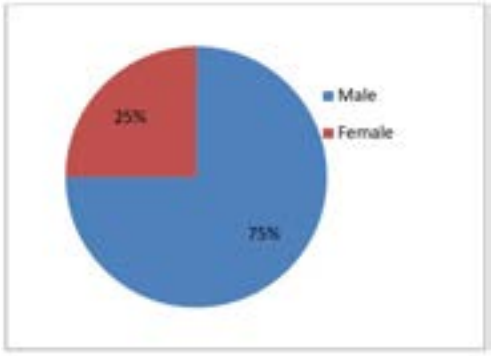

Figure 1. Gender distribution of patients.

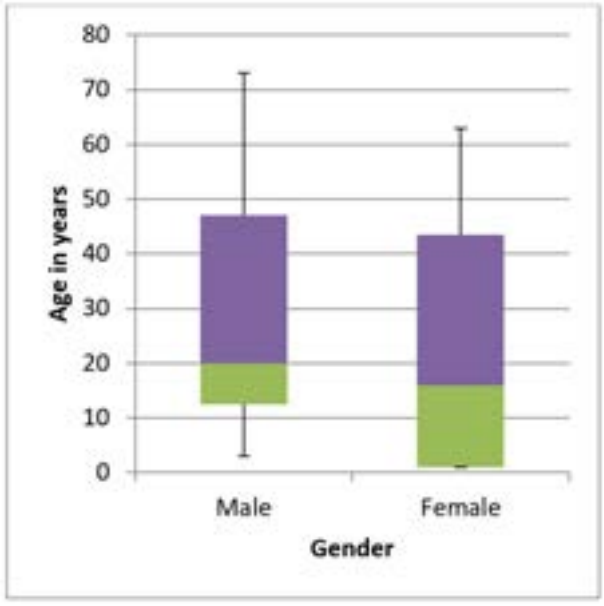

Figure 2. Box plots showing age distribution of male and female patients.

Clinical presentation

The most common presenting symptoms were headache (n = 28, 24.6%), fever (n = 21, 18.4%), seizures (n = 17, 14.9%), and altered sensorium (n = 17, 14.9%). Other presentations included vomiting (n = 13, 11.4%), hemiparesis (n = 11, 9.7%), progressive head enlargement in infants (n = 3, 2.6%), visual impairment (n = 2, 1.8%), and cranial neuropathy (n = 2, 1.8%) (Figure 4).

Neuroimaging findings

Most patients (n = 28, 87.5%) underwent cranial CT scans, 1 patient had MRI, and 3 infants had transfontanelle ultrasound scans (TFUSS) prior to subsequent imaging. Single lesions were observed in 27 patients, while 5 had multiple lesions. Lesion laterality included the left hemisphere (n = 14, 43.8%), right hemisphere (n = 9, 28.1%), bilateral (n = 7, 21.9%), and midline (n = 2, 6.3%) (Table 2).

The frontal (n = 21, 43.8%), parietal (n = 15, 31.3%), and temporal lobes (n = 8, 16.7%) were most commonly involved. Less commonly affected sites were the occipital lobe (n = 2, 4.2%), cerebellum (n = 1, 2.1%), and ventricles (n = 1, 2.1%) (Figure 5).

Among 43 lesions, cerebral abscesses (n = 18, 41.9%), subdural empyemas (n = 7, 16.3%), and epidural abscesses (n = 6, 14.0%) were most common. Other lesions included skull osteomyelitis (n = 5, 11.6%), subgaleal abscess (n = 5, 11.6%), cerebellar abscess (n = 1, 2.3%), and pyoventricle (n = 1, 2.3%) (Figure 6).

Laboratory investigations

White blood cell counts ranged from 3,600 to 35,300/mm^3, with no significant difference between males (14,785 ± 7,076/mm^3) and females (14,993 ± 6,947/mm^3, p = 0.943). No blood cultures were performed.

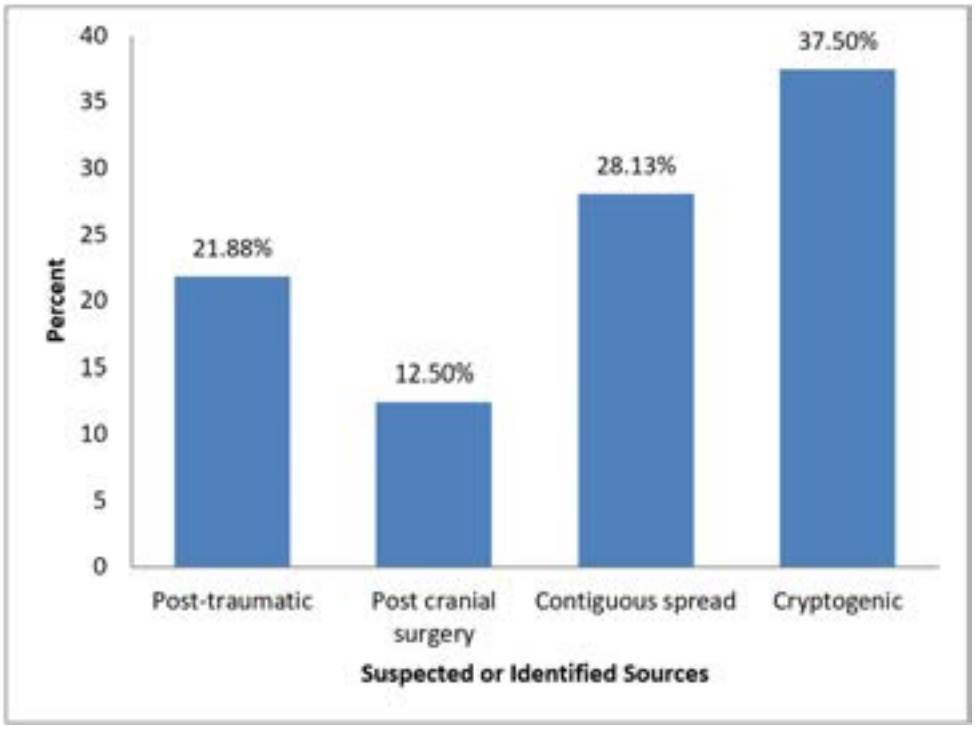

Figure 3. Suspected or identified sources of intracranial infections.

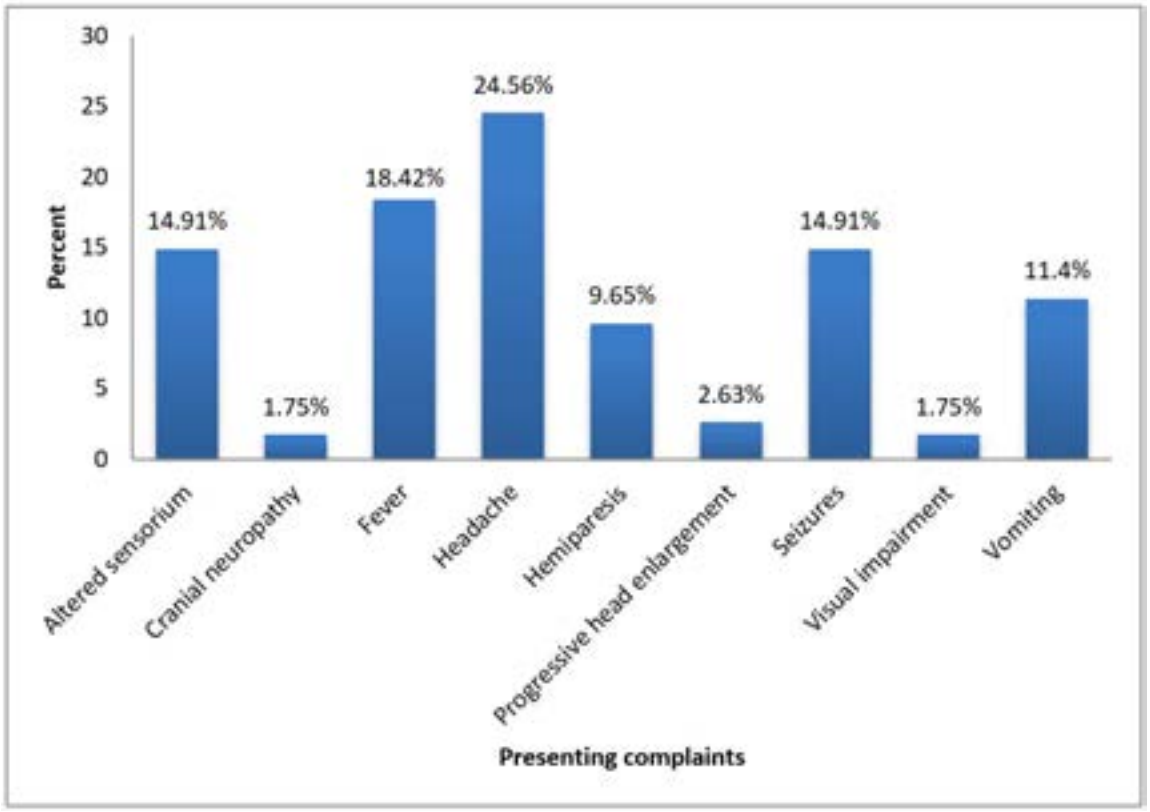

Figure 4. Frequency of presenting complaints among patients.

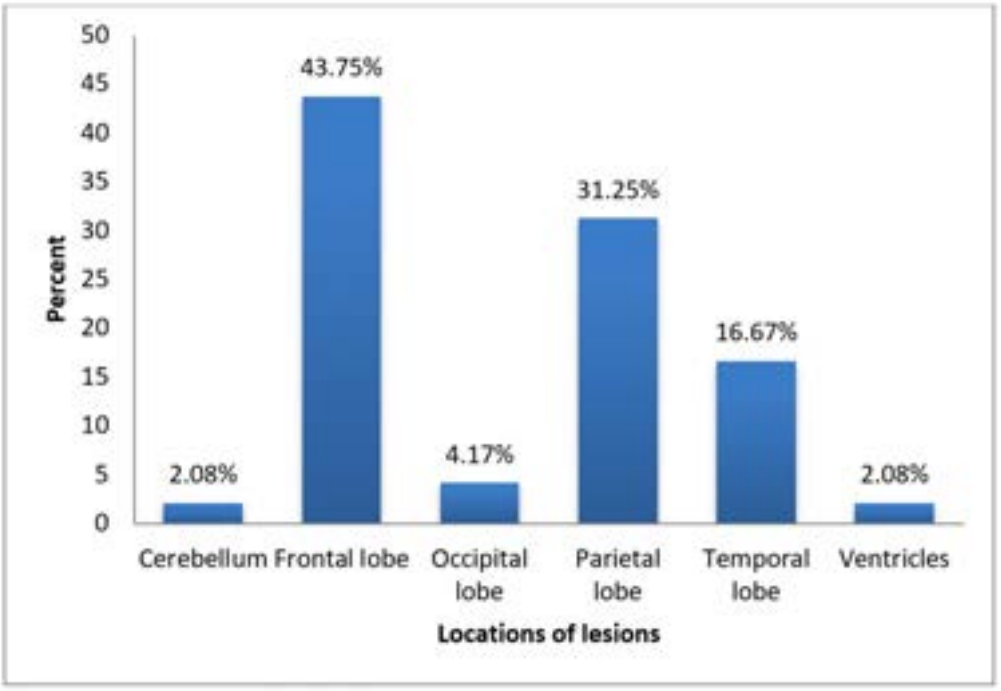

Figure 5. Brain regions involved in intracranial infections.

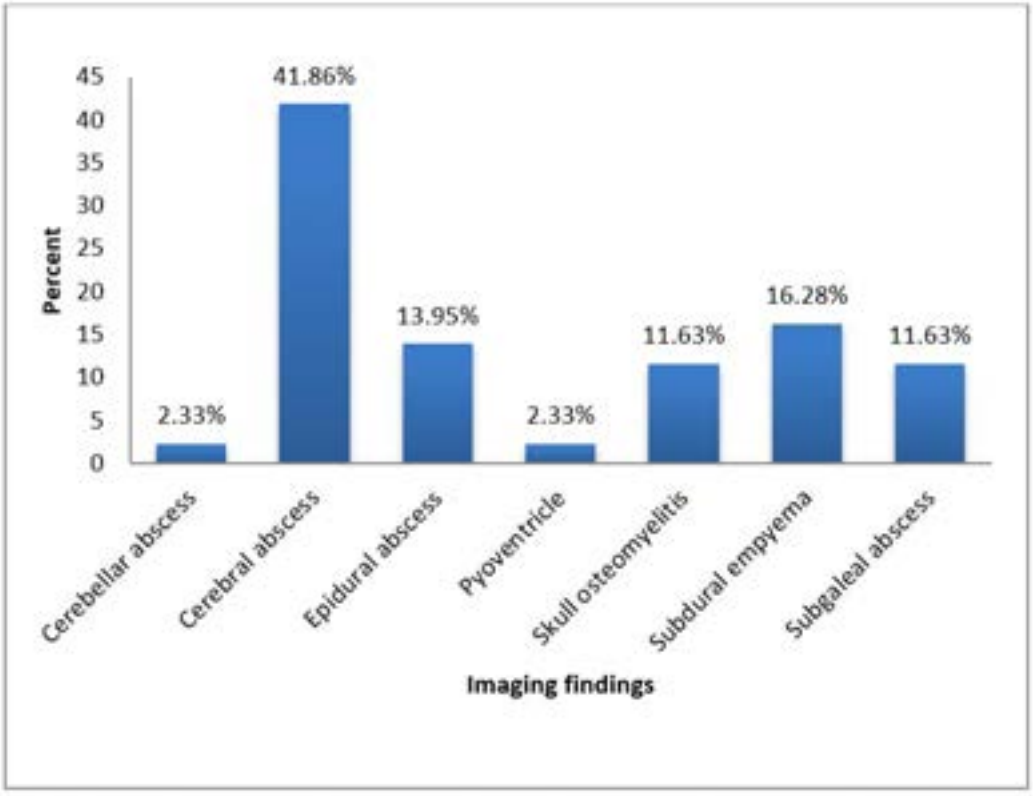

Figure 6. Types of intracranial lesions observed.

Surgical interventions

All 32 patients underwent open surgical procedures, totaling 37 interventions. Burr hole craniostomy was the most common procedure (n = 23, 71.9%), followed by craniotomy with membranectomy (n = 9, 28.1%) and craniectomy with membranectomy (n = 5, 15.6%) (Table 3). Nine adjunctive procedures were performed in 7 patients, including external ventricular drain insertion (n = 3), ventriculoperitoneal shunt (n = 1), myelomeningocele repair (n = 1), sinus antrostomy and irrigation (n = 2), aural toileting with wick dressing (n = 1), and functional endoscopic sinus surgery (n = 1).

Volume of collections and microbiology

Collection volumes ranged from 10–220 mL (median 40 mL; mean 50.31 ± 41.31 mL) and were skewed (Kolmogorov–Smirnov, $p < 0.001$). Median volume was slightly higher in females (40 mL, mean rank 17.88) compared to males (37.5 mL, mean rank 16.04), but this was not statistically significant ($U = 85$, $p = 0.628$) (Figure 7, Table 4).

Culture-positive collections were identified in 5 patients (15.6%): Escherichia coli (n = 3), Klebsiella pneumoniae and MRSA (n = 1), and Klebsiella oxytoca plus Pseudomonas aeruginosa (n = 1). The remaining 27 collections (84.4%) were culture-negative.

Outcome and complications

At two months post-surgery, 25 patients (78.1%) had favorable outcomes, while 7 (21.9%) had unfavorable outcomes. Twenty complications were recorded: surgical site infections (n = 9, 45.0%), mortality (n = 5, 25%), recurrence (n = 3, 15%), epilepsy (n = 2, 10%), and decubitus ulcer (n = 1, 5%) (Table 5).

Logistic regression analysis

Among predictor variables, only Glasgow Coma Scale (GCS) score at presentation significantly predicted outcome ($p = 0.016$). The positive unstandardized coefficient ($B = 0.806$) indicates that higher GCS scores increased the likelihood of favorable outcomes. Age, number of lesions, and collection volume had negative B values, suggesting higher values reduced the probability of favorable outcomes. White blood cell count had no impact, while male gender had an odds ratio of 1.641 for favorable outcome (Table 6).

Table 3. Surgical interventions.

Procedure	N	% of Cases
Burr hole drainage	23	71.9
Craniotomy & membranectomy	9	28.1
Craniectomy & membranectomy	5	15.6
Total procedures	37	115.6

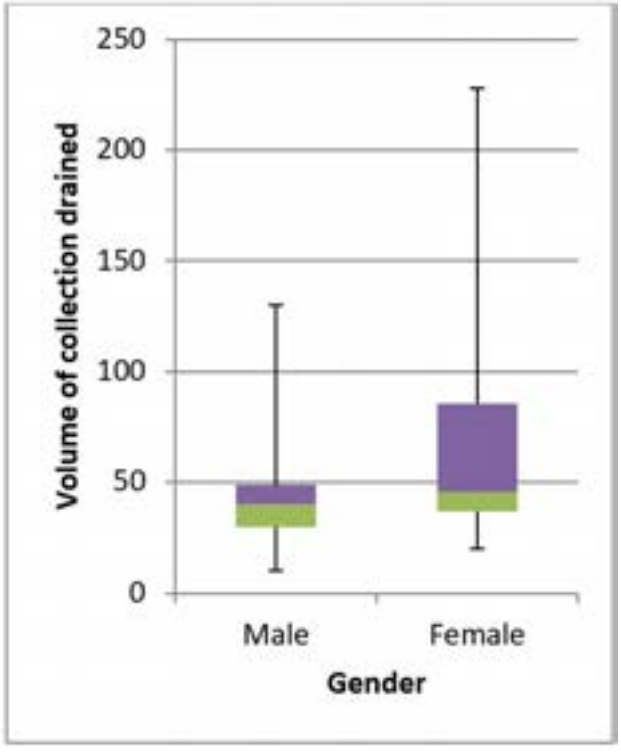

Figure 7. Box plot showing volumes of collections drained in male and female patients.

Table 4. Comparison of collection volumes by gender.

Gender	N	Mean Rank	Sum of Ranks
Male	24	16.04	385.00
Female	8	17.88	143.00
Total	32		

Mann-Whitney U = 85.000, P = 0.628.

DISCUSSION

This study demonstrated a preponderance of male patients (male-to-female ratio, 3:1), consistent with previous reports by Jarrar et al.[15] and some other authors[16-19]. The higher male incidence has been partly attributed to increased risk of cranial trauma and meningitis[17]; as well as anatomical differences such as larger paranasal sinuses, higher diploic vein vascularity, more rapid frontal sinus development in the first two decades, and congenital narrowing of paranasal sinus ostia in males[20].

The median age of patients in this study was 19.5 years, similar to the median ages reported by Evans et al.[16] for subdural and extradural empyemas (24 and 14 years, respectively). Peak incidence was observed in the 0–20-year age group, in agreement with findings by Jolayemi et al.[17] although their study focused solely on subdural empyemas. Cryptogenic infections constituted 37.5% of cases, comparable to the 56% reported by Soren et al.[21]

The most common presenting symptoms were headache, fever, seizures, and altered sensorium; a pattern that reflects the common trend in literature[17,21-23]. Imaging confirmed intracranial infections in all patients, with most (84.4%) presenting with a single lesion, consistent with previous reports by Sangi et al.[23] (84.3%) and Popescu et al.[24] (83%).The frontal lobe was the most commonly involved in this study, consistent with what was reported by Nkweren et al.[25] and some other workers[24,26,27]. In contrast, Prasad et al.[22] reported temporal lobe dominance in children. This difference likely reflects age-related factors: children's sinuses are still developing, and they are less exposed to trauma or penetrating injuries. In their cohort, chronic suppurative otitis media was the predominant predisposing factor, which preferentially affects the temporal lobe.

The most common lesions observed were cerebral abscesses, subdural empyemas, and epidural abscesses, corroborating findings by Calfee and Wispelwey[28] and Accorsi et al.[29]. Burr hole drainage was the primary surgical intervention, with craniotomy and craniectomy performed in selected cases. Seven patients required adjunctive procedures, including external ventricular drain (EVD) insertion, ventriculoperitoneal shunt placement, myelomeningocele repair, sinus antrostomy and irrigation, aural toileting with wick dressing, and functional endoscopic sinus surgery (FESS). These interventions addressed complications (e.g., hydrocephalus) or underlying causes (e.g., chronic suppurative otitis media, sinusitis), highlighting the importance of multidisciplinary management in achieving favorable outcomes. Similarly, Jolayemi et al.[17] reported that 81.6% of patients underwent burr hole drainage, with one patient receiving an EVD as adjunctive therapy.

Culture-positive collections were identified in only 15.6% of patients. In similar studies by Jolayemi et al.[17] and Ko et al.[12], the culture positivity rates were 4.1% and 49% respectively; while Prasad et al.[22] reported a pus culture positivity rate of 25%

Table 5. Postoperative complications.

Complication	N	% of Cases
Surgical site infection	9	45.0
Recurrence	3	15.0
Mortality	5	25.0
Epilepsy	2	10.0
Decubitus ulcer	1	5.0
Total	20	100.0

Table 6. Logistic regression analysis of predictors of outcome.

	B	S.E.	Wald	df	Sig.	Exp(B)
Age	-0.024	0.030	0.649	1	0.421	0.976
Gender	0.495	1.318	0.141	1	0.707	1.641
GCS	0.806	0.335	5.776	1	**0.016**	2.238
Number of lesions	-1.718	2.393	0.516	1	0.473	0.179
WBC	0.000	0.000	0.003	1	0.960	1.000
Volume of collection drained	-0.039	0.021	3.567	1	0.059	0.962
Constant	-4.834	4.508	1.150	1	0.284	0.008

and blood culture positivity rate of 16.7%. Low culture yield is commonly attributed to preoperative antibiotic therapy[17], a situation mirrored in our study where most patients were already on antibiotics prior to surgery. In this index study, no patient had a blood culture done. In this study, Escherichia coli was the most frequently isolated organism, consistent with findings by Sangi et al.[23] Other organisms cultured included Klebsiella pneumonia, methicilin resistant Staphylococcus aureus, Klebsiella oxytoca and Pseudomonas aeuriginosa.

Prompt surgical intervention combined with prolonged antibiotic therapy remains the cornerstone of management. In our center, empiric triple-antibiotic therapy (vancomycin, metronidazole, and a third-generation cephalosporin, usually ceftriaxone) is initiated once diagnosis is confirmed. Parenteral therapy is continued for 2 weeks, followed by 4 weeks of oral antibiotics (typically cefixime and metronidazole), totaling 6 weeks. Antibiotics are adjusted based on sensitivity results. Neurological outcomes (Glasgow Outcome Score) were assessed at 2 months post-surgery, following completion of the antibiotic course.

Favorable outcomes were observed in 78.1% of patients, consistent with prior reports[12,26]. Among patients with an unfavorable outcome, 5 deaths (15.6%) were recorded aligning with findings by Udoh et al.[30], Popescu et al.[24] and others[12,23,25].

Logistic regression analysis identified higher preoperative GCS scores as the most significant predictor of favorable outcome, corroborating results from prior studies by Park et al.[31] and some other authors[26,32,33].

LIMITATIONS

This study's retrospective design and relatively small sample size are notable limitations. Additionally, the absence of routine blood cultures may have limited microbiological characterization.

CONCLUSION

Surgical intracranial infections continue to pose challenges in neurosurgical practice, affecting patients across all age groups. Clinical presentation and etiology are heterogeneous, and neuroimaging remains pivotal for diagnosis. Management should be multimodal and multidisciplinary, with burr hole drainage serving as a reliable primary intervention. Preoperative GCS score is the most important prognostic factor influencing outcomes.

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CORRESPONDING AUTHOR

Olukorede Olabanji Adekunle, MBBS, FMCS, FWACS
Division of Neurosurgery, Department of Surgery
University of Ilorin Teaching Hospital

Ilorin, Kwara State, Nigeria
E-mail: ooadekunle@rocketmail.com

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Analysis of Two Techniques in the Management of Chronic Subdural Hematomas Treated by Burr-Hole Trepanation

Análise de Duas Técnicas no Manejo dos Hematomas Subdurais Crônicos Tratados por Trepanação

Bárbara Velani Souza[1]
Maria Fernanda Possari Vitro[1]
Maria Paula Marcone Schreiner[1]
Melryan Isabele Giraldi do Carmo[1]
Bruno Moraes de Oliveira[2]
Murilo Scapin[3]
Sergio Murilo Georgeto[4]

ABSTRACT

Introduction: *Chronic subdural hematoma (CSDH) is characterized by the accumulation of blood between the dura mater and the arachnoid, most commonly after trauma. Burr-hole drainage is the standard treatment, whether or not a postoperative drain placement.* **Objective:** *To compare clinical outcomes of patients undergoing burr-hole drainage for CSDH, irrespective of postoperative drainage use.* **Methods:** *A case–control study was conducted following approval by the Research Ethics Committee (No. 85976225.0.0000.5231). Medical records of patients treated in a tertiary hospital between 2020 and 2024 were reviewed, excluding those who died within the first seven postoperative days. Variables analyzed included epidemiological characteristics, anticoagulant use, procedure duration, surgical site infection, length of hospital stay, type of admission, and clinical outcome. Statistical analyses were performed using SPSS software, with significance set at $p < 0.05$.* **Results:** *Among the 156 patients evaluated, postoperative drainage was associated with a reduced length of hospital stay. A weak positive correlation between age and hospitalization duration was also observed.* **Conclusion:** *Postoperative drain placement in the management of CSDH was associated with better clinical outcomes and reduced hospitalization compared with cases managed without drainage.*

Keywords: *Chronic subdural hematoma; Drainage; Neurosurgery*

RESUMO

Introdução: *O hematoma subdural crônico (HSDC) é o acúmulo de sangue entre os folhetos durais decorrente de traumas de crânio. O tratamento predominante é a drenagem cirúrgica com ou sem colocação de dreno pós-operatório.* **Objetivo:** *Comparar desfechos clínicos em pacientes com ou sem dreno no pós-operatório.* **Métodos:** *Estudo de caso-controle aprovado pelo Comitê de Ética em Pesquisa (CAEE 85976225.0.0000.5231), a partir da análise de prontuários de pacientes submetidos à trepanação do HSDC em Hospital Terciário entre 2020 e 2024, excluídos óbitos nos primeiros 7 dias pós-operatórios. As variáveis analisadas foram epidemiológicas, uso de anticoagulantes, duração do procedimento, infecção em ferida operatória, tempo de internação, tipo de entrada e desfecho. Realizou-se análise estatística através do software SPSS com $p<0,05$.* **Resultados:** *Dentre os 156 pacientes, o uso de dreno esteve associado a um menor tempo de internação e apresentou uma fraca correlação positiva entre idade e tempo internado.* **Discussão:** *Consoante à literatura, evidencia o efeito do dreno por promover remoção eficiente do hematoma, prevenção de novo acúmulo e evitar potenciais consequências.* **Conclusão:** *O uso de drenagem contínua para o HSDC é superior ao método de drenagem única, devido à melhor evolução clínica e menor tempo de hospitalização.*

Palavras-Chave: *Hematoma subdural crônico; Drenagem; Neurocirurgia*

[1]Universidade Estadual de Londrina, Londrina, PA, Brazil.
[2]Programa de Pós-graduação em Fisiopatologia Clínica e Laboratorial, Universidade Estadual de Londrina, Londrina, PA, Brazil.
[3]Department of Neurosurgery, Hospital Universitário de Londrina, Londrina, PA, Brazil.
[4]Neurosurgery Department, Universidade Estadual de Londrina, Londrina, PA, Brazil.

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INTRODUCTION

Chronic subdural hematoma (CSDH) results from the accumulation of blood within the subdural space, most commonly secondary to head trauma. Certain clinical conditions may predispose individuals to its development, including arterial hypertension, type 2 diabetes mellitus, and alcoholism[1]. Men older than 65 years are at increased risk due to the gradual atrophy of cerebral tissue, which leads to greater tension on the bridging veins transversing the subdural space, thereby predisposing them to rupture[2].

Management may involve either conservative or surgical approaches. The choice of therapeutic strategy depends on symptom severity and hematoma size[3].

Conservative treatment is indicated for asymptomatic patients or those with minimal symptoms. This approach consists of clinical monitoring combined with periodic imaging studies[4].

Surgical intervention is generally indicated for patients with CSDH who present significant neurological manifestations or evidence of hematoma progression. The most commonly employed techniques are burr hole drainage and craniotomy. Burr hole surgical drainage is considered the initial method of choice for most symptomatic cases and is performed through one or two cranial openings.

A single burr hole technique is preferred because it offers high efficacy, low invasiveness, and shorter operative time[5,6]. The patient is positioned supine, with slight elevation and rotation of the head to expose the affected hemisphere[7]. After antisepsis and a linear 2–3 cm incision in the parietal region (Figure 1), the preferred site due to greater hematoma thickness, a single burr hole is created using a high-speed drill[5,7]. Cruciate opening of the dura mater (Figure 2) allows immediate drainage of the liquefied hematoma, followed by gentle irrigation with warm saline solution until the effluent becomes clear[6,8,9]. When a drain is used, a closed-system subdural drain is subsequently inserted and maintained for 24–48 hours, a practice supported by robust evidence demonstrating reduced recurrence rates[5,8,10]. After drain fixation, closure is performed in anatomical layers (Figure 3), and the patient remains under neurological monitoring and postoperative radiological surveillance. High rates of clinical and radiological resolution have been reported, and this technique is considered one of the safest and most standardized approaches in the management of CSDH[5,6,11].

For large hematomas or in the presence of multiple septations, craniotomy remains a widely used option[13].

After evacuation of CSDH, placement of a drainage system in the operative bed has become an increasingly important technical variable. Among the main options, the following stand out: (1) a passive subdural drain, often connected to an external drainage system adapted from external ventricular drainage (EVD) kits, configured for passive drainage without the application of negative pressure, with the reservoir maintained at head level to prevent excessive drainage and cerebral collapse[14,15]; and (2) an active subgaleal drain, coupled to a negative-pressure system, designed to actively evacuate residual fluid as well as reduce superficial air and fluid collections[16]. These strategies aim to optimize removal of residual blood and reduce the risk of recurrence, and are selected according to clinical characteristics and institutional protocols.

There are controversies regarding the surgical management of this condition, as outlined above. The present study aimed to investigate the effectiveness of postoperative drain placement in CSDH.

MATERIALS AND METHODS

This research was conducted as an analytical observational case-control study, approved by the Research Ethics Committee (CAEE 85976225.0.0000.5231), with the objective of comparing clinical outcomes in patients who did or did not receive an external drain in the postoperative period of CSDH. Patients of both sexes, aged over 20 years, admitted to a tertiary teaching hospital between 2020 and 2024 were included in the study.

Subjects were selected by convenience sampling, based on analysis of information contained in medical records. After applying the stated inclusion criteria, patients who died within the first 7 days following the surgical procedure were excluded. Patients who met all eligibility criteria were selected to compose the study

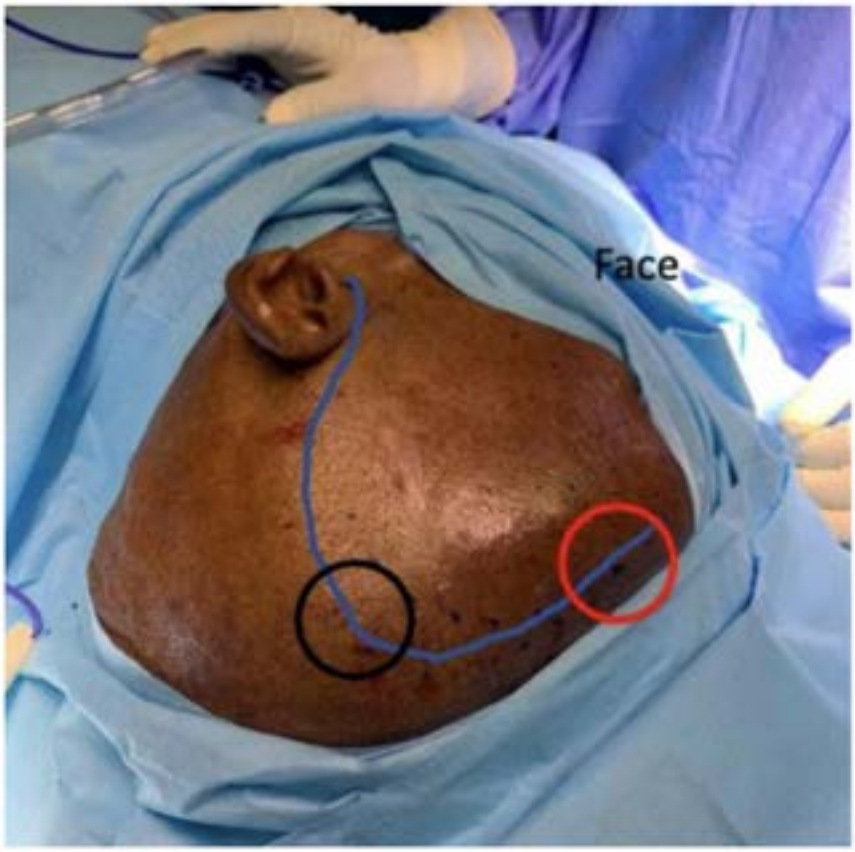

Figure 1. The Blue Line indicates the scalp incision for a craniotomy. A burr hole placed in the area of the Red Circle should be horizontal. A burr hole placed in the area of the Black Circle should be vertical. If conversion from burr hole to craniotomy is necessary, the incisions could easily be integrated into the scalp flap.
Source: Reproduced from Davis R, Barutwanayo G. Burrhole Craniotomy. Vanderbilt Global Surgical Atlas (Open Manual of Surgery in Resource-Limited Environments). Licensed under Creative Commons Attribution-ShareAlike 3.0 (CC BY-SA 3.0)[12].

sample. Data were then collected from the electronic medical records available in the hospital's Medview system.

The sample consisted of a total of 156 patients, divided into those treated for CSDH with drain placement (n = 69) and those without drain placement (n = 87).

The analyzed variables were classified as continuous and categorical. Continuous variables included age, procedure duration, and length of hospital stay. Categorical variables included sex, race, use of medications affecting coagulation, occurrence of surgical site infection, type of admission (new case or recurrence), and discharge outcome (improvement or death).

Statistical analysis of the collected data was performed using SPSS software version 31, and the significance level adopted for all analyses was $p<0.05$. Continuous variables were described using median and interquartile range (IQR 25–75) and compared between groups using the Mann–Whitney U test. Categorical variables were compared using the chi-square test. Correlations among significant variables were assessed using Spearman's rank correlation coefficient.

RESULTS

The median age was 73 years (IQR 25–75: 66–78) in the drain group and 73 years (IQR 25–75: 62–79) in the no-drain group ($p = 0.905$).

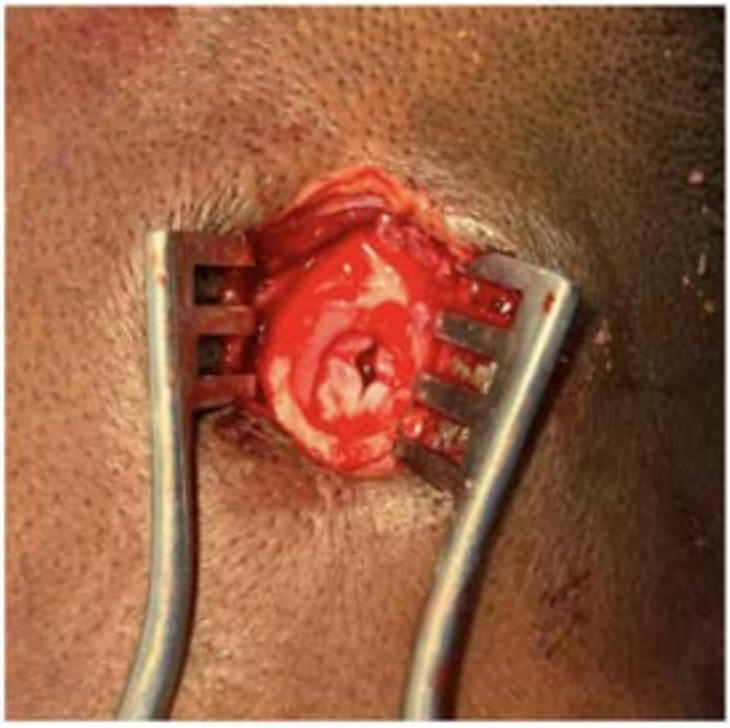

Figure 2. Burr hole with cruciate incision in the dura.
Source: Reproduced from Davis R, Barutwanayo G. Burrhole Craniotomy. Vanderbilt Global Surgical Atlas (Open Manual of Surgery in Resource-Limited Environments). Licensed under Creative Commons Attribution-ShareAlike 3.0 (CC BY-SA 3.0)[12].

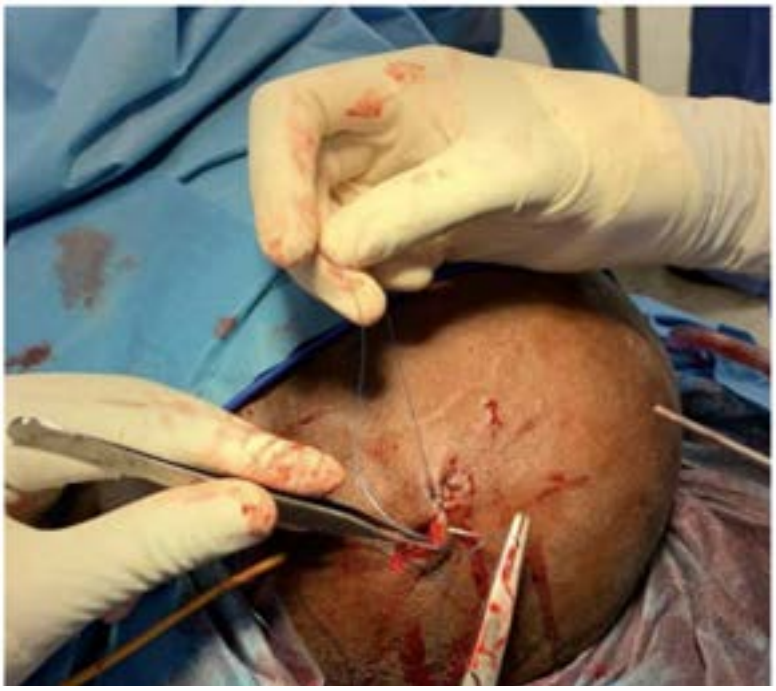

Figure 3. The scalp can be closed in one or two layers. Care is taken to close the Galea and to avoid incorporating the drain in the closure.
Source: Reproduced from Davis R, Barutwanayo G. Burrhole Craniotomy. Vanderbilt Global Surgical Atlas (Open Manual of Surgery in Resource-Limited Environments). Licensed under Creative Commons Attribution-ShareAlike 3.0 (CC BY-SA 3.0)[12].

The median procedure duration was 40 minutes (IQR 25–75: 35–65) in the drain group and 45 minutes (IQR 25–75: 30–75) in the no-drain group (p = 0.375).

Length of hospital stay showed a statistically significant difference between groups, with a median of 5 days (IQR 25–75: 4–13) in the drain group versus 8 days (IQR 25–75: 5–16) in the no-drain group (p = 0.031), representing an absolute difference of 3 days in the median (approximately 37.5% relative reduction in median length of stay) (Table 1).

No statistically significant differences were observed between the groups for the evaluated categorical variables (Table 2).

The proportion of male patients was 82.6% in the drain group and 80.5% in the no-drain group (p = 0.732). Skin color distribution (White, Brown, Black, Asian, not reported) showed no significant difference between groups (p = 0.547). Regarding type of admission—first presentation versus recurrence—no significant difference was observed (p = 0.423). Postoperative infection rates were similar between groups (13% in the drain group vs 11.5% in the no-drain group; p = 0.769). At discharge, the proportions of patients classified as "improved" and "death" also did not differ significantly between groups (improved: 87% vs 82.8%; death: 13% vs 17.2%; p = 0.470). Use of anticoagulants and antiplatelet agents was comparable between groups (e.g., anticoagulants: 94.1% vs 92.9%; p = 0.887).

Table 1. Comparison of continuous variables between the drain and no-drain groups. Results are expressed as median (IQR 25–75). A p value < 0.05 was considered statistically significant.

	Drain (N=69)	No drain (N=87)	p-value
Age (years)	73 (66-78)	73 (62-79)	0.905
Procedure duration (min)	40 (35-65)	45 (30-75)	0.375
Length of Hospital Stay (days)	5 (4-13)	8 (5-16)	**0.031**

Table 2. Comparison of categorical variables between the drain and no-drain groups. Results are expressed as n (%). A p value < 0.05 was considered statistically significant.

		Drain (N=69)	No drain (N=87)	p-value
Sex	Male	57 (82.6)	70 (80.5)	0.732
	Female	12 (17.4)	17 (19.5)	
Skin color	White	56 (81.2)	70 (80.5)	0.547
	Brown	5 (7.2)	5 (5.7)	
	Black	4 (5.8)	6 (6.9)	
	Asian	4 (5.8)	3 (3.4)	
	Not reported	0 (0)	3 (3.4)	
Admission type	First admission	61 (88.4)	73 (83.9)	0.423
	Recurrence	8 (11.6)	14 (16.1)	
Postoperative infection	Yes	9 (13)	10 (11.5)	0.769
	No	60 (87)	77 (88.5)	
Discharge status	Improved	60 (87)	72 (82.8)	0.470
	Death	9 (13)	15 (17.2)	
Medications	Anticoagulants	16 (94.1)	13 (92.9)	0.887
	Antiplatelet agents	1 (5.9)	1 (7.1)	

Spearman's correlation analysis (Table 3) demonstrated a positive, weak, yet statistically significant correlation between age and length of hospital stay (r = 0.162; p = 0.043), indicating that more advanced age was associated with a slight increase in hospitalization duration. It should be emphasized that the observed correlation was weak (r = 0.16), suggesting that age accounts for only a small proportion of the variability in length of stay.

The remaining correlations tested among age, procedure duration, and length of hospital stay did not reach statistical significance.

In this dataset, the presence of a drain was associated with a reduction in median length of hospital stay (5 days vs 8 days), whereas no differences were observed between groups in age, procedure duration, postoperative infection rates, mortality, or use of anticoagulant/antiplatelet therapy.

The observed association between drain use and shorter hospitalization does not establish causality. It is plausible that unmeasured factors—such as intraoperative clinical severity, surgeon-specific criteria for drain placement, comorbidities, late complications, or discharge protocols—may have influenced the decision to place a drain and, consequently, the length of hospital stay.

DISCUSSION

The present study analyzes the clinical outcomes of patients who underwent surgical evacuation of CSDH by burr-hole trepanation, comparing results between those treated with (Figure 4A-B) and without the use of a subdural drain (Figure 5A-B).

Table 3. Spearman correlation analysis.

	Age (years)	Procedure Duration (min)	Length of Hospital Stay (days)
Age (years)		-0.0156 (0.052)	0.162 (**0.043**)
Procedure Duration (min)	-0.156 (0.052)		-0.034 (0.676)
Length of Hospital Stay (days)	0.162 (**0.043**)	-0.034 (0.676)	

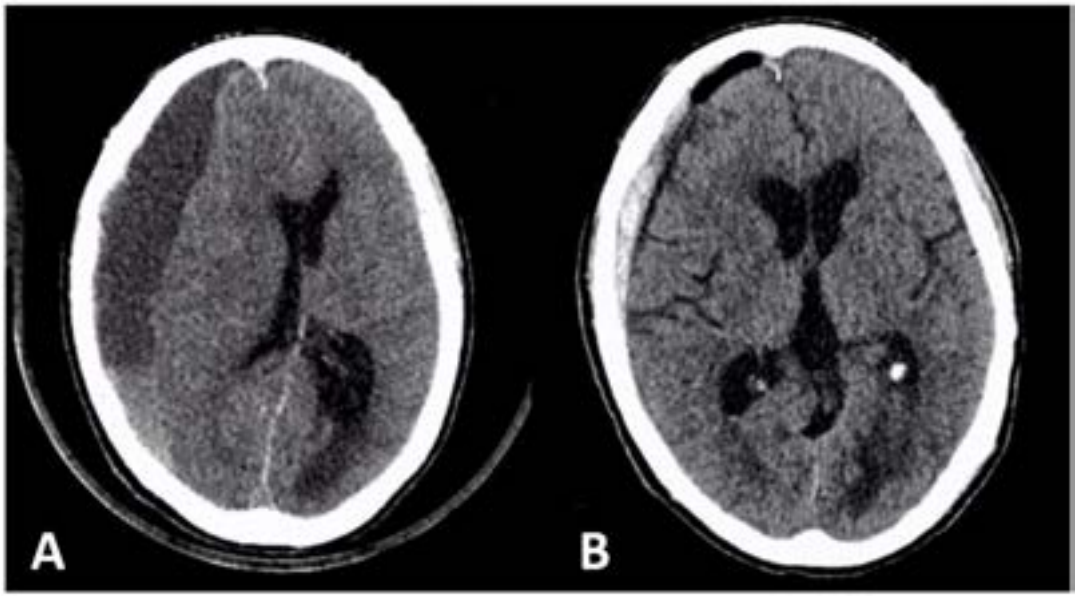

Figure 4. Computed tomography of preoperative CSDH (A) and postoperative CSDH with drain placement (B).
Source: Medview Personal Archive.

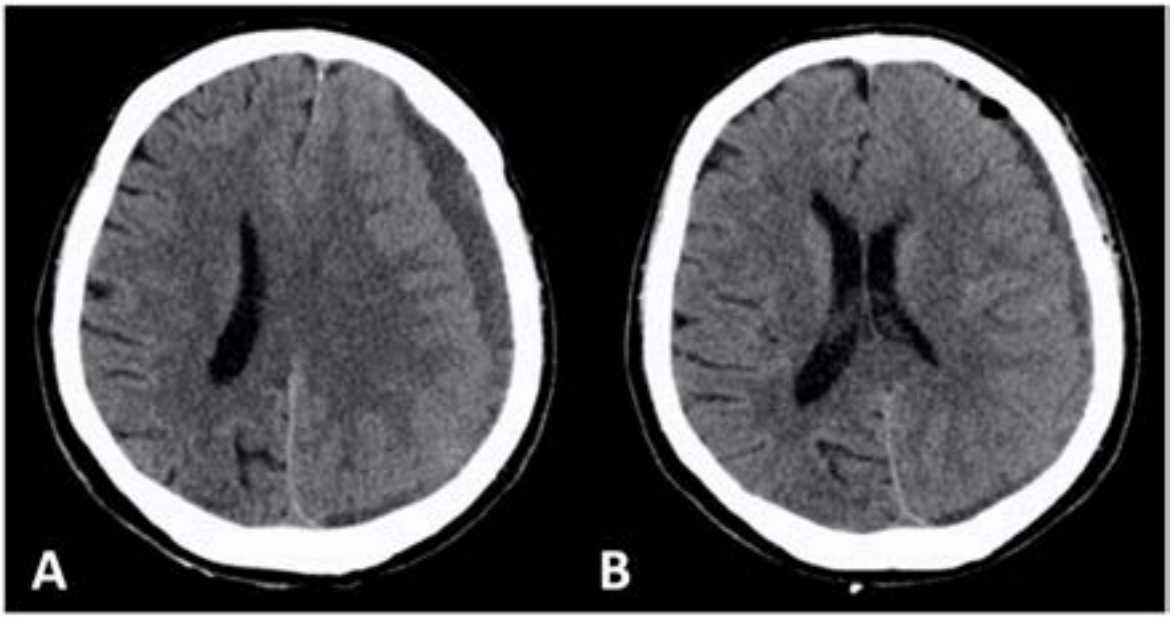

Figure 5. Computed tomography of preoperative CSDH (A) and postoperative CSDH without drain placement (B).
Source: Medview Personal Archive.

Drain use was associated with a shorter length of hospital stay, with no significant differences observed in age, recurrence rate, procedure duration, postoperative wound infection, or mortality. A positive, albeit weak, correlation was identified between age and length of hospitalization, suggesting that older patients tend to remain hospitalized for longer periods.

These findings are consistent with well-established evidence in the literature. The use of continuous drainage after CSDH evacuation has been associated with reduced hospital stay by promoting efficient removal of residual hematoma and preventing subdural fluid reaccumulation. The proposed pathophysiological mechanism involves maintenance of negative pressure within the subdural space, which facilitates cerebral reexpansion and reduces the potential space for blood recollection[16].

Although the study did not identify statistically significant differences in mortality or recurrence rates between groups, the literature suggests that the benefits of postoperative drain use may become more evident during long-term follow-up, particularly through a reduced need for reinterventions[18]. In this context, the shorter length of hospital stay observed in the drain group may be related to decreased residual accumulation and reduced early recurrence, factors previously described as determinants of prolonged hospitalization.

Despite the absence of significant differences in postoperative wound infection rates between groups, this issue remains controversial. Some authors suggest that drain use may increase the risk of infection, especially when maintained for prolonged periods; however, recent meta-analyses indicate that the benefits of drains in reducing recurrence and length of stay outweigh this potential risk when appropriate aseptic management is ensured[16,18]. The data obtained in the present study reinforce these findings.

Among the main limitations of this case–control study there is information bias, since subject selection regarding drain use was based entirely on data contained in surgical reports and/or medical records, and the relatively small sample size, which limits the generalizability of the results and may explain the lack of statistical significance for some variables.

Future prospective, multicenter studies with larger sample sizes are warranted to confirm the potential association between drainage use and postoperative wound infection, as well as other study variables, with the aim of further optimizing management strategies.

CONCLUSION

In summary, continuous drainage therapy for CSDH is superior to single drainage methods, as it is associated with better clinical outcomes and shorter hospital stays, without an increase in infectious complications. These findings, which are consistent with current literature, support drainage as an essential component of the surgical management of CSDH.

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CORRESPONDING AUTHOR

Bárbara Velani Souza, MS
Medical student
Universidade Estadual de Londrina
Londrina, Paraná, Brasil
E-mail: barbaravelani@gmail.com

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Idiopathic Intracranial Hypertension Outside the Classical Profile: a scoping review of atypical phenotypes and their clinical and therapeutic implications

Hipertensão Intracraniana Idiopática Fora do Perfil Clássico: revisão de escopo sobre fenótipos atípicos e suas implicações clínicas e terapêuticas

Daniel Serfaty Fonseca[1]
Deisiane da Silva Mesquita Serfaty[2]
André Giacomelli Leal[3]
Nicolau Conte Neto[4]

ABSTRACT

This study aims to map how atypical phenotypes of idiopathic intracranial hypertension, particularly male sex, normal body mass index, and older age, influence clinical presentation, neuroimaging findings, visual risk, and the need for invasive treatment. This scoping review was conducted according to the Joanna Briggs Institute methodology and reported in accordance with PRISMA-ScR, based on a comprehensive search across multiple databases. Fourteen studies composed the final qualitative synthesis. Male sex was the atypical subgroup most consistently associated with greater visual severity at presentation, whereas patients with normal body mass index and older individuals showed a more heterogeneous profile, including severe papilledema, predominance of visual manifestations, and delayed diagnosis. Neuroimaging contributed to diagnostic support, but no specific pattern reliably distinguished these subgroups. Idiopathic intracranial hypertension outside the classical profile is a legitimate expression of the disease and requires active diagnostic suspicion, since early recognition is decisive to reduce therapeutic delay and prevent avoidable visual loss.

Keywords: *Pseudotumor cerebri; Papilledema; Neuroimaging; Blindness; Optic nerve diseases; Idiopathic intracranial hypertension*

RESUMO

Este estudo visa mapear como fenótipos atípicos da hipertensão intracraniana idiopática, especialmente sexo masculino, índice de massa corporal normal e idade mais avançada, influenciam a apresentação clínica, os achados de neuroimagem, o risco visual e a necessidade de tratamento invasivo. Esta revisão de escopo foi conduzida de acordo com a metodologia do Joanna Briggs Institute e relatada conforme a diretriz PRISMA-ScR. Foi realizada busca abrangente em múltiplas bases de dados, sem restrição de idioma ou período. Quatorze estudos compuseram a síntese qualitativa final. O sexo masculino foi o subgrupo atípico mais consistentemente associado a maior gravidade visual na apresentação. Pacientes com índice de massa corporal normal e indivíduos mais velhos apresentaram perfil mais heterogêneo, incluindo papiledema grave, predomínio de manifestações visuais e atraso diagnóstico. A neuroimagem contribuiu para o suporte diagnóstico, mas nenhum padrão específico permitiu diferenciar de forma confiável esses subgrupos. A hipertensão intracraniana idiopática fora do perfil clássico representa uma manifestação legítima da doença e exige suspeição diagnóstica ativa. O reconhecimento precoce desses fenótipos é decisivo para reduzir atrasos terapêuticos e prevenir perda visual evitável.

Palavras-Chave: *Pseudotumor cerebral; Papiledema; Neuroimagem; Cegueira; Doenças do nervo óptico; Hipertensão intracraniana idiopática*

[1]Hospital das Clínicas, Faculdade de Medicina da Universidade de São Paulo – FMUSP, São Paulo, SP, Brazil.
[2]Fundação Oswaldo Cruz – FIOCRUZ, Rio de Janeiro, RJ, Brazil.
[3]Instituto de Neurologia de Curitiba – INC, Curitiba, PR, Brazil.
[4]Universidade Federal do Pará – UFPA, Belém, PA, Brazil.

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INTRODUCTION

Idiopathic intracranial hypertension (IIH), the primary form of the pseudotumor cerebri syndrome, is defined by elevated intracranial pressure in the absence of a mass lesion, hydrocephalus, infection, cerebral venous thrombosis, or another identifiable secondary cause, with normal cerebrospinal fluid composition. It is therefore an exclusion syndrome whose recognition depends on the integration of clinical history, neuro-ophthalmologic examination, neuroimaging, and an appropriately performed lumbar puncture[1-3].

From an epidemiological perspective, IIH predominantly affects women of reproductive age, particularly in the presence of obesity or recent weight gain, and its incidence has increased in parallel with the global rise in obesity. Although this is the most frequent profile, the disease is not restricted to a single demographic pattern, as it is also associated with broader metabolic alterations such as central adiposity, insulin resistance, and hyperleptinemia. This relationship between intracranial pressure, metabolism, and hormones broadens the understanding of IIH beyond an exclusively demographic or anatomic perspective[1,2,4].

Despite the centrality of the classical phenotype in clinical practice and in most therapeutic studies, IIH also occurs outside this typical profile. In a multicenter study involving 721 patients, men accounted for 9% of the sample, presented with less headache as the initial symptom, but more visual complaints and an approximately twofold higher risk of severe visual loss compared with women[5-8].

In a more recent German cohort, Knoche et al.[8] observed that male sex and severe baseline papilledema remained independently associated with worse visual outcomes in patients with IIH. In addition, a case-control study in men with IIH found a higher frequency of symptoms compatible with androgen deficiency and obstructive sleep apnea, suggesting that atypical profiles may carry their own clinical and pathophysiological particularities[7,8].

These findings have relevant diagnostic and prognostic implications, since clinical reasoning is often anchored in the model of a young woman with obesity. Cases outside this profile tend to experience delayed diagnosis, especially when the absence of excess body weight lowers initial suspicion or when presentation occurs with visual complaints, incidental papilledema, or less exuberant manifestations[9,10].

Because permanent visual loss is the most severe outcome of IIH, recognizing whether atypical phenotypes differ with regard to symptomatology, imaging findings, visual risk, and clinical course has direct implications for therapeutic decision-making. Contemporary management includes weight reduction when appropriate, acetazolamide as first-line therapy, and, in fulminant, progressive, or refractory situations, procedures such as optic nerve sheath fenestration, cerebrospinal fluid diversion, and, in carefully selected cases, venous stenting[5,9,10].

However, the comparative basis supporting these decisions was built predominantly from the traditional phenotype[1-3]. In this context, the present scoping review aimed to map the available evidence on atypical phenotypes of idiopathic intracranial hypertension, especially male sex, normal BMI or absence of obesity, and older age, describing their clinical, radiologic, neuro-ophthalmologic, therapeutic, and evolutionary characteristics, as well as the main gaps in the literature.

MATERIALS AND METHODS

This was a scoping review of the literature conducted according to the Joanna Briggs Institute methodology and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) checklist. The protocol was submitted to the Open Science Framework platform.

The review was guided by the PCC strategy, in which the population comprised patients with idiopathic intracranial hypertension defined according to recognized diagnostic criteria; the concept corresponded to atypical phenotypes of the disease, including male sex, normal body mass index or absence of obesity, older age, presentations without headache, incidental findings, and familial forms; and the context encompassed clinical, radiologic, neuro-ophthalmologic, therapeutic, and evolutionary aspects described across different care settings. The review question was: "What are the characteristics and gaps in the literature regarding atypical phenotypes of idiopathic intracranial hypertension outside the classical profile?".

The bibliographic search was performed in MEDLINE via PubMed, Embase, LILACS via the Virtual Health Library, SciELO, Scopus, and Web of Science, without language restriction or time limit. The search strategy combined controlled descriptors and free terms related to idiopathic intracranial hypertension and pseudotumor cerebri, adapted to each database, including the terms "Pseudotumor Cerebral", "Hipertensão Intracraniana Idiopática", "Pseudotumor Cerebri", and "Idiopathic Intracranial Hypertension".

In addition to the electronic search, manual screening of the reference lists of the included studies was performed in order to identify relevant publications not retrieved from indexed databases. This strategy was especially important to locate seminal studies on atypical phenotypes of idiopathic intracranial hypertension, including the male subgroup. In these cases, studies identified by backward reference searching could be included provided they met the review eligibility criteria.

Primary human studies contributing to the mapping of atypical phenotypes of idiopathic intracranial hypertension were included. Eligible studies comprised observational designs such as cohorts, case-control studies, cross-sectional studies, retrospective chart reviews, consecutive case series, and single case reports. Studies without a comparison group were also included provided they presented clinical, radiologic, therapeutic, or evolutionary descriptions relevant to at least one atypical phenotype of interest.

Editorials, letters without original data, narrative reviews, systematic reviews, meta-analyses, and publications with insufficient data for extraction were excluded. Studies whose caseload referred exclusively to secondary intracranial hypertension without separate analysis of idiopathic cases were also excluded, as were duplicate publications, with the most complete version being retained.

After duplicate removal, two independent reviewers screened titles and abstracts and subsequently assessed the full texts of potentially eligible articles. Disagreements were resolved by consensus and, when necessary, with the participation of a third reviewer.

Data extraction was independently performed by two reviewers using a previously tested standardized form. Information was collected on author, year of publication, country, study design, sample size, diagnostic criteria adopted, demographic characteristics, atypical phenotype described, presenting symptoms, neuroimaging findings, opening pressure, neuro-ophthalmologic findings, treatment used, clinical and visual evolution, and presence or absence of a comparison group.

Data synthesis was descriptive and narrative, with findings organized by phenotypic subgroups and thematic axes, including demographic profile, clinical presentation, radiologic findings, visual risk, therapy, and outcomes. Formal risk-of-bias assessment of the included studies was not performed, in keeping with the mapping nature of a scoping review. Because this review was based on previously published studies without access to individually identifiable data, approval by a Research Ethics Committee was not required.

RESULTS

Figure 1 presents the PRISMA-ScR flowchart of the review and describes the stages of identification, screening, eligibility, and study inclusion. Initially, 10,685 records were identified across databases, distributed among PubMed (n = 1,519), SciELO (n = 9), LILACS (n = 54), Scopus (n = 4,240), Web of Science (n = 3,871), and Embase (n = 5,232). After removal of 4,828 duplicate records, 5,857 studies proceeded to title screening. At this stage, 5,606 records were excluded for not meeting eligibility criteria, leaving 251 for abstract screening.

At the next stage, 229 records were excluded after abstract screening, so that 22 articles were selected for full-text assessment. Of these, seven studies were excluded for the reasons described in the flowchart. Ultimately, 10 studies from the primary search were included in the review. In addition, four studies were incorporated through backward reference searching, totaling 14 studies in the final sample.

Temporal analysis showed a scattered distribution over the years, with greater concentration in 2022 and 2026, with two studies in each year[9,11-13]. The remaining years contributed one publication each[6-8,10,14-19]. This pattern indicates that production on IIH outside the classical profile remains discontinuous, bringing together both recent studies and seminal works retrieved by backward reference searching.

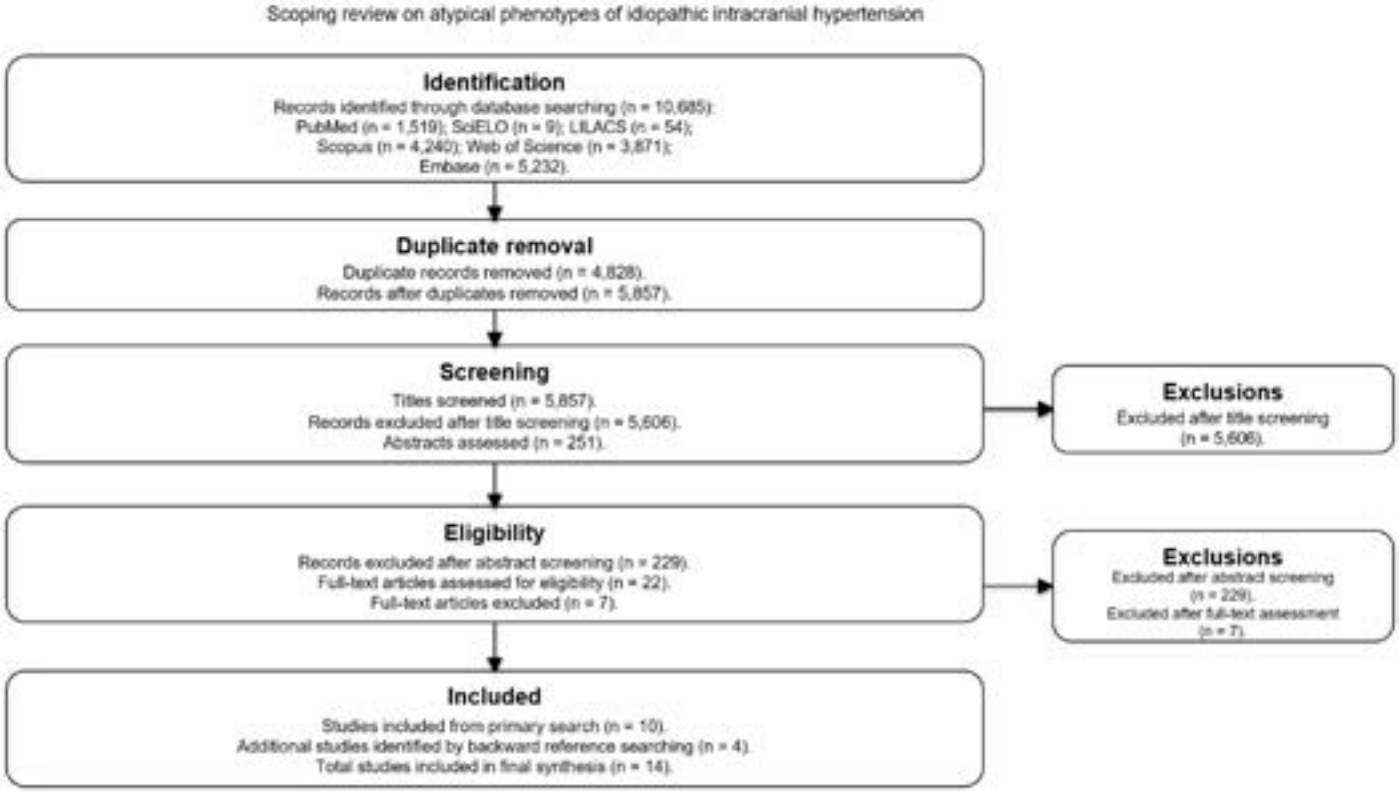

Figure 1. PRISMA-ScR flowchart of study selection.

Older studies focused mainly on comparisons between men and women and on the clinical description of male cases or specific subgroups[6,18,19]. In more recent years, the literature began to incorporate atypical phenotypes more explicitly, with emphasis on normal BMI, older age, familial forms, and visual outcomes in contemporary cohorts[8,9,12,13]. This shift suggests progressive expansion of the field, although still marked by methodological heterogeneity and the predominance of retrospective studies.

Regarding geographic distribution, the United States predominated, with three included studies[6,7,18]. Two studies did not allow precise identification of the country of origin[9,11]. The remaining studies showed a single-study distribution across Spain[10], Saudi Arabia[14], Germany[8], Turkey[15], China[16], Canada[12], Kuwait[13], and Israel[19]. There was also one multicenter study involving four centers located in Switzerland, Portugal, Turkey, and Israel[17].

This distribution demonstrates diversity of clinical settings, but with concentration in tertiary centers and in middle- and high-income countries, as well as low representation of Latin American and African contexts and of less specialized health systems.

Table 1 brings together markedly different designs and scales, ranging from single case reports[9,10,14,15] to large cohorts and multicenter studies[6,8,11-13,16-19]. Studies focused predominantly on male sex or on phenotypes considered unusual, which explains the high frequency of investigations composed exclusively of men or of atypical subgroups defined by BMI and age.

From a demographic standpoint, two patterns stand out. The first is the recurrent presence of diagnosis at older age among men or individuals with normal BMI compared with the classical disease profile, a finding visible in larger cohorts such as those by Donaldson et al.[12] and Bruce et al.[6].

The second refers to the heterogeneity of nutritional status. Although part of the literature maintains a link with overweight or obesity, several cases and series showed IIH occurring in non-obese patients or in individuals with BMI within the normal range, including familial forms[9,10,13,15]. This set of findings weakens a restrictive view of the disease as a phenomenon exclusive to obese women of childbearing age.

Table 1. Study characteristics.

Authors	Sample size	Age	Sex	BMI
Remolí Sargues et al.[10]	1	68 years	Male	22 kg/m²
Al Abdulsalam and Ajlan[14]	1	21 years	Male	38 kg/m²
Knoche et al.[8]	191 in the total cohort	35.5 ± 12.5 years	165 women and 26 men	34.4 ± 8.4 kg/m²
Eren et al.[15]	1	23–24 years	Male	19.8 kg/m²
Ahmed et al., 2026	1	34 years	Male	23.1 kg/m²
Tian[16]	199	36 years, range 27 to 45	145 women and 54 men	26 kg/m²
Shaia et al.[11]	84 men with IIH in the male analysis	29.37 ± 13.28 years	Male	Not reported
Rosenblatt et al.[17]	244	32.53 ± 10.69 years	217 women and 27 men	32.43 ± 6.95 kg/m²
Donaldson et al.[12]	243 total; 50 atypical	27.3 ± 5.6 in the typical group; 37.2 ± 11.8 in men; 48.0 ± 7.5 in those ≥40 years; 32.3 ± 9.8 in the normal-BMI group	Typical female group; 17 men in the atypical group	34.9 ± 5.8 in the typical group; 36.5 ± 11.2 in men; 23.4 ± 1.7 in the normal-BMI group
Behbehani et al.[13]	4	Father with current age not reported; offspring aged 38, 41, and 32 years	3 males and 1 female	Non-obese; BMI values of 23.5, 20.6, and 24.7 kg/m² in the offspring
Bruce et al.[6]	721	Overall median 28 years; men 37 years	66 men and 655 women	Men 33.2 kg/m²; women 37.4 kg/m²
Fraser et al.[7]	24 cases and 48 controls	Median 34 years in cases	Male	31.7 kg/m² in cases; 29.9 kg/m² in controls
Lee et al.[18]	32 men reviewed; 6 with IIH + sleep apnea	33 to 55 years	Male	Not reported; all overweight
Kesler et al.[19]	134 after exclusions	Mean age 35 years in men and 31.5 years in women	18 men and 116 women	Not reported; overweight in 25% of men and 77.6% of women

Table 2 shows that the clinical presentation of atypical phenotypes is not uniform. In part of the sample, especially in case reports and series focused on men, visual symptoms assumed a central role, sometimes with little or no headache, as occurred in the studies by Remolí Sargues et al.[10], Eren et al.[15], and Bruce et al.[6].

In older patients, headache also appeared less frequently, without implying lower baseline visual severity[12]. This pattern helps explain cases of delayed diagnosis in groups that fall outside the best-known epidemiological profile.

With regards to neuro-ophthalmologic findings, papilledema remained the dominant diagnostic axis, but its intensity and symmetry varied. Presentations ranged from subtle and incidental forms[10] to fulminant cases with exuberant bilateral edema and severe visual loss[14]. In larger series, male sex was associated with worse baseline visual field or worse visual prognosis, although not always with a marked difference in visual acuity at presentation[6,8,12].

In the field of neuroimaging, the studies demonstrated diagnostic usefulness, but without a pattern capable of consistently distinguishing atypical subgroups. Signs such as empty sella, posterior globe flattening, optic nerve sheath distension, and transverse sinus stenosis appeared in different contexts, but with value mainly for diagnostic support and exclusion of secondary causes rather than isolated phenotypic stratification[9,12,16].

Table 3 shows the predominance of clinical treatment with acetazolamide, either alone or in combination, as the first therapeutic choice. In cases with more aggressive evolution, especially with rapid visual deterioration, invasive procedures such as cerebrospinal fluid diversion or optic nerve sheath fenestration were used[6,13,14].

Table 2. Clinical presentation of the included studies.

No.	Presenting symptoms	Papilledema	Visual acuity	Visual field	Neuroimaging findings
1	Asymptomatic; incidental diagnosis on ophthalmologic examination	Bilateral, low grade, compatible with Frisén 1	20/40 RE and 20/20 LE	No defects initially or after 12 months	MRI and MR venography normal
2	Global headache and progressive bilateral visual loss	Marked bilateral papilledema with hyperemia and hemorrhages	Hand motion RE and light perception LE; later 20/100 RE and 20/200 LE	Residual peripheral constriction at follow-up	Optic nerve sheath enlargement and partially empty sella; venogram without thrombosis
3	Visual disturbance 89%, headache 84%, vertigo 45%, diplopia 39%	184/191 with papilledema; median Frisén 2	Baseline BCVA 0.17 ± 0.38 logMAR	19/47 with MD < -6 dB at follow-up	MRI used to exclude secondary causes; no discriminative value attributed to imaging findings
4	Blurred vision and diplopia, without headache	Bilateral, grade 4; macular edema in LE	20/20 RE and 20/50 LE; improved to 20/20 at follow-up	Enlarged blind spot and central visual loss	MRI and MRV without secondary cause
5	Progressive daily headache, transient visual obscurations, and pulsatile tinnitus	Bilateral, more pronounced on the right	6/6 in both eyes	Mild peripheral constriction, stable at follow-up	Partially empty sella, posterior globe flattening, perioptic distension, and optic nerve tortuosity
6	Headache 59.3%, visual loss 57.8%, nausea/vomiting 28.1%	Not reported in aggregate form	Not reported in aggregate form	Not reported in accessible excerpts	Optic nerve sheath distension 79.9% and transverse sinus stenosis 73.9%
7	Not detailed in the accessible abstract	Not numerically reported	Not numerically reported	Not reported	Not reported
8	Not reported in aggregate form	Not reported in aggregate form	Initial VA 0.073 ± 0.28 logMAR; final 0.043 ± 0.12	Initial MD ~ -5.74 ± 5.7 dB; final ~ -4.07 ± 4.5 dB	Neuroimaging used for exclusion; no systematic description of morphologic signs
9	Similar distribution across groups; headache less frequent in those ≥40 years; men with worse baseline MD	Persistent at follow-up in similar proportions across groups	Not presented as a central aggregate variable	Men with worse baseline MD and a trend toward worse final MD	Empty sella, posterior scleral flattening, and transverse sinus stenosis similar across groups
10	Headache, pulsatile tinnitus, and transient visual obscurations; unilateral and asymmetric presentations in some cases	Variable, including bilateral, unilateral, and asymmetric forms	Father with 20/200 RE and hand motion LE; offspring with 20/20 bilaterally	Enlarged blind spot, nasal step, and asymmetric field defects	MRI/MRV normal in the described cases
11	Men with less headache and more initial visual changes	Median Frisén 3 at baseline	Men with worse logMAR at presentation and follow-up	Men with worse visual field at baseline and follow-up	MRI in 92%; no systematic description of morphologic signs
12	Focus on associated factors, not detailed clinical description	Not reported	Not reported	Not reported	Normal neuroimaging for inclusion
13	Headache, transient visual obscurations, blurred vision, tinnitus, and vertigo	Bilateral in all 6 cases with sleep apnea	20/20 or better in both eyes	Enlarged blind spot in all; normalization in 5 of 6	Normal neuroimaging for IIH
14	Men with headache 81.3%, transient visual obscurations 68.8%, and tinnitus 5.5%	Present in all cases	Not reported	Some men with residual nasal defects and/or optic atrophy	CT in all; some had MRI and few had MRV

Table 3. Clinical treatment characteristics of the included studies.

No.	Clinical treatment	Follow-up time	Main outcomes
1	Acetazolamide 250 mg twice daily	12 months	Resolution of nasal disc elevation, stable RNFL, preserved visual field
2	Acetazolamide 2 g/day, later 1 g/day; surgery due to visual worsening	7 months	Headache improvement, visual stabilization, and partial improvement of edema and visual field
3	Weight loss when indicated; acetazolamide, topiramate, and furosemide; some underwent VP shunt or bariatric surgery	Median 2.0 years; mean 3.7 ± 3.5	Poor visual outcome in 30%; male sex and severe papilledema were independent predictors
4	Acetazolamide 1500 mg/day + topiramate 50 mg/day	1 month	Visual improvement to 20/20, regression of papilledema, and resolution of macular edema
5	Acetazolamide 500 mg twice daily, symptomatic management, and dietary counseling	3 months	Reduction of headaches, resolution of visual symptoms, and perimetric stabilization
6	Medication in 58.8%; regimens not detailed	Not reported	42.2% with symptom resolution and 57.8% with improvement; 36.2% underwent surgery
7	Not detailed in the accessible abstract	Not reported	Postpubertal men presented 12.9% poor visual outcome; worse results associated with smoking, diabetes, hypertension, and worse baseline vision
8	Acetazolamide in 93.7%; variable second-line treatment across centers; surgery in 8.2%	Mean 54 months	Overall visual outcomes similar across centers; baseline VA and VF predicted final outcome
9	Medical treatment still in use in part of the groups; surgery in 8.4% of the typical group and 14.3% in men and normal-BMI patients	17.4 to 30.0 months according to subgroup	No statistical difference in final visual outcome between typical and atypical groups; baseline MD was the most consistent predictor
10	Acetazolamide in the described cases; one case with weight loss; surgeries in selected cases	Heterogeneous and incomplete	Father with major visual loss and shunt; one case with fenestration; one with papilledema resolution after 10 weeks
11	Medication in 89% of men; diet in 46%; shunt in 15%; optic nerve sheath fenestration in 21%	Median 12.5 weeks in men	Men had about twice the risk of severe visual loss
12	Not reported	Not reported	Association between male IIH, androgen deficiency, and obstructive sleep apnea
13	1 with acetazolamide; 4 with acetazolamide + CPAP; 1 with CPAP alone	Not reported	Improvement or resolution of papilledema in all; visual field normalization in 5 of 6
14	Diamox predominated; some received prednisone, methazolamide, weight loss, or lumboperitoneal shunt	1-year outcome assessment	No statistical difference between men and women regarding outcome; men were less frequently overweight

In subgroups with sleep apnea, the addition of CPAP appeared as a measure associated with anatomical and functional improvement in part of the cases[18]. In larger cohorts, use of topiramate, furosemide, and surgical strategies varied according to clinical severity and service pattern[8,12,17].

From a prognostic standpoint, the findings converge on the idea that the main problem in atypical phenotypes lies in visual risk. Male sex repeatedly emerged as a marker of worse baseline visual field or worse visual prognosis, whether in comparative cohorts or in more recent multivariable analyses[6,8].

On the other hand, normal BMI and older age were not uniformly associated with worse final outcomes, although they were related to less usual and sometimes less noisy symptomatic presentations[12]. In several studies, the best predictor of evolution was visual severity at presentation rather than the phenotype in isolation[12,17].

DISCUSSION

The findings of this scoping review support that IIH outside the classical profile represents a consistent expression of the clinical heterogeneity of the disease. The synthesis of the 14 studies shows that male sex, normal body mass index, older age, and presentations with lower frequency of headache do not exclude the diagnosis. On the contrary, in part of the literature, these elements were associated with greater difficulty in clinical recognition and with worse visual status at the time of initial assessment[6-19].

With regard to male sex, this was the most consistent axis in the final sample. Bruce et al.[6], in a multicenter cohort of 721 patients, showed that men reported less headache as the initial symptom, more visual complaints, and an approximately twofold higher risk of severe visual loss compared with women. In the same direction, Knoche et al.[8], analyzing a retrospective German cohort, identified male sex and severe baseline papilledema as independent predictors of worse visual outcomes. Donaldson et al.[12], although they did not find a statistically significant difference in final outcome between typical and atypical groups, recorded worse mean deviation on visual field testing among men at diagnosis, reinforcing the notion of greater initial functional severity in this subgroup[6,8,12].

Thus, male sex does not in itself determine worse evolution in every scenario, but it is recurrently associated with a less typical symptomatic presentation and with a more concerning visual profile[6,8,12].

Lower frequency of headache among atypical phenotypes emerged as a central element in understanding delayed diagnosis. Bruce et al.[6] demonstrated lower headache frequency in men both as an initial symptom and at the first neuro-ophthalmologic assessment. Corroborating this finding, Donaldson et al.[12] observed that patients aged 40 years or older had headache less frequently than the typical group, although without an expressive difference in the remaining symptoms. In this context, the reports by Eren et al.[15] and Remolí Sargues et al.[10] are illustrative, as they describe men with papilledema and neuro-ophthalmologic alterations compatible with IIH but without the classical headache syndrome, shifting the weight of diagnostic reasoning toward ophthalmologic examination, perimetry, and confirmation by lumbar puncture[6,10,12,15].

Regarding body mass index, the results also weaken the restrictive view of IIH as a disease circumscribed to obesity. Cases in non-obese patients or in those with normal BMI were described in different contexts of the sample, including isolated male reports and a familial series. Ahmed et al.[9] documented IIH in a non-obese man with a BMI of 23.1 kg/m², bilateral papilledema, and signs of intracranial hypertension on neuroimaging.

Similarly, Remolí Sargues et al.[10] reported an incidental male case with a BMI of 22 kg/m² and an opening pressure of 500 mmH2O, while Eren et al.[15] described presentation without headache in a young, lean man. In addition, Donaldson et al.[12] showed that patients with normal BMI were diagnosed at older ages, without this necessarily translating into worse final visual outcomes.

From this perspective, normal BMI appears to reduce initial clinical suspicion, but it does not exclude papilledema, visual field abnormalities, or the need for treatment. The familial findings reported by Behbehani et al.[13] broaden this discussion by showing a father and offspring without obesity but with variable phenotypic presentations, suggesting that adiposity is not a necessary requirement for syndrome expression.

With regard to age, the final sample suggests that patients outside the classical profile tend to be diagnosed later. In Donaldson et al.[12], both men and individuals with normal BMI presented a higher mean age than the typical group. Bruce et al.[6] also reported older age among men compared with women.

This pattern may reflect lower clinical suspicion in unusual groups, especially when symptoms of intracranial hypertension do not follow the classical pattern. However, the data do not allow one to claim that higher age is, by itself, a universal predictor of worse visual outcomes. Donaldson et al.[12] indicated lower headache frequency in older patients, but without a consistent difference in final visual results. Thus, older age appears to function more as a variable of presentation and recognition than as an isolated prognostic determinant.

In the neuro-ophthalmologic field, papilledema remained the central axis in almost the entire sample, although with different intensities and patterns. Presentations ranged from subtle cases detected incidentally on routine ophthalmologic examination, as in the report by Remolí Sargues et al.[10], to fulminant presentations with marked visual loss and the need for urgent surgical intervention, as in Al Abdulsalam and Ajlan[14].

In this regard, Knoche et al.[8] add relevant prognostic evidence by showing that severe baseline papilledema was independently associated with worse visual outcomes. Consequently, the degree of papilledema seems to have more direct value for risk stratification than isolated demographic variables. This interpretation helps reconcile the divergences among studies, since sex, BMI, and age did not always retain independent effects in all analyses, whereas the functional and anatomic severity of ocular presentation remained a more stable marker of evolution[6,8,12].

Data on visual field testing reinforce the centrality of baseline neuro-ophthalmologic assessment. In the study by Bruce et al.[6], worse visual acuity and worse visual field were demonstrated in men, both at presentation and at follow-up. Similarly, Donaldson et al.[12] pointed out that mean deviation at presentation was the most consistent predictor of final visual outcome, regardless of whether the patient belonged to the typical or atypical group.

In parallel, Knoche et al.[8] corroborate the prognostic importance of baseline visual status alongside sex and papilledema severity. Thus, the literature reviewed suggests that distinguishing between typical and atypical profiles increases diagnostic suspicion, but therapeutic decision-making should rely above all on the severity of the initial neuro-ophthalmologic presentation[6,8,12].

As for neuroimaging findings, the review points to diagnostic usefulness but low discriminatory ability between phenotypes. Signs such as partial empty sella, posterior globe flattening, optic nerve sheath distension, and optic nerve tortuosity were described in different studies and across varied subgroups, such as those of Ahmed et al.[9], Tian[16], and Donaldson et al.[12].

With regard to treatment, the final sample showed a predominance of acetazolamide as first-line therapy, both in larger cohorts and in case reports. Tian[16] recorded symptomatic relief with medication in a substantial portion of the Chinese cohort, although more than one third of patients also underwent surgical intervention. In individual reports, Eren et al.[15], Ahmed et al.[9], and Remolí Sargues et al.[10] documented clinical improvement and visual stabilization with medical management.

On the other hand, in cases with rapid visual deterioration or insufficient response, cerebrospinal fluid diversion and optic nerve sheath fenestration were employed, as demonstrated by Al Abdulsalam and Ajlan[14], Behbehani et al.[13], and Bruce et al.[6]. This pattern supports the idea that therapy should be guided less by demographic phenotype and more by the speed of progression and the degree of visual threat.

Some studies suggest that male phenotypes may involve additional pathophysiologic factors. Fraser et al.[7] found an association between IIH in men and symptoms compatible with androgen deficiency and obstructive sleep apnea, whereas Lee et al.[18] identified a substantial frequency of sleep apnea in men with IIH and reported clinical improvement with CPAP alone or associated with acetazolamide.

From this perspective, the literature suggests that hormonal, respiratory, and hemodynamic mechanisms may coexist with classical factors, especially in men. This does not justify inferring causality from the present sample, but it does indicate that the pathophysiology of atypical profiles likely extends beyond the traditional association between obesity, female sex, and fertile age[7,18].

The divergences between studies regarding the prognostic weight of sex, age, and BMI must be interpreted in light of methodology. The final sample brought together case reports, small series, single-center retrospective studies, multicenter cohorts, and designs with not entirely uniform criteria for visual outcomes.

In view of the findings, convergence can be seen in three central points: men tend to present greater baseline visual impairment, especially on visual field testing[6,8,12]; patients with normal BMI and older individuals frequently generate lower clinical suspicion, which may delay diagnosis[9,10,12,15]; and initial visual severity, especially regarding visual field and papilledema, constitutes the main parameter for estimating evolution[6,8,12]. In this context, IIH outside the classical profile appears to require broader diagnostic vigilance and early neuro-ophthalmologic assessment.

CONCLUSION

The findings of this scoping review indicate that IIH outside the classical profile represents a legitimate manifestation of the disease, especially among men, individuals with normal BMI, and older patients.

These groups tend to present with less frequent headache and greater baseline visual impairment, which may contribute to delayed diagnosis and greater functional risk at the time of assessment. Baseline neuro-ophthalmologic severity, especially papilledema and visual field abnormalities, emerged as the main prognostic marker among the included studies.

Important gaps nevertheless persist in the literature, including predominance of retrospective studies, methodological heterogeneity, low standardization of visual outcomes, and limited geographic representativeness. In this scenario, the present review reinforces the need to expand clinical suspicion in nontraditional profiles and points to the importance of prospective multicenter studies capable of better defining the clinical, visual, and therapeutic determinants of atypical IIH.

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CORRESPONDING AUTHOR

Daniel Serfaty Fonseca, MD, PhD
Faculdade de Medicina da Universidade de São Paulo (FMUSP)
Hospital das Clínicas
São Paulo, São Paulo, Brazil
E-mail: drdanielserfaty@gmail.com

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Evaluating Treatment Modalities for Spinal Stenosis: a comparative meta-analysis of surgical and conservative strategies

Avaliando Modalidades de Tratamento para Estenose Espinal: uma metanálise comparativa de estratégias cirúrgica e conservadora

José Gabriel Abreu Moreira[1]
Antomir Santos Pereira[1]
Raul de Carvalho Cavalcante Filho[1]
Mariana Leticia de Bastos Maximiano[2]
Mariana Lee Han[3]
Alice Mi Lee[4]
Lívia Barbosa Cavalcanti[5]
Raphael Bertani de Magalhães[6]

ABSTRACT

Introduction*: This meta-analysis evaluates the comparative effectiveness of surgical versus nonsurgical interventions for spinal stenosis, a degenerative condition characterized by narrowing of the spinal canal, resulting in neural compression, pain, and functional limitation.* **Objective***: to synthesize available evidence to determine whether one therapeutic strategy demonstrates superiority.* **Methodology***: A systematic review was conducted in accordance with Cochrane Collaboration methods and PRISMA guidelines. Comparative studies evaluating surgical and conservative management in adults with radicular symptoms were included, while reviews, case reports, and non-English publications were excluded. Extracted outcomes included the Oswestry Disability Index, Short Form-36, and Roland–Morris Disability Questionnaire.* **Results***: Nine eligible studies comprising 685 patients met the inclusion criteria. Pooled analysis demonstrated a statistically significant reduction in ODI scores favoring surgical treatment, indicating greater functional improvement. In contrast, SF-36 and Roland–Morris outcomes showed inconsistent or non-significant differences between treatment groups, largely due to substantial heterogeneity and variability in study quality. Most studies presented moderate to serious risk of bias, primarily related to confounding and nonrandomized designs.* **Conclusion***: Surgical intervention was associated with superior functional outcomes compared with conservative treatment, although quality-of-life measures yielded heterogeneous results. Treatment decisions should be individualized based on clinical severity, functional impairment, and patient preferences.*

Keywords: *Spinal stenosis, Pain, Surgical, Conservative treatment*

RESUMO

Introdução: *Esta meta-análise avalia a efetividade comparativa das intervenções cirúrgicas e não cirúrgicas no tratamento da estenose lombar do canal vertebral, uma condição degenerativa caracterizada pelo estreitamento do canal espinhal, levando à compressão neural, dor e limitação funcional.* **Objetivo***: resumir a evidência disponível visando determinar se alguma estratégia terapêutica demonstra superioridade.* **Metodologia:** *revisão sistemática segundo as diretrizes da Colaboração Cochrane e do PRISMA. Foram incluídos estudos comparativos que avaliaram o tratamento cirúrgico versus conservador em adultos com sintomas radiculares. Revisões, relatos de caso e publicações não disponíveis em língua inglesa foram excluídos. Os desfechos analisados incluíram o Oswestry Disability Index, o Short Form-36 e o Questionário de Incapacidade de Roland–Morris. As análises estatísticas foram conduzidas no RStudio, utilizando modelos de efeitos aleatórios.* **Resultados:** *nove estudos, 685 pacientes, atenderam aos critérios de inclusão. A análise agrupada demonstrou redução estatisticamente significativa nos escores do ODI a favor do tratamento cirúrgico, indicando melhor recuperação funcional. Os escores do SF-36 e do Roland–Morris foram inconsistentes ou não significativos entre os grupos, influenciados pela heterogeneidade e variabilidade metodológica.* **Conclusão:** *A cirurgia mostrou-se superior na melhora funcional; contudo, os resultados de qualidade de vida foram heterogêneos, reforçando a necessidade de decisões terapêuticas individualizadas.*

Palavras-Chave: *Estenose Espinhal, Dor, Cirurgia, Tratamento conservador*

[1]Department of Medical Sciences, Universidade Federal da Paraiba, João Pessoa, PB, Brazil.
[2]Department of Medicine, Universidade Federal Fluminense, RJ, Brazil.
[3]Faculty of Medicine, Universidade de São Paulo, SP, Brazil.
[4]Department of Medicine, Universidade Federal de Minas Gerais, MG, Brazil.
[5]Department of Neurosurgery, Hospital de Clínicas, Universidade de São Paulo, SP, Brazil.
[6]Faculty of Medicine, Universidade de Pernambuco, Recife, PE, Brazil.

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INTRODUCTION

Spinal stenosis refers to a narrowing of the central spinal canal or intervertebral foramen at single or multiple levels that can compress communicating nerves and other adjacent structures. The etiology of central canal or intervertebral foraminal narrowing can include one or more of the following: the intrinsic shape of the canal, degenerative changes that decrease the canal size, or movement of one anatomic segment in relation to another[1].

The principal symptoms are lower-back pain as well as unilateral or bilateral groin and leg pain, numbness, or weakness. Neurogenic claudication, defined as pain, paresthesia, and cramping of one or both lower limbs compromise brought on by standing or walking and relieved by sitting, is the most specific symptom of spinal stenosis, although not all patients report it.r extremities due to neurologic[2,3].

The impact of back, groin, or leg pain and numbness caused by spinal stenosis can vary widely among individuals and can be a key factor in deciding which treatment to opt and when to adopt it. The goals of treatment are to relieve pain and to maintain and/or improve usual activities. These outcomes correlate better with patient satisfaction than more objective measures such as walking distance. For some people, nonsurgical interventions treat symptoms well. For others, pain may make it impossible to do their usual daily activities, socialize, work, or participate in family life. For such individuals, surgical treatment is reasonable consideration[4].

Although some literature compares these methods, no meta-analysis has been observed to date. Several published articles present a positive perspective on either surgical or non-surgical treatment but without a concrete answer as to which intervention is superior. Our study aims to address this gap by analyzing the available data and providing a comprehensive overview of both methods.

METHODS

This systematic review and meta-analysis strictly followed the methodologies outlined by the Cochrane Collaboration and the reporting guidelines established by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement.

Search strategy and data extraction

To identify pertinent research studies, we systematically reviewed the following databases: PubMed, Embase, and Web of Science. Our search was conducted using a specific search strategy: ("Foraminal Stenosis" OR "Spinal Stenosis" OR "foramen stenosis" OR "neuroforaminal stenosis" OR "Radiculopathy" OR "nerve root compression" OR "root level" OR "nerve impingement" OR "nerve root irritation" OR "neural foraminal narrowing" OR "neurogenic claudication" OR "spinal nerve entrapment" OR "spinal radiculopathy") AND ("Surgical Decompression" OR "foraminotomy" OR "laminectomy" OR "decompressive surgery" OR "surgical treatment" OR "spinal decompression" OR "spine surgery" OR "minimally invasive spine surgery" OR "MIS decompression") AND ("Drug Infiltration" OR "injections, epidural" OR "epidural steroid injection" OR "conservative management" OR "non-surgical treatment" OR "non-operative treatment" OR "nerve block" OR "nerve root block" OR "facet joint injection" OR "rehabilitation therapy" OR "physical therapy" OR "physiotherapy" OR "manual therapy" OR "exercise therapy" OR "pain management" OR "non-invasive treatment").

Studies included in this meta-analysis compared surgical and non-surgical treatments for adult patients with radicular symptoms and met the following criteria: (1) Studies comparing surgical and non-surgical interventions for all types of stenosis; (2) Adults with radicular pain or neurogenic claudication; (3) Studies reporting pain, function, or quality-of-life outcomes; and (4) incorporated both randomized and non-randomized (observational) study designs.

In contrast, exclusion criteria encompassed (1) publications categorized as reviews, letters, meta-analyses, case reports, or comments; (2) publications in languages other than English; (3) studies without full text; (4) studies presenting outcomes from patient groups that overlapped with those in other studies; (5) studies lacking precise patient count information; (6) studies lacking outcome information or with unclear outcome descriptions; (7) studies including only patients who presented complications; (8) patients with spondylolisthesis grade ≥ 2 or other severe instability requiring fusion;with tumors, infections, fractures. (9) patients with prior surgical interventions for the same condition.

Outcomes definitions

The endpoints of interest included: (1) SF36 score, (2) Oswestry Disability Index (ODI), (3) Roland Morris Score.

SF36 36-Item Short Form Health Survey. Higher scores represent better physical status. SF-36 scale ranges from 0 to 100, with lower scores indicating more severe symptoms. ODI is a questionnaire used to assess disability due to low back pain. It consists of 10 sections, each scoring from 0 to 5, covering pain intensity, personal care, lifting, walking, sitting, standing, sleeping, sex life, social life, and traveling. Roland Morris Score is an instrument used to assess functional limitations caused by low back pain. It consists of 24 statements related to daily activities, which the patient marks according to their current condition. The score ranges from 0 to 24, with higher values indicating a greater degree of disability.

Quality assessment

We utilized Version 2 of the Cochrane risk-of-bias tool for randomized trials (RoB 2) to assess the risk of bias in the 7 included studies. This tool evaluates bias across seven key domains: confounding, selection of participants, classification of interventions, deviations from intended interventions, missing data, measurement of outcomes, and selection of the reported result.

Statistical analysis

The analysis of treatment effects included 95% confidence intervals, and heterogeneity was assessed using the I^2 statistic. A I^2 value above 50% indicates high heterogeneity, therefore a random-effects model to address potential variability among the included studies was used. For dichotomous outcomes, the odds ratio (OR) was employed to ensure a standardized metric for comparison across studies. Statistical analyses were conducted using RStudio using the "meta" package[5].

RESULTS

Study selection

Our study selection process involved a comprehensive search that yielded a total of 960 articles, obtained from three databases, Cochrane, PubMed and Embase. To ensure data integrity, 228 duplicated reports were excluded, followed by the exclusion of 696 studies based on title and abstract reviews. Subsequently, a full-text review was conducted on the remaining 36 studies. Ultimately, 9 studies met our criteria and were included in the final analysis, ensuring the relevance and reliability of our dataset. The PRISMA Flow Diagram illustrating the visual process of study selection can be found in Figure 1.

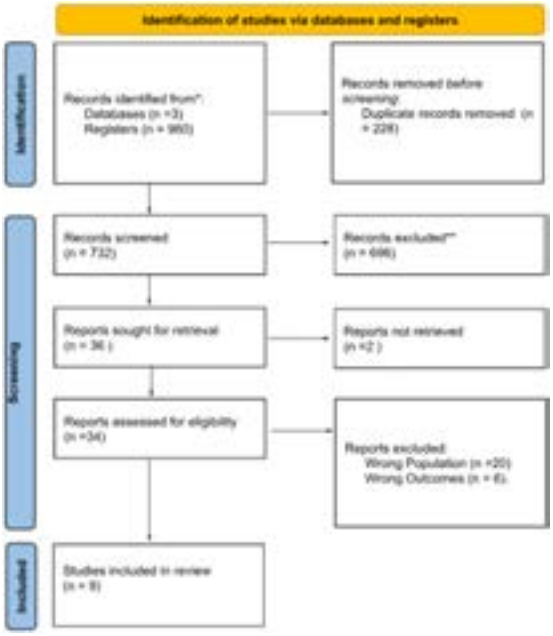

Figure 1. Prisma Flow Diagram. *Number of all bases together; ** Number excluded from all databases combined.

Baseline characteristics

This review summarizes baseline characteristics from nine studies[6-14], encompassing a total of 685 patients. Of these, 381 were allocated to surgical treatment groups and 304 to control groups.

The mean age of patients was reported in all nine studies for both surgical and control groups. In the surgical groups, the mean age ranged from 49 years[10] to 74.2 years[8]. For the control groups, the mean age ranged from 44 years[10] to 78.7 years[8]. Eight studies (all except Karm, 2018[14], whose data were unusable) provided sex distribution. In the Rodrigues and Natour[12] study, the reported male/female numbers for the control group (7/25) were inconsistent with the stated total of 31 control patients. Based on the consistent data from 357 surgical patients (across eight studies) and 253 control patients (across seven studies), the overall female prevalence was approximately 54.6% (333 out of 610 patients).

Body Mass Index (BMI) was reported in five studies[9,11-14]. For the surgical groups, mean BMI ranged from 24.3 kg/m2[14] to 31.5 kg/m2[9]. In the control groups, mean BMI ranged from 21.8 kg/m2[11] to 31.1 kg/m2[9]. Specific patient symptoms were detailed in two studies: Rodrigues and Natour[12] described symptoms for the surgical group as "pain, weakness, numbness, and tingling that worsen with gait and improve with rest... for at least 6 months," while Slatis et al.[13] noted "Low back pain on walking, Pain in lower limbs in standing position, Pain in lower limbs on walking" for their surgical cohort. Other studies either listed symptom data as not available (NA) or did not specify.

Information on previous interventions was provided by one study[9], which reported 8 patients in the surgical group and 17 patients in the control group had undergone prior interventions. Coexisting conditions were reported in four studies. Athiviraham and Yen[7] detailed that in the surgical group, 17 patients (without fusion) and 12 patients (with fusion) had coexisting conditions, while 6 patients in the control group had conditions such as coronary artery disease, diabetes mellitus, COPD, or peripheral vascular disease. Brown[8] reported diabetes in 5 patients within the surgical group. Engquist et al.[10] noted the number of smokers (Surgical: 8, Control: 9) and patients on sick leave (Surgical: 23, Control: 21). Rodrigues 2021 reported diabetes (Surgical: 6, Control: 9) and systemic hypertension (Surgical: 21, Control: 16). Table 1 presents further details on these baseline characteristics.

Outcomes characteristics

Regarding functional and quality-of-life outcomes, several metrics were assessed across the included studies. A total of 8 studies reported outcome data, with patient numbers varying across groups. The SF-36 PCS was available in two studies, with one study reporting a score of 41.19 ± 1.97 for the surgical group. For the SF-36 MCS the surgical group in the same study.

ODI was assessed in at least one study, showing mean scores of 27.4 (±7.0) for the surgical group and 34.8 (±8.2) for the control group. Additionally, Roland Morris Disability Questionnaire (RMDQ) scores were reported in another study, with surgical patients showing an average of 8.7 (±6.1) and control patients, 7.8 (±1.2).

Follow-up duration across studies ranged from 3 to 24 months (Table 2).

Risk of bias of the included studies

The risk of bias assessment for the included studies using the ROBINS-I and ROBINS-II tool highlights significant variability across several domains. Most studies exhibited a "High" and "Moderate" risk of bias due to confounding, with only three studies showing a "Low" risk. In terms of participant selection, the majority were rated as having a "Low" risk, which does not affect the comparability between groups. Furthermore, all studies demonstrated a "Low" risk in classifying interventions and managing deviations from intended protocols, indicating effective control over treatment assignment. Additionally, nearly all studies were rated as "Low" risk for measurement of outcomes and selection of reported results, suggesting reliability in these areas. The visual analysis of bias can be found in Figure 2 and Figure 3.

Overall, many studies were classified with a "Moderate" or "Serious" overall risk of bias, primarily driven by concerns about confounding and participant selection. Only a few studies achieved a "Low" overall risk[8,12,13], highlighting the challenges in conducting robust comparative analyses within observational research. These findings underscore the importance of cautious interpretation of the results, particularly in light of prevalent confounding and selection bias, which significantly impact the quality of evidence in this field.

Pooled analysis of included studies

SF36 PCS score

A primary meta-analysis of four studies (312 patients), presented in Figure 4, initially showed a significant standardized mean

Table 1. Baseline characteristics of included studies and patients.

Study/ Year	Baseline													
	Patients (n)		Mean age		Sex (male/female)		BMI (kg/m²)		Symptoms		Previous Intervention		Coexisting Conditions	
	Surgical	Control	Surgical	Control	Surgical	Control	Surgical	Control	Surgical	Control	Surgical	Control	Surgical	Control
Anderson et al., 2006[6]	42	33	71.4	68.5	19/23	11/22	NA	NA	NA	NA	NA	NA	NA	NA
Athiviraham and Yen, 2007[7]	88	24	w/o fusion: 63; w/ fusion: 70	69	w/o fusion: 32/17; w/ fusion: 14/25	10/14	NA	NA	NA	NA	NA	NA	w/o fusion: 17; w/ fusion: 12	6 (includes coronary artery disease, diabetes mellitus, peripheral vascular disease)
Brown, 2012[8]	21	17	74.2	78.7	13/8	8/9	NA	NA	NA	NA	NA	NA	NA	Diabetes - 5 patients
Delitto et al., 2015[9]	87	82	66.6	69.8	44/43	44/38	31.5	31.1	NA	NA	8 patients	17 patients	NA	NA
Engquist et al., 2013[10]	31	32	49	44	14/17	19/13	NA	NA	NA	NA	NA	NA	smokers - 8; sick leave - 23	smokers - 9; sick leave - 21
Minetama et al., 2018[11]	7	21	65.7 ± 10.4	71.5 ± 5.2	1/6	9/12	25.3 ± 3.2	21.8 ± 3.1	NA	NA	NA	NA	NA	NA
Rodrigues and Natour, 2021[12]	31	31	60.71 (±7.41)	60.22 (±7.22)	8/23	7/25	29.28	26.52	Pain, weakness, numbness, and tingling that worsen with gait and improve with rest, whether they are associated with low back pain for at least 6 months		NA	NA	Diabetes - 6 patients; Hipertension Systemic - 21 patients	Diabetes - 9 patients; Systemic Hipertension - 16 patients
Slatis et al., 2010[13]	50	44	63 (±9)	62 (±9)	11/39	20/24	28 ± 4	27 ± 4	Low back pain on walking, Pain in lower limbs in standing position, Pain in lower limbs on walking.		NA	NA	NA	NA
Karm et al., 2018[14]	24	20	65.5 ± 6.4	66.1 ± 12.2	17/7	9/11	24.3 ± 2.2	24.3 ± 2.4	NA	NA	NA	NA	NA	NA

BMI: Body Mass Index; NA: not applied

Table 2. Outcomes Characteristics.

Study/Year	Outcomes Characteristics											
	Patients (n)			SF36 PCS		SF36 MCS		Oswestry		Roland Morris Score		Follow-Up (months)
	Surgical	Control	Total	Surgical	Control	Surgical	Control	Surgical	Control	Surgical	Control	
Anderson et al., 2006[6]	42	33	75	41.19 ± 1.97	28.14 ± 1.10	56.29 ± 1.25	49.66 ± 2.22	NA	NA	NA	NA	24
Athiviraham and Yen, 2007[7]	88	24	112	NA	NA	NA	NA	NA	NA	8.7 (± 6.1)	7.8 (± 1.2)	24
Brown, 2012[8]	21	17	38	NA	NA	NA	NA	27.4 (±7.0)	34.8 (± 8.2)	NA	NA	3
Delitto et al., 2015[9]	87	82	169	49.5 (± 6.4)	47.6 (± 6.9)	NA	NA	25.2 (± 1.88)	27.0 (± 4.2)	NA	NA	24
Engquist et al., 2013[10]	31	32	63	NA	NA	NA	NA	NA	NA	NA	NA	24
Minetama et al., 2018[11]	7	21	28	70.7 ± 11	70.2 ± 21.5	68.6 ± 17.3	62.9 ± 22.3	NA	NA	5.4 ± 3.3	4.8 ± 4.7	24
Rodrigues and Natour, 2021[12]	31	31	62	25.65 (± 1.17)	39.84 (± 11.89)	63.74 (± 34.46)	65.00 (± 37.74)	35.74 (± 20.03)	47.81 (± 16.69)	12.71 (± 6.53)	13.63 (± 7.07)	24
Slatis et al., 2010[13]	50	44	94	NA	NA	NA	NA	24.2 ±19.7	29.8 ± 22.1	NA	NA	24
Karm et al., 2018[14]	24	20	44	NA	NA	NA	NA	37.7 ± 12.4	41.3 ± 14.3	NA	NA	6

SF36 PCS: Short Form, Physical Component Summary; SF36 MCS: Mental Component Summary. NA: not applied

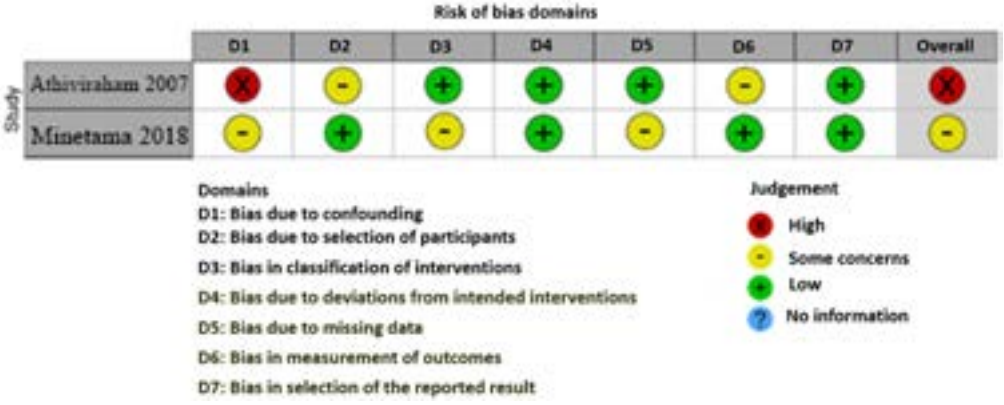

Figure 2. Robins-I Table.

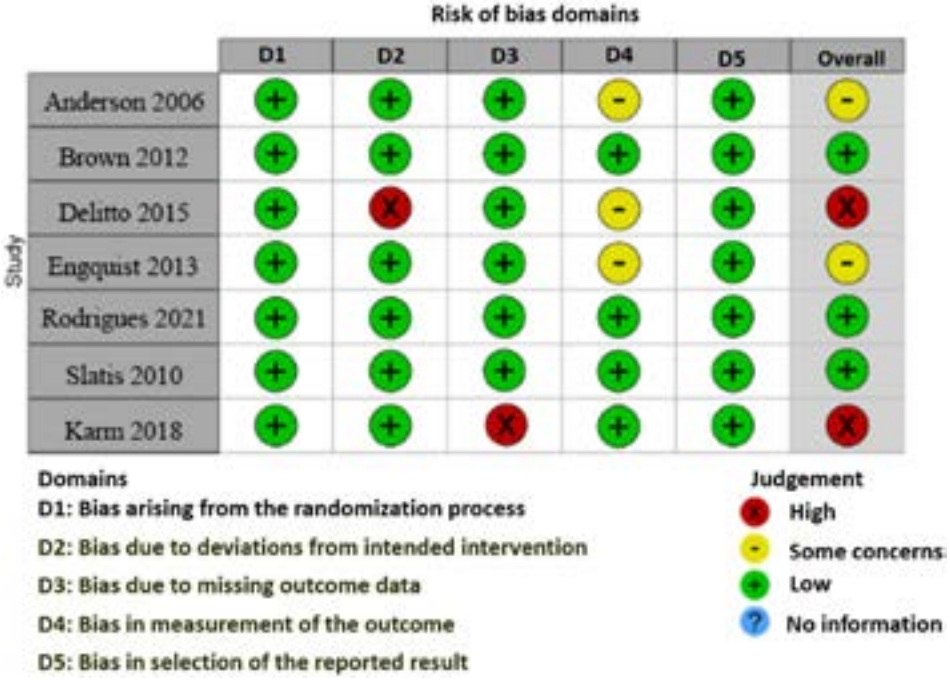

Figure 3. ROBS-II Table.

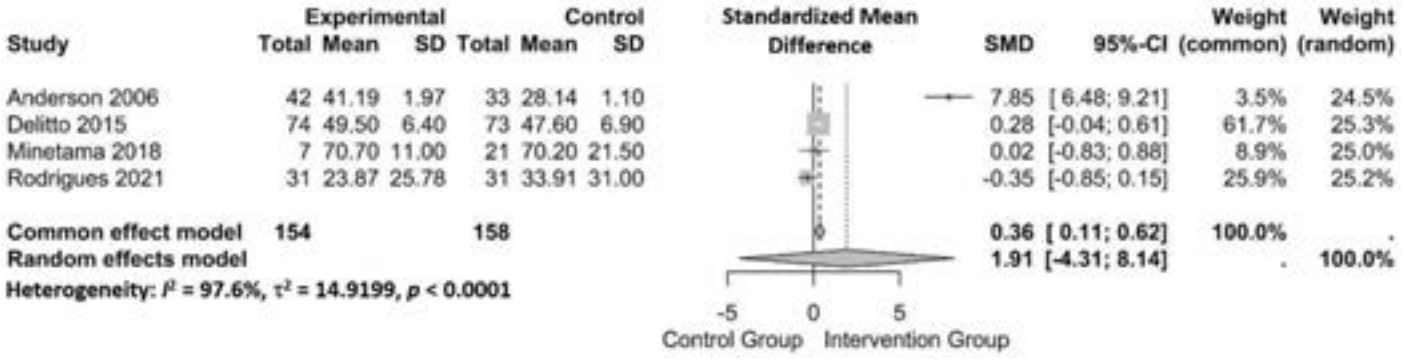

Figure 4. SF36 PCS Score Forest Plot.

difference (SMD) (0.3614; 95% CI 0.1061 to 0.6167). However, substantial heterogeneity (I^2 = 97.6%) led to a random effects model, which revealed no statistically significant difference between groups (SMD = 1.9140; 95% CI -4.3113 to 8.1394).

A sensitivity analysis, available in Figure 5, was conducted after excluding the Anderson et al.[6] study due to its influence on heterogeneity, which involved three studies (237 patients). After its exclusion, no statistically significant differences were found in either model (common: SMD = 0.0907; 95% CI -0.1692 to 0.3506; random: SMD = 0.0174; 95% CI -0.8400 to 0.8748). Heterogeneity was reduced to moderate (I^2 = 53.7%), indicating the Anderson et al.[6] study was a key factor in the observed heterogeneity and in the initial results.

SF36 MCS score

A primary meta-analysis of three studies involving 165 patients, presented in Figure 6, initially showed a significant standardized mean difference (SMD) (1.0501; 95% CI 0.6741 to 1.4262). However, considerable heterogeneity (I^2 = 96.8%) led to a random effects model, which revealed no statistically significant difference between groups (SMD = 1.3936; 95% CI -3.6926 to 6.4797).

A sensitivity analysis, available in Figure 7, was conducted after excluding the Anderson (2006) study due to its influence on heterogeneity. This analysis involved two studies (90 patients). After its exclusion, no statistically significant differences were found in either model (common: SMD = 0.1942; 95% CI -0.2371 to 0.6255; random: SMD = 0.1942; 95% CI -0.294 to 0.6830). Heterogeneity was eliminated (I^2 = 0.0%), indicating the Anderson et al.[6] study was the primary driver of heterogeneity in the initial analysis.

Oswestry Disability Index (ODI)

A meta-analysis of five studies, involving 407 patients, presented in Figure 8, showed that experimental intervention was associated with a significant reduction in ODI scores. The common effect model resulted in an SMD of -0.6573 (95% CI -0.8582 to -0.4564). Despite a moderate heterogeneity (I^2 = 43.3%; p = 0.1329), the random effects model also indicated a significant reduction

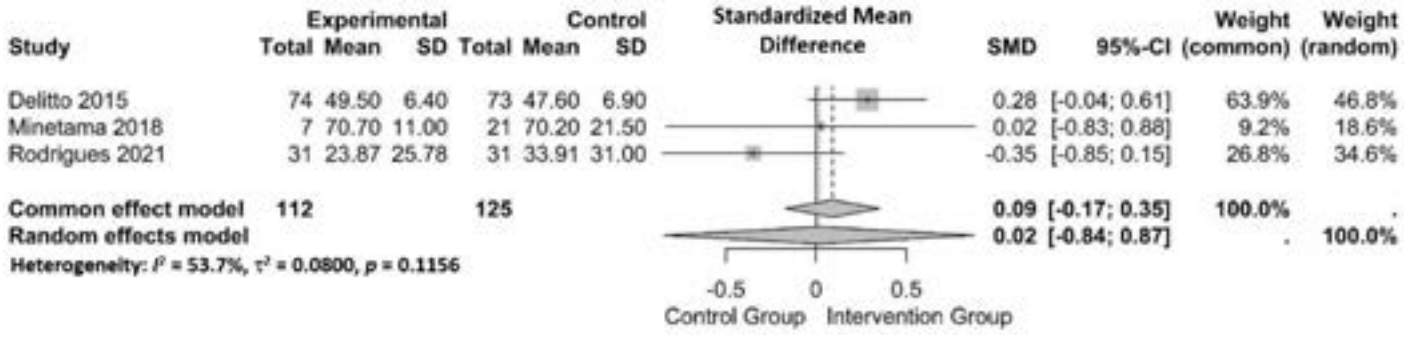

Figure 5. SF36 PCS, sensitivity analysis, Forest Plot.

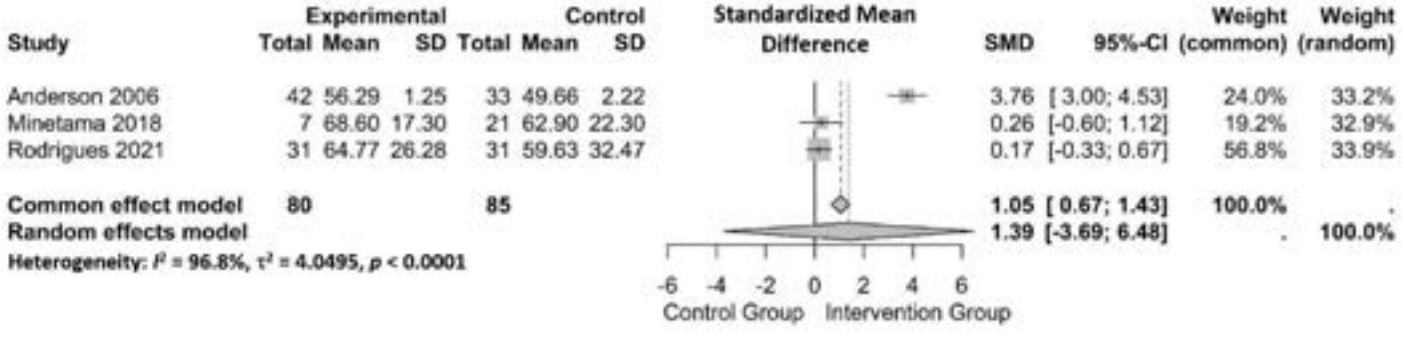

Figure 6. SF36 MCS Score Forest Plot.

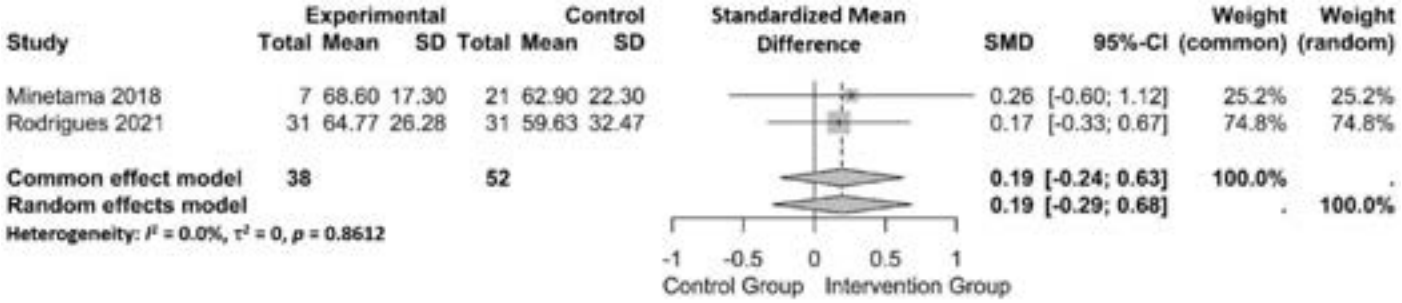

Figure 7. SF36 MCS Score Forest Plot.

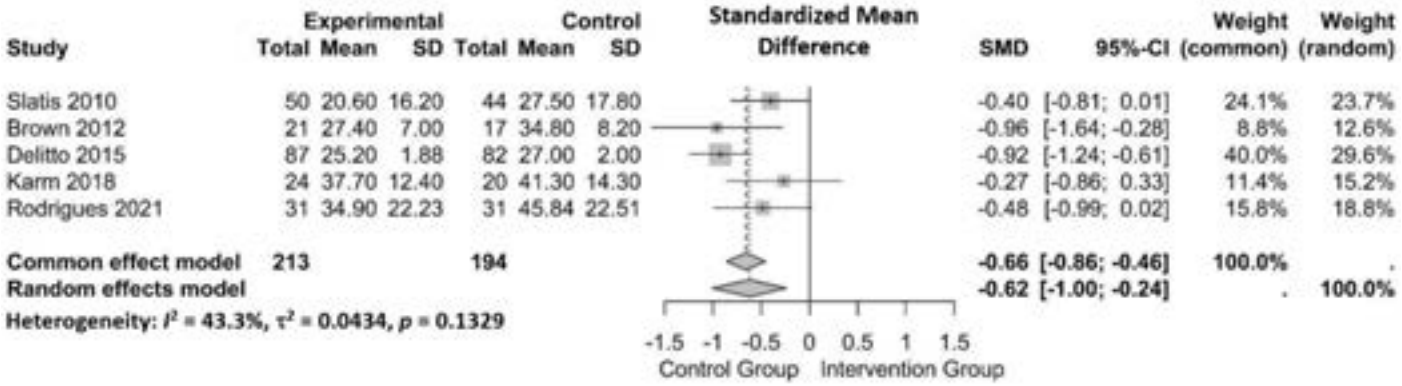

Figure 8. ODI Forest Plot.

(SMD = -0.6220; 95% CI -1.0038 to -0.2403). Both models suggest improved functionality and reduced disability.

Roland Morris score

A meta-analysis of three studies, with 202 patients, presented in Figure 9, showed no statistically significant difference in Roland Morris Scores between experimental and control groups. The common effects model indicated an SMD of 0.0265 (95% CI -0.2854 to 0.3384), with no significant heterogeneity (I^2 = 0.0%; p = 0.5910). The random effects model produced identical results.

DISCUSSION

This meta-analysis compares surgical intervention with conservative management in patients with lumbar stenosis. A comprehensive literature review was conducted to gather all pertinent studies on the subject. The objective was to offer crucial insights into the comparative efficacy and safety of surgical versus conservative treatment in patients with lumbar stenosis. This information aims to equip clinicians with comprehensive knowledge to support informed decision-making regarding treatment options.

Our analysis incorporates data from nine selected studies, encompassing a total of 686 patients, focusing on the following outcomes: patient pain reduction, assessment of patients' mental status, and limitations and disabilities associated with low back pain. The principal findings of our study were as follows: Analysis of the Oswestry Disability Index (ODI) score revealed a statistically significant difference favoring the surgical approach over conservative management in the analyzed sample. However, a sensitivity analysis was conducted for this score due to substantial heterogeneity. This heterogeneity possibly arised from differing methodologies across the included studies, variations in the criteria used to define a "case" of lumbar stenosis (LS) —for instance, purely radiological versus symptomatic—or different thresholds for symptoms.

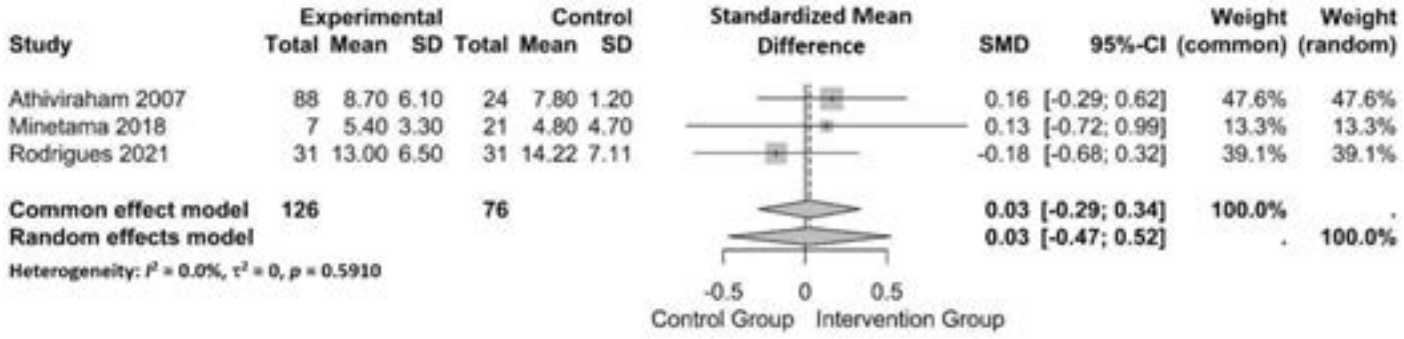

Figure 9. Roland Morris Score Forest Plot.

The predominance of "Low" and "Moderate" risk of bias classifications, particularly concerning outcome measurement and selective reporting, suggests that the reported treatment effects were not unduly confounded by these potential sources of bias. Furthermore, variability in participant selection criteria across studies may lead to differences in baseline characteristics, which are crucial determinants of treatment outcomes. Additionally, reliance on observational data, particularly when randomization is not feasible, elevates the risk of selection bias.

The reported annual incidence is 5 cases per 100,000 individuals. This figure is consistently presented across various sources and is five times higher than the incidence of cervical stenosis. These conditions represent a significant medical concern due to their high morbidity, frequently associated with unfavorable outcomes[15-16]. It is crucial to distinguish between the radiological diagnosis of LS (i.e., the finding of canal narrowing on imaging studies) and the presence of symptomatic LS (i.e., when such narrowing elicits clinical manifestations). Many individuals exhibit radiological evidence of stenosis without developing symptoms[17].

This discrepancy underscores that the mere observation of lumbar stenosis on magnetic resonance imaging (MRI) or other imaging modalities does not determine that this stenosis is the cause of the patient's pain or other symptoms. Not all individuals with anatomical spinal stenosis develop symptoms, presenting a challenge in accurately determining the prevalence of clinically manifest disease. The high prevalence of radiological LS in asymptomatic individuals suggests that anatomical narrowing of the spinal canal is, in fact, considerably more common than the clinically manifest disease.

Several treatment options are available for lumbar stenosis, including laminectomy, the use of surgical implants, and conservative management. Surgical treatment, particularly laminectomy, is considered a more invasive technique but remains crucial, especially for patients with high disease severity and in instances of functional impairment accompanied by pain and diminished quality of life. Concurrently, with a view to long-term rehabilitation and for patients who wish to avoid or are unsuitable candidates for invasive procedures, conservative management may yield patient improvements[17].

In this meta-analysis, analyses of the SF-36 Physical Component Summary (PCS), SF-36 Mental Component Summary (MCS) scores —which directly assess patient quality of life by evaluating physical health and mental health, respectively— and Roland Morris Disability Questionnaire did not achieve statistical significance in inter-group comparisons. These findings highlight the complex interplay of factors influencing patient outcomes, suggesting that although certain complications may arise, their impact on the overall efficacy of the treatment modalities might not be as pronounced as previously hypothesized.

CONCLUSION

This article provides a comprehensive assessment of the comparative effectiveness of surgical versus conservative treatment in patients with lumbar spinal stenosis. Surgical intervention demonstrated a statistically significant improvement in Oswestry Disability Index (ODI) scores, supporting its benefit in functional outcomes. An initial analysis of the Short Form-36 Mental Component Summary (SF-36 MCS) also showed statistical

significance in favor of surgery; however, this effect was not sustained in the sensitivity analysis, likely due to substantial heterogeneity among the included studies.

Outcomes related to the SF-36 Physical Component Summary, SF-36 Mental Component Summary and the Roland-Morris Disability Questionnaire did not consistently differ between groups, suggesting that improvements in physical health and daily function may depend on multiple factors beyond the choice of treatment modality.

In conclusion, while surgery remains a critical option for patients with severe functional impairment or refractory symptoms, conservative management may be effective for selected individuals with milder presentations or higher surgical risk. Therefore, treatment decisions should be tailored to each patient's clinical profile, functional limitations, and preferences. Further high-quality randomized controlled trials with standardized outcome assessments are needed to refine guidelines and support shared decision-making in the management of lumbar spinal stenosis.

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CORRESPONDING AUTHOR

José Gabriel Abreu Moreira, MS
Medical student

Department of Medical Sciences, Universidade Federal da Paraiba
João Pessoa, Paraíba, Brazil
E-mail: jgam@academico.ufpb.br

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Bypass, Minimally Invasive and Endoscopic Procedures in Moyamoya Disease: current clinical impact and future perspectives

Bypass, Procedimentos Minimamente Invasivos e Endoscópicos na Doença de Moyamoya: impacto clínico atual e perspectivas para o futuro

Thiago de Mendonça Nonato Oliveira[1]
André Giacomelli Leal[2]

ABSTRACT

Moyamoya disease (MMD) is a progressive cerebrovascular arteriopathy characterized by stenosis of the internal carotid artery and its branches, associated with the formation of anomalous collateral circulation. It presents a bimodal age distribution, with a higher prevalence in East Asian populations and variable risk among population groups. Clinical management aims to reduce ischemic and hemorrhagic events, while surgical revascularization constitutes the main therapeutic strategy. This study aims to critically analyze the evidence on direct and indirect revascularization, as well as less invasive approaches, evaluating functional benefits, risks, limitations, and future perspectives in neurosurgery. Recent clinical studies and reviews on direct (STA-MCA, OA-MCA and grafts) and indirect (EDAS, EMS, EAS, EDS, EMAS) bypass were reviewed. Outcomes included cerebral perfusion, ischemic/hemorrhagic events, collateral development, neurological function (mRS), and perioperative complications, with emphasis on cerebral hyperperfusion syndrome. Direct bypass offers immediate restoration of flow and early functional improvement, making it preferable in adults with a high risk of ischemia. Indirect bypass, which is less invasive, promotes gradual angiogenesis and greater safety in children. Hybrid approaches and minimally invasive techniques are emerging as promising alternatives. The selection of the procedure should be individualized, considering age, vascular anatomy, and clinical risk.

Keywords: *Moyamoya disease; Cerebral revascularization; Neurosurgery; Minimally invasive surgical procedures; Neuroendoscopy*

RESUMO

Doença de Moyamoya (DMM) é uma arteriopatia cerebrovascular progressiva caracterizada por estenose da artéria carótida interna e seus ramos, associada à formação de circulação colateral anômala. Apresenta distribuição etária bimodal, com maior prevalência em populações do Leste Asiático e risco variável entre grupos populacionais. O manejo clínico visa reduzir eventos isquêmicos e hemorrágicos, enquanto a revascularização cirúrgica constitui a principal estratégia terapêutica. Este estudo objetiva analisar criticamente as evidências sobre revascularização direta e indireta, bem como abordagens menos invasivas, avaliando benefícios funcionais, riscos, limitações e perspectivas futuras em neurocirurgia. Foram revisados estudos clínicos recentes e revisões sobre bypass direto (ATC-ACM, AO-ACM e enxertos) e indireto (EDAS, EMS, EAS, EDS, EMAS). Os desfechos incluíram perfusão cerebral, eventos isquêmicos/hemorrágicos, desenvolvimento de colaterais, função neurológica (escala de Rankin modificada) e complicações perioperatórias, com ênfase em síndrome de hiperperfusão cerebral. O bypass direto oferece restauração imediata do fluxo e melhora funcional precoce, tornando-o preferível em adultos com alto risco de isquemia. O bypass indireto, menos invasivo, promove angiogênese gradual e maior segurança em crianças. Abordagens híbridas e técnicas minimamente invasivas emergem como alternativas promissoras. A seleção do procedimento deve ser individualizada, considerando idade, anatomia vascular e risco clínico.

Palavras-Chave: *Doença de Moyamoya; Revascularização cerebral; Neurocirurgia; Cirurgia minimamente invasiva; Neuroendoscopia*

[1]Centro Universitário Aparício Carvalho – FIMCA, Porto Velho, RO, Brasil.
[2]Chief of Vascular Neurosurgery Department, Instituto de Neurologia de Curitiba – INC, Curitiba, PR, Brasil.

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INTRODUCTION

Moyamoya disease (MMD) is characterized by intimal hyperplasia and fibrosis of the arterial wall[1], leading to progressive stenosis of the terminal portion of the internal carotid artery (ICA), its proximal branches, and the vessels of the circle of Willis. This process results in the development of an abnormal collateral vascular network to compensate for reduced cerebral blood flow[2]. The disease was first described in 1957 by Takeuchi and Shimizu in Japan. The term "moyamoya" refers to a hazy or "puff-of-smoke" appearance, reflecting the characteristic angiographic pattern of abnormal collateral vessels[3].

When similar clinical manifestations are associated with an underlying condition, the disorder is referred to as moyamoya syndrome (MMS). However, since diagnostic criteria rely heavily on angiographic findings, caution is advised in the use of the term "moyamoya syndrome"[4].

MMD occurs most frequently in East Asian countries, particularly Japan and Korea, although studies have also reported a progressive increase in cases in Western populations. In the United States, an incidence rate of 0.086 per 100,000 inhabitants has been reported. In contrast, an analysis using the Nationwide Inpatient Sample Database identified a higher incidence of 0.57 per 100,000 individuals. This same study demonstrated a female predominance, with women accounting for approximately 72% of reported cases[5].

The disease exhibits a bimodal age distribution, with peak incidence between 5 and 10 years and between 25 and 49 years of age, highlighting the heterogeneity of MMD. Early clinical manifestations are more commonly observed in pediatric patients, whereas adult presentations tend to occur during middle adulthood[6]. Significant differences in risk have been observed among population groups, with reported incidence rates of 4.6 among Asian Americans, 2.2 among Black individuals, and 0.5 among Hispanic populations[7].

Although MMD has no definitive cure, early diagnosis and timely implementation of appropriate interventions—such as surgical revascularization procedures and medical management with antiplatelet agents—may improve outcomes by reducing the risk of ischemic or hemorrhagic complications[8].

Management of MMD typically includes surgical revascularization procedures, with bypass surgery being the primary approach aimed at restoring cerebral blood flow (CBF) and reducing the risk of stroke in affected patients[9].

Among the available techniques, direct methods involve extracranial-to-intracranial (EC–IC) anastomosis, most commonly between the superficial temporal artery and the middle cerebral artery (STA–MCA)[10,11]. Indirect methods include encephaloduroarteriosynangiosis (EDAS)[12], encephalomyosynangiosis (EMS), encephaloarteriosynangiosis (EAS), encephalodurosynangiosis (EDS), encephalomyoarteriosynangiosis (EMAS), as well as various combinations of these techniques[1,13,14].

The development of collateral circulation following revascularization is associated with improved clinical prognosis, while adequate bypass patency ensures sustained CBF and reduces the incidence of postoperative ischemic events (PIEs)[1]. The effectiveness of revascularization is closely related to the functional performance of the bypass, which may be compromised by primary or secondary graft failure[13].

Despite technical advances and encouraging outcomes, significant challenges remain regarding the selection of the optimal revascularization strategy, its impact on long-term clinical outcomes, and future innovations in the field. Therefore, the present article aims to critically review the available evidence on the role of direct and indirect bypass techniques in the management of Moyamoya disease, highlighting current clinical benefits, limitations of each approach, and emerging trends that may redefine neurovascular surgical practice.

MATERIALS AND METHODS

A systematic review was conducted based on studies published in the PubMed, SciELO, Jornal Brasileiro de Neurocirurgia (JBNC), Thieme, and other databases selected for their broad coverage of neurosurgical and scientific literature. Articles published between 2020 and 2025 (the last six years) were included. Studies written in English, Portuguese, and/or Spanish were considered, with no restrictions regarding study design, in order to ensure a comprehensive, current, and reliable body of evidence.

Descriptors and keywords were defined using the Medical Subject Headings (MeSH) and the Health Sciences Descriptors (DeCS) and were combined using Boolean operators to increase search sensitivity. All retrieved records were exported to the Mendeley® reference manager, which was used for organization, duplicate removal, and storage of the selected articles.

Inclusion criteria comprised: original studies or randomized clinical trials addressing revascularization in Moyamoya disease; pediatric or adult patients diagnosed with MMD or Moyamoya syndrome; interventions involving direct, indirect, or combined bypass procedures (STA–MCA, EDAS, EMS, among others), as well as minimally invasive and endoscopic procedures; outcomes including cerebral perfusion, ischemic or hemorrhagic events, and neurological function (modified Rankin Scale [mRS], Matsushima grading); and publications in English, Portuguese, or Spanish between 2020 and 2025.

Exclusion criteria included studies not aligned with the proposed theme and objectives; abstracts only; studies involving non-human populations; articles lacking relevant clinical data or outcome assessment; publications prior to 2020; and articles that did not include any of the predefined descriptors.

The study selection process followed the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). Initially, titles and abstracts were screened according to the predefined inclusion and exclusion criteria. Extracted data included information on the study population, interventions performed, outcomes assessed, and main results.

After applying the eligibility criteria, sources of information and search strategies were defined. Subsequently, the retrieved studies underwent a structured selection process consisting of identification, screening, eligibility assessment, and final inclusion. Finally, study selection was performed independently, with conflicts resolved through reviewer consensus (Figure 1).

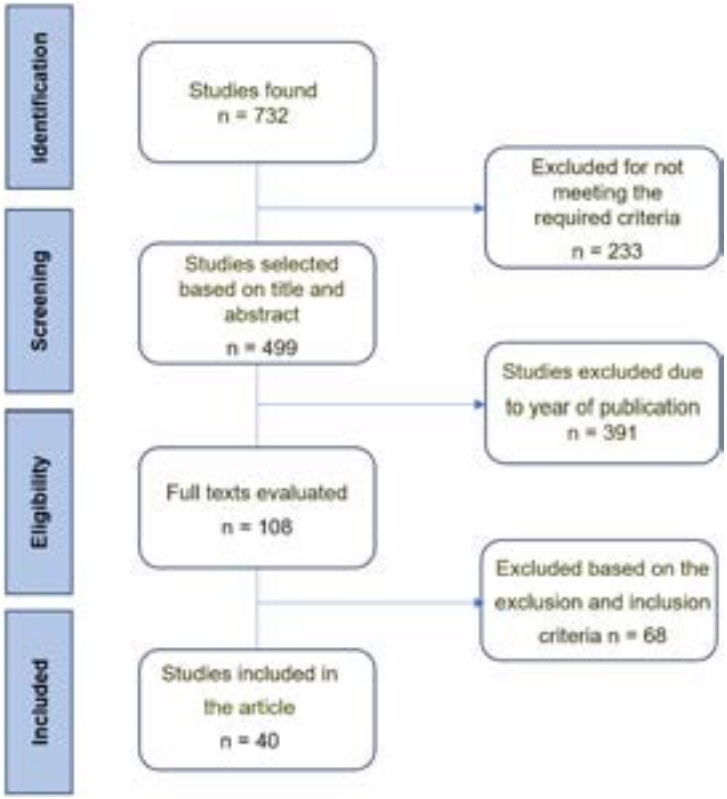

Figure 1. Methodological flowchart for defining the literature base.

RESULTS

Cerebrovascular revascularization strategies

According to Greenberg's Handbook of Neurosurgery[15], there are two main groups of cerebrovascular revascularization (bypass) procedures, which are further detailed in Table 1:

1) Direct revascularization procedures[20]: These techniques demonstrate superior outcomes compared with indirect methods; however, they require both donor and recipient vessels of adequate caliber (≥ 1 mm external diameter). They include superficial temporal artery–middle cerebral artery (STA–MCA) bypass (the procedure of choice), occipital artery–MCA (OA–MCA), radial artery–MCA (RA–MCA), saphenous vein graft bypass, as well as extracranial–intracranial (EC–IC) bypasses.

2) Indirect revascularization procedures[21]: These techniques are predominantly used in younger patients (approximately ≤15 years of age), as they do not require sufficient vessel caliber for direct anastomosis. They include encephalomyosynangiosis (EMS), encephaloduroarteriosynangiosis (EDAS), encephaloarteriosynangiosis (EAS), encephalodurosynangiosis (EDS), encephalomyoarteriosynangiosis (EMAS), and combinations of these methods.

Functional and clinical benefits of direct bypass

A study conducted by Shi et al.[22] analyzed 98 patients with Moyamoya disease who underwent surgery at Nanjing Drum Tower Hospital in 2023 using three STA–MCA direct bypass techniques: 1D1R anastomosis (one donor to one recipient), 1D2R (one donor to two recipients), and 2D2R (two donors to two recipients), all performed using the EC–IC technique. The authors reported improved cerebral perfusion, increased ischemic tolerance, reduced complication rates, and short-term functional improvement[22,23]. Table 2 presents a stratified analysis of the effects of EC–IC bypass across the studied groups.

An enhanced STA–MCA bypass technique, which combines two branches of the superficial temporal artery through a direct bypass associated with an adhesive, has the potential to supply blood flow to multiple ischemic cerebral regions, reduce the risk of hyperperfusion associated with single-vessel bypass, and preserve adequate scalp perfusion. This approach may result in a lower incidence of complications and improved clinical outcomes when compared with conventional combined bypass techniques[24].

Direct bypass represents one of the most relevant therapeutic strategies for patients with Moyamoya disease, a rare and progressive condition characterized by stenosis of intracranial arteries at the base of the brain. Evidence from clinical studies demonstrates that this procedure increases cerebral perfusion and reduces the incidence of new strokes in adult patients with MMD[25].

Table 1. Comparative table between direct and indirect revascularization/bypass procedures.

Associated condition	Direct Procedure	Indirect Procedure
Surgical technique	A direct connection (anastomosis) is made between a donor artery (outside the brain) and a recipient artery (inside the brain). The most common is the anastomosis between the superficial temporal artery (outside the skull) and a middle cerebral artery (inside the brain).	A vascularized tissue, such as a muscle or part of an artery, is placed on the surface of the brain to stimulate the growth of new blood vessels (neoangiogenesis) over time. Examples include encephaloduroarteriosynangiosis (EDAS) and encephalomyosynangiosis (EMS).
Blood flow	It restores blood flow to the brain immediately.	The additional blood flow is established gradually as the new blood vessels develop, which can take 3 to 6 months for the effects to be noticed.
Suitable for adults	Frequently used in adults, especially those with recent and rapidly progressive symptoms, such as those of a stroke. It is also considered the treatment of choice in adults with Moyamoya disease.	It is generally considered less effective for adults than for children, as the ability to form new blood vessels (neoangiogenesis) is less robust in adults.
Suitable for children	It is more challenging to perform in pediatric patients. Studies indicate that direct bypass may be superior in preventing recurrent ischemic strokes in children.	This is usually the preferred technique for pediatric patients, who have a more effective natural ability to heal and form new blood vessels than adults.
Revascularization rate	Generally, it provides a significantly greater degree of revascularization compared to indirect bypass.	Revascularization is less significant and may result in inadequate collateral flow in some cases.

Source: Adapted from Nguyen et al.[16,17], Ayyad et al.[18], Nielsen et al.[19].

Table 2. Effects of EC-IC on each direct bypass technique STA-MCA.

Aspect	1DR1	1DR2	2DR2
Cerebral perfusion	Perfusion increases, but infarct volumes and hypoperfusion are greater under controlled hypotension.	Wider perfusion; better tolerance to hemispheric ischemia.	Wider and more efficient perfusion; greater reduction in infarct volumes and hypoperfusion.
Functional outcomes (mRS)	Functional improvement is present, but less than in 1D2R and 2D2R.	Improved functional prognosis; significant reduction in deficits.	Favorable functional results, similar to or better than 1D2R.
Neovascularization (Matsushima)	Grade A reached in approximately 37.5% of cases.	Grade A reached in 67.5%.	Grade A was reached in 76.2%.
Ischemic and hemorrhagic events	Increased risk of postoperative myocardial infarction; moderate CHS.	Lower risk of new heart attacks; shorter duration of heart rate.	No new heart attacks; risk of subcutaneous cholesterol present, but manageable.
Surgical occlusion time	Shorter.	Longer duration of occlusion.	Intermediary.
Intraoperative hemodynamics	Higher MVV in donor vessels, which may increase the risk of hypoperfusion and complications.	Moderate MVV; more balanced flow; good tolerance to ischemia.	Efficient flow distribution; hemispheric autoregulation; ample perfusion.
Protection against recurrent events (stroke, TIA, hemorrhage)	Protection is present, but less compared to multiple techniques.	Significant protection; prevention of recurring events.	Maximum protection; reduction of infarction volumes and hypoperfusion; effective prevention of recurrent events.

mRS – Modified Rankin Scale; Matsushima – Angiographic classification system that evaluates the outcome of surgical revascularization in patients with Moyamoya disease; CHS – Cerebral Hyperperfusion Syndrome; MVV – Mean Velocity Value.
Source: Adapted from Shi et al.[22].

By restoring cerebral blood flow, the surgical technique optimizes oxygen and nutrient delivery to brain regions previously compromised by ischemia[23]. This process is associated with improved neurological performance, reflected by reductions in motor deficits, sensory disturbances, and visual impairments, as well as decreased all-cause mortality, hemorrhagic stroke–related mortality, and incidence of hemorrhagic stroke when compared with non-surgically managed patients with MMD[26].

Perioperative management of cerebral hyperperfusion (CHP), using both STA–MCA and OA–PCA bypasses, is essential and may contribute to favorable long-term clinical outcomes. A case of symptomatic CHP following direct bypass of the posterior circulation in a patient with MMD has been reported, representing a rare complication in this vascular territory[27].

In certain cases, complementary revascularization of the posterior circulation becomes necessary after initial anterior circulation surgery, either due to the development of new posterior cerebral artery (PCA) stenosis or persistent hypoperfusion within the corresponding territory[27].

Functional and clinical benefits of indirect bypass

A study by Khan et al.[28] analyzed eight patients with Moyamoya disease who underwent indirect revascularization via EDAS due to progression to hemorrhagic disease. This retrospective analysis demonstrated the contribution of EDAS to improved functional outcomes in patients with hemorrhagic MMD while confirming the safety of the procedure, as shown in Table 3.

These findings further emphasize the need for future investigations, preferably multicenter longitudinal studies with extended follow-up, to more comprehensively evaluate the surgical outcomes of EDAS in Moyamoya disease[28].

Indirect revascularization is considered a less invasive alternative compared with direct bypass, as it does not involve anastomosis between small intracranial arteries. This characteristic confers greater procedural safety, particularly in pediatric patients and in those deemed unsuitable for direct techniques[28]. In the context of Moyamoya disease—especially in children—indirect revascularization is frequently regarded as the treatment of choice, as it contributes to the prevention of strokes and recurrent ischemic events[29].

Table 3. Positive impacts of EDAS surgery on hemorrhagic MMD.

Positive impact	Evidence
Reduction of hemorrhagic recurrence	No patient experienced recurrent intracranial hemorrhage in the first 6 months; rates were lower than those reported in previous studies.
Functional improvement (mRS)	Approximately 72% of patients showed improvement in the mRS score, indicating significant recovery of neurological function.
Robust collateral development	Evaluation using the Matsushima system showed 57.2% grade A and 42.8% grade B, indicating adequate formation of collateral circulation.
Procedure safety	Low incidence of symptomatic postoperative cerebral ischemia (only 2 patients), indicating a safe profile, even in the pediatric age range.
	Symptomatic postoperative cerebral ischemia was observed in only two patients in the study, who were 9 and 15 years old.
Pediatric and adult applicability	Benefits observed in both children and adults, reinforcing the role of EDAS in improving cerebral perfusion and preventing ischemic or hemorrhagic events.
Clinical relevance	This confirms EDAS as an effective strategy for patients with hemorrhagic MMD, contributing to functional stability and a favorable prognosis.

mRS – modified Rankin scale, used; Matsushima – angiographic classification system that assesses the outcome of surgical revascularization in patients with Moyamoya disease.
Source: Adapted from Khan et al.[28].

Unlike direct revascularization, which provides immediate vascular connection, indirect techniques promote a gradual angiogenic process, culminating in the development of a collateral network capable of restoring cerebral blood supply in a more natural and durable manner[30]. This progressive vascular formation has a positive impact on clinical evolution, favoring neurological improvement and reducing ischemia-related symptoms such as motor deficits, visual disturbances, and headaches[14].

Although the neovascularization process is slower, indirect revascularization has demonstrated efficacy in reducing the risk of new ischemic stroke episodes, establishing itself as a safe and effective therapeutic strategy, particularly in younger populations affected by Moyamoya disease[14].

Risks and limitations of bypass in moyamoya disease

Both direct and indirect bypass surgeries have demonstrated significant benefits; however, several studies report postoperative stroke and neurological deterioration in patients who experienced an acute MMD- or MMS-related stroke prior to surgery[31]. These outcomes are largely associated with risks inherent to general anesthesia and the possibility of intraoperative bleeding[32].

Despite interstudy variability, patients who underwent revascularization within 90 days of an acute stroke exhibited considerable complication rates, with postoperative stroke occurring in 15–22% of cases and neurological deterioration in 17–33%[31].

Although long-term outcomes of STA–MCA bypass for Moyamoya disease are generally favorable, focal cerebral hyperperfusion syndrome (CHP) remains one of the main complications, characterized by localized increases in blood flow at the anastomotic site[33].

This condition may lead to transient focal neurological deficits, regional vasogenic edema, and, in more severe cases, potentially fatal intracerebral hemorrhage. Despite recent advances in perioperative management, delayed hemorrhage associated with focal hyperperfusion continues to represent a significant clinical challenge[33].

Regarding limitations of indirect revascularization, this approach does not provide immediate increases in cerebral blood flow, leaving patients vulnerable to stroke during the perioperative period and while angiogenesis occurs in response to the graft. Due to this delay in hemodynamic improvement, the addition of a direct bypass—known as a combined bypass technique—may represent a more advantageous alternative, as it allows restoration of cerebral flow in the immediate postoperative period[34].

The future of bypass in moyamoya disease

One emerging perspective in the treatment of MMD is balancing the heart–brain perfusion conflict through anesthetic management during combined surgery, integrating cerebral function monitoring with myocardial protection[10].

This concept was addressed by Zhang et al.[10], who reported a patient with MMD associated with coronary artery disease treated under general anesthesia using a combined approach: off-pump coronary artery bypass grafting with placement of three grafts, associated with extracranial–intracranial arterial bypass. The procedure resulted in excellent prognostic outcomes.

A study by Lee et al.[31] demonstrated the efficacy of multiple burr hole (MBH) therapy combined with erythropoietin (EPO) as an institutional strategy to reduce invasiveness and enhance neovascularization in patients with MMD during acute neurological deterioration and perioperative stroke. The authors emphasized the importance of rapid transdural collateral formation and increased cerebral blood flow, analyzing the feasibility of MBH performed under local anesthesia as a minimally invasive alternative for high-risk patients. Concurrently, EPO was highlighted as an adjuvant agent promoting angiogenesis.

Cases of MMD associated with intraventricular hemorrhage due to aneurysm rupture, although rare, warrant further investigation due to their high lethality. Historically, conservative management was the most commonly adopted approach; however, approximately 60% of cases resulted in unfavorable outcomes due to clinical progression or rebleeding. With advances in microneurosurgery, surgical approaches have been increasingly employed[35].

Available treatment options include microscope-assisted craniotomy, endovascular therapy, and neuroendoscopy[36]. In a recent study by Zhou et al.[35], a case of pure intraventricular hemorrhage resulting from rupture of a distal anterior choroidal artery aneurysm was successfully treated using a three-dimensional reconstruction and navigation system combined with neuroendoscopic techniques, achieving a favorable clinical outcome.

Minimally invasive transcranial neuroendoscopic approaches offer significant advantages in aneurysm treatment, including enhanced illumination, superior instrument maneuverability, and high-definition visualization of intracranial structures[37,38]. When combined with three-dimensional reconstruction systems and precise stereotactic navigation, this technique represents a strategic alternative, particularly for aneurysms located in terminal arterial segments where the absence of collateral circulation poses greater therapeutic challenges[37,38].

In a procedure reported by Ikezawa et al.[11], endovascular treatment was successfully performed using a dual-catheter technique via the superficial temporal artery for a post–STA–MCA bypass anastomotic aneurysm, achieved through coil embolization. Complete aneurysm exclusion was confirmed without procedure-related complications. This case involved a patient who developed an anastomotic aneurysm one year after STA–MCA bypass for Moyamoya disease, which was effectively treated with endovascular coil embolization.

Several studies indicate that many patients achieve favorable outcomes with indirect bypass alone, reflecting the effectiveness of gradual angiogenesis-induced revascularization. However, combining direct and indirect bypass offers the advantage of immediate augmentation of cerebral blood flow, which may be critical in high ischemic-risk situations[39]. It is important to recognize that the additional flow provided by direct bypass may induce transient hemodynamic changes, such as fluid shifts and hyperperfusion, requiring careful clinical management[40].

Accordingly, the integration of direct and indirect techniques emerges as a promising strategy, balancing the safety of gradual flow augmentation with the benefits of immediate revascularization. Further studies involving larger cohorts are required to determine whether combined bypass is superior to isolated indirect revascularization in preventing postoperative cerebral infarction in pediatric patients with rapidly progressive MMD[34].

To facilitate understanding of the different surgical approaches to Moyamoya disease, Table 4 provides a comparative synthesis of direct and indirect bypass procedures. Current clinical benefits, major limitations of each technique, and future trends that may redefine neurosurgical practice are highlighted. This analysis offers an integrated view of revascularization strategies, emphasizing both immediate and gradual hemodynamic efficacy, as well as clinical challenges and emerging innovations that may optimize outcomes for pediatric and adult patients.

Table 4. Characteristics of Direct and Indirect Bypass in Moyamoya Disease.

Feature	Direct Bypass	Indirect Bypass
Description	Direct anastomosis between an extracranial (donor) and intracranial (recipient) artery, usually STA-MCA, OA-MCA, or with a vein graft.	Placement of vascularized tissue (muscle, artery, dura mater) over the brain to stimulate gradual neoangiogenesis (e.g., EDAS, EMS, EAS, EDS, EMAS).
Current clinical benefits	Immediate restoration of cerebral blood flow;	Less invasive and safer in children;
	Rapid reduction in the risk of recurrent stroke;	Gradual formation of robust collateral circulation;
	Increased cerebral perfusion and resistance to ischemia;	Reduces the risk of immediate perioperative myocardial infarction;
	- Rapid functional benefit (mRS) and greater degree of neovascularization (Matsushima A).	- Significant functional benefits in the medium/long term, especially in pediatrics.
Limitations	Technically complex procedure; requires vessels of adequate caliber (≥ 1 mm);	Non-immediate blood flow; risk of ischemia during the initial period;
	Higher risk of focal cerebral hyperperfusion (FCH);	Degree of revascularization may be insufficient in adults;
	Risk of perioperative ischemic complications in cases of recent stroke;	Results depend on individual angiogenic capacity;
	- Less applicable to young children.	- Clinical effect may take months to manifest.
Future trends / Innovations	Enhanced STA-MCA bypass with multiple branches and adhesives to optimize perfusion and reduce hyperperfusion;	Combination with direct bypass (hybrid technique) for balance between immediate and gradual flow;
	Minimally invasive and endoscopic techniques to reduce surgical time and morbidity;	Development of controlled angiogenic induction techniques;
	- Combination with adjuvant agents (e.g., erythropoietin) to stimulate neovascularization.	- Use of advanced intraoperative monitoring to optimize collateral formation and reduce perioperative risk.
Preferred target population	Adults with progressive or recurrent symptoms; children with adequate blood vessels and a high risk of ischemia.	Young children (~5–15 years old), patients with bleeding disorders, or those with a technical inability to undergo direct bypass.
Clinical evidence	Studies demonstrate ample perfusion, reduction of infarctions and ischemic events, functional protection[22,24].	Studies indicate robust collateral formation, safe functional improvement, and a reduction in hemorrhagic recurrence[28].

DISCUSSION

Surgical revascularization remains the cornerstone of treatment for Moyamoya disease, and the findings discussed herein reinforce the functional distinction between direct and indirect techniques described in the literature. Direct bypass, particularly STA–MCA anastomosis, demonstrates a clear advantage in the immediate restoration of cerebral blood flow, which translates into early functional improvement and increased ischemic tolerance in adult patients.

These results are consistent with data reported by Shi et al.[22], Lu et al.[24], and Lim et al.[25] who demonstrated improved cerebral perfusion, reduced ischemic events, and better short-term neurological outcomes, thereby consolidating direct bypass as the preferred strategy in patients with high hemodynamic risk.

In contrast, indirect revascularization continues to play a central role, especially in the pediatric population. Studies by Khan et al.[28], Talahma et al.[29], and Atai et al.[30] have shown that techniques such as EDAS and EMS promote effective progressive angiogenesis, with a positive impact on ischemic stroke prevention and a low rate of perioperative complications.

Although the lack of immediate blood flow augmentation represents a recognized limitation, favorable long-term

functional outcomes and a strong safety profile support the widespread use of these techniques in children, in agreement with previous findings in the literature. Cerebral hyperperfusion syndrome (CHP) remains one of the major limitations of direct bypass, representing a critical factor in the risk–benefit balance of this approach.

As described by Tashiro et al.[33] and Kimata et al.[27], focal hyperperfusion at the anastomotic site may result in transient neurological deficits, vasogenic edema, and, in more severe cases, intracerebral hemorrhage. These data reinforce earlier observations that the success of direct bypass depends not only on microsurgical technique but also on meticulous perioperative management, particularly in procedures involving multiple donor vessels or posterior circulation territories.

Comparative analysis also indicates that, although effective, indirect revascularization may be insufficient in scenarios of rapid clinical progression or severe ischemia. This limitation has driven growing interest in combined strategies that associate direct and indirect bypass techniques.

Studies by Choi et al.[39] and Hayashi et al.[34] suggest that this hybrid approach offers the benefit of immediate cerebral blood flow augmentation while simultaneously promoting gradual collateral development. Nevertheless, uncertainties remain regarding the superiority of this strategy in pediatric populations, underscoring the need for prospective studies with greater statistical power.

Within the scope of emerging approaches, minimally invasive techniques—such as multiple burr hole therapy combined with erythropoietin—represent a conceptual shift in the treatment of Moyamoya disease. Lee et al.[31] demonstrated that this strategy may reduce surgical invasiveness and stimulate accelerated transdural collateral formation, particularly in high-risk patients or during acute phases of neurological deterioration.

These findings expand the available therapeutic spectrum and reinforce the importance of individualized approaches based on the patient's clinical and hemodynamic profile. Advances in neuroendoscopy, three-dimensional navigation, and endovascular treatment have further broadened therapeutic possibilities in complex cases, particularly in hemorrhagic Moyamoya disease associated with aneurysms.

Studies by Zhou et al.[35] and Ikezawa et al.[11] demonstrate that the integration of these technologies enables less invasive approaches with precise anatomical visualization and favorable clinical outcomes. In line with recent literature, the data discussed indicate that personalization of the surgical strategy—taking into account patient age, vascular pattern, clinical stage, and individual risk—is essential, pointing toward a future of multimodal, integrated, and evidence-based management in Moyamoya disease.

CONCLUSION

Comparative analysis of the different revascularization methods in Moyamoya disease demonstrates that both direct and indirect bypass techniques play fundamental roles in disease management. Direct bypass stands out for providing immediate restoration of cerebral blood flow, offering rapid protection against new ischemic events and improving functional prognosis in adult patients, particularly those with progressive clinical manifestations.

Indirect bypass, although associated with a delayed hemodynamic response, has demonstrated high efficacy in pediatric patients due to the robust angiogenic capacity of this population. Moreover, it represents a technique of lower surgical complexity and reduced intraoperative risk.

Therefore, selection of the optimal technique should be guided by clinical, age-related, and anatomical factors, as well as the individual risk profile of each patient. Current literature suggests that combining methods—integrating direct and indirect strategies—may represent a promising alternative by uniting immediate restoration of cerebral perfusion with the safety of gradual angiogenesis.

In parallel, the incorporation of new technologies, including minimally invasive approaches, advanced intraoperative monitoring, and the use of pharmacological adjuvants, expands therapeutic perspectives and contributes to progressively safer and more effective procedures.

Despite the relevance of these advances, it is essential to acknowledge that bypass procedures are not free of risks, including complications such as cerebral hyperperfusion syndrome,

hemorrhage, and perioperative ischemic events. Nevertheless, the observed benefits—particularly in terms of functional improvement, mortality reduction, and prevention of recurrent strokes—significantly outweigh the potential adverse effects.

Furthermore, continuous technical and scientific advancements in the field have progressively reduced historical limitations of these procedures, allowing revascularization to be established as the most effective and durable strategy for the treatment of Moyamoya disease.

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CORRESPONDING AUTHOR

Thiago de Mendonça Nonato Oliveira, MS
Medical student
Centro Universitário Aparício Carvalho – FIMCA
Porto Velho, Rondônia, Brasil
E-mail: thiagocientifico23@gmail.com

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A Rare Case of Unilateral Hearing Loss Following Traumatic Intracranial Hematoma: in-depth review of the underlying mechanisms

Um Caso Raro de Perda Auditiva Unilateral Após Hematoma Intracraniano Traumático: revisão dos mecanismos subjacentes

Thea Gianina Tjandra[1]
Maria Monica[1]
Nyoman Golden[1]

ABSTRACT

Traumatic intracranial hematoma (tICH) rarely presents with hearing loss, especially in an ipsilateral pattern. We report a unique case of a 65-year-old male who developed right-sided hearing loss two days after a motor vehicle accident. Head CT revealed a hematoma in the right temporal lobe and a cerebral contusion in the left temporal lobe. Craniotomy was performed, and the patient's hearing returned completely postoperatively without additional neurological deficits. While auditory processing involves both hemispheres, most fibers decussate, making cortical deafness due to a unilateral lesion unusual. However, the acoustic radiation can be affected by lesions near the internal capsule and putamen, possibly explaining this symptom. This case suggests that dominant ipsilateral auditory control may occur and can be disrupted by tICH. Additionally, elevated intracranial and perilymphatic pressures caused by trauma may further impair hearing. Understanding the neuroanatomical basis of such cases may guide early recognition and intervention. Ipsilateral hearing loss should be considered a potential, albeit rare, symptom of temporal lobe tICH, and clinicians should be aware of its implications in trauma settings.

Keywords: *Craniocerebral trauma; Intracranial hemorrhage, traumatic; Hearing loss; Brain injuries*

RESUMO

O hematoma intracraniano traumático (HICT) raramente se apresenta com perda auditiva, especialmente em um padrão ipsilateral. Relatamos um caso único de um homem de 65 anos que desenvolveu perda auditiva à direita dois dias após um acidente automobilístico. A tomografia computadorizada de crânio revelou um hematoma no lobo temporal direito e uma contusão cerebral no lobo temporal esquerdo. Foi realizada craniotomia, e a audição do paciente retornou completamente no pós-operatório, sem déficits neurológicos adicionais. Embora o processamento auditivo envolva ambos os hemisférios, a maioria das fibras decussa, tornando a surdez cortical decorrente de uma lesão unilateral incomum. Entretanto, a radiação acústica pode ser afetada por lesões próximas à cápsula interna e ao putâmen, o que possivelmente explica esse sintoma. Este caso sugere que pode ocorrer um controle auditivo ipsilateral dominante, que pode ser comprometido pelo HICT. Além disso, o aumento das pressões intracraniana e perilinfática causado pelo trauma pode contribuir para o prejuízo auditivo. A compreensão da base neuroanatômica desses casos pode auxiliar no reconhecimento precoce e na intervenção adequada. A perda auditiva ipsilateral deve ser considerada um sintoma potencial, embora raro, do HICT no lobo temporal, e os clínicos devem estar atentos às suas implicações em contextos de trauma.

Palavras-Chave: *Traumatismo craniocerebral; Hemorragia intracraniana traumática; Perda auditiva; Lesões cerebrais*

[1]Division of Neurosurgery, Department of Surgery, Faculty of Medicine, Ngoerah Hospital, Udayana University, Bali, Indonesia.

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INTRODUCTION

Temporal lobe intracerebral hematoma (ICH) is a rare clinical condition, accounting for approximately 5% of all cerebral hemorrhage cases, and it is even less common following traumatic head injury. Hearing loss as an initial symptom of ICH is exceptionally rare[1]. The central auditory nervous system, which governs hearing perception, includes several critical brain regions such as the primary auditory cortex (Brodmann areas 41 and 42) located in Heschl's gyrus, subcortical structures like the internal capsule (particularly its posterior aspect), the posterior insula, thalamic regions, parts of the parietal lobe superior to Heschl's gyrus, the supramarginal gyrus, segments of the anterior angular gyrus, the inferior frontal lobe, and the brainstem[2]. Because hearing perception involves bilateral cerebral cortices, cortical deafness resulting from a unilateral lesion is considered unusual.

Currently, the understanding of hearing loss mechanisms in traumatic intracerebral hematoma remains limited, with only a few case reports attempting to elucidate the possible pathophysiological pathways. There is a need for a comprehensive review to better characterize this rare presentation.

In this report, we present a case of unilateral hearing loss associated with temporal lobe ICH and provide a detailed discussion on the pathophysiology of hearing loss caused by traumatic cerebral lesions. This aims to enhance clinicians' awareness and understanding of this rare phenomenon.

CASE PRESENTATION

A 65-year-old male came to our emergency room with complaints of sudden hearing loss in his right ear after experiencing motor collision 2 days prior. The complaints was accompanied with tinnitus that has been persistent since the day before. Physical examination revealed stable vital signs, GCS E4V5M6, and no neurological deficits. Head Computed Tomography (CT) scan without contrast revealed ICH in the right temporal region with volume of 5 cc and no midline shift (Figure 1). Additionally, a cerebral contusion in the left temporal region with perifocal oedema was observed (Figure 2).

We performed an immediate craniotomy right clot removal. Intracranial hematoma was evacuated thoroughly with linear incision (Figure 3).

All symptoms were resolved right away and patient was discharged 2 days after the surgery. Follow up examination showed excellent clinical improvements and no notable deficits.

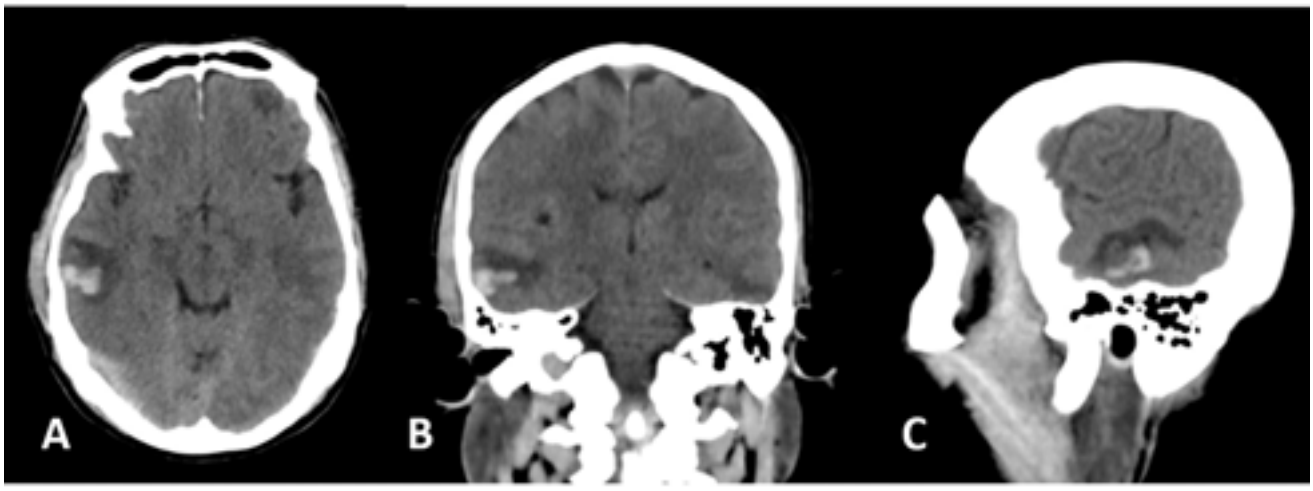

Figure 1. A-C. Head CT scan without contrast showed right temporal traumatic ICH with volume of 5 cc and left temporal cerebral contusion, with no midline shift observed.

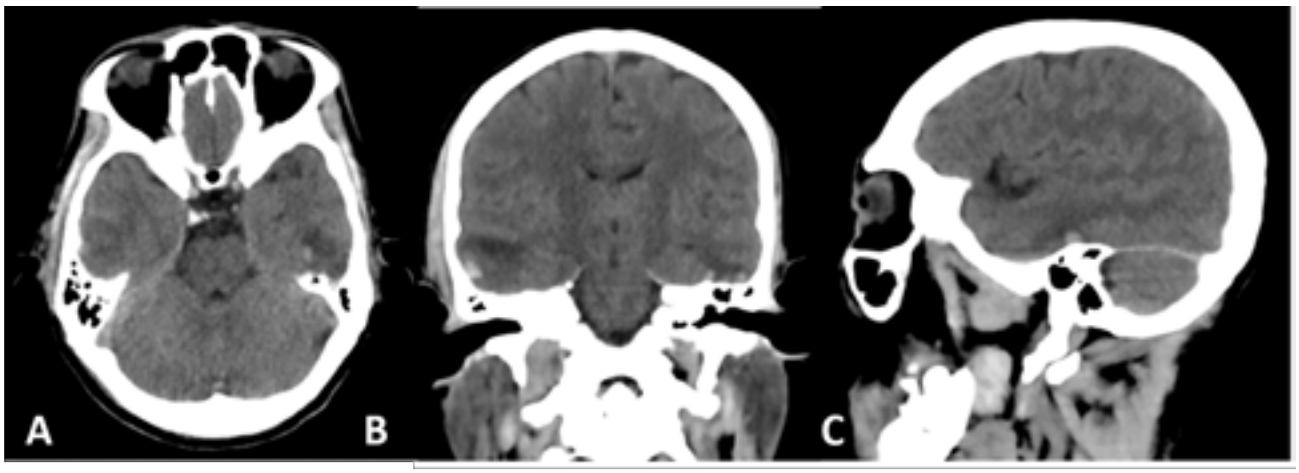

Figure 2. A-C. Cerebral contusion in the left temporal region was also revealed.

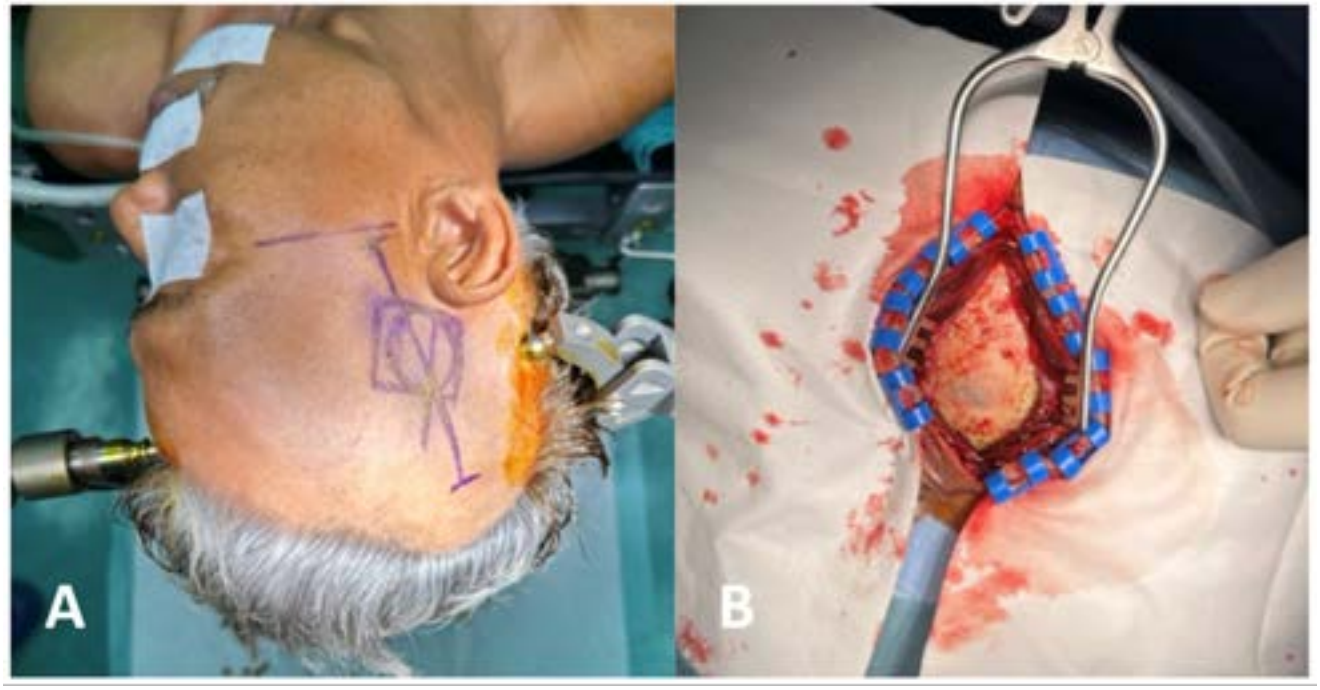

Figure 3. A-B. Craniotomy right clot removal was done with linear incision.

DISCUSSION

Cortical deafness is a very rare condition, especially in cases of tICH. This scarcity may be explained by the prevailing theory of the auditory function, wherein bilateral involvement of the primary auditory cortices or anatomical areas of central auditory pathway must be necessary[3].

Sound stimulation of the hair cells generates action potentials, which are transmitted via the auditory nerve to both the dorsal and ventral cochlear nuclei as part of the afferent pathway. Majority of nerve fibres theoretically project to the contralateral superior olivary complex, while a smaller proportion enters the ipsilateral side. Subsequently, the fibres ascend to the inferior colliculus, a complex relay centre involved in processing various auditory functions. From the inferior colliculus, projections reach both

the contralateral and ipsilateral medial geniculate bodies before ultimately terminating in Heschl's gyrus within the superior temporal gyrus, where sound is consciously perceived[4,5].

Based on the anatomical pathway, specific lesions and presentations vary considerably. An extremely high proportion of fibres from the medial geniculate body course through the posterior part of the internal capsule before projecting onto the auditory cortex. Thus, lesion in this specific area medial to the posterior temporal and inferior parietal lobes is commonly involved in central deafness when Heschl's gyrus was not. Subsequent damage to the right insulotemporal region resulted in profound hearing loss, presumably because of the damage of cortico-cortical connections that directly involve the opercular cortex, inferior frontal lobe, superior temporal plane (including Heschl's gyrus), limbic zones, and several thalamic nuclei including the medial geniculate body[2].

Second proposed mechanism of cortical deafness is cerebral edema and secondary neuronal injury induced by ICH. Direct neural damage or signal interruption due to oedema can impair transmission along both auditory pathways, potentially resulting in sensorineural hearing loss. When symptoms arise primarily from neural compression rather than irreversible structural damage, surgical intervention should be considered, as it offers the greatest potential for functional recovery[1].

Lastly, head injury causes elevated intracranial pressure and increased perilymphatic pressure, with greater effect on the trauma side. Patients with TBI could have elevated intracranial pressure due to contusion or hemorrhage, causing sustained increased pressure in the perilymph, negatively affecting the inner ear function[6].

In this case, right sided hearing loss caused by right temporal traumatic ICH was aggravated by the presence of cerebral contusion at the opposite hemisphere. This fact implies bilateral involvement of auditory function. We found the contralateral ear not affected, suggesting the asymmetry can also be dominant ipsilateral, which was further supported by marked clinical improvement following surgical intervention. We also found tinnitus to be present in our case. Similar case explained the possible mechanism was due to auditory phantoms used by the brain to fill in the blanks in condition of deprived auditory inputs[7].

CONCLUSION

To the best of our knowledge, this case represented an exceedingly rare presentation in the context of traumatic brain injury. We learnt that bilateral involvement should be present in anatomical auditory pathway for cortical hearing loss to happen, but unilateral lesion in significant auditory area could also cause hearing loss. We also found that ipsilateral predominant of central auditory pathway may occur. This could be a consequence of strictly disconnected auditory fibers or direct injury causing increased perilympathic pressure. However, this report was lack in terms of assessing central deafness because we did not perform audiometric tests thoroughly.

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CORRESPONDING AUTHOR

Thea Gianina Tjandra, MD
Udayana University
Ngoerah Hospital
Bali, Indonesia
E-mail: theagianinatj@gmail.com

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Thea Gianina Tjandra: Conceptualization, Data Curation, Writing – Original Draft, Visualization. Maria Monica: Investigation, Literature Review, Writing – Review & Editing. Nyoman Golden: Supervision, Validation, Writing – Review & Editing. All authors confirm that the CRediT contributions listed above are accurate and were agreed upon by all contributors.

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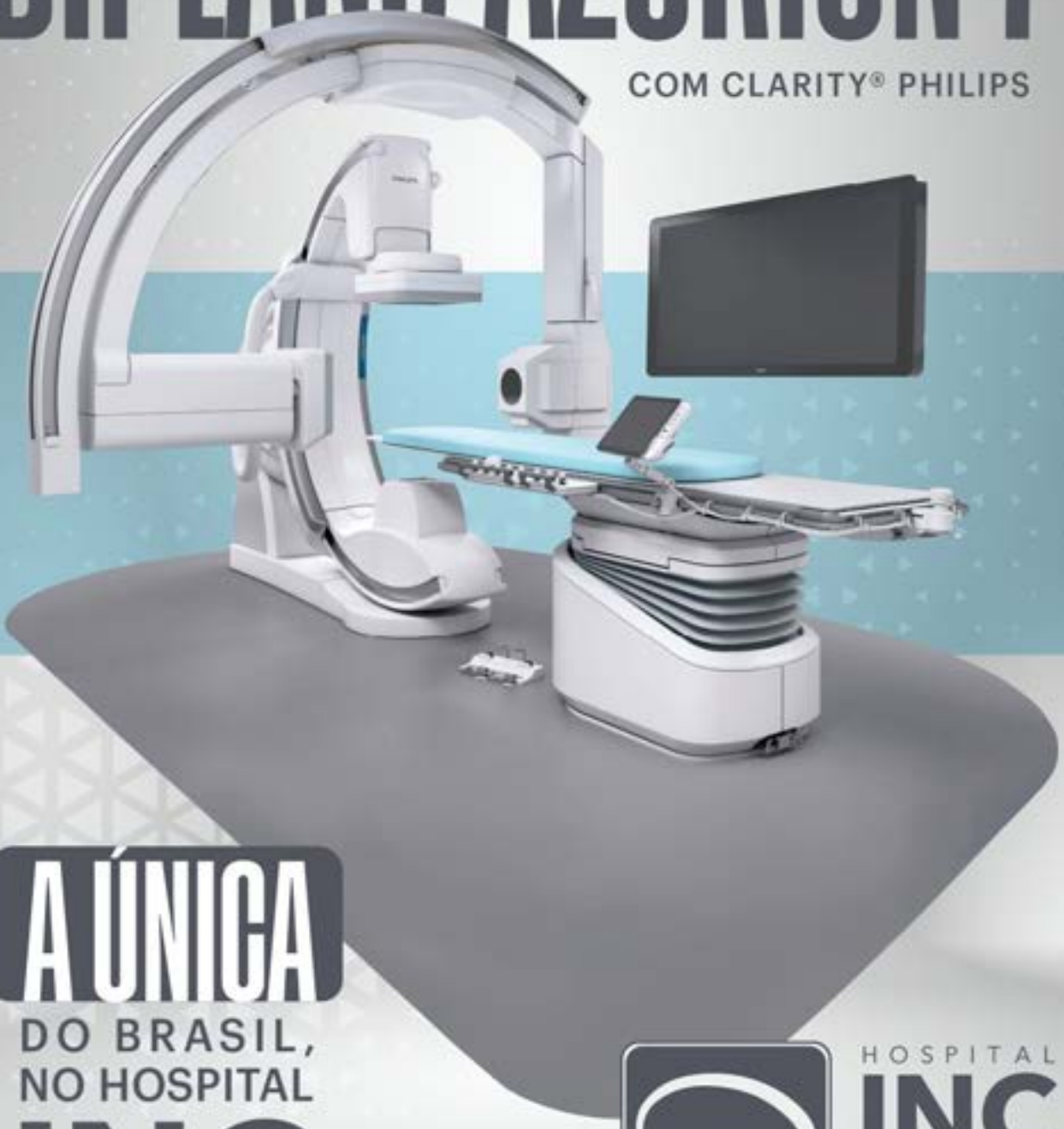

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Case Report

Intraoperative Indocyanine Green Videoangiography for Pediatric Brainstem Arteriovenous Malformation Management

Videoangiografía Intraoperatoria con Verde de Indocianina para el Manejo de una Malformación Arteriovenosa del Tallo Cerebral en una Paciente Pediátrica

Alejandro Ramos Girón[1]
Julian Alberto Arenas-Trujillo[1]
Yessid Araque Puello[1]
Juanita Cure Casilimas[1]

ABSTRACT

Brain arteriovenous malformations (AVMs) represent a significant therapeutic challenge due to their complex anatomy and considerable risk of hemorrhage. Brainstem AVMs (bsAVMs) are particularly critical because of their proximity to eloquent structures. Recent technological advances, including intraoperative indocyanine green (ICG) videoangiography, have improved surgical precision and safety in selected cases. We report the case of a pediatric patient with a bsAVM who underwent endovascular embolization and microsurgical resection assisted by intraoperative (ICG) videoangiography. This technique allowed real-time visualization of feeding and draining vessels, which facilitated accurate occlusion and minimized the risk of neurological deficit. Postoperative imaging confirmed partial resection of the nidus and clipping of an aneurysm. A narrative literature review was conducted to contextualize this approach. Current evidence supports the role of ICG videoangiography in enhancing intraoperative decision-making, reducing complications, and improving outcomes in AVM surgery. Even so, classifications such as Spetzler-Martin and de Oliveira guide decision-making through risk stratification; patient management remains individualized, often requiring multimodal strategies. This case illustrates the feasibility and utility of ICG videoangiography in pediatric brainstem AVM surgery, offering greater precision in vascular identification and occlusion. Further studies are needed to establish standardized protocols and long-term outcomes for pediatric patients.

Keywords: *Arteriovenous malformations; Brain stem, indocyanine green; Microscopy, fluorescence; Cerebellopontine angle; Intracranial aneurysm; Cranial fossa, posterior*

RESUMEN

Las malformaciones arteriovenosas cerebrales (MAVs) representan un reto terapéutico por su anatomía compleja y riesgo considerable de hemorragia. Las MAVs de tallo cerebral (MAVt) son críticas por su proximidad a estructuras elocuentes. Recientes avances tecnológicos como la videoangiografía intraoperatoria con verde de indocianina (VIC) mejoran la precisión y seguridad quirurgicas en casos seleccionados. Presentamos el caso de una paciente pediátrica con MAVt llevada a embolización y resección microquirúrgica con videoangiografía VIC. Esta técnica permitió la visualización al instante de vasos nutricios y aferentes, facilitó la oclusión precisa y minimizó el riesgo de déficit. Las imágenes postoperatorias confirmaron la resección parcial del nido y el clipaje de un aneurisma. Se realizó una revisión narrativa para contextualizar este enfoque. La evidencia actual respalda la videoangiografía VIC para realizar decisiones intraoperatorias, reducir complicaciones y mejorar resultados quirúrgicos en MAVs. Aunque las clasificaciones como Spetzler-Martin y de Oliveira orientan la toma de decisiones estratificando el riesgo; el manejo debe individualizarse mediante estrategias multimodales, frecuentemente requiriendo estrategias multimodales. Este caso ilustra la viabilidad de la videoangiografía VIC intraoperatoria para las MAVt pediátricas, ofreciendo mayor precisión en la identificación y oclusión vascular. Se necesitan estudios para determinar protocolos y resultados a largo plazo en pacientes pediátricos.

Palabras-Clave: *Malformaciones arteriovenosas; Tallo encefálico, verde de indocianina; Microscopía de fluorescencia; Ángulo pontocerebeloso; Aneurisma intracraneal; Fosa craneal posterior*

[1]Department of Neuroscience, Clínica del Country and Clínica la Colina, Bogotá, Colombia.

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INTRODUCTION

Brain arteriovenous malformations (AVMs) are rare vascular lesions[1] with an estimated prevalence of 18 cases per 100,000 adults[2] and 28 per 100,000 children[3]. Their annual incidence ranges from 1.1 to 1.3 cases per 100,000 adults and up to 20 cases per 100,000 in the pediatric population[4]. Hemorrhage is a serious complication, and three predictors—presentation with bleeding, deep location of the nidus, and deep venous drainage—significantly increase the risk of bleeding within the first year after diagnosis[5]. While patients without these predictors have an annual risk of bleeding of about 1%, in those with all three, the risk rises to around 34%[5]. Bleeding is associated with higher rates of mortality and severe disability compared to unruptured malformations[6].

Approximately 13% of AVMs are located in the posterior fossa, and brainstem AVMs represent about one-quarter of those lesions[7,8]. Posterior fossa AVMs are 2.6 times more likely to present with bleeding[9], with rates reported to reach 75%. Furthermore, these lesions imply higher morbidity and mortality rates than AVMs in other locations because of their proximity to eloquent structures[7,10,11], and management remains challenging as surgical risks may equal or exceed those of natural history[12]. Recent advances, such as intraoperative indocyanine green videoangiography, have improved the feasibility of microsurgical treatment in selected patients. This report describes the case of a pediatric patient with a ruptured brainstem AVM managed through a multimodal approach, including endovascular embolization, microsurgical resection with intraoperative indocyanine green videoangiography, and radiosurgery. It includes a narrative review of the current literature on AVMs, including pathophysiology, clinical presentation, imaging, classification, and therapeutic strategies.

CASE PRESENTATION

A 6-year-old female patient was brought to the emergency department with a 7-hour history of thunderclap headache, transient lower limbs hemiparesis, vomiting, and irritability progressing to drowsiness. The patient had no relevant medical, family, or psychosocial history and no known genetic conditions. She had not undergone previous neurosurgical or endovascular interventions, and there was no history of chronic illness, trauma, or medication use. Immunizations were up to date, and developmental milestones were appropriate for age.

On physical examination, the patient was hemodynamically stable but drowsy and irritable, with a Glasgow Coma Scale score of 14/15. Pupils were isochoric and reactive, and primary gaze was centered without nystagmus. Neurological assessment revealed right facial asymmetry consistent with cranial nerve VII involvement, dense left hemiparesis, and signs of right cerebellar dysfunction. Pathological reflexes included bilateral Babinski, while Hoffman's sign was negative. No meningeal signs were present. Therefore, the patient was considered to suffer from an alternating brainstem syndrome, specifically incomplete Foville's syndrome. Differential diagnoses included hemorrhagic or ischemic stroke of the pons, a tumor, a pontine abscess, and a pontine AVM.

Due to the sudden onset of symptoms and altered mental status, a brain computed tomography (CT) was indicated, and it revealed a right cerebellar hematoma with a suspected ipsilateral vascular malformation (Figure 1A). A contrast-enhanced MRI confirmed a right infratentorial brainstem AVM with a diameter of about 3 cm, contiguous to the floor of the fourth ventricle, pons, medulla oblongata, and right cerebellar hemisphere, associated with vermian hematoma extending to the right cerebellum (Figure 1B). The digital subtraction angiography (DSA) revealed a 4 cm right medial cerebellar AVM supplied by the anterior inferior cerebellar artery (AICA), posterior inferior cerebellar artery (PICA), and basilar perforator arteries, with giant aneurysms draining into the Galen vein and the straight sinus (Figure 1C). CT angiography (CTA) confirmed the brainstem AVM was fed by the right AICA, right PICA, and basilar perforating arteries, multiple venous aneurysms, vascular tangles, and deep efferent venous drainage to the vena magna and straight sinus (Figure 1D). The Spetzler-Martin grade was IV, and the lesion's intimate relationship to brainstem nuclei, deep cerebellar nuclei, and high eloquent areas represented a significant surgical challenge.

Initial care included comprehensive pediatric ICU measures for intracranial pressure control. Subsequently, the patient underwent endovascular embolization accessing the nidus through the right vertebral artery and achieving about 25% occlusion of the brainstem AVM; however, two giant aneurysms remained uncontrolled.

Three weeks later, it was decided by multidisciplinary consensus to proceed with a combined microsurgical resection assisted by intraoperative indocyanine green videoangiography to manage the remaining component of the lesion. With the patient in the prone position and head fixation in a three-pin Mayfield clamp,

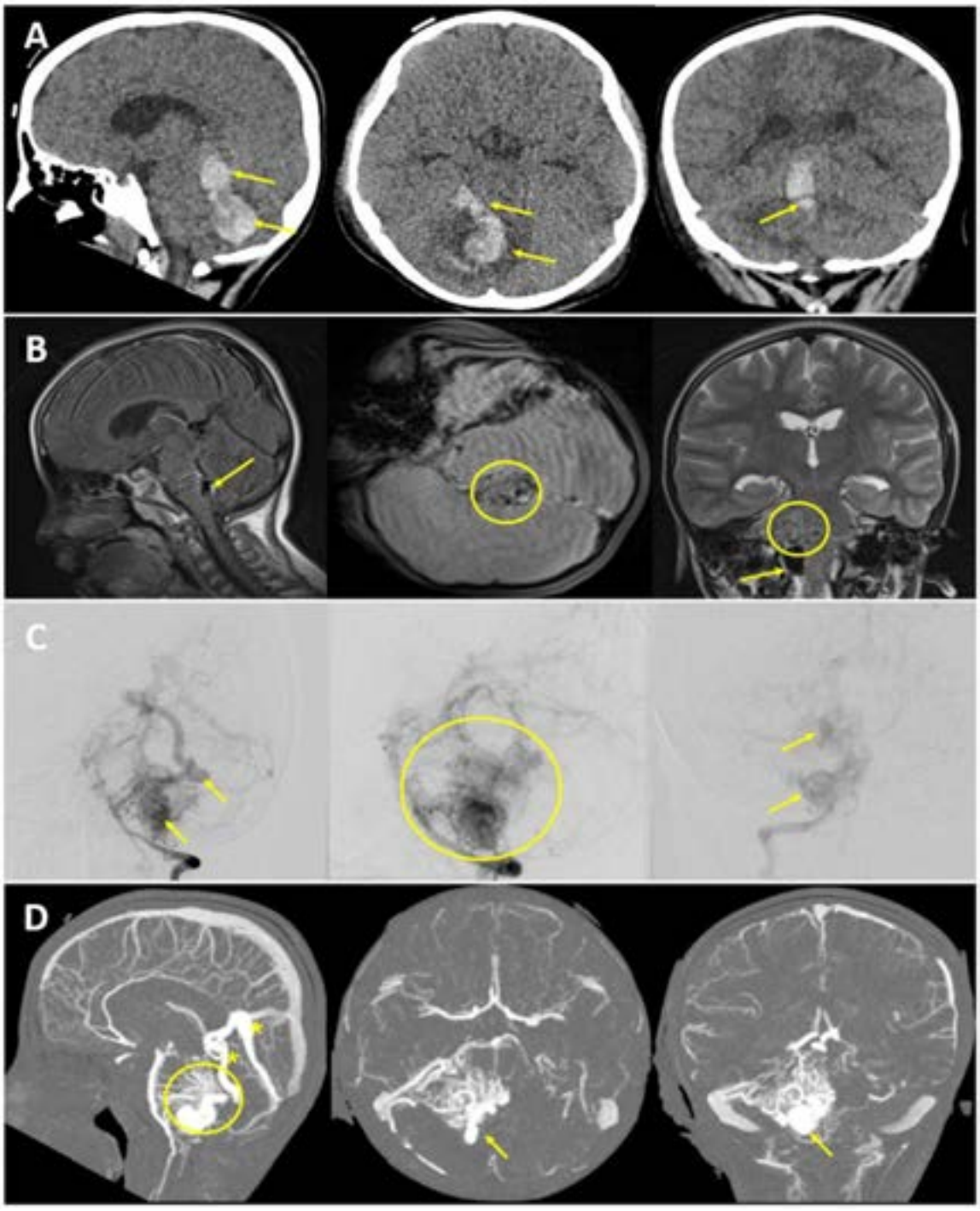

Figure 1. Diagnostic imaging of a pediatric patient with a brainstem arteriovenous malformation. **A.** Computed Tomography (CT): A hypodense area is observed in the infratentorial region, located posterior to the brainstem and anterior to the right cerebellar hemisphere (arrows). **B.** Magnetic Resonance Imaging (MRI): An intraparenchymal hematoma measuring 2.6 × 2.5 × 2.6 cm is identified in the right cerebellar hemisphere, causing mass effect on the fourth ventricle and cerebellar subarachnoid spaces, resulting in trans-tentorial herniation. Associated abnormal vascular structures (circles) with aneurysmal areas (arrows) are also noted. **C.** Digital Subtraction Angiography (DSA): An arteriovenous malformation adjacent to the brainstem (circle) is visualized, with giant aneurysms (arrows) and venous drainage into the vein of Galen and straight sinus (asterisks). **D.** CT Angiography (CTA): A medial right cerebellar vascular nidus is observed, supplied by the posterior inferior cerebellar artery (PICA) and anterior inferior cerebellar artery (AICA) (circle), with deep venous drainage into the vein of Galen and straight sinus (asterisks), and giant aneurysms (arrows).

a suboccipital approach was performed under high magnification with a Leica M530-OHX FL800 microscope equipped with a fluorescence-infrared module, using a neuronavigation guide, continuous motor monitoring, somatosensory evoked potentials, and cranial nerve monitoring.

Indocyanine green was administered intravenously as a peripheral bolus (0.5 mg/kg), allowing a high-contrast visualization of arterial feeders, draining veins, nidus components, and associated aneurysms. Most of the brainstem AVM was successfully resected. A small residual nidus adjacent to the right lateral pontine segment was managed by in situ occlusion of its feeding arteries and draining veins. Additionally, an aneurysm was clipped, and a residual venous component with direct connections to the brainstem was wrapped. Finally, a previously embolized giant venous aneurysm was also wrapped (Figure 2). There were no intraoperative complications or aneurysmal bleeding.

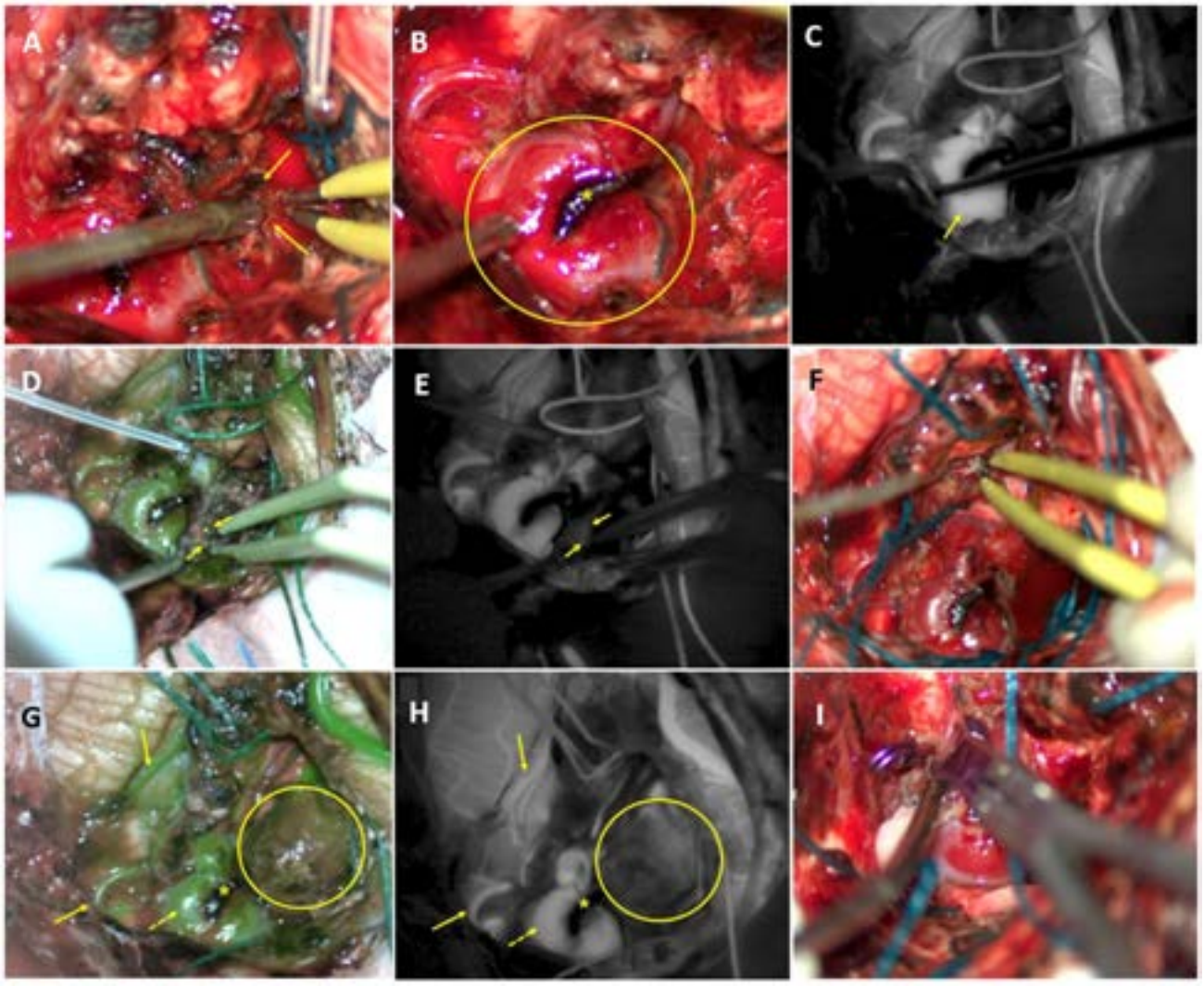

Figure 2. Intraoperative images of posterior fossa arteriovenous malformation. **A.** Visualization of the vascular nidus (arrows) of the arteriovenous malformation. **B.** Image showing a giant venous aneurysm (circle) and a draining vein (asterisk). **C.** Dissection of a giant venous aneurysm guided by indocyanine green under a near-infrared (NIR) light filter (yellow arrow). **D** and **E.** Image showing an in situ occlusion guided by indocyanine green; in the color phase (E), it appears there is no vascular structure, but the NIR phase (F) used enabled identification and occlusion of a feeding vessel barely detectable under visible light (arrows). **F.** In situ occlusion of the AVM parenchymal component at the brainstem. **G** and **H.** Indocyanine green video angiography; color phase (H) and NIR phase (I) show an excluded draining vein (asterisk), a giant aneurysm (doted arrows), an embolized giant aneurysm (circle), and non-excluded vessels (arrows). **I.** Clipping of a vessel feeding a giant aneurysm.

The patient then received comprehensive postoperative care in the pediatric intensive care unit. Clinical postoperative assessment revealed stable vital signs, adequate contact with the environment, ataxia with right lateropulsion, right peripheral facial paralysis, and left hemiparesis. Postoperative imaging showed a remnant of the brainstem AVM closely related to the right side of the brainstem and fed by a branch of the right vertebral artery that runs through the brainstem (Figures 3 and 4). Radiosurgery was indicated to achieve complete obliteration of the intraparenchymal remnant of the AVM. In addition, a neurovascular flap and tunneling of the left VII cranial nerve were performed to improve facial function.

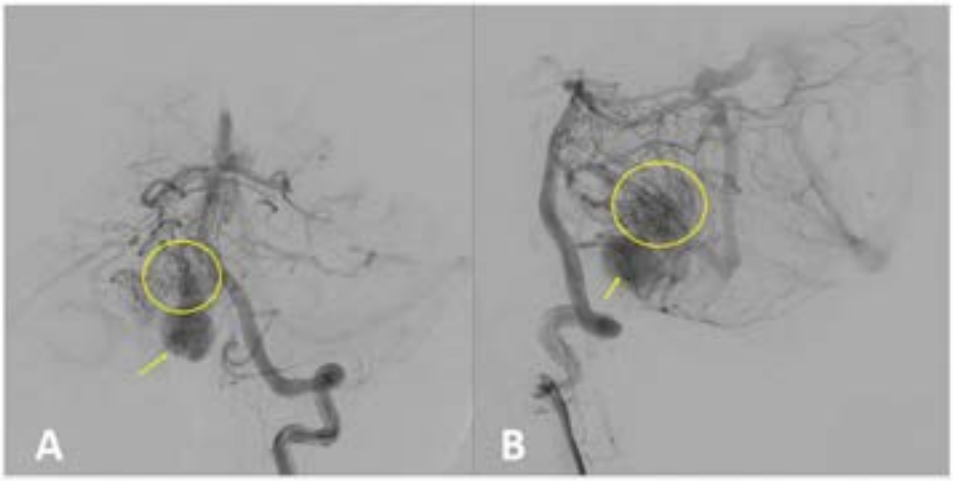

Figure 3. Postoperative brain angiography. Coronal (**A**) and sagittal (**B**) views showed a residual aneurysm (arrow) and residual nidus of the arteriovenous malformation (circle).

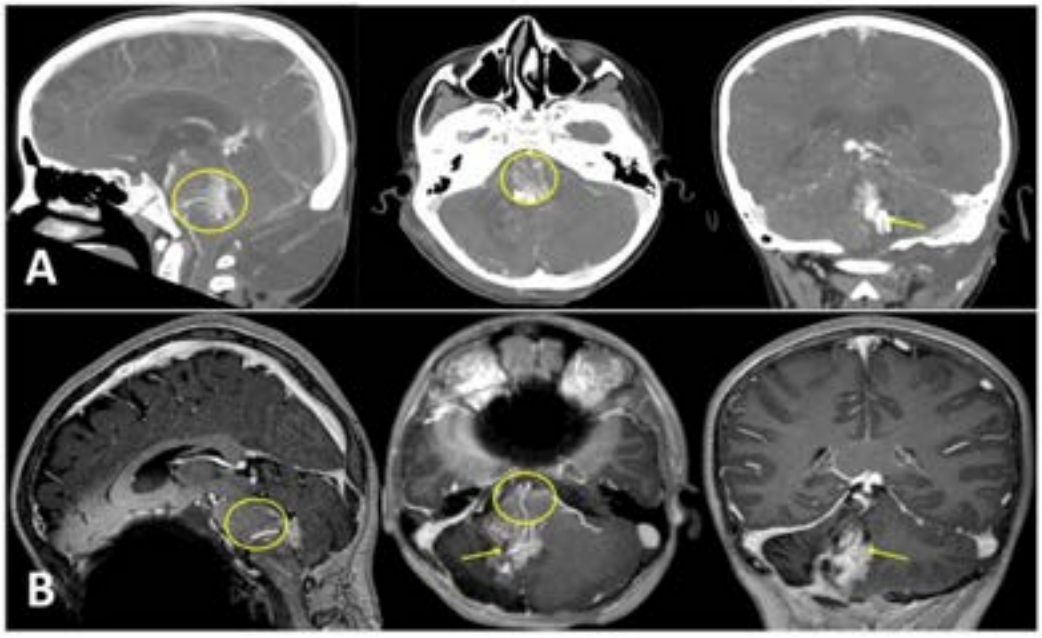

Figure 4. Postoperative brain imaging. **A.** Postoperative CT angiography showed a residual arteriovenous malformation adjacent to the brainstem parenchyma, supplied by a branch of the right vertebral artery traversing the brainstem (circles), and a hyperintense image posterior to the brainstem and anterior to the cerebellum suggestive of an aneurysm clip (arrow). **B.** Postoperative MR angiography showed a residual arteriovenous malformation located near the brainstem (arrows), supplied by a branch of the right vertebral artery passing through the brainstem (circles).

At 1-year follow-up, the patient remains with right facial palsy and right deafness. The patient is still in comprehensive rehabilitation, with no new hemorrhagic events and no neurological deterioration.

DISCUSSION

Pathophysiology

Brain AVMs result from an abnormal connection between high-pressure arterial and low-pressure venous systems through a capillary-free nidus[13,14], leading to vascular tortuosity and dilations that increase the risk of rupture and hemorrhage[15]. Congenital AVMs arise from defects in embryonic capillary vessels development[16], whereas de novo AVMs are linked to inflammatory processes and local angiogenesis[17].

Clinical manifestations

The most frequent clinical manifestation of AVMs is intracranial hemorrhage, occurring in approximately 72% of cases and up to 92% in brainstem AVMs[18], as in the case reported here. Other symptoms include seizures (30%)[19,20], headache (14%)[20], focal neurological deficits[14], hydrocephalus, vertigo, and facial pain[11,21].

Imaging studies

When acute intracranial hemorrhage is suspected, brain CT is the first-line imaging modality due to its speed and availability[22,23], with a sensitivity exceeding 90% for detection of subarachnoid hemorrhage[24] and other hemorrhagic events[1]. At further characterization CTA provides a detailed visualization of AVM architecture, including aneurysms and vascular tangles, with a sensitivity of 95% and specificity of 99%[25], making it indispensable in suspected cases. Likewise, contrast-enhanced MRI, with sensitivity and specificity near 98–99% for detecting AVMs[25], is valuable for detecting small vessels (<1 mm), aneurysms, small nests (<10 mm) and for planning surgical interventions[1]. Despite these advances, DSA remains the gold standard for diagnosing AVMs, offering superior accuracy for identifying angiographic architecture and hemodynamic characteristics of AVMs, as well as small nidus and early venous drainage compared to CT or MRI[1].

Risk stratification

Several classifications have been described for risk stratification to guide therapeutic decision-making. Traditionally, the most widely used system has been the Spetzler–Martin classification, introduced in 1986, which classifies AVMs in five categories based on size, venous drainage, and adjacent localization to eloquent parenchyma[26]. Based on analysis of a large case series, Dr. Evandro de Oliveira proposed a modification in the Spetzler-Martin AVM classification[27]. This modification subdivides Grade III lesions into IIIA (superficial, medium-sized, near eloquent areas), IIIB (deep but accessible regions such as limbic or callosal areas), and IIIC (small AVMs in highly eloquent areas like the insular block), allowing for more tailored treatment strategies. Grades I and II are generally suitable for surgical resection with acceptable morbidity and mortality rates, except for patients with poor clinical conditions or limited life expectancy, where radiosurgery should be considered. Grade IIIA lesions are usually managed with preoperative embolization followed by surgery; IIIB lesions can often be treated surgically; and IIIC lesions are typically treated with radiosurgery due to prohibitive surgical risk. Grades IV and V carry a very high risk of permanent deficits with surgery, so conservative management is preferred, reserving intervention for cases with progressive neurological decline or recurrent hemorrhage, often after embolization, as in the case presented here.[13,26].

Other classification systems have been proposed to improve prognostic accuracy and guide treatment selection. For example, Spetzler and Ponce proposed an adaptation of the Spetzler–Martin classification, which consisted of grouping Spetzler–Martin classification grades I and II into category A (low risk), grade III into category B (intermediate risk), and grades IV and V into category C (high risk)[28]. Likewise, Lawton and Young developed a supplementary scale that, when combined with Spetzler–Martin, enhances predictive performance. A combined score ≤6 correlates with acceptable preoperative risk, whereas a score ≥7 indicates an unacceptable perioperative risk[29,30].

Treatment approaches

Treatment options for AVMs include medical management and an operative treatment that comprise microsurgery, embolization, radiosurgery, or a combination of the last three[14]. The primary objective of operative treatment is complete nidus and shunt occlusion as this is the only way to eliminate the risk of intracranial hemorrhage[31]. Each modality carries a distinct risk–benefit profile that must be tailored to the AVM's anatomical and clinical characteristics.

Endovascular embolization is generally used as an adjunct before definitive treatment with microsurgery or radiosurgery in brainstem AVMs[32-34]. As monotherapy, it achieves complete occlusion in only about 23.5% of cases, with mortality and morbidity rates of 4.3% and 5.1%, respectively, making additional intervention necessary in most patients[31]. Its curative potential is limited to AVMs with small, compact nests, few feeders, and a single draining vein[35-37].

Radiosurgery techniques, including stereotactic systems such as Gamma Knife® and linear accelerators like CyberKnife®, deliver highly focused radiation to induce progressive vascular sclerosis[38], achieving obliteration rates of 50–90% depending on AVM size[14]. However, the effect requires a latency period of up to 4 years to generate the desired obliteration effect[14]. Radiosurgery is generally reserved for AVMs in highly eloquent areas, patients with Spetzler–Martin scores >6, or those with significant comorbidities[38].

Microsurgery offers superior hemorrhage prevention and obliteration rates compared to radiosurgery without a latency period[11,39]. Most AVMs are dissected with the intention to resect them; however, this carries a risk of injury to adjacent neurovascular structures[38]. Among the microsurgical options, there is in situ occlusion as an alternative for managing AVMs, this treatment consists of occluding the feeding vessels of the AVM without performing extensive dissection of the surrounding tissues, thus providing a balance between preserving neurological function and AVM occlusion [21]. Regarding brainstem AVMs, in situ occlusion is generally reserved for those AVMs that do not separate cleanly from the brainstem, that penetrate the parenchyma, or are more anterior in location, where it is difficult to visualize and preserve perforating arteries like in anterior pontine and lateral medullary AVMs[21]. In the present case, a combined approach was preferred for maximum obliteration.

Intraoperative indocyanine green videoangiography in AVM microsurgery

Key intraoperative tools for microsurgery include neuronavigation, digital subtraction angiography, and video angiography using fluorescein or indocyanine green. The latter is particularly useful for identifying residual nidus and abnormal vascular structures in real time[38]. Indocyanine green is a water-soluble molecule that acts as a non-specific dye, with approximately 95% protein binding. It has a tricarbocyanine structure that fluoresces when stimulated by infrared light, exhibits low toxicity, minimal pharmacodynamic interaction with organs, and is metabolized and eliminated hepatically.[40]

Within two seconds of injecting a 5 mg bolus of indocyanine green through a peripheral vein and exciting it with infrared light, the intravascular dye can be visualized in real-time as it flows through the arterial and venous pathways of the AVM inside the brain. FLOW800 technology enables the creation of perfusion maps that display blood flow dynamics within the AVM, thereby improving the precision of resecting AVM vessels while preserving normal ones[40]. This technology facilitates identification of exclusion zones within the AVM, maintains perfusion in unaffected vessels, and optimizes aneurysm clipping.

Intraoperative videoangiography with indocyanine green is therefore a valuable tool for real-time identification of AVM angioarchitecture, enabling precise visualization of feeding arteries, the nidus, draining veins, and flow dynamics[41]. This improves intraoperative decision-making and contributes to safer AVM resection. Limitations of indocyanine green include cross-reactivity with iodinated compounds and the inability to visualize deep intracortical AVMs, ultimately requiring corticotomy to expose the aberrant vessels and confirmatory imaging for remnants[40].

Evidence-based management for brainstem AVMs

Brainstem AVMs pose unique challenges due to their proximity to critical neurovascular structures. Evidence from large series in the general population consistently demonstrates superior obliteration and functional outcomes with microsurgical intervention, particularly when combined with adjunctive modalities.

In 2017, Madhugiri et al.[11] analyzed 39 cases of brainstem AVMs and proposed a classification based on vertical location (midbrain, pons, medulla), axial position (anterior, lateral, anterolateral, posterolateral), lesion plane (pial, parenchymal, mixed), and hemorrhagic status. They found that surgical management was strongly associated with higher angiographic cure rates compared with endovascular therapy or radiosurgery (OR=19, p=0.001). Combined approaches (surgery plus endovascular or radiosurgery) achieved even greater obliteration (OR=23, p<0.001). Predictors of cure included AVM size <15 mm, pial location, and surgical treatment. Patients undergoing surgery—alone or combined—also showed better modified Rankin Scale (mRS) score than those treated with radiosurgery or endovascular therapy alone (OR=4, p=0.030). Functional independence (mRS 0–1) was predicted by female sex (OR=10, p=0.013) and complete obliteration (OR=13, p=0.009), while anatomical location and venous drainage were not significant factors.

In 2015, Han et al.[21] analyzed 29 brainstem AVM cases to compare complete resection and neurological deficit rates (mRS ≥2) between microsurgical resection and in situ occlusion (circumferential occlusion of feeding arteries). They also proposed a classification with six subtypes: anterior/posterior mesencephalic, anterior/lateral pontine, and anterior/lateral bulbar. Surgical approaches varied by location: trans-tentorial orbitozygomatic for anterior midbrain, supracerebellar infratentorial or interhemispheric for posterior midbrain, extended retrosigmoid for pontine AVMs, and extreme lateral craniotomy for bulbar AVMs. In situ occlusion achieved the highest success in anterior pontine AVMs (83%). Overall, surgical mortality was 7% (linked to rupture), and neurological deterioration occurred at 14%. Complete occlusion rates reached 100% for lateral pontine and anterior midbrain AVMs, with functional improvement (mRS) in 75–100% of cases. Hemorrhagic presentation is correlated with an 83% deficit rate. Most patients (77%) improved or maintained mRS postoperatively, particularly those with pontine AVMs. Lateral pontine AVMs had the best outcomes, while posterior midbrain and anterior pontine AVMs showed higher rates of worsening and mortality.

In 2021, Chen and Li[42] reviewed 61 brainstem AVM cases comparing conservative management with interventions (surgery, embolization, radiosurgery). For unruptured brainstem AVMs, no significant differences were found among treatment options regarding mortality, mRS worsening, or hemorrhage. Microsurgery and radiosurgery achieved significantly higher obliteration rates than conservative management. Partial obliteration was associated with a slightly increased rupture risk compared to natural history (10% vs. 7%, p=0.046). In ruptured AVMs, endovascular embolization was linked to higher mortality than other treatments.

Management of pediatric AVMs remains less defined in the literature. This age group was not included in the Randomized Trial of Unruptured Brain AVMs (ARUBA)[43]. Two recent retrospective studies[44,45] including the pediatric population, have shown that excellent clinical outcomes and high obliteration rates can be achieved in patients eligible for ARUBA, especially in Spetzler-Martin grade I to II AVMs treated with surgical resection. Stereotactic radiosurgery (SRS) may represent another acceptable treatment modality for pediatric AVMs, especially in patients at excessive surgical risk[45]. Higher Spetzler-Martin grades of AVM were mainly treated with microsurgery compared to radiosurgery in these series[45].

CONCLUSIONS

We report the case of a ruptured pediatric Spetzler–Martin grade IV brainstem AVM; this is a very rare disease and a life-threatening condition that pose many diagnostic and treatment challenges. Due to its location in the pons, adjacent to the right middle cerebellar peduncle and the fourth ventricle, the patient's age, and the lesion high frailty brainstem AVM patients have a high risk of neurovascular damage and neurological sequalae. This case underscores the importance of a multimodal strategy involving a precise diagnostic approach, the use of multimodal imaging for detailed treatment planification, and the usefulness of indocyanine green video angiography which allowed real-time visualization of feeding arteries, draining veins, and residual nidus components during the surgery. This approach enhanced surgical precision, facilitated safe clipping of venous aneurysms, and optimized in situ occlusion of residual vascular structures, thereby reducing the risk of intraoperative complications such as severe injury to adjacent eloquent tissue and normal vascular structures, and increasing the likelihood of maintaining satisfactory functional status.

Even though the information and findings described in this clinical case report cannot be generalized and should be understood as evidence used to generate hypotheses, the benefits described underscore the potential role of indocyanine green videoangiography during the microsurgery resection to improve safety and outcomes in high-risk pediatric brainstem AVMs microsurgery and contribute clinical information to the limited scientific literature available about pediatric brainstem AVMs.

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CORRESPONDING AUTHOR

Julian Alberto Arenas-Trujillo, MD
Clínica del Country and Clínica la Colina
Department of Neuroscience
Bogotá, Colombia.
E-mail: ja.arenas904@uniandes.edu.co

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Preoperative Embolization in Management of Giant Olfactory Groove Meningioma

Embolização Pré-Operatória no Manejo de Meningiomas Gigantes da Goteira Olfatória

Breno Nery[1]
Eduardo Quaggio[1]
José Alencar de Sousa Segundo[1]
Mateus Wendler Ferreira Lopes[2]
Francisco Thiago de Moura Sousa[2]
Marina Rodrigues Ramalho[2]
Emilly Rayssa Passos de Lima[2]

ABSTRACT

Giant olfactory groove meningiomas (OGMs) usually originate from the cribriform plate of the ethmoidal bone and represent a significant challenge in neurosurgical practice. These tumors often exhibit bilateral involvement and may compress the frontal lobes and cranial nerves. Regarding treatment, preoperative embolization of the ethmoidal arteries via the ophthalmic artery may be an important strategy to reduce intraoperative blood loss and surgical time, particularly in patients at high cardiovascular risk. This study compares the outcomes of preoperative embolization in the management of two patients with giant OGMs and suggests that this procedure should be considered for patients who cannot tolerate significant blood loss.

Keywords: *Meningioma; Skull base neoplasms; Preoperative period; Therapeutic embolization*

RESUMO

Os meningiomas gigantes da goteira olfatória geralmente se originam da lâmina crivosa do osso etmoide e representam um desafio significativo na prática neurocirúrgica. Esses tumores frequentemente apresentam envolvimento bilateral e podem comprimir os lobos frontais e os nervos cranianos. No que diz respeito ao tratamento, a embolização pré-operatória das artérias etmoidais por meio da artéria oftálmica pode representar uma estratégia importante para reduzir a perda sanguínea intraoperatória e o tempo cirúrgico, particularmente em pacientes com alto risco cardiovascular. Este estudo compara os desfechos da embolização pré-operatória no manejo de dois pacientes com OGMs gigantes e sugere que esse procedimento deve ser considerado em pacientes que não toleram perdas sanguíneas significativas.

Palavras-Chave: *Meningioma; Neoplasias da base do crânio; Período pré-operatório; Embolização terapêutica*

[1]Neurosurgery Department, Hospital Beneficência Portuguesa de Ribeirão Preto, Ribeirão Preto, SP, Brazil.
[2]Centro Universitário UNIFACISA, Campina Grande, PB, Brazil.

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INTRODUCTION

Meningiomas represent the most prevalent primary central nervous system (CNS) neoplasm, originating from the arachnoid cap cells of the meninges that envelope the brain and spinal cord. While predominantly benign and slow-growing, these lesions can cause significant morbidity due to compression of adjacent neuroanatomical structures, increased intracranial pressure, and alterations in cerebrospinal fluid (CSF) dynamics. Despite their generally indolent clinical course, specific subtypes exhibit high recurrence potential and aggressive biological behavior, necessitating specialized surveillance and therapeutic intervention[1].

The World Health Organization (WHO) classification categorizes meningiomas into three histological grades: benign (Grade I), atypical (Grade II), and anaplastic or malignant (Grade III). These classifications are based on morphological and biological criteria that correlate directly with recurrence risk and overall prognosis. This heterogeneity explains why management strategies range from serial neuroimaging observation to complex surgical approaches and, in select cases, adjuvant radiotherapy for disease control[1].

Among the various anatomical locations, olfactory groove meningiomas (OGMs) are a distinct variant originating from the basal portion of the frontal lobe over the cribriform plate of the ethmoid bone. This region houses the olfactory nerve filaments responsible for olfaction and is situated at the anterior skull base, immediately superior to the nasal cavities. Due to their deep-seated location and initially silent growth, OGMs frequently reach massive dimensions prior to clinical diagnosis[2].

Giant olfactory groove meningiomas can extend bilaterally into the frontal lobes and the anterior fossa, leading to behavioral changes, cognitive deficits, anosmia, and, in advanced stages, signs of intracranial hypertension. Surgical management remains the primary therapeutic pillar; however, it is technically demanding given the proximity to critical neurovascular structures and the risk of significant intraoperative hemorrhage during resection. In this context, preoperative embolization has been investigated as an adjuvant strategy to reduce tumoral blood flow and facilitate surgical removal, although its definitive impact on prognosis and postoperative complications remains a subject of debate in the literature[2,3].

Preoperative embolization is an endovascular technique widely utilized in surgical neuro-oncology to reduce tumoral vascularity and, consequently, intraoperative blood loss. In meningiomas—extra-axial tumors characterized by slow growth and high vascularity—this strategy aims to facilitate surgical resection, decrease operative time, and potentially mitigate perioperative complications. The procedure involves the selective occlusion of tumor-feeding arteries using particulate embolic agents, liquid embolic systems, or microcoils, administered via an endovascular approach under angiographic guidance[3].

In the specific context of olfactory groove meningiomas, the application of this technique requires particular caution. Located at the anterior skull base, these tumors are frequently supplied by branches of the ophthalmic and anterior ethmoidal arteries—vessels in close proximity to the orbital vasculature and the optic nerve. This anatomical proximity poses a considerable technical challenge, increasing the risk of retinal ischemia, optic neuropathy, and cerebral infarction. Therefore, the theoretical benefit of embolization—achieving a cleaner and more homeostatically controlled resection—must be weighed against the risk of potentially devastating adverse events[3].

At least, this study underlines the importance of preoperative embolization for better patient outcomes in the case of olfactory groove meningioma through case reports in two different situations, comparing technical approaches and respective results.

CASE PRESENTATION

Case 1

A 54-year-old female patient presented to an ophthalmology appointment with gradual left visual loss for the past 3 years. She developed left amaurosis for 2 years and right visual loss 3 months prior to the surgery. Head MRI showed an olfactory groove meningioma (OGM) with bilateral optic nerve compression (Figures 1 to 6). The patient suffers from heart failure and tachyarrhythmia. The ethmoidal arteries were embolized via the dilated ophthalmic artery and the patient was operated one week later after the procedure. Surgery was uneventful and took 4 hours. Besides, the patient had 250 ml of blood loss and needed noradrenaline due to hemodynamic instability. All preoperative deficits were improved.

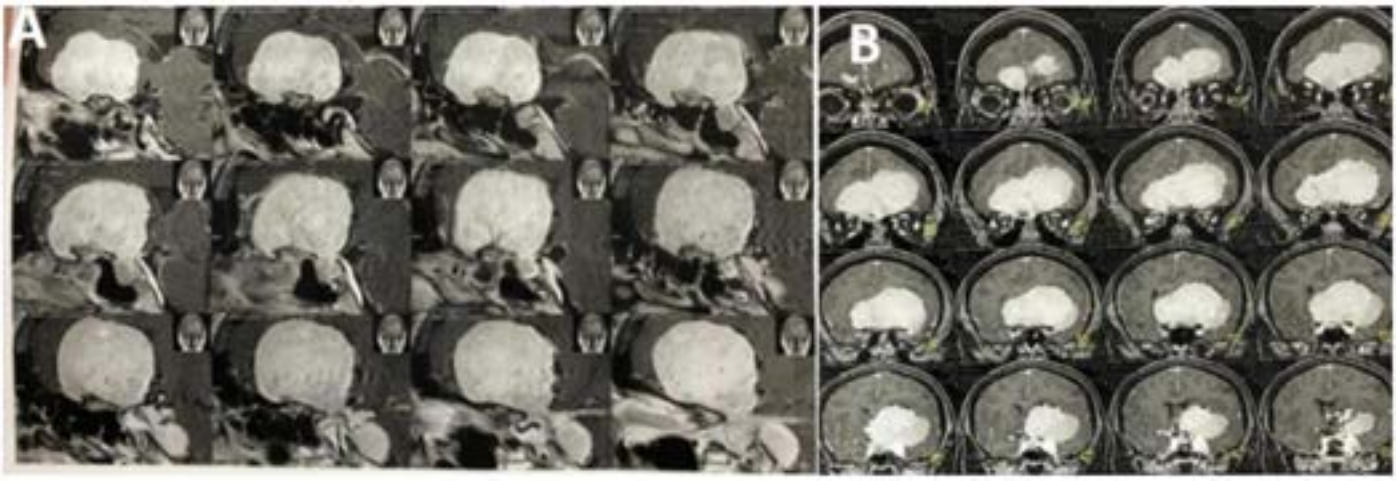

Figure 1. Preoperative MRI: **A.** Sagittal view showing the OGM pressing on the optic nerves/chiasm. **B.** Coronal view of the OGM.

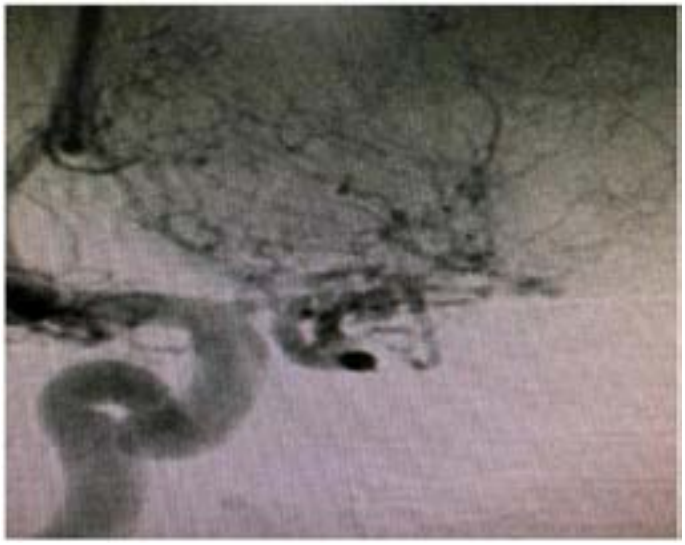

Figure 2. Preoperative Arteriography showing significant dilation of the ophthalmic artery and anterior and posterior ethmoid branches.

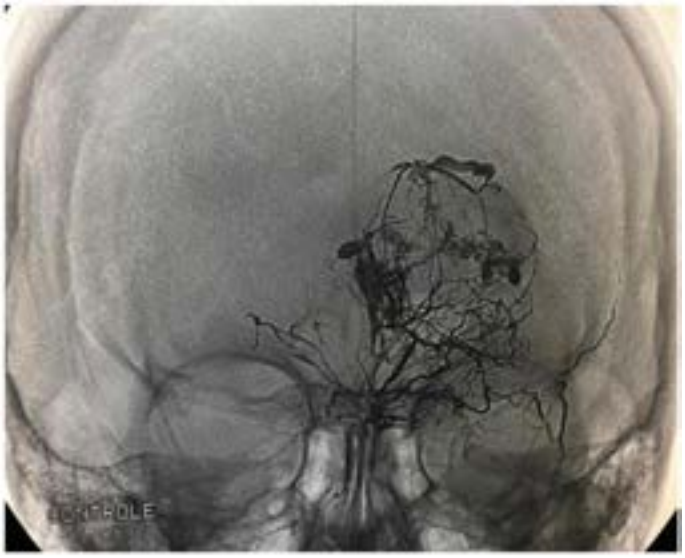

Figure 3. Postoperative embolization showing a well irrigated lesion.

Case 2

Female patient, 32 years old, no comorbidities. Progressive bilateral vision loss, personality changes and headache. CTscan showed a giant OGM without dilated ophthalmic arteries (Figure 7). This patient was submitted to the same approach as patient 1, but the preoperative embolization was not performed. Finally, the surgery was uneventful and took 8 hours. A total of 600 ml was estimated for the blood loss. All preoperative deficits were improved, including personality changes.

DISCUSSION

Giant olfactory groove meningiomas (OGM) most commonly originate in the cribriform plate of the ethmoid bone, proximal to the anterior cranial base[4]. These tumors tend to be bilateral and when over-proliferation occurs, they start pressing on the frontal lobes and may affect vision by compressing on the optic nerve[5].

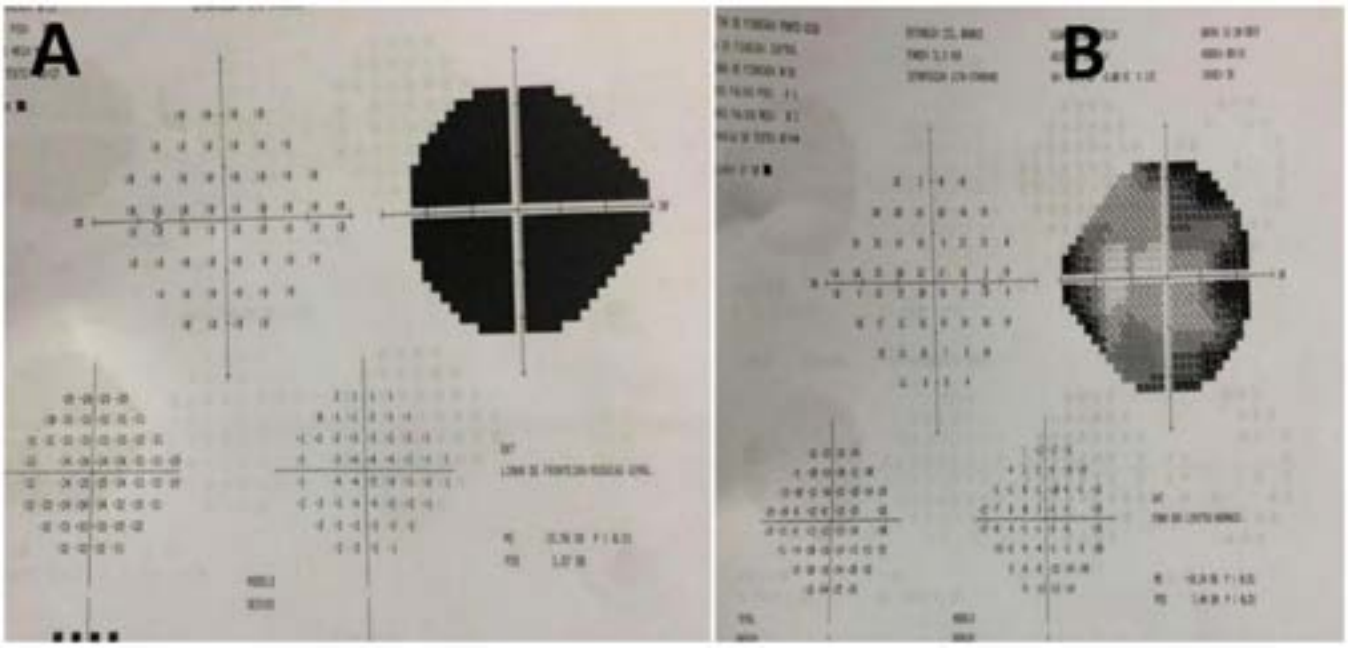

Figure 4. A-B. Preoperative campimetry.

This study underscores the importance of preoperative embolization in the management of giant OGM in two different patients treated by our team. Both cases underwent tumor resection and there were no complications.

The patient 1 lost 250 ml of blood during the surgery and developed hemodynamic instability, treated with noradrenaline 40 ml/h for two days. Surgery took 4 hours. The tumor was surgically removed via subfrontal and anterior interhemispheric approach, with an almost complete recovery of vision. Carrying out arterial embolization pre-operatively, the outcomes of the surgery are improved as a result of the prevention of blood loss[6-8]. Preventing blood loss was very important due to the unstable cardiovascular system of the patient. Patient 2 was submitted to the same approach, but did not underwent preoperative embolization, with surgery duration of 8 hours and 600 ml of blood loss. These results reinforce that the preoperative embolization is crucial to reduce surgery time and prevent other negative outcomes.

Regarding clinical findings related to this type of tumor, patient 1 developed headache and progressive bilateral visual deficit, while patient 2 presented, in addition to these, personality changes. Furthermore, there are a lot of other signs and symptoms that can be present in giant OGM. Calvanese et al.[9] describes a case of a 57-year-old woman who presented anosmia, indicating

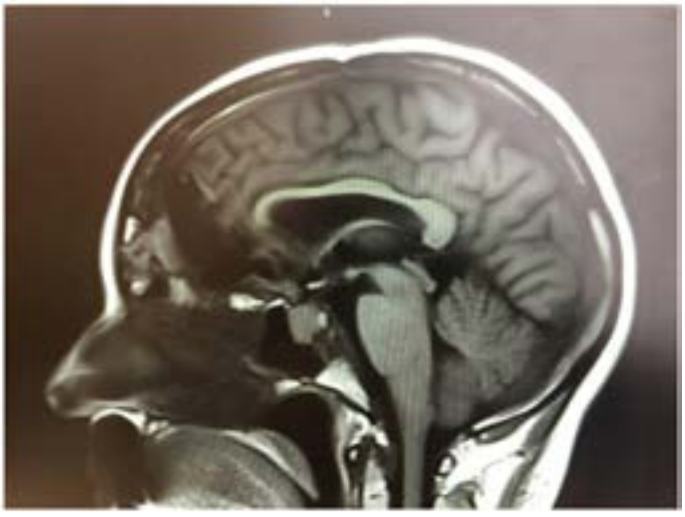

Figure 5. Postoperative MRI coronal view.

that the first cranial nerve is also affected. Equally important, the frontal lobe involvement is associated to behavior changes and cognitive decline: Lallani et al.[10] mentioned a 28-year-old female presenting a Montreal Cognitive Assessment (MOCA) equal to 16/22 and aggressive behavior resulting in a charge of child abuse for the death of her toddler daughter. Thus, it can be concluded that a complete clinical investigation combined with image exams are two essential pillars aiming for the diagnosis of OGM and, if possible, his treatment.

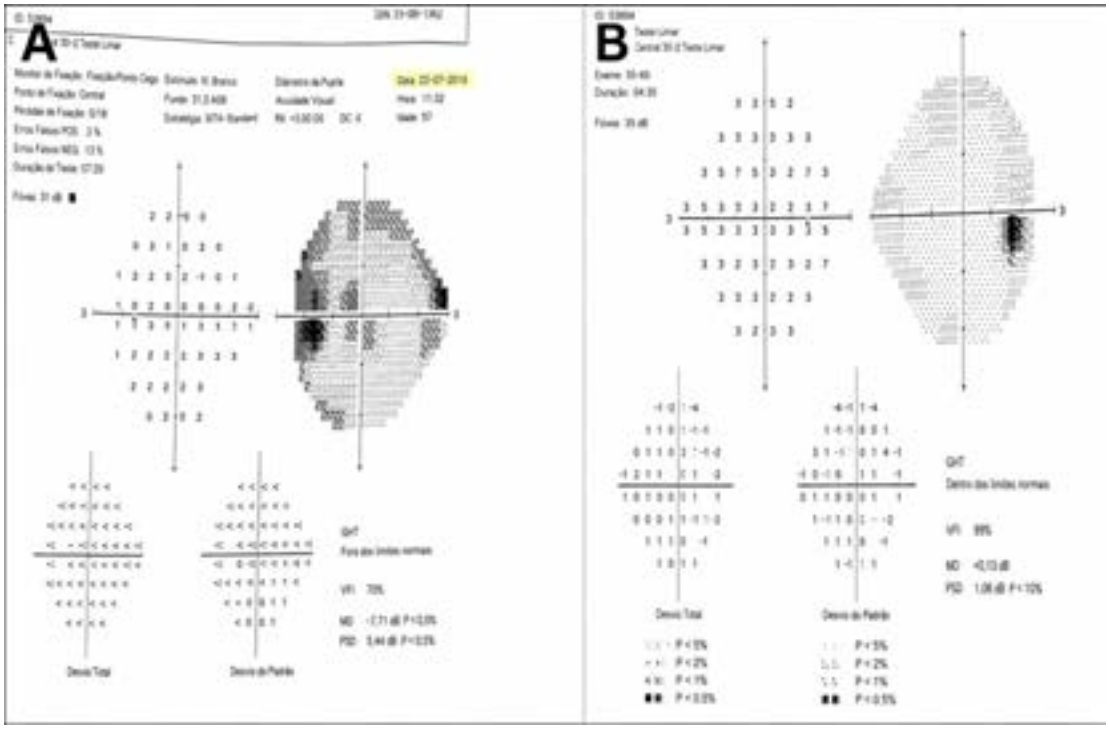

Figure 6. A-B. Postoperative campimetry.

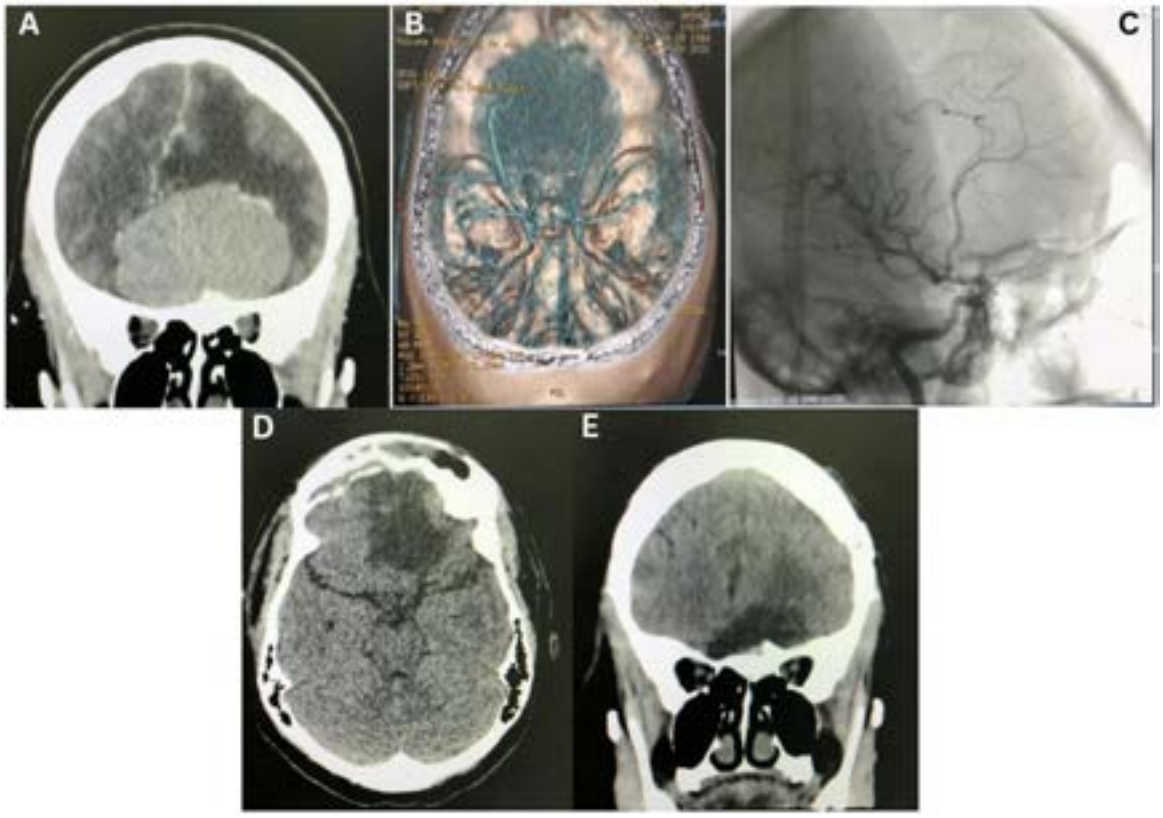

Figure 7. A-B. Preoperative CT scan of case 2 and C. angiography. D and E. control CT scan showing gross total resection.

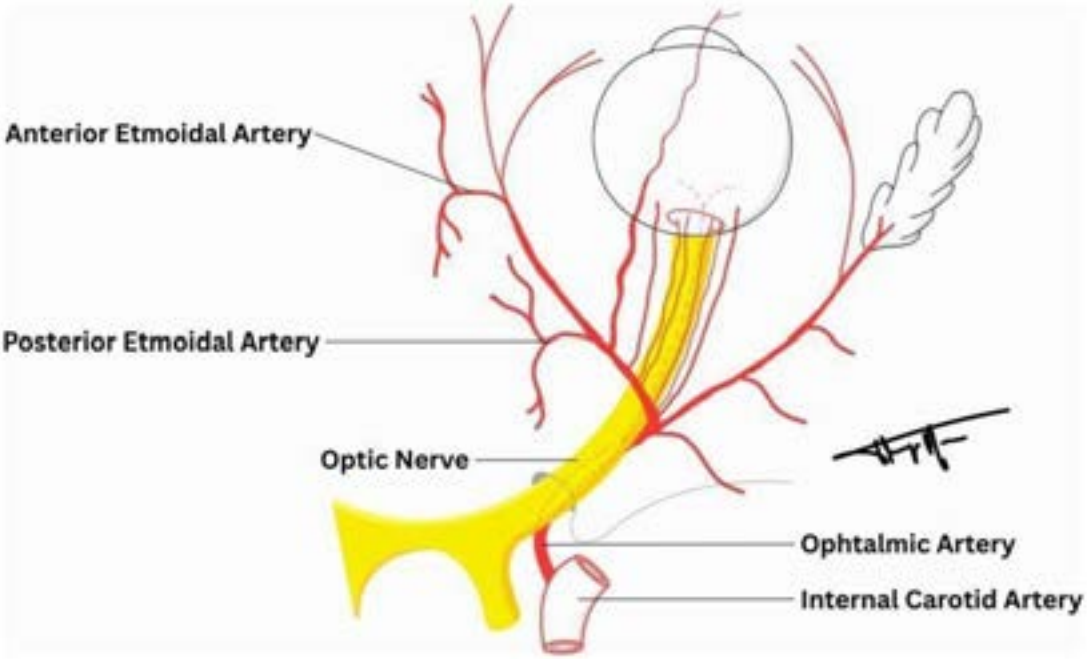

Figure 8. Schematic illustration of the ophthalmic artery and its branches.

Subsequently, preoperative embolization must be discussed. This technique aims to decrease blood loss and operative time, reducing the risk of complications. In cases of giant OGM, the Transophthalmic Artery Embolization (TOAE) is the most common procedure performed, decreasing the tumor blood supply through precise microcatheter techniques to navigate the ophthalmic artery with accuracy and safety[11]. In spite of this, Wei et al.[12] describes a notable case of a giant OGM in a 55-year-old male, embolized using an alternative approach. The meningeal blood supply was interrupted through bipolar coagulation of the epidural meningeal vessels surrounding the crista galli. The tumor was completely removed with significantly reduced blood loss. This report, although rare, reinforces the idea that the TOAE is not the only way to embolize Giant OGM (Figure 8).

A wide variety of liquid embolic agents has been described to realize this procedure. Przybylowski et al.[13], in a retrospective cohort study, reported a series of 28 meningiomas that were submitted to preoperative embolization without complications. As a result, the embolic agent used were Onyx alone (n = 71%), n-butyl cyanoacrylate alone (n = 11%), coils/particles and Onyx/n-butyl cyanoacrylate (n = 7%) and Onyx and coils (n = 4%). In conclusion, in spite of the variety of embolic agents, the aforementioned study corroborates the idea of an "Onyx Era" in the neurosurgery scenario.

With respect to the effectiveness, a huge variety of studies demonstrates that the preoperative embolization is responsible for decreasing intraoperative bleeding, anesthetic and surgical time. Akimoto et al.[14] - by a retrospective propensity-matched analysis - describes 186 patients with WHO grade I meningiomas who underwent surgical resection. Of these, 71 patients were submitted to embolization and the results show a considerable decrease of blood loss and shorter operation time. Nevertheless, there is a heterogeneity in the literature: some studies did not find a difference between embolized and not embolized patients[15,16]. In spite of this, the preoperative embolization is still indicated in cases who present hemodynamic instability, giant tumors (>4 cm), high tumor vascularization and difficult surgical access[17,18].

However, preoperative embolization is not without potential adverse outcomes, including ischemic complications, cranial nerve deficits, and visual impairment, particularly when the ophthalmic artery is involved. In this context, Ilyas et al.[8] conducted a study including 403 embolized meningiomas, reporting an overall complication rate of 12%, with major complications occurring in 6% of cases. Notably, the procedure-related mortality rate was 0.2%. Thus, a multidisciplinary approach is essential to optimize outcomes and minimize procedure-related risks.

Finally, Aydin et al.[19] described a rare and aggressive presentation of giant OGM as a collision tumor complex (CTC), defined by the coexistence of two or more benign or malignant tumors with distinct histopathological features occurring adjacently within the same anatomical region. In their case, a 65-year-old male with OGM and a non-functioning pituitary adenoma underwent a right frontal craniotomy. Recognizing CTCs is crucial, as their presence may significantly influence diagnostic accuracy, surgical planning, and overall therapeutic strategy.

To conclude, the methodological heterogeneity among studies, the lack of consensus regarding optimal indications, the scarcity of large-scale randomized clinical trials, and the absence of standardized protocols represent the most important limitations about this topic[14]. Addressing these gaps is essential to improve surgical outcomes and to refine treatment paradigms for giant OGM, which continue to represent a demanding and impactful entity in neurosurgical practice.

CONCLUSION

Our findings emphasize the importance of preoperative embolization in the management of giant OGM and its influence on patient blood loss and surgical duration. Through an analysis of the available literature and the report of both cases—describing their clinical presentations, surgical approaches employed, and outcomes achieved—this review reinforces the benefits of preoperative embolization in attaining superior surgical and postoperative results, particularly in patients with high cardiovascular risk who may not tolerate significant blood loss. By discussing the surgical challenges these tumors represent in neurosurgery and presenting similar practical cases, our study contributes to the currently limited literature on the subject.

Thus, based on the cases presented above, preoperative embolization of the ophthalmic arteries during the management of giant OGM may represent a crucial strategy for reducing intraoperative blood loss in patients at high cardiovascular risk.

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CORRESPONDING AUTHOR

Mateus Wendler Ferreira Lopes, MS
Medical student
Centro Universitário UNIFACISA
Campina Grande, Paraíba, Brazil
E-mail: mateus.lopes@maisunifacisa.com.br

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Subarachnoid Hemorrhage as the Presenting Feature of Moyamoya Disease: a case report

Hemorragia Subaracnoidea como Forma de Presentación de la Enfermedad de Moyamoya: caso clínico

Facundo Rodríguez[1]
Camila Brignoni[1]
Agustín Carámbula[1]
Matías Negrotto[2]
Pedro Grille[1]
Marcelo Barbato[1]
Federico Verga[1]

ABSTRACT

Moyamoya disease is a chronic cerebrovascular disorder characterized by progressive stenosis and eventual occlusion of the internal carotid arteries, resulting from smooth muscle cell hyperplasia with superimposed luminal thrombosis. Clinical manifestations most commonly include ischemic or hemorrhagic stroke, with the predominant phenotype varying according to age at presentation. In adults, hemorrhagic events predominate, particularly intraparenchymal hematomas and intraventricular hemorrhage, whereas subarachnoid hemorrhage is an uncommon initial manifestation. We report a case of Moyamoya disease with a fulminant presentation characterized by concurrent subarachnoid, intraparenchymal, and intraventricular hemorrhage.

Keywords: *Moyamoya disease; Subarachnoid hemorrhage; Neuroimaging; Duplex Doppler Ultrasonography.*

RESUMEN

La enfermedad de Moyamoya es un trastorno cerebrovascular crónico caracterizado por estenosis progresiva y eventual oclusión de las arterias carótidas internas, como resultado de hiperplasia de las células del músculo liso con trombosis luminal superpuesta. Las manifestaciones clínicas más frecuentes incluyen eventos cerebrovasculares isquémicos o hemorrágicos, cuyo fenotipo predominante varía según la edad de presentación. En los adultos predominan los eventos hemorrágicos, particularmente los hematomas intraparenquimatosos y la hemorragia intraventricular, mientras que la hemorragia subaracnoidea constituye una forma de presentación inicial poco frecuente. Presentamos un caso de enfermedad de Moyamoya con una presentación fulminante caracterizada por hemorragia subaracnoidea, intraparenquimatosa e intraventricular concomitantes.

Palabras-Clave: *Enfermedad de Moyamoya; Hemorragia subaracnoidea; Neuroimagen; Ecografía Doppler dúplex.*

[1]Intensive Care Unit - ICU, Maciel Hospital, Administración de los Servicios de Salud del Estado - ASSE, Montevideo, Uruguay.
[2]Maciel Hospital, Administración de los Servicios de Salud del Estado - ASSE, Montevideo, Uruguay.

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INTRODUCTION

Moyamoya disease (MMD) is a chronic cerebrovascular condition characterized by progressive stenosis and/or occlusion of the intracranial internal carotid arteries, accompanied by the development of a fragile collateral vascular network at the base of the brain[1-3]. First described in Japan[4], its definition has undergone several revisions over time. According to the most recent guidelines from the Research Committee on Moyamoya Disease (RCMD), MMD is defined as a stenotic–occlusive arteriopathy predominantly affecting the terminal portion of the intracranial internal carotid artery, in the absence of alternative causes of arterial stenosis. These guidelines distinguish the idiopathic form, referred to as Moyamoya disease, from Moyamoya syndrome, which is associated with acquired or hereditary conditions[1].

The disease is more prevalent among individuals of Asian ancestry, particularly in Japanese populations, in whom the highest estimated incidence is approximately 1 case per 100,000 inhabitants. Incidence rates are up to tenfold lower in Western countries; however, the true incidence is likely underestimated, partly due to incomplete diagnostic evaluation. The age distribution is bimodal, with incidence peaks around 10 and 40 years, and there is a marked female predominance, with a female-to-male ratio of approximately 2.6:1[5].

A substantial genetic contribution has been recognized, as approximately 12% of patients report a positive family history, and several genes implicated in disease pathogenesis have been identified. Although the precise mode of inheritance remains under investigation, an autosomal dominant pattern with incomplete penetrance has been proposed[5].

The underlying vascular abnormalities account for the heterogeneous clinical presentation of MMD, which may be broadly categorized into: (1) ischemic events, including transient ischemic attacks and cerebral infarction; (2) hemorrhagic events, comprising intracerebral hematomas and intraventricular hemorrhage, and less frequently subarachnoid hemorrhage (SAH), usually related to rupture of fragile collateral or transdural anastomotic vessels; and (3) other nonspecific neurological manifestations, such as seizures, persistent severe headache, or neurocognitive and neuropsychiatric disturbances. In some cases, the diagnosis is made incidentally in otherwise asymptomatic individuals[3].

Limited awareness of this condition contributes to misdiagnosis and diagnostic delay. Presentation as severe SAH is uncommon, with only a limited number of cases reported in the literature. Here, we describe a patient with MMD who presented in a fulminant manner with concomitant subarachnoid, intraparenchymal, and intraventricular hemorrhage. We obtained informed consent from the family members for the publication of the following case.

CASE PRESENTATION

A 49-year-old Caucasian woman with a medical history notable for major depressive disorder, four previous suicide attempts, active tobacco use, and prior cocaine consumption presented with abrupt-onset confusion and somnolence. On admission, she was in deep coma, with a Glasgow Coma Scale (GCS) score of 3, preserved pupillary light reflexes, and mild nuchal rigidity. Orotracheal intubation was promptly performed.

Non-contrast cranial computed tomography (CT) demonstrated SAH, a left gangliobasal intraparenchymal hematoma, diffuse intraventricular hemorrhage with supratentorial ventricular dilatation, and a right frontal cortico-subcortical hypodense area consistent with a chronic sequela. Computed tomography angiography (CTA) revealed absence of flow in the left internal carotid artery (ICA); the right ICA was reduced in caliber, and both middle cerebral arteries (MCAs) appeared markedly attenuated and thread-like. In addition, a small saccular aneurysmal dilatation adjacent to the hematoma was identified (Figure 1).

The patient was admitted to the intensive care unit (ICU), jointly managed with the neurosurgical team, and an urgent external ventricular drain (EVD) was placed. She remained hemodynamically and respiratory stable, with no improvement in neurological status. Twenty-four hours after admission, cerebral catheter angiography demonstrated bilateral stenosis of the internal carotid arteries, more pronounced on the left, with prominent proliferation of fine, serpiginous vessels and extensive leptomeningeal collateral circulation arising from the posterior cerebral arteries (PCAs), findings consistent with MMD (Figure 2).

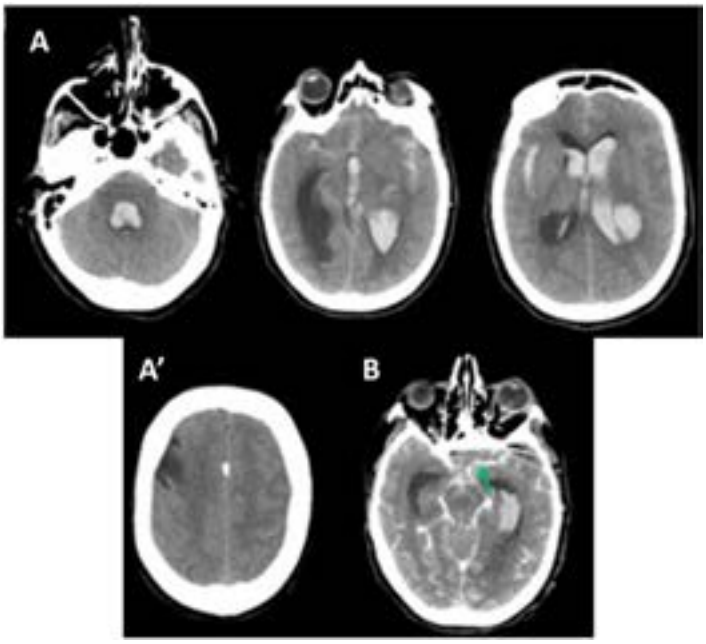

Figure 1. A. Non-contrast cranial computed tomography (CT) demonstrating subarachnoid hemorrhage (SAH), a left basal ganglia hematoma, and intraventricular hemorrhage with ventricular dilatation. A'. A right frontal cortico-subcortical hypodense area consistent with established ischemic injury is also observed. **B.** Computed tomography angiography (CTA) showing marked attenuation ("thread-like" appearance) of the left middle cerebral artery (MCA) flow signal (arrow).

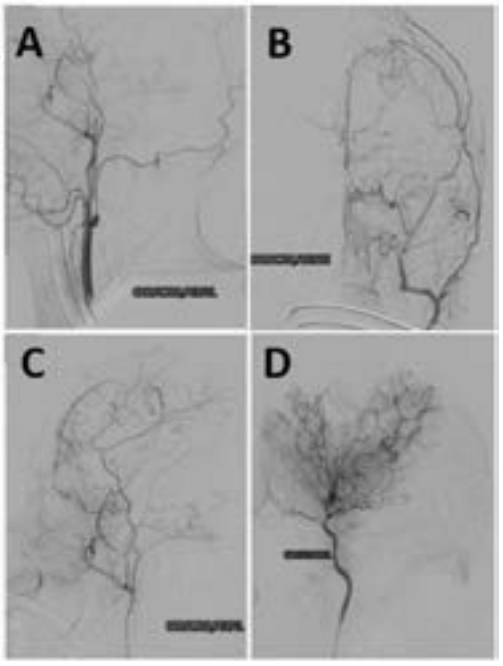

Figure 2. A. Lateral projection after left common carotid artery injection demonstrating diffuse tapering of the left internal carotid artery (ICA) from the suprabulbar cervical segment, with a thread-like flow pattern and abrupt termination at the clinoid segment. **B.** Anteroposterior projection of the left external carotid artery (ECA). **C.** Lateral projection of the left ECA showing marked leptomeningeal collateral circulation within the left cerebral hemisphere, with multiple vessels crossing the midline. **D.** Lateral projection of the right ICA demonstrating supraclinoid narrowing, termination at the origin of the M1 segment, and progressive narrowing of the right A1 segment with distal occlusion. Prominent development of fine, serpiginous moyamoya-type collateral vessels arising from the right M1 segment.

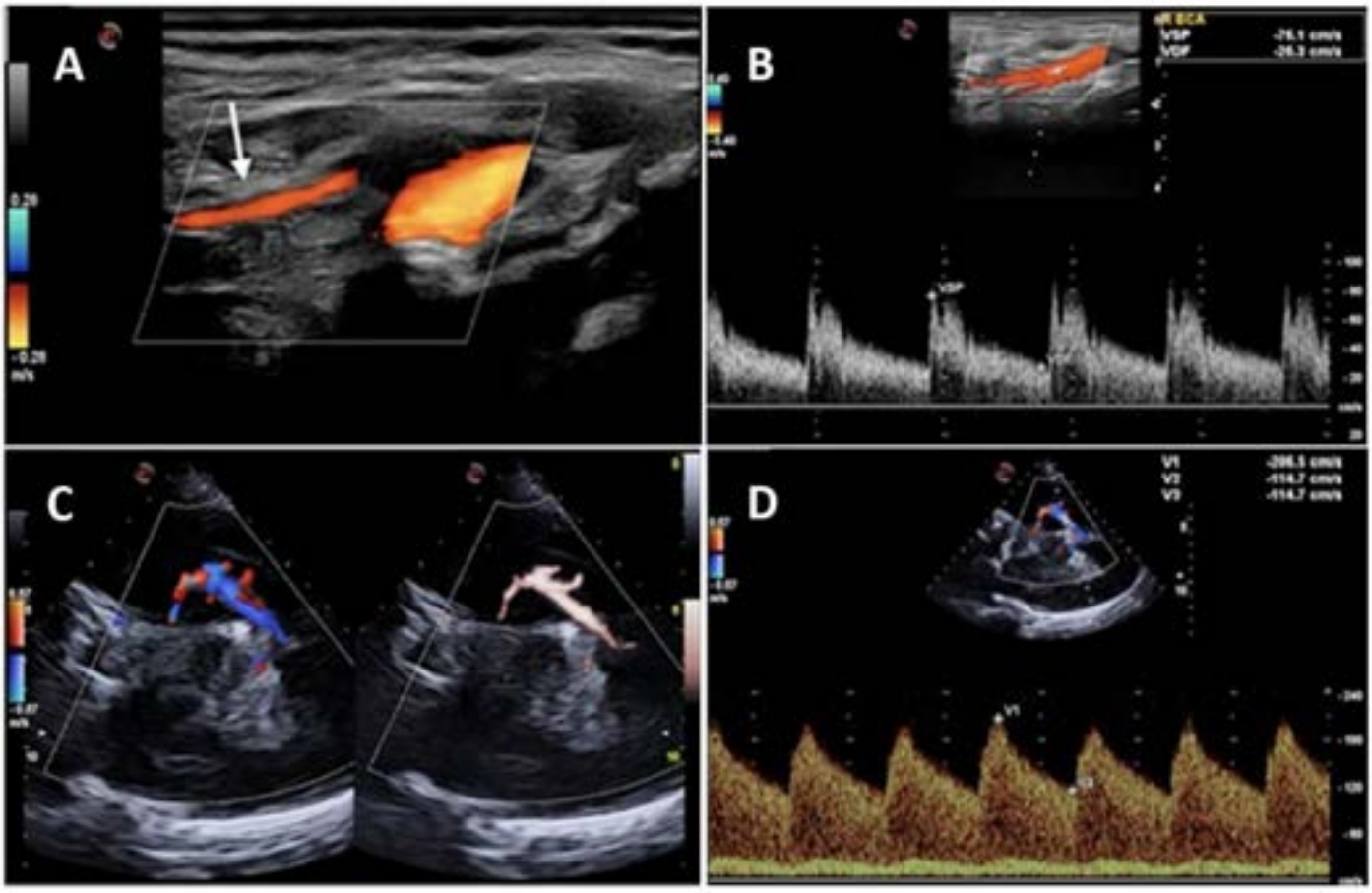

Figure 3. A. Color Doppler ultrasound of the left cervical vessels showing thread-like flow in the proximal segment of the internal carotid artery (ICA) (arrow). **B.** Duplex ultrasound of the right cervical vessels (color and spectral Doppler) showing an "internalized" external carotid artery (ECA) waveform with a low-resistance flow pattern. **C, D.** Transcranial duplex ultrasound through the transtemporal window (color Doppler, C; spectral Doppler. D. demonstrating prominent collateral recruitment from the posterior circulation, with increased flow velocities in the posterior cerebral artery (PCA) P1–P2 segments (peak systolic velocity [PSV], 206 cm/s).

During the ICU course, non-invasive neuromonitoring using quantitative infrared pupillometry was performed and remained within normal limits. Duplex ultrasonography of the supra-aortic trunks demonstrated a pre-stenotic flow pattern in the left common carotid artery (CCA) and a thread-like flow with markedly reduced velocities in the ipsilateral ICA. Both external carotid arteries (ECAs) exhibited an "internalized" waveform characterized by low resistance and low pulsatility, reflecting their collateral contribution to intracranial perfusion.

Transcranial duplex ultrasonography revealed a post-stenotic flow pattern in the M1 segment of both MCAs, with severe flow impairment on the left and moderate impairment on the right. The PCAs demonstrated markedly increased flow velocities in both the P1 and P2 segments, as well as in their cortical branches (anterior temporal and occipitotemporal arteries), consistent with secondary leptomeningeal collateralization toward the ipsilateral middle cerebral artery and anterior cerebral artery territories (Figure 3).

Despite discontinuation of pharmacological sedation, the patient remained in deep coma, with bilateral extensor posturing and absence of ocular or purposeful motor responses. The EVD remained patent, with appropriate hemorrhagic drainage. On day 6 of admission, she developed ventriculostomy-associated bacteremia due to Acinetobacter baumannii, along with primary polymicrobial bacteremia, progressing to refractory septic shock and death on day 9 after admission.

DISCUSSION

Moyamoya disease is an uncommon cerebrovascular disorder associated with substantial morbidity and mortality. It is characterized by progressive occlusion of the intracranial internal carotid arteries—particularly at their terminal segments—together with the development of a fragile collateral vascular network, in the absence of alternative causes of arterial stenosis[1]. A "two-hit" hypothesis has been proposed, whereby genetic susceptibility interacts with environmental factors, including alcohol consumption[6]. Although the precise pathophysiological mechanisms remain incompletely understood, arterial occlusion is thought to result from a combination of smooth muscle cell hyperplasia and superimposed luminal thrombosis[2].

Diagnosis is based on the demonstration of bilateral stenosis or occlusion of the terminal intracranial ICA in association with abnormal collateral vascular networks. Cerebral catheter angiography remains the diagnostic gold standard; however, non-invasive imaging modalities, such as magnetic resonance angiography and transcranial duplex ultrasonography, play an important complementary role, particularly when invasive angiography is not readily available[6]. In our case, extracranial and transcranial duplex ultrasonography provided complementary hemodynamic information, demonstrating both severe anterior circulation compromise and compensatory posterior circulation recruitment, thereby reinforcing the angiographic diagnosis and highlighting the value of non-invasive modalities in the assessment of MMD.

The natural history of MMD has classically been described in six angiographic stages reflecting the evolution of compensatory vascular mechanisms, although these stages do not necessarily correlate with clinical severity. In the final stage, there is complete disappearance of both moyamoya collateral vessels and the internal carotid artery, with cerebral perfusion predominantly maintained by the external carotid arteries through leptomeningeal anastomoses.

The clinical spectrum includes ischemic, hemorrhagic, and non-specific neurological manifestations[3,7]. Whereas cerebral ischemia predominates in children, hemorrhage represents a classical presentation in adults, with reported incidences ranging from 21% to 69% in Asian series[8]. Mortality rates in hemorrhagic cases range from 6.8% to 28.6% and are associated with considerable long-term morbidity[3]. Although SAH is an uncommon manifestation, it carries significant prognostic implications.

SAH in MMD appears to occur more frequently in adult women, and most published reports consist of isolated case descriptions. Only a limited number of studies have specifically examined its incidence. In one of the largest available series, Wan et al. reported 34 patients presenting with SAH, accounting for 9.7% of 349 cases[9]. It has been proposed that the extensive compensatory collateral networks formed in response to carotid stenosis predispose to SAH through rupture of fragile transdural anastomotic vessels. Such rupture may result from the formation of microaneurysms or pseudoaneurysms, particularly involving branches of the ophthalmic and middle meningeal arteries that traverse the dura mater, arachnoid space, and leptomeninges to supply the cerebral parenchyma[9].

In hemorrhagic presentations, acute management depends on the type and severity of intracranial bleeding and may include surgical evacuation of hematoma, placement of an external ventricular drain, or aneurysm clipping in cases of SAH, with the aim of preventing rebleeding. However, these interventions address acute complications and do not modify the underlying disease process or halt its progression[10].

Definitive management strategies are broadly divided into medical and surgical approaches, both aimed at reducing the risk of recurrent ischemic or hemorrhagic events. Medical therapy, despite limited supporting evidence, typically includes antiplatelet agents and, in selected cases, systemic anticoagulation. Surgical revascularization remains the cornerstone of treatment and represents the only intervention shown to alter the natural history of the disease by reducing reliance on fragile collateral networks and limiting further pathological collateral formation[9]. A variety of techniques are available, including direct, indirect, and combined approaches[7]. Nevertheless, despite its efficacy, surgical treatment is associated with a non-negligible risk of complications.

MMD should therefore be considered in the differential diagnosis of intracerebral hemorrhage, particularly in younger adult women and especially in cases of SAH, as management strategies and prognosis may differ substantially.

CONCLUSION

MMD should be considered in the differential diagnosis of patients presenting with SAH, particularly when no aneurysm is identified at typical anatomical sites or when vascular abnormalities suggestive of the condition are evident on neuroimaging. Although more prevalent in Asian populations, the disease is likely underrecognized in other regions, potentially leading to delays in diagnosis and appropriate management. Early recognition, supported by characteristic angiographic findings and complementary non-invasive investigations, may facilitate timely and appropriate therapeutic planning.

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CORRESPONDING AUTHOR

Federico Verga, MD
Administración de los Servicios de Salud del Estado – ASSE
Maciel Hospital, Intensive Care Unit - ICU
Montevideo, Uruguay.
E-mail: vergafederico@gmail.com

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CRediT

Facundo Rodríguez: Conceptualization, Writing - Original Draft. Camila Brignoni: Conceptualization, Writing - Original Draft. Matías Negrotto: Writing - Original Draft. Agustín Carámbula: Writing - Original Draft.
Pedro Grille. Conceptualization, Supervisión. Marcelo Barbato: Conceptualization, Supervision. Federico Verga: Conceptualization, Writing - Review & Editing, Supervision.

Pioneering Experience in Brazil with the Cavux® FFS System in the Cervical Spine: report of three consecutive cases with posterior facet stabilization

Experiência Pioneira no Brasil com o Sistema Cavux® FFS na Coluna Cervical: relato de três casos consecutivos com estabilização facetária posterior

Reinaldo Rodrigues Pamplona[1]
Vinicius Santos Baptista[2]

ABSTRACT

Introduction: *The CAVUX® Facet Fixation System (FFS) represents a minimally invasive alternative for posterior cervical fusion and stabilization, enabling percutaneous interfacet arthrodesis. Although used internationally, no prior studies have documented its application in Brazil.* **Case presentation:** *We report the first Brazilian experience using the CAVUX® FFS in three patients with persistent axial neck pain and cervicobrachialgia following previous anterior cervical arthrodesis. All presented multilevel foraminal stenosis and underwent posterior percutaneous interfacet fixation at three cervical levels. Procedures were performed under general anesthesia with intraoperative neurophysiological monitoring and dual C-arm fluoroscopy, with a mean surgical time of one hour, estimated blood loss of 50 mL, and hospital discharge within 24 hours. At 3-month follow-up, all patients demonstrated consistent pain reduction (mean VAS 9⟶4) and functional improvement, with no neurological complications or intraoperative events.* **Conclusion:** *The CAVUX® FFS proved to be a safe, feasible, and effective technique for posterior cervical stabilization, offering rapid recovery and minimal morbidity. This report documents the first national use of the system and expands regional knowledge of minimally invasive posterior cervical fusion techniques.*

Keywords: *Cervical vertebrae; Arthrodesis; Spinal fusion; Minimally invasive surgical procedures; Spinal implants*

RESUMO

Introdução: *O sistema CAVUX® Facet Fixation System (FFS) representa uma alternativa minimamente invasiva para fusão e estabilização cervical posterior, promovendo artrodese interfacetária por via percutânea. Embora já utilizado em outros países, não há relatos publicados sobre sua aplicação no Brasil.* **Relato dos casos:** *Apresentamos a primeira experiência brasileira com o uso do CAVUX® FFS em três pacientes com dor cervical axial e cervicobraquialgia refratárias após artrodese anterior prévia. Todos apresentavam estenose foraminal em múltiplos níveis e foram submetidos à fixação posterior percutânea interfacetária em três níveis cervicais. Os procedimentos foram realizados sob anestesia geral, com monitorização eletrofisiológica e uso de dois arcos em radioscopia, apresentando tempo cirúrgico médio de 1 hora, sangramento estimado médio de 50 mL e alta em até 24 horas. Em três meses, observou-se redução consistente da dor e melhora funcional significativa, sem complicações neurológicas ou intercorrências intraoperatórias.* **Conclusão:** *O CAVUX® FFS mostrou-se seguro, tecnicamente viável e eficaz para estabilização cervical posterior, com recuperação rápida e mínima morbidade. Este relato inaugura o uso documentado do sistema no Brasil e amplia o conhecimento nacional sobre técnicas de fusão cervical minimamente invasiva.*

Palavras-Chave: *Coluna cervical; Artrodese; Fusão vertebral; Cirurgia minimamente invasiva; Coluna vertebral, implantes*

[1]Fundação de Neurologia e Neurocirurgia, Instituto do Cérebro, Salvador, BA, Brazil
[2]Department of Neurology and Neurosurgery, Universidade Federal de São Paulo – UNIFESP, São Paulo, SP, Brazil.

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INTRODUCTION

Cervical spinal fusion was an established intervention for the treatment of degenerative pathologies, segmental instability, and pseudarthrosis following anterior arthrodesis. However, conventional approaches such as traditional posterior cervical fusion were associated with greater morbidity, significant muscular dissection, and potential postoperative neurological complications[1].

In this context, the CAVUX® FFS (Facet Fixation System) emerged as an innovative, minimally invasive alternative: an integrated implant composed of a cage and screw, inserted bilaterally through a posterior approach, traversing the facet joints to provide temporary stabilization while bony fusion occurred[2-4]. This technique had been specifically approved by the FDA for single-level anterior cervical pseudarthrosis revision (C3-C7).

The effectiveness of the CAVUX® FFS in the cervical spine was demonstrated through the REVISE Clinical Study, based on real-world evidence involving 191 cases with a mean follow-up of 39 months. Among patients with complete follow-up, 96% were considered fused and 75% presented continuous bony bridging confirmed by computed tomography, with segmental ROM below 2°. The technique utilized the CORUS™ Spinal System, which allowed posterior cervical fusion with soft-tissue preservation, achieving outcomes comparable to circumferential fusion but with lower morbidity[1].

Despite these data, no published clinical study had been identified regarding national experience with the application of CAVUX® FFS at the cervical level. Therefore, our study represented the first Brazilian case report involving this technology, contributing to fill this gap.

In this work, we presented three consecutive cases of posterior cervical fusion using the CAVUX® FFS system, describing the technical aspects of implantation, clinical course, operative time, complications, and radiological and pain outcomes. To strengthen the interpretation of our findings, we also performed a systematized narrative review of the literature to guide the discussion and compare our results with previously reported experiences. This review involved a comprehensive search in the main scientific databases — PubMed, Embase, CENTRAL, and LILACS — conducted in a systematic manner, using broad search strategies across all platforms and in-depth exploration within each database to identify the best available evidence on the topic. Through this integrated approach, we aimed to provide initial evidence on the feasibility, safety, and clinical efficacy of this innovation in our setting, thereby supporting its applicability and encouraging further scientific investigation in this field.

CASE PRESENTATION

Case 1

A 44-year-old patient with a history of anterior cervical arthrodesis from C3 to C6 presented with persistent axial cervical pain and bilateral cervicobrachialgia, more pronounced on the left side. The patient had previously undergone posterior fixation with lateral mass screws (C3-C6) and subsequently failed to respond to a six-month course of conservative management, which included thrice-weekly motor physiotherapy sessions without significant improvement.

Advanced imaging studies — magnetic resonance imaging (MRI) and computed tomography (CT) of the cervical spine — revealed foraminal stenosis at C4-C6, confirming persistent segmental instability and foraminal compression. Given the inadequate response to conservative therapy and the anatomical findings, the surgical team opted for a posterior percutaneous implantation of CAVUX® FFS devices at three cervical levels (C4-C6) to achieve facet joint stabilization and promote fusion. Notably, this represented one of the first reported applications of the CAVUX® FFS system in the Northeastern region of Brazil.

The procedure was performed under general anesthesia without inhalational agents, with intraoperative electromyographic (ENMG) neuromonitoring to ensure neural integrity. Two C-arm fluoroscopy units (anteroposterior and lateral) were used simultaneously to enhance intraoperative precision. The total operative time was approximately 1 hour, and estimated blood loss was 50 mL. No intraoperative complications were reported. Postoperatively, the patient was discharged within 12 to 24 hours after the procedure, demonstrating stable neurological status and satisfactory pain control.

Pharmacological management prior to surgery included pregabalin 300 mg/day and methadone 10 mg/day. The intervention resulted in a notable reduction in neuropathic and nociceptive pain, as reflected by the Leeds Assessment of Neuropathic Symptoms and Signs (LANSS) score, which decreased from 21 preoperatively to 13 at 3 months, and the Visual Analog Scale (VAS) score, which decreased from 9 to 5 over the same period.

The postoperative imaging study (Figure 1) demonstrated optimal positioning of the implants, adequate facet joint alignment, and restoration of foraminal patency, confirming the technical success of the procedure.

Case 2

The second case involved a 56-year-old patient with a prior history of combined anterior and posterior cervical arthrodesis from C3 to C6, who continued to experience severe axial neck pain and left-sided cervicobrachialgia despite previous interventions. A six-month program of motor physiotherapy (three sessions per week) failed to produce meaningful improvement.

Preoperative MRI and CT imaging revealed persistent foraminal stenosis at C4-C6, consistent with residual nerve root compression and instability at the previously instrumented levels. Based on these findings and the persistence of symptoms, the patient underwent posterior percutaneous facet fixation using the CAVUX® FFS system at three cervical levels (C4-C6) to restore posterior stability and promote fusion.

As in the previous case, the procedure was carried out under general anesthesia with continuous intraoperative electromyographic monitoring, using dual C-arm fluoroscopy (anteroposterior and lateral views) to guide implant placement. The operative time was approximately one hour, with an estimated blood loss of 50 mL. The postoperative course was uneventful, and the patient was discharged within 24 hours with no neurological deficits.

Preoperative medication included pregabalin 300 mg/day and methadone 10 mg/day. Three months after surgery, the patient reported a reduction in pain intensity, with the VAS score decreasing from 10/10 to 4/10, and the LANSS score improving from 20 to 11.

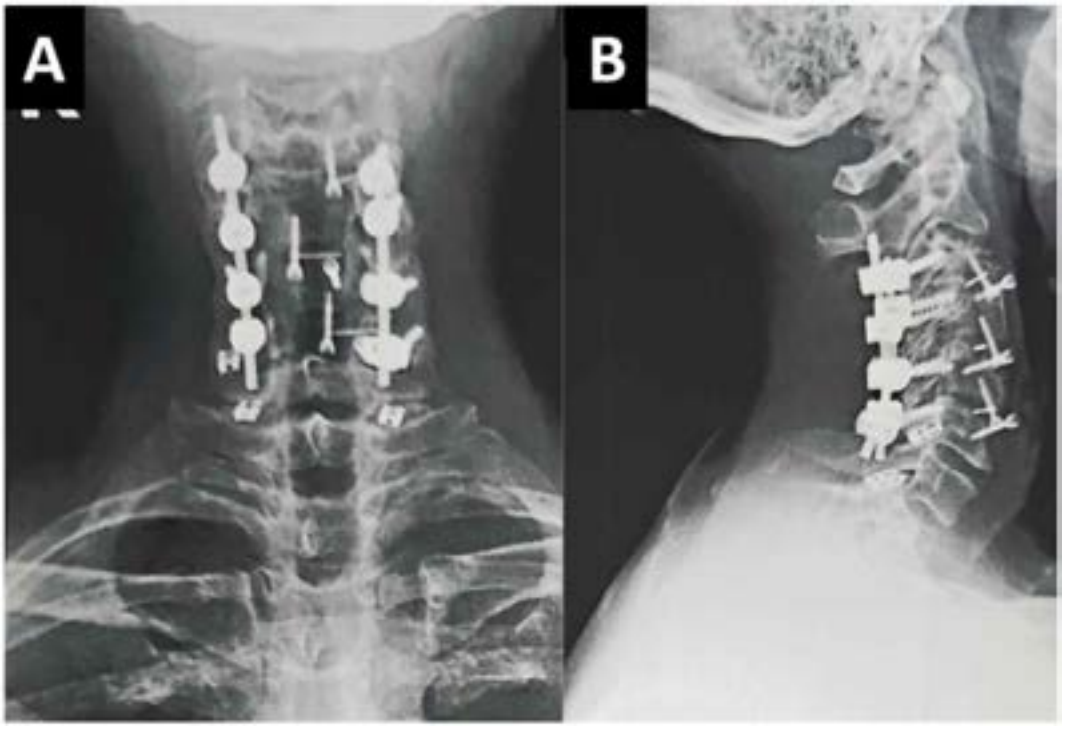

Figure 1. Postoperative Cervical Spine Radiographs (Case 1). **A.** Anteroposterior, and **B**. lateral radiographic views demonstrating adequate positioning of CAVUX® FFS implants at levels C4-C6, with satisfactory facet joint alignment and restoration of foraminal height following posterior percutaneous fixation.

Case 3

The third case involved a patient with a history of anterior cervical arthrodesis from C5 to C7, who continued to experience axial neck pain and bilateral cervicobrachialgia, more pronounced on the left side, despite extensive conservative management. The patient had undergone eight months of motor physiotherapy (three sessions per week) with no clinical improvement.

Preoperative MRI and CT scans revealed foraminal stenosis at levels C4-C7, suggesting persistent compression and instability adjacent to the previously fused segments. Given these findings, the surgical team opted for a posterior percutaneous facet fixation using the CAVUX® FFS system at three cervical levels (C4-C7) to achieve posterior stabilization and promote fusion.

The procedure was performed under general anesthesia without inhalational agents, with continuous intraoperative electromyographic neuromonitoring and the use of dual C-arm fluoroscopy (anteroposterior and lateral projections) to ensure accurate device placement. The operative time was approximately one hour, with an estimated blood loss of 50 mL, and no intraoperative complications. The patient was discharged within 12 to 24 hours postoperatively in stable condition.

Preoperative medications included pregabalin 300 mg/day and methadone 10 mg/day. At the three-month follow-up, the patient demonstrated significant pain reduction, with the LANSS score improving from 19 to 13 and the VAS score decreasing from 9/10 to 4/10.

Postoperative computed tomography confirmed adequate positioning of the CAVUX® implants at C4-C7, with restoration of foraminal height and alignment. The clinical photograph revealed minimal percutaneous scars, highlighting the minimally invasive nature and favorable aesthetic outcome of the procedure (Figure 2).

DISCUSSION

A narrative review was conducted across four major databases—PubMed, Embase, CENTRAL, and LILACS—to identify all available literature addressing the CAVUX® Facet Fixation System (FFS) and related posterior cervical interfacet fusion techniques. The search yielded 8 unique studies: PubMed (8), Embase (8, overlapping), CENTRAL (1, duplicate), and LILACS (0). No

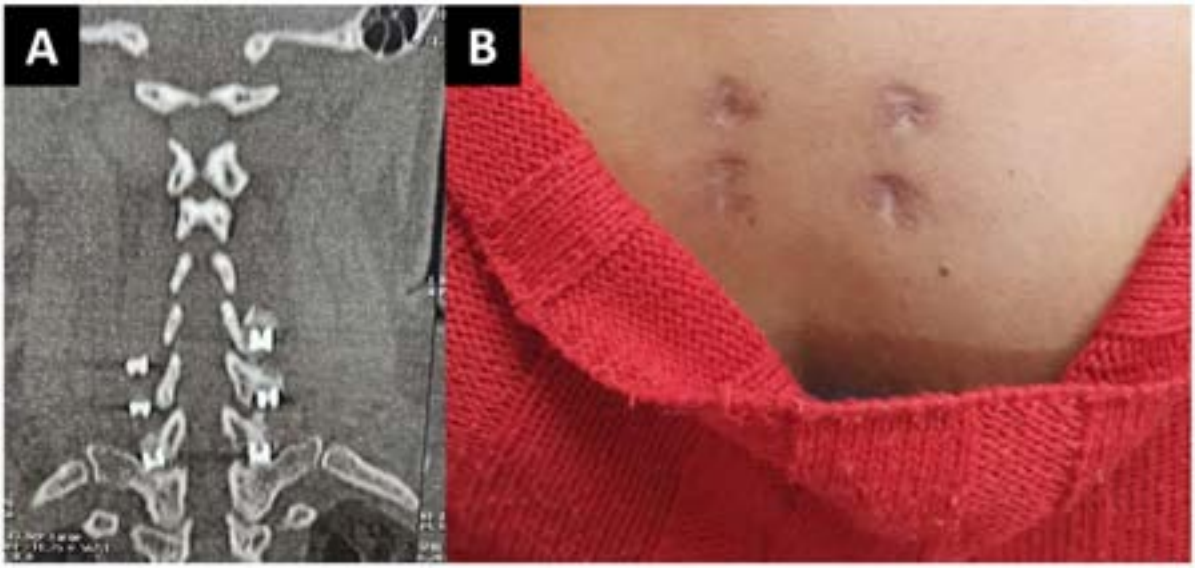

Figure 2. Postoperative Imaging and Clinical Aspect (Case 3). **A.** Postoperative computed tomography demonstrating CAVUX® FFS implants at levels C4-C7, showing appropriate positioning and restoration of foraminal height. **B.** Clinical photograph showing small percutaneous incision scars (C5-C6 and C6-C7), illustrating the minimally invasive character and excellent cosmetic outcome of the posterior CAVUX® fixation procedure.

active clinical trials or unpublished registry data were identified on ClinicalTrials.gov, indicating that this remains a sparsely explored topic in the scientific literature. The limited volume of publications underscores the novelty of posterior interfacet fixation systems such as CAVUX® and the scarcity of regional data, particularly within Latin America.

The most directly relevant evidence derives from Hisey et al.[5], who analyzed 51 patients treated with cervical interfacet devices across 79 levels (C3-C7). The authors reported significant improvements in pain and disability indices, with 76.5% of cases being revisions after anterior cervical discectomy and fusion (ACDF). Despite these challenging demographics, outcomes remained favorable, with a 19.6% reoperation and 7.8% device removal rate, aligning with expectations for revision cervical populations[5]. These findings demonstrate that the CAVUX® system can provide meaningful symptom relief even in previously operated spines.

Complementary evidence from Youssef et al.[6], a systematic review and meta-analysis of posterior cervical fusion procedures (including interfacet techniques), reported a pooled fusion rate of 98.25% and significant improvement in patient-reported outcomes, with an overall 9% complication rate. This synthesis reinforces the concept that posterior fixation—whether by conventional lateral mass screws or interfacet devices—yields high fusion success when appropriately indicated.

Ramos et al.[7] further contributed to the evidence base by examining multilevel percutaneous interfacet distraction and fusion in degenerative radiculopathy. Their cohort of 30 patients achieved 90% fusion at 2 years and durable pain reduction, although adjacent segment degeneration occurred in 13.3%—a known trade-off of increased segmental stiffness. These long-term data confirm that minimally invasive facet fixation can achieve solid arthrodesis with lower muscular disruption compared to traditional open fusion approaches.

Biomechanical and technical reports have also elucidated the mechanical rationale behind CAVUX®. Cofano et al.[8] described how interfacet spacers increase segmental stiffness and enable indirect foraminal decompression by restoring disc height. Rossi and Coric[9] emphasized the tissue-sparing advantages of minimally invasive posterior cervical fusion, positioning facet-based systems as viable alternatives for patients unfit for extended lateral mass or pedicle instrumentation. Aydogan et al.[10] previously demonstrated that facet and lateral mass screw fixation can yield rigid stabilization with high fusion rates when proper technique is applied, establishing the mechanical foundation upon which newer systems like CAVUX® have evolved.

Taken together, the current literature—although limited in number—supports the biological and mechanical feasibility of posterior cervical interfacet fixation. Across studies, fusion rates consistently exceed 90%, pain and disability scores improve significantly, and the complication profile remains acceptable for complex cervical populations[11,12]. Nevertheless, the lack of prospective and randomized data limits definitive comparisons with standard posterior instrumentation. Moreover, published cohorts often include heterogeneous indications, multilevel constructs, and manufacturer-supported designs, which may influence outcome reporting.

In the context of this case series, our findings parallel those of prior literature, demonstrating rapid postoperative pain reduction, minimal blood loss, and short hospital stays following percutaneous posterior fixation with the CAVUX® system. These results highlight the potential role of the technique as a less invasive, revision-friendly solution for cervical stabilization, especially in patients with prior anterior constructs or high surgical risk.

Strengths and limitations

The main strength of this report lies in its pioneering nature, representing the first documented Brazilian experience with the CAVUX® Facet Fixation System. The detailed case descriptions, imaging documentation, and consistent clinical outcomes contribute valuable early evidence on the system's safety and feasibility in real-world neurosurgical practice.

Given its exploratory design, certain inherent limitations apply. The small sample size and absence of a comparative group reflect the study's descriptive purpose rather than a methodological flaw. As the initial national experience, the objective was to document feasibility, technical aspects, and early results, not to establish statistical efficacy or superiority. Future multicenter and prospective studies with longer follow-up are warranted to confirm these preliminary findings and to refine patient selection criteria and long-term outcome evaluation.

CONCLUSION

This report presents the first Brazilian clinical experience with the CAVUX® Facet Fixation System, demonstrating that posterior percutaneous interfacet fixation is a feasible, safe, and minimally invasive alternative for cervical stabilization. Across the three consecutive cases, the procedure was associated with short operative times, minimal blood loss, rapid postoperative recovery, and consistent pain reduction, without neurological complications or implant-related adverse events.

When interpreted alongside the limited but growing international literature, these results reinforce the clinical viability and biomechanical rationale of facet-based posterior fixation as a complement or alternative to traditional lateral mass or pedicle constructs—particularly in revision settings or patients with prior anterior fusion.

Although further research with larger, prospective cohorts is needed to validate these preliminary findings, this early experience expands regional knowledge on minimally invasive posterior cervical fusion and establishes a foundation for the safe and evidence-based adoption of the CAVUX® system in Brazil.

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CORRESPONDING AUTHOR

Vinicius Santos Baptista, MS
Medical student
Universidade Federal de São Paulo – UNIFESP
São Paulo, São Paulo, Brazil
E-mail: vinicius.baptista@unifesp.br

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Reinaldo Rodrigues Pamplona: Conceptualization, Methodology, Supervision, Writing – Original Draft, Review & Editing. Vinicius Santos Baptista: Investigation, Methodology, Project Administration, Validation, Writing – Original Draft, Review & Editing.

Alcohol as a Risk Factor for the Development of Chronic Subdural Hematoma

Álcool como Fator de Risco para o Desenvolvimento de Hematoma Subdural Crônico

Carlos Umberto Pereira[1]
Samuel Pedro Pereira Silveira[2]
Antonio Carlos Silveira Azevedo[3]

ABSTRACT

Introduction: *Abusive alcohol use has been increasing with age and causing serious health problems, including chronic subdural hematoma (CSDH). Alcohol has been considered a modifiable risk factor in the development of CSDH. When submitted to surgical drainage, it presents serious complications and increased morbidity and mortality.* **Case presentation**: *MAS, a 65-year-old male, with a history of systemic arterial hypertension and diabetes mellitus. He had a history of daily alcoholic beverage intake and frequent falls from standing height. Neurological examination revealed somnolence, isocoric and photoreactive pupils, right hemiparesis, and a Glasgow Coma Scale score of 9. Non-contrast cranial computed tomography demonstrated a hypodense frontoparietal lesion on the left. The patient underwent hematoma drainage. There was hematoma recurrence, and the patient developed respiratory complications, ultimately leading to death.* **Conclusion**: *Alcohol has been a risk factor in the development of CSDH by increasing the risk of accidental falls and traumatic brain injury. Due to capillary fragility, cerebral atrophy, and coagulation disorders secondary to hepatic impairment, it predisposes the elderly to the development of this type of hematoma.*

Keywords: *Hematoma, subdural, chronic; Risk factors; Alcoholism; Craniocerebral trauma; Brain diseases; Elderly*

RESUMO

Introdução: *O uso abusivo de álcool tem aumentado com a idade e provocado sérios problemas de saúde, dentre eles o hematoma subdural crônico (HSDC). O álcool tem sido considerado um fator de risco modificável no desenvolvimento do HSDC. Quando submetido à drenagem cirúrgica, apresenta sérias complicações e aumento na morbidade e mortalidade.* **Relato do caso**: *MAS, 65 anos de idade, sexo masculino, portador de hipertensão arterial sistêmica e diabetes mellitus. Apresentava história de ingestão diária de bebida alcoólica e quedas frequentes da própria altura. O exame neurológico revelou sonolência, pupilas isocóricas e fotorreagentes, hemiparesia direita e escore de 9 na Escala de Coma de Glasgow. A tomografia computadorizada de crânio sem contraste demonstrou lesão hipodensa frontoparietal à esquerda, compatível com HSDC. O paciente foi submetido à drenagem cirúrgica do hematoma. No pós-operatório, houve recidiva do hematoma, seguida de complicações respiratórias, evoluindo a óbito.* **Conclusão**: *O álcool constitui fator de risco no desenvolvimento do HSDC ao aumentar o risco de quedas acidentais e traumatismo cranioencefálico. Devido à fragilidade capilar, à atrofia cerebral e aos distúrbios de coagulação secundários ao comprometimento hepático, predispõe o idoso ao desenvolvimento deste tipo de hematoma. A melhor compreensão de sua patogênese, a identificação dos fatores de risco, os avanços no diagnóstico por imagem e no tratamento têm contribuído significativamente para a melhora do prognóstico desta condição.*

Palavras-Chave: *Hematoma subdural crônico; Fatores de risco; Alcoolismo; Traumatismo cranioencefálico; Doenças encefálicas; Idoso*

[1]Department of Neurosurgery, Universidade Federal de Sergipe – UFS, Aracaju, SE, Brazil.
[2]Faculty of Medicine, Universidade Federal do Triângulo Mineiro – UFTM, Uberaba, MG, Brazil.
[3]Neurosurgery Service Hospital de Urgências João Alves Filho, Aracaju, SE, Brazil.

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INTRODUCTION

Abusive alcohol use is considered a major public health problem, particularly in the elderly age group, causing high morbidity and mortality. Its use is associated with biopsychosocial, cultural, and spiritual factors. Alcohol has widespread effects across all age groups, altering physiology and neuropsychological functions, and is considered a risk factor for chronic subdural hematoma (CSDH)[1,2]. Rate of mortality and morbidity in alcoholic individuals increase with advanced age, cerebral atrophy, coagulopathies, and CSDH[3,4].

The following have been reported in the literature as risk factors for CSDH: advanced age, male sex, epilepsy, intracranial hypotension, hemodialysis, chronic or abusive alcohol consumption, falls, mild traumatic brain injury (TBI), surgical interventions (internal intracranial shunting, lumbar puncture, spinal anesthesia, spinal surgery with dural laceration and cerebrospinal fluid fistula), use of anticoagulants, and antiplatelet agents[4-8]. Alcoholism causes cerebral atrophy, which becomes an independent risk factor for the development of CSDH[9]. Abusive alcohol use is related to CSDH due to the patient becoming more prone to falls, cerebral atrophy related to prolonged alcohol use, and coagulopathies resulting from hepatic damage[7,10-12]. High rates of trauma, cerebral atrophy, and coagulopathies due to hepatic alterations are the probable causes of the high incidence of alcoholism associated with CSDH[2,7,10,13].

The authors present a review of the literature on the association between abusive alcohol use and CSDH, discussing epidemiology, clinical presentation, imaging findings, treatment, and prognosis.

METHODS

This study comprises two components: a case report and a narrative literature review.

Case report

An illustrative clinical case of a patient with CSDH associated with chronic alcoholism was documented from medical records at the institution. The following data were collected: demographic characteristics (age, sex), comorbidities, alcohol consumption history, clinical presentation, neurological examination findings (Glasgow Coma Scale score, motor deficits, pupillary reactivity), neuroimaging findings (non-contrast cranial computed tomography), surgical treatment performed, postoperative course, complications, and clinical outcome.

Literature review

A systematic search of the literature was conducted using the PubMed/MEDLINE, LILACS, and SciELO databases, covering publications from 1970 to 2024. The following MeSH descriptors and Boolean operators were used: "Hematoma, Subdural, Chronic" AND "Alcoholism" OR "Alcohol Drinking" OR "Alcohol-Related Disorders" AND "Risk Factors". Reference lists of selected articles were also reviewed for additional relevant citations. Inclusion criteria were: original articles, case reports, case series, systematic reviews, and meta-analyses addressing the association between alcohol use and CSDH in adult patients. No language restrictions were applied. Exclusion criteria were: studies focusing exclusively on pediatric populations, acute subdural hematoma without chronic components, or studies not reporting alcohol as a specific variable. Data extraction was performed by two independent reviewers, with disagreements resolved by consensus with a third author.

Objective

To determine the prevalence and clinical relevance of CSDH in alcoholic patients, and to characterize the pathophysiological mechanisms, epidemiology, clinical features, imaging findings, treatment options, and prognosis associated with this combination.

CASE PRESENTATION

MAS, a 65-year-old male, with a medical history of systemic arterial hypertension and diabetes mellitus. He reported a history of daily alcoholic beverage intake and frequent falls from standing height. Neurological examination on admission revealed somnolence, isocoric and photoreactive pupils, and right hemiparesis, with a Glasgow Coma Scale (GCS) score of 9. Non-contrast cranial computed tomography demonstrated a hypodense frontoparietal lesion on the left, consistent with CSDH. The patient underwent surgical drainage of the hematoma. In the postoperative period, hematoma recurrence was documented. The patient subsequently developed respiratory complications and died.

DISCUSSION

Risk factors commonly associated with the etiopathogenesis of CSDH include: alcoholism, advanced age, arachnoid cysts, coagulopathy, and anticoagulant therapy[6]. According to Bacigaluppi et al.[14], the most frequent comorbidities are systemic arterial hypertension and diabetes mellitus. Several studies have associated alcohol use with CSDH[2,11,15]. CSDH is generally related to traumatic injury, with a history of TBI or fall from standing height being the most common mechanism. However, alcohol-related problems are frequently underestimated, and alcohol consumption among the elderly is increasingly prevalent. Alcohol is a modifiable risk factor in the formation of CSDH[1,16,17].

Abusive alcohol consumption accelerates cerebral atrophy, which itself is an independent risk factor in the formation of CSDH and is a normal finding in the elderly population[18,19]. Chronic alcoholism predisposes to increased intraoperative bleeding due to an imbalanced coagulation profile. It also promotes cerebral atrophy, which causes shearing of bridging veins that may rupture spontaneously or following mild TBI, leading to the formation of CSDH[16]. Cerebral atrophy also creates a potential space for CSDH formation, causing minimal or no compressive symptoms until late-stage disease, accounting for a large number of cases with delayed presentation.

The literature demonstrates that the association between alcohol and CSDH varies between 8.7% and 62%[1,9,11,15,20-22]. Chen et al.[9] reported CSDH due to falls, with 16% attributed to alcohol use. Yogi et al.[20], in a series of 160 patients, found that 18% regularly consumed alcohol. Whaley et al.[20] reported alcohol intoxication at the time of injury in 45% of patients treated for TBI. Martinez Palomino et al.[1], in 218 patients, found that 19 (8.7%) had CSDH resulting from abusive alcohol use. Mirand et al.[21], in a community-based study of persons aged 60 to 94 years, found that 62% were frequent drinkers (13% male, 2% female). Fogelholm and Waltimo[22] identified a history of alcoholism in half of their cases. Won et al.[2] found that alcoholism was the most prevalent disease in their study of CSDH in young adults, a finding also observed by other authors[11,23]. The condition is more common in males[2,5,11,15,23]. CSDH in adults demonstrates a higher prevalence of chronic alcoholism and bleeding tendency compared to patients over 65 years of age[5,11,23]. A prospective study in healthy adults aged 16 to 60 years who had fallen from standing height revealed a high incidence of TBI in those who had consumed alcohol[24].

According to Iyer et al.[25], alcohol is a central nervous system (CNS) depressant. As a result, neurons within the brain process nerve impulses more slowly. Falls or mild TBI can cause CSDH, which begins as a benign acute hemorrhage and evolves into CSDH. Alcohol has been identified as a factor predisposing to cerebral hemorrhage due to the elevated risk of TBI[25]. Thus, falls or mild TBI can lead to CSDH, which initiates as a benign acute hemorrhage; therefore, chronic alcoholism is highly predisposed to this type of neurological complication[26]. Chronic alcohol consumption is associated with reduced cerebral volume; when combined with a history of mild TBI, it promotes the formation of CSDH[27].

Kostic et al.[7] reported alcoholism as a risk factor for spontaneous CSDH in the elderly. One of the factors responsible for the high incidence of bleeding in elderly individuals is alcohol abuse, which leads to elevated vascular fragility, especially in the bridging veins located in the subdural space. In chronic alcoholism, these veins become stretched due to cerebral atrophy, and application of minimal force leads to their rupture and consequently to CSDH formation[3,28]. Since most patients with CSDH and abusive alcohol use are elderly and frequently have chronic comorbidities, they are more prone to delayed rehabilitation and more postoperative complications[27].

The subdural space is located between the dura mater and the arachnoid membrane. A layer of border cells exists in this space, with bridging veins that traverse the cells and the subdural space. In patients with cerebral atrophy, such as the elderly or those with abusive alcohol use, the arachnoid layer separates further from the dura mater as brain volume decreases, and the traversing veins become increasingly stretched, making them more susceptible to rupture, even in cases of mild TBI.

Clinical presentation

The clinical manifestations are multiple and complex, potentially mimicking other pathological processes[12,22,29]. They are dependent on the patient's clinical condition, age, size and location of the hematoma, rate of hematoma growth, and whether it is unilateral or bilateral[29]. Symptoms of CSDH are heterogeneous, with the majority presenting as hemiparesis, headache, and cognitive deterioration. Focal neurological deficits have been emphasized in the literature, with an incidence of 58%, hemiparesis being the most common[12].

Nocturnal and progressive, lateralized headache that does not improve with simple analgesics has been reported in 14% to 80% of cases, being more common in young adult patients than in elderly patients[12,22]. In the elderly, cognitive disorders are frequent[10], which may lead to delayed diagnosis by mimicking other conditions such as dementia and Alzheimer's disease[30].

As hematoma growth and progression continue, intracranial hypertension and cerebral compression result in a variety of clinical manifestations, which may resolve after hematoma drainage or recur with re-bleeding, including headache, nausea or vomiting, motor or sensory deficits, gait disturbance, and coma[31].

Imaging

Several authors[6,32] indicate that CT is the preferred cost-effective method in clinical practice and can identify the size, thickness, midline shift, or subdural clots. MRI can determine the internal anatomy and hematoma size. CT provides rapid imaging at low cost[16]. It demonstrates a concavo-convex hypodense lesion located over the fronto-parietal convexity, which is the most common location for CSDH. MRI is useful in the diagnosis of bilateral isodense CSDH and for the detection of multiple loculations, neomembranes, fresh blood, and membrane thickness.

Treatment

Conservative treatment has been performed using corticosteroids, atorvastatin, mannitol, tranexamic acid, and ACE inhibitors[33]. Most of these agents act on the inflammatory process and angiogenic reaction involved in hematoma formation. Conservative treatment is indicated, when necessary, in patients who refuse surgery or present a high surgical risk.

CSDH is generally treated surgically. Early intervention is indicated to confirm the presence of the hematoma, prevent irreversible brain injury and death due to hematoma expansion, elevated intracranial pressure (ICP), and cerebral herniation. In symptomatic patients with a diagnosis of CSDH and apparent cerebral compression, surgical drainage through burr hole, twist drill, or craniotomy remains the primary treatment objective, whereas asymptomatic CSDH without cerebral compression is frequently managed conservatively with neurological surveillance, symptomatic care including ICP control, anticoagulant management, and serial imaging. Burr hole with irrigation and a closed subdural drainage system is the most commonly used surgical technique[4,17], with craniotomy reserved for extensive hematomas, producing rapid clinical results and functional improvement in over 80% of patients.

Complications

Among the postoperative complications of CSDH in patients with chronic alcoholism, hematoma recurrence is the most prominent. It is a frequent postoperative complication, occurring in 3% to 34% of operated cases[34]. Predisposing factors for recurrence include: male sex, advanced age, systemic arterial hypertension, alcohol consumption, diabetes mellitus, hepatic cirrhosis, renal insufficiency, and coagulopathy[35]. Excessive alcohol use is considered in the literature as a significant factor contributing to high postoperative complication rates in CSDH[30,36].

Alcohol abuse is well recognized as a factor contributing to postoperative complications in CSDH, including infection, postoperative bleeding due to prolonged bleeding time caused by hepatic dysfunction, and pulmonary complications[37]. The reason patients who abuse alcohol suffer more complications may be related to prolonged bleeding time in the postoperative period[38]. Chen et al.[39] found that patients with hepatic cirrhosis and CSDH are significantly more likely to present serious comorbidities and higher mortality rates. Roka et al.[5] found no correlation between alcohol use and final outcome.

According to Oh et al.[40], it is difficult to find studies that demonstrate a significant association between alcoholism and CSDH recurrence. Yogi et al.[15] found a strong significant association between hematoma recurrence during intraoperative brain re-expansion and alcohol use as a positive predictive effect for greater hematoma recurrence. Platelet deficiency and coagulation factor deficiency are the accepted rationale for inducing a hypercoagulable state in persons with chronic alcoholism and alcoholic hepatopathy, thereby predisposing to CSDH development following mild TBI[41,42].

CONCLUSION

CSDH is common in elderly patients. Alcohol as a risk factor in its development results from an increased risk of accidental falls, venous fragility, increased subdural space secondary to cerebral atrophy, and coagulation dysfunction, leading to the formation of chronic subdural hematoma. A better understanding of its pathogenesis, the identification of risk factors, advances in imaging diagnosis, and improvements in treatment have greatly improved the prognosis of this condition.

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CORRESPONDING AUTHOR

Carlos Umberto Pereira, MD, PhD
Retired Professor
Universidade Federal de Sergipe – UFS
Department of Neurosurgery
Aracaju, Sergipe, Brazil
E-mail: umberto@infonet.com.br

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