Patrones hemodinámicos valorados por Doppler transcraneal en pacientes neurocríticos relacionados a mortalidad temprana en una unidad de cuidados intensivos de la ciudad de Barranquilla, (Colombia) año 2023 - 2024

Nombres y apellidos

German Eduardo Guerrero Bacca
Código estudiantil: 2021214435702

Jaime David Cure Ruz
Código estudiantil: 2017114081500

Trabajo de Investigación presentado como requisito para optar el título de:
Especialista en Medicina Crítica y Cuidados Intensivos

Tutores:

RICARDO LUIS ROMERO FIGUEROA
MD | Intensivista | Asesor científico

ABUL ENRIQUE ARIZA ALGARIN
MD | Intensivista | Asesor de contenido

DEISSY NORIEGA ANGUILA
MD | Epidemiología | Asesor metodológico

RESUMEN

Introducción: La monitorización por imágenes es una práctica utilizada en pacientes neurocríticos. La ultrasonografía Doppler transcraneal permite obtener información de la circulación cerebral para la toma de decisiones clínicas oportunas.
Objetivos: Analizar los patrones hemodinámicos valorados por ultrasonografía Doppler transcraneal y mortalidad temprana en pacientes neurocríticos, Barranquilla (Colombia) en el año 2023 - 2024.
Materiales y métodos: Análisis descriptivo, prospectivo de pacientes neurocríticos entre 16 y 80 años ingresaron a la unidad de cuidados intensivos de la Clínica General del Norte del año 2023 al 2024. Se analizaron los patrones hemodinámicos del Doppler transcraneal y su asociación con los desenlaces clínicos a los 30 días (supervivencia vs. mortalidad) a través de modelo de regresión logística binaria calculando valor de probabilidades.
Resultados: En el presente estudio se incluyeron 116 sujetos, con una edad media de aproximadamente 59 años (±18 años). La mortalidad global fue del 19.8% (n=23). En los patrones evaluados del Doppler transcraneal el hallazgo de hipertensión endocraneana mostraron la mayor proporción de desenlaces fatales (46,7%), y un patrón de flujo normal se relacionó con un marcador de supervivencia. Condiciones clínicas (trastornos hipertensivos del embarazo, trauma craneoencefálico y entre otros) no se relacionaron con los patrones de Doppler transcraneal.
Conclusiones: En el presente estudio se evidenció que los patrones hemodinámicos cerebrales identificados mediante Doppler transcraneal al ingreso se relacionan de manera relevante con la evolución clínica de los pacientes neurocríticos. En particular, los patrones de alteración del flujo cerebral mostraron asociación con una mayor mortalidad temprana, destacando el potencial valor pronóstico de esta herramienta no invasiva en pacientes con injuria cerebral.

Palabras clave: Injuria cerebral; Críticamente enfermos; Doppler transcraneal; Muerte; Supervivencia.

ABSTRACT

Introduction: Imaging monitoring is a practice used in neurocritical patients. Transcranial Doppler ultrasound provides information on cerebral circulation for timely clinical decision-making.

Objectives: To analyze the hemodynamic patterns assessed by transcranial Doppler ultrasound and early mortality in neurocritical patients, Barranquilla (Colombia) in 2023-2024.

Materials and methods: Descriptive, prospective analysis of neurocritical patients between 16 and 80 years old admitted to the intensive care unit of the Clínica General del Norte from 2023 to 2024. The hemodynamic patterns of transcranial Doppler and their association with clinical outcomes at 30 days (survival vs. mortality) were analyzed through a binary logistic regression model calculating probability values.

Results: The present study included 116 subjects, with a mean age of approximately 59 years (±18 years). Overall mortality was 19.8% (n=23). Among the transcranial Doppler patterns evaluated, the finding of intracranial hypertension showed the highest proportion of fatal outcomes (46.7%), and a normal flow pattern was associated with a survival marker. Clinical conditions (hypertensive disorders of pregnancy, head trauma, among others) were not associated with transcranial Doppler patterns.

Conclusions: The present study shows that cerebral hemodynamic patterns identified by transcranial Doppler on admission are significantly associated with the clinical outcome of neurocritical patients. In particular, patterns of cerebral flow disturbances are associated with higher early mortality, highlighting the potential prognostic value of this noninvasive tool in patients with brain injury.

Keywords: Brain injury; Critically ill; Transcranial Doppler; Death; Survival.

REFERENCIAS BIBLIOGRÁFICAS

1. Bellner J, Romner B, Reinstrup P, Kristiansson K-A, Ryding E, Brandt L. Transcranial Doppler sonography pulsatility index (PI) reflects intracranial pressure (ICP). Surg Neurol [Internet]. 2004 Jul;62(1):45–51. Available from: https://doi.org/10.1016/j.surneu.2003.12.007
2. Chan K-H, Miller JD, Dearden NM, Andrews PJD, Midgley S. The effect of changes in cerebral perfusion pressure upon middle cerebral artery blood flow velocity and jugular bulb venous oxygen saturation after severe brain injury. J Neurosurg [Internet]. 1992 Jul;77(1):55–61. Available from: https://doi.org/10.3171/jns.1992.77.1.0055
3. Czosnyka M, Matta BF, Smielewski P, Kirkpatrick PJ, Pickard JD. Cerebral perfusion pressure in head-injured patients: a noninvasive assessment using transcranial Doppler ultrasonography. J Neurosurg [Internet]. 1998 May;88(5):802–8. Available from: https://doi.org/10.3171/jns.1998.88.5.0802
4. Compton JS, Redmond S, Symon L. Cerebral blood velocity in subarachnoid haemorrhage: a transcranial Doppler study. J Neurol Neurosurg Psychiatry [Internet]. 1987 Nov 1;50(11):1499–503. Available from: https://doi.org/10.1136/jnnp.50.11.1499
5. Gosling RG, King DH. The Role of Measurement in Peripheral Vascular Surgery. Proc R Soc Med [Internet]. 1974 Jun;67(6P1):447–9. Available from: https://doi.org/10.1177/00359157740676p113
6. Homburg A-M, Jakobsen M, Enevoldsen E. Transcranial doppler recordings in raised intracranial pressure. Acta Neurol Scand [Internet]. 2009 Jan 29;87(6):488–93. Available from: https://doi.org/10.1111/j.1600-0404.1993.tb04142.x
7. Aaslid R. Transcranial Doppler assessment of cerebral vasospasm. Eur J Ultrasound [Internet]. 2002 Nov;16(1–2):3–10. Available from: https://doi.org/10.1016/S0929-8266(02)00045-9
8. BERGUER R, HWANG NHC. Critical Arterial Stenosis. Ann Surg [Internet]. 1974 Jul;180(1):39–50. Available from: https://doi.org/10.1097/00000658-197407000-00007
9. Ekelund A, Sä Veland H, Romner B, Brandt L. Is transcranial Doppler sonography useful in detecting late cerebral ischaemia after aneurysmal subarachnoid haemorrhage? Br J Neurosurg [Internet]. 1996 Jan 23;10(1):19–25. Available from: https://doi.org/10.1080/bjn.10.1.19
10. Giller CA, Hatab MR, Giller AM. Estimation of Vessel Flow and Diameter during Cerebral Vasospasm Using Transcranial Doppler Indices. Neurosurgery [Internet]. 1998 May 1;42(5):1076–81. Available from: https://doi.org/10.1097/00006123-199805000-00077
11. Aaslid R, Markwalder T-M, Nornes H. Noninvasive transcranial Doppler ultrasound recording of flow velocity in basal cerebral arteries. J Neurosurg [Internet]. 1982 Dec;57(6):769–74. Available from: https://doi.org/10.3171/jns.1982.57.6.0769
12. Kirkham FJ, Padayachee TS, Parsons S, Seargeant LS, House FR, Gosling

RG. Transcranial measurement of blood velocities in the basal cerebral arteries using pulsed Doppler ultrasound: Velocity as an index of flow. Ultrasound Med Biol [Internet]. 1986 Jan;12(1):15–21. Available from: https://doi.org/10.1016/0301-5629(86)90139-0

13. Hurst RW, Schnee C, Raps EC, Farber R, Flamm ES. Role of transcranial Doppler in neuroradiological treatment of intracranial vasospasm. Stroke [Internet]. 1993 Feb;24(2):299–303. Available from: https://doi.org/10.1161/01.str.24.2.299
14. Grosset DG, Straiton J, du Trevou M, Bullock R. Prediction of symptomatic vasospasm after subarachnoid hemorrhage by rapidly increasing transcranial Doppler velocity and cerebral blood flow changes. Stroke [Internet]. 1992 May;23(5):674–9. Available from: https://doi.org/10.1161/01.str.23.5.674
15. Shrestha GS, Nepal G, Brasil S. Low-Cost Strategies for the Development of Neurocritical Care in Resource-Limited Settings. Neurocrit Care [Internet]. 2025 Jan 28; Available from: https://doi.org/10.1007/s12028-025-02215-2
16. D'Andrea A, Fabiani D, Cante L, Caputo A, Sabatella F, Riegler L, et al. Transcranial Doppler ultrasound: Clinical applications from neurological to cardiological setting. J Clin Ultrasound [Internet]. 2022 Oct 11;50(8):1212–23. Available from: https://doi.org/10.1002/jcu.23344
17. Tsivgoulis G, Alexandrov A V. Ultrasound in Neurology. Contin Lifelong Learn Neurol [Internet]. 2016 Oct;22(5):1655–77. Available from: https://doi.org/10.1212/con.0000000000000374
18. Prust ML, Mbonde A, Rubinos C, Shrestha GS, Komolafe M, Saylor D, et al. Providing Neurocritical Care in Resource-Limited Settings: Challenges and Opportunities. Neurocrit Care [Internet]. 2022 Oct 16;37(2):583–92. Available from: https://doi.org/10.1007/s12028-022-01568-2
19. Sharma S, Lubrica RJ, Song M, Vandse R, Boling W, Pillai P. The Role of Transcranial Doppler in Cerebral Vasospasm: A Literature Review. In 2020. p. 201–5. Available from: https://doi.org/10.1007/978-3-030-04615-6_32
20. Sharma VK, Tsivgoulis G, Lao AY, Malkoff MD, Alexandrov A V. Noninvasive Detection of Diffuse Intracranial Disease. Stroke [Internet]. 2007 Dec;38(12):3175–81. Available from: https://doi.org/10.1161/strokeaha.107.490755
21. Sarkar S, Ghosh S, Ghosh SK, Collier A. Role of transcranial Doppler ultrasonography in stroke. Postgrad Med J [Internet]. 2007 Nov 1;83(985):683–9. Available from: https://doi.org/10.1136/pgmj.2007.058602
22. Ley-Pozo J, Bernd Ringelstein E. Noninvasive detection of occlusive disease of the carotid siphon and middle cerebral artery. Ann Neurol [Internet]. 1990 Nov 8;28(5):640–7. Available from: https://doi.org/10.1002/ana.410280507
23. Schneider PA, Rossman ME, Torem S, Otis SM, Dilley RB, Bernstein EF. Transcranial Doppler in the management of extracranial cerebrovascular disease: Implications in diagnosis and monitoring. J Vasc Surg [Internet]. 1988 Feb;7(2):avs0070223. Available from: https://doi.org/10.1067/mva.1988.avs0070223
24. Lazaridis C, Robertson CS. The Role of Multimodal Invasive Monitoring in

Acute Traumatic Brain Injury. Neurosurg Clin N Am [Internet]. 2016 Oct;27(4):509–17. Available from: https://doi.org/10.1016/j.nec.2016.05.010

25. Kirkman MA, Smith M. Multimodality Neuromonitoring. Anesthesiol Clin [Internet]. 2016 Sep;34(3):511–23. Available from: https://doi.org/10.1016/j.anclin.2016.04.005
26. Forsyth RJ, Raper J, Todhunter E. Routine intracranial pressure monitoring in acute coma. Cochrane Database Syst Rev [Internet]. 2015 Nov 2;2016(2). Available from: https://doi.org/10.1002/14651858.cd002043.pub3
27. Walter U. Transcranial sonography of the cerebral parenchyma: Update on clinically relevant applications. Perspect Med [Internet]. 2012 Sep;1(1–12):334–43. Available from: https://doi.org/10.1016/j.permed.2012.02.014
28. Bartels E. Transcranial color-coded duplex ultrasonography in routine cerebrovascular diagnostics. Perspect Med [Internet]. 2012 Sep;1(1–12):325–30. Available from: https://doi.org/10.1016/j.permed.2012.06.001
29. Rasulo FA, De Peri E, Lavinio A. Transcranial Doppler ultrasonography in intensive care. Eur J Anaesthesiol [Internet]. 2008 Feb;25:167–73. Available from: https://doi.org/10.1017/s0265021507003341
30. Lindegaard K-F, Bakke SJ, Grolimund P, Aaslid R, Huber P, Nornes H. Assessment of intracranial hemodynamics in carotid artery disease by transcranial Doppler ultrasound. J Neurosurg [Internet]. 1985 Dec;63(6):890–8. Available from: https://doi.org/10.3171/jns.1985.63.6.0890
31. Schwarze JJ, Sander D, Kukla C, Wittich I, Babikian VL, Klingelhöfer J. Methodological Parameters Influence the Detection of Right-to-Left Shunts by Contrast Transcranial Doppler Ultrasonography. Stroke [Internet]. 1999 Jun;30(6):1234–9. Available from: https://doi.org/10.1161/01.str.30.6.1234
32. Forteza AM, Babikian VL, Hyde C, Winter M, Pochay V. Effect of Time and Cerebrovascular Symptoms on the Prevalence of Microembolic Signals in Patients With Cervical Carotid Stenosis. Stroke [Internet]. 1996 Apr;27(4):687–90. Available from: https://doi.org/10.1161/01.str.27.4.687
33. Abadal JM, Llompart-Pou JA, Homar J, Pérez-Bárcena J, Ibáñez J. Aplicaciones del dúplex transcraneal codificado en color en la monitorización del enfermo neurocrítico. Med Intensiva [Internet]. 2007 Dec;31(9):510–7. Available from: https://doi.org/10.1016/s0210-5691(07)74858-1
34. Harders AG, Gilsbach JM. Time course of blood velocity changes related to vasospasm in the circle of Willis measured by transcranial Doppler ultrasound. J Neurosurg [Internet]. 1987 May;66(5):718–28. Available from: https://doi.org/10.3171/jns.1987.66.5.0718
35. Seidel, G, Gerriets T, Kaps, M, Missler, U. Dislocation of the Third Ventricle Due to Space-Occupying Stroke Evaluated by Transcranial Duplex Sonography. J Neuroimaging [Internet]. 1996 Oct;6(4):227–30. Available from: https://doi.org/10.1111/jon199664227
36. Proust F, Callonec F, Clavier E, Lestrat JP, Hannequin D, Thiébot J, et al. Usefulness of Transcranial Color-Coded Sonography in the Diagnosis of Cerebral Vasospasm. Stroke [Internet]. 1999 May;30(5):1091–8. Available from: https://doi.org/10.1161/01.str.30.5.1091

37. Kaspera W, Majchrzak H, Ładziński P, Tomalski W. Color Doppler Sonographic Evaluation of Collateral Circulation in Patients with Cerebral Aneurysms and the Occlusion of the Brachiocephalic Vessels. Neurosurgery [Internet]. 2005 Dec 1;57(6):1117–26. Available from: https://doi.org/10.1227/01.neu.0000186009.62401.3c
38. Bazzocchi M, Quaia E, Zuiani C, Moroldo M. Transcranial Doppler: state of the art. Eur J Radiol [Internet]. 1998 May;27:S141–8. Available from: https://doi.org/10.1016/s0720-048x(98)00055-2
39. Diringer MN, Edwards DF. Admission to a neurologic/neurosurgical intensive care unit is associated with reduced mortality rate after intracerebral hemorrhage. Crit Care Med [Internet]. 2001 Mar;29(3):635–40. Available from: https://doi.org/10.1097/00003246-200103000-00031
40. Mayer SA, Kossoff SB. Withdrawal of life support in the neurological intensive care unit. Neurology [Internet]. 1999 May;52(8):1602–1602. Available from: https://doi.org/10.1212/wnl.52.8.1602
41. Fakhry SM, Trask AL, Waller MA, Watts DD. Management of Brain-Injured Patients by an Evidence-Based Medicine Protocol Improves Outcomes and Decreases Hospital Charges. J Trauma Inj Infect Crit Care [Internet]. 2004 Mar;56(3):492–500. Available from: https://doi.org/10.1097/01.ta.0000115650.07193.66
42. Zapa Pérez NM, Martínez Lemus JD, Torres Ramírez A, Jiménez Monsalve CA. Costos médicos directos de los pacientes con ataque cerebrovascular isquémico en un hospital público de Bogotá, Colombia. Acta Neurológica Colomb [Internet]. 2024 Jan 23;40(1). Available from: https://doi.org/10.22379/anc.v40i1.873
43. Rincon F, Mayer SA. Neurocritical care: a distinct discipline? Curr Opin Crit Care [Internet]. 2007 Apr;13(2):115–21. Available from: https://doi.org/10.1097/mcc.0b013e32808255c6
44. Diringer MN, Bleck TP, Claude Hemphill J, Menon D, Shutter L, Vespa P, et al. Critical Care Management of Patients Following Aneurysmal Subarachnoid Hemorrhage: Recommendations from the Neurocritical Care Society's Multidisciplinary Consensus Conference. Neurocrit Care [Internet]. 2011 Oct 20;15(2):211. Available from: https://doi.org/10.1007/s12028-011-9605-9
45. Raj R, Bendel S, Reinikainen M, Hoppu S, Laitio R, Ala-Kokko T, et al. Costs, outcome and cost-effectiveness of neurocritical care: a multi-center observational study. Crit Care [Internet]. 2018 Dec 20;22(1):225. Available from: https://doi.org/10.1186/s13054-018-2151-5
46. Kaplan ZLR, van der Vlegel M, van Dijck JTJM, Pisică D, van Leeuwen N, Lingsma HF, et al. Intramural Healthcare Consumption and Costs After Traumatic Brain Injury: A Collaborative European NeuroTrauma Effectiveness Research in Traumatic Brain Injury (CENTER-TBI) Study. J Neurotrauma [Internet]. 2023 Oct 1;40(19–20):2126–45. Available from: https://doi.org/10.1089/neu.2022.0429
47. Organised inpatient (stroke unit) care for stroke. Cochrane Database Syst Rev [Internet]. 2013 Sep 11; Available from:

https://doi.org/10.1002/14651858.cd000197.pub3
48. Véliz E, Fica A. Costo de las neumonías asociadas a la ventilación mecánica en pacientes adultos en un hospital general en Chile. Rev Chil infectología [Internet]. 2017 Oct;34(5):447–52. Available from: http://dx.doi.org/10.4067/S0716-10182017000500447
49. Kumar G, Shahripour RB, Harrigan MR. Vasospasm on transcranial Doppler is predictive of delayed cerebral ischemia in aneurysmal subarachnoid hemorrhage: a systematic review and meta-analysis. J Neurosurg [Internet]. 2016 May;124(5):1257–64. Available from: https://doi.org/10.3171/2015.4.jns15428
50. Panerai RB. Transcranial Doppler for evaluation of cerebral autoregulation. Clin Auton Res [Internet]. 2009 Aug 16;19(4):197–211. Available from: https://doi.org/10.1007/s10286-009-0011-8
51. Carey BJ, Panerai RB, Potter JF. Effect of Aging on Dynamic Cerebral Autoregulation During Head-Up Tilt. Stroke [Internet]. 2003 Aug;34(8):1871–5. Available from: https://doi.org/10.1161/01.str.0000081981.99908.f3
52. Robba C, Cardim D, Sekhon M, Budohoski K, Czosnyka M. Transcranial Doppler: a stethoscope for the brain-neurocritical care use. J Neurosci Res [Internet]. 2018 Apr 7;96(4):720–30. Available from: https://doi.org/10.1002/jnr.24148
53. Kalanuria A, Nyquist PA, Armonda RA, Razumovsky A. Use of Transcranial Doppler (TCD) Ultrasound in the Neurocritical Care Unit. Neurosurg Clin N Am [Internet]. 2013 Jul;24(3):441–56. Available from: https://doi.org/10.1016/j.nec.2013.02.005
54. World Health Organization. Neurological Disorders: Public Health Challenges [Internet]. World Health Organization. 2006 [cited 2025 May 21]. Available from: https://www.who.int/publications/i/item/9789241563369
55. Stocchetti N, Colombo A, Ortolano F, Videtta W, Marchesi R, Longhi L, et al. Time Course of Intracranial Hypertension after Traumatic Brain Injury. J Neurotrauma [Internet]. 2007 Aug;24(8):1339–46. Available from: https://doi.org/10.1089/neu.2007.0300
56. Zanier ER, Ortolano F, Ghisoni L, Colombo A, Losappio S, Stocchetti N. Intracranial pressure monitoring in intensive care: clinical advantages of a computerized system over manual recording. Crit Care [Internet]. 2007 Jan 18;11(1):R7. Available from: https://doi.org/10.1186/cc5155
57. Peterson EC, Wang Z, Britz G. Regulation of Cerebral Blood Flow. Int J Vasc Med [Internet]. 2011;2011:1–8. Available from: https://doi.org/10.1155/2011/823525
58. Cardim D, Robba C, Czosnyka M, Savo D, Mazeraud A, Iaquaniello C, et al. Noninvasive Intracranial Pressure Estimation With Transcranial Doppler: A Prospective Observational Study. J Neurosurg Anesthesiol [Internet]. 2020 Oct;32(4):349–53. Available from: https://doi.org/10.1097/ana.0000000000000622
59. Cardim D, Robba C, Bohdanowicz M, Donnelly J, Cabella B, Liu X, et al. Non-invasive Monitoring of Intracranial Pressure Using Transcranial Doppler

Ultrasonography: Is It Possible? Neurocrit Care [Internet]. 2016 Dec 3;25(3):473–91. Available from: https://doi.org/10.1007/s12028-016-0258-6
60. Schmidt B, Klingelhöfer J. Clinical applications of a non-invasive ICP monitoring method. Eur J Ultrasound [Internet]. 2002 Nov;16(1–2):37–45. Available from: https://doi.org/10.1016/s0929-8266(02)00044-7
61. Cardim D, Robba C, Donnelly J, Bohdanowicz M, Schmidt B, Damian M, et al. Prospective Study on Noninvasive Assessment of Intracranial Pressure in Traumatic Brain-Injured Patients: Comparison of Four Methods. J Neurotrauma [Internet]. 2016 Apr 15;33(8):792–802. Available from: https://doi.org/10.1089/neu.2015.4134
62. Cardim D, Schmidt B, Robba C, Donnelly J, Puppo C, Czosnyka M, et al. Transcranial Doppler Monitoring of Intracranial Pressure Plateau Waves. Neurocrit Care [Internet]. 2017 Jun 20;26(3):330–8. Available from: https://doi.org/10.1007/s12028-016-0356-5
63. Kareemi H, Pratte M, English S, Hendin A. Initial Diagnosis and Management of Acutely Elevated Intracranial Pressure. J Intensive Care Med [Internet]. 2023 Jul 19;38(7):643–50. Available from: https://doi.org/10.1177/08850666231156589
64. Shrestha GS, Nepal G, Prabhakar H, Prust ML. Cost-effectiveness of neurocritical care in settings with limited resources. Lancet Glob Heal [Internet]. 2023 Sep;11(9):e1343. Available from: https://doi.org/10.1016/s2214-109x(23)00326-1
65. Shrestha GS, Lamsal R. Neurocritical Care in Resource-limited Settings. J Neurosurg Anesthesiol [Internet]. 2020 Oct;32(4):285–6. Available from: https://doi.org/10.1097/ana.0000000000000720
66. Baska A, Sporysz-Janiec K, Figura M, Andruszkiewicz P, Zawadka M. Transcranial sonography: practical use in the intensive care unit. Anaesthesiol Intensive Ther [Internet]. 2025 Jan 17;56(5):267–76. Available from: https://doi.org/10.5114/ait.2024.146640
67. Mattioni A, Cenciarelli S, Eusebi P, Brazzelli M, Mazzoli T, Del Sette M, et al. Transcranial Doppler sonography for detecting stenosis or occlusion of intracranial arteries in people with acute ischaemic stroke. Cochrane Database Syst Rev [Internet]. 2020 Feb 19;2020(2). Available from: https://doi.org/10.1002/14651858.cd010722.pub2
68. Andruszkiewicz P, Sobczyk D. Ultrasonografia w intensywnej terapii. Anestezjol Intens Ter [Internet]. 2013 Sep 29;45(3):177–81. Available from: https://doi.org/10.5603/ait.2013.0036
69. Bidkar PU, Kannabiran N, Chatterjee P. Clinical applications of ultrasound in neurosurgery and neurocritical care: A narrative review. Med J Armed Forces India [Internet]. 2024 Jan;80(1):16–28. Available from: https://doi.org/10.1016/j.mjafi.2023.06.007
70. Harding U, Goeters C, Schmidt C. Ultraschall in der Anästhesie und Intensivmedizin - Ultraschall in der Intensivmedizin. AINS - Anästhesiologie · Intensivmed · Notfallmedizin · Schmerztherapie [Internet]. 2011 Mar 11;46(3):190–201. Available from: https://doi.org/10.1055/s-0031-1274931

71. Mejia LLP, Ergin BB, Rivera Lara L. Neuro-ICU: Cerebral Hemodynamics and Transcranial Doppler (TCD/TCCS) Waveform Interpretation in the Most Common Neurocritical Pathologies. In: Neurosonology in Critical Care [Internet]. Cham: Springer International Publishing; 2022. p. 299–318. Available from: https://doi.org/10.1007/978-3-030-81419-9_17
72. Shahripour RB, Azarpazhooh MR, Akhuanzada H, Labin E, Borhani-Haghighi A, Agrawal K, et al. Transcranial Doppler to evaluate postreperfusion therapy following acute ischemic stroke: A literature review. J Neuroimaging [Internet]. 2021 Sep 15;31(5):849–57. Available from: https://doi.org/10.1111/jon.12887
73. Fatima N, Shuaib A, Chughtai T, Ayyad A, Saqqur M. The role of transcranial doppler in traumatic brain injury: A systemic review and meta-analysis. Asian J Neurosurg [Internet]. 2019 Sep 9;14(3):626–33. Available from: http://dx.doi.org/10.4103/ajns.AJNS_42_19
74. Norcliffe-Kaufmann L, Galindo-Mendez B, Garcia-Guarniz A-L, Villarreal-Vitorica E, Novak V. Transcranial Doppler in autonomic testing: standards and clinical applications. Clin Auton Res [Internet]. 2018 Apr 18;28(2):187–202. Available from: https://doi.org/10.1007/s10286-017-0454-2
75. Muñoz-Sanchez MA, Murillo-Cabezas F, Egea-Guerrero JJ, Gascón-Castillo ML, Cancela P, Amaya-Villar R, et al. Emergency transcranial Doppler ultrasound: Predictive value for the development of symptomatic vasospasm in spontaneous subarachnoid hemorrhage in patients in good neurological condition. Med Intensiva (English Ed [Internet]. 2012 Dec;36(9):611–8. Available from: https://doi.org/10.1016/j.medine.2012.12.003
76. Schwab S, Steiner T, Aschoff A, Schwarz S, Steiner HH, Jansen O, et al. Early Hemicraniectomy in Patients With Complete Middle Cerebral Artery Infarction. Stroke [Internet]. 1998 Sep;29(9):1888–93. Available from: https://doi.org/10.1161/01.str.29.9.1888
77. Shah M, Biller J. Medical and Surgical Management of Intracerebral Hemorrhage. Semin Neurol [Internet]. 1998 Mar 19;18(4):513–9. Available from: https://doi.org/10.1055/s-2008-1040904
78. Archer DP, Shaw DA, Leblanc RL, Tranmer BI. Haemodynamic considerations in the management of patients with subarachnoid haemorrhage. Can J Anaesth [Internet]. 1991 May;38(4):454–70. Available from: https://doi.org/10.1007/bf03007583
79. Tissue Plasminogen Activator for Acute Ischemic Stroke. N Engl J Med [Internet]. 1995 Dec 14;333(24):1581–8. Available from: https://doi.org/10.1056/nejm199512143332401
80. Kassell NF, Peerless SJ, Durward QJ, Beck DW, Drake CG, Adams HP. Treatment of Ischemic Deficits from Vasospasm with Intravascular Volume Expansion and Induced Arterial Hypertension. Neurosurgery [Internet]. 1982 Sep 1;11(3):337–43. Available from: https://doi.org/10.1227/00006123-198209000-00001
81. Iberti TJ. Treatment of ischemic deficits from vasospasm with intravascular volume expansion and induced arterial hypertension. Neurosurgery [Internet]. 1983 Jun;12(6):705???6. Available from: https://doi.org/10.1097/00006123-

198306000-00024
82. Diringer MN. Neuroendocrine Regulation of Sodium and Volume Following Subarachnoid Hemorrhage. Clin Neuropharmacol [Internet]. 1995 Apr;18(2):114–26. Available from: https://doi.org/10.1097/00002826-199504000-00003
83. Nelson RJ. Blood Volume Measurement Following Subarachnoid Haemorrhage. In: Neuroendocrinological Aspects of Neurosurgery [Internet]. Vienna: Springer Vienna; 1990. p. 114–21. Available from: https://doi.org/10.1007/978-3-7091-9062-3_15
84. Raphael J-C, Chevret S, Auriant I, Sharshar T, Bouget J, Bolgert F. Treatment of the adult Guillain–Barré syndrome: indications for plasma exchange. Transfus Sci [Internet]. 1999 Feb;20(1):53–61. Available from: https://doi.org/10.1016/s0955-3886(98)00092-7)
85. Beauchamp NJ, Barker PB, Wang PY, VanZijl PCM. Imaging of Acute Cerebral Ischemia. Radiology [Internet]. 1999 Aug;212(2):307–24. Available from: https://doi.org/10.1148/radiology.212.2.r99au16307
86. Guerra WK-W, Gaab MR, Dietz H, Mueller J-U, Piek J, Fritsch MJ. Surgical decompression for traumatic brain swelling: indications and results. J Neurosurg [Internet]. 1999 Feb;90(2):187–96. Available from: https://doi.org/10.3171/jns.1999.90.2.0187
87. Wijdicks EFM. The history of neurocritical care. In 2017. p. 3–14. Available from: http://dx.doi.org/10.1016/B978-0-444-63600-3.00001-5
88. Andersen EW, Ibsen B. The Anaesthetic Management of Patients with Poliomyelitis and Respiratory Paralysis. BMJ [Internet]. 1954 Apr 3;1(4865):786–8. Available from: https://doi.org/10.1136/bmj.1.4865.786
89. Yundt KD, Diringer MN. THE USE OF HYPERVENTILATION AND ITS IMPACT ON CEREBRAL ISCHEMIA IN THE TREATMENT OF TRAUMATIC BRAIN INJURY. Crit Care Clin [Internet]. 1997 Jan;13(1):163–84. Available from: https://doi.org/10.1016/s0749-0704(05)70300-6
90. Xu A-D, Wang Y-J, Wang DZ. Consensus Statement on the Use of Intravenous Recombinant Tissue Plasminogen Activator to Treat Acute Ischemic Stroke by the Chinese Stroke Therapy Expert Panel. CNS Neurosci Ther [Internet]. 2013 Aug;19(8):543–8. Available from: https://doi.org/10.1111/cns.12126
91. Jauch EC, Saver JL, Adams HP, Bruno A, Connors JJ (Buddy), Demaerschalk BM, et al. Guidelines for the Early Management of Patients With Acute Ischemic Stroke. Stroke [Internet]. 2013 Mar;44(3):870–947. Available from: https://doi.org/10.1161/STR.0b013e318284056a
92. Berkhemer OA, Fransen PSS, Beumer D, van den Berg LA, Lingsma HF, Yoo AJ, et al. A Randomized Trial of Intraarterial Treatment for Acute Ischemic Stroke. N Engl J Med [Internet]. 2015 Jan 1;372(1):11–20. Available from: https://doi.org/10.1056/NEJMoa1411587
93. Goyal M, Demchuk AM, Menon BK, Eesa M, Rempel JL, Thornton J, et al. Randomized Assessment of Rapid Endovascular Treatment of Ischemic Stroke. N Engl J Med [Internet]. 2015 Mar 12;372(11):1019–30. Available

from: https://doi.org/10.1056/NEJMoa1414905
94. Huo X, Ma G, Tong X, Zhang X, Pan Y, Nguyen TN, et al. Trial of Endovascular Therapy for Acute Ischemic Stroke with Large Infarct. N Engl J Med [Internet]. 2023 Apr 6;388(14):1272–83. Available from: https://doi.org/10.1056/NEJMoa2213379
95. Sarraj A, Hassan AE, Abraham MG, Ortega-Gutierrez S, Kasner SE, Hussain MS, et al. Trial of Endovascular Thrombectomy for Large Ischemic Strokes. N Engl J Med [Internet]. 2023 Apr 6;388(14):1259–71. Available from: https://doi.org/10.1056/NEJMoa2214403
96. Chen H-S, Cui Y, Zhou Z-H, Zhang H, Wang L-X, Wang W-Z, et al. Dual Antiplatelet Therapy vs Alteplase for Patients With Minor Nondisabling Acute Ischemic Stroke. JAMA [Internet]. 2023 Jun 27;329(24):2135. Available from: https://doi.org/10.1001/jama.2023.7827
97. Hutchinson PJ, Adams H, Mohan M, Devi BI, Uff C, Hasan S, et al. Decompressive Craniectomy versus Craniotomy for Acute Subdural Hematoma. N Engl J Med [Internet]. 2023 Jun 15;388(24):2219–29. Available from: https://doi.org/10.1056/NEJMoa2214172
98. Kochanek PM, Snyder J V., Sirio CA, Saxena S, Bircher NG. Specialty neurointensive care—Is it just a name or a way of life? Crit Care Med [Internet]. 2001 Mar;29(3):692–3. Available from: https://doi.org/10.1097/00003246-200103000-00053
99. McDermott M, Jacobs T, Morgenstern L. Critical care in acute ischemic stroke. In 2017. p. 153–76. Available from: https://doi.org/10.1016/b978-0-444-63600-3.00010-6
100. Mullhi RK, Singh N, Veenith T. Critical care management of the patient with an acute ischaemic stroke. Br J Hosp Med [Internet]. 2021 Jan 2;82(1):1–9. Available from: https://doi.org/10.12968/hmed.2020.0123
101. Smith M, Reddy U, Robba C, Sharma D, Citerio G. Acute ischaemic stroke: challenges for the intensivist. Intensive Care Med [Internet]. 2019 Sep 25;45(9):1177–89. Available from: https://doi.org/10.1007/s00134-019-05705-y
102. Qaryouti D, Greene-Chandos D. Neurocritical Care Aspects of Ischemic Stroke Management. Crit Care Clin [Internet]. 2023 Jan;39(1):55–70. Available from: https://doi.org/10.1016/j.ccc.2022.07.005
103. Wentworth DA, Atkinson RP. Implementation of an Acute Stroke Program Decreases Hospitalization Costs and Length of Stay. Stroke [Internet]. 1996 Jun;27(6):1040–3. Available from: https://doi.org/10.1161/01.str.27.6.1040
104. Bowen J, Yaste C. Effect of a stroke protocol on hospital costs of stroke patients. Neurology [Internet]. 1994 Oct;44(10):1961–1961. Available from: https://doi.org/10.1212/wnl.44.10.1961
105. Venkatasubba Rao CP, Suarez JI, Martin RH, Bauza C, Georgiadis A, Calvillo E, et al. Global Survey of Outcomes of Neurocritical Care Patients: Analysis of the PRINCE Study Part 2. Neurocrit Care [Internet]. 2020 Feb 4;32(1):88–103. Available from: https://doi.org/10.1007/s12028-019-00835-z
106. Kramer AH, Zygun DA. Do Neurocritical Care Units Save Lives? Measuring

The Impact of Specialized ICUs. Neurocrit Care [Internet]. 2011 Jun 18;14(3):329–33. Available from: https://doi.org/10.1007/s12028-011-9530-y
107. Suarez JI. Outcome in neurocritical care: Advances in monitoring and treatment and effect of a specialized neurocritical care team. Crit Care Med [Internet]. 2006 Sep;34(Suppl):S232–8. Available from: https://doi.org/10.1097/01.ccm.0000231881.29040.25
108. Hoffmann M, Lefering R, Rueger JM, Kolb JP, Izbicki JR, Ruecker AH, et al. Pupil evaluation in addition to Glasgow Coma Scale components in prediction of traumatic brain injury and mortality. Br J Surg [Internet]. 2011 Dec 22;99(Supplement_1):122–30. Available from: https://doi.org/10.1002/bjs.7707
109. Balestreri M, Czosnyka M, Chatfield DA, Steiner LA, Schmidt EA, Smielewski P, et al. Predictive value of Glasgow Coma Scale after brain trauma: change in trend over the past ten years. J Neurol Neurosurg Psychiatry [Internet]. 2004 Jan;75(1):161–2. Available from: http://www.ncbi.nlm.nih.gov/pubmed/14707332
110. Menken M, Munsat TL, Toole JF. The Global Burden of Disease Study. Arch Neurol [Internet]. 2000 Mar 1;57(3):418. Available from: https://doi.org/10.1001/archneur.57.3.418
111. Feigin VL, Vos T. Global Burden of Neurological Disorders: From Global Burden of Disease Estimates to Actions. Neuroepidemiology [Internet]. 2019;52(1–2):1–2. Available from: https://doi.org/10.1159/000495197
112. Mayr VD, Dünser MW, Greil V, Jochberger S, Luckner G, Ulmer H, et al. Causes of death and determinants of outcome in critically ill patients. Crit Care [Internet]. 2006 Nov 3;10(6):R154. Available from: https://doi.org/10.1186/cc5086
113. Angus DC, Shorr AF, White A, Dremsizov TT, Schmitz RJ, Kelley MA. Critical care delivery in the United States: Distribution of services and compliance with Leapfrog recommendations*. Crit Care Med [Internet]. 2006 Apr;34(4):1016–24. Available from: https://doi.org/10.1097/01.ccm.0000206105.05626.15
114. Halpern NA, Pastores SM. Critical care medicine in the United States 2000–2005: An analysis of bed numbers, occupancy rates, payer mix, and costs*. Crit Care Med [Internet]. 2010 Jan;38(1):65–71. Available from: https://doi.org/10.1097/ccm.0b013e3181b090d0
115. Zacharia BE, Vaughan KA, Bruce SS, Grobelny BT, Narula R, Khandji J, et al. Epidemiological trends in the neurological intensive care unit from 2000 to 2008. J Clin Neurosci [Internet]. 2012 Dec;19(12):1668–72. Available from: https://doi.org/10.1016/j.jocn.2012.04.011
116. Feigin VL, Vos T, Nichols E, Owolabi MO, Carroll WM, Dichgans M, et al. The global burden of neurological disorders: translating evidence into policy. Lancet Neurol [Internet]. 2020 Mar;19(3):255–65. Available from: https://doi.org/10.1016/s1474-4422(19)30411-9
117. Silva GS, Maldonado NJ, Mejia-Mantilla JH, Ortega-Gutierrez S, Claassen J, Varelas P, et al. Neuroemergencies in South America: How to Fill in the Gaps? Neurocrit Care [Internet]. 2019 Dec 24;31(3):573–82. Available from:

https://doi.org/10.1007/s12028-019-00775-8
118. Suarez JI, Martin RH, Bauza C, Georgiadis A, Venkatasubba Rao CP, Calvillo E, et al. Worldwide Organization of Neurocritical Care: Results from the PRINCE Study Part 1. Neurocrit Care [Internet]. 2020 Feb 7;32(1):172–9. Available from: https://doi.org/10.1007/s12028-019-00750-3
119. Vincent J-L, Moreno R. Clinical review: Scoring systems in the critically ill. Crit Care [Internet]. 2010;14(2):207. Available from: https://doi.org/10.1186/cc8204
120. Zygun D, Berthiaume L, Laupland K, Kortbeek J, Doig C. SOFA is superior to MOD score for the determination of non-neurologic organ dysfunction in patients with severe traumatic brain injury: a cohort study. Crit Care [Internet]. 2006 Aug 1;10(4):R115. Available from: https://doi.org/10.1186/cc5007
121. Réa-Neto Á, Bernardelli RS, de Oliveira MC, David-João PG, Kozesinski-Nakatani AC, Falcão ALE, et al. Epidemiology and disease burden of patients requiring neurocritical care: a Brazilian multicentre cohort study. Sci Rep [Internet]. 2023 Oct 30;13(1):18595. Available from: https://doi.org/10.1038/s41598-023-44261-w
122. Rodríguez-Boto G, Rivero-Garvía M, Márquez-Rivas J. Hipertensión intracraneal. Med Clin (Barc) [Internet]. 2012 Sep;139(6):268–72. Available from: https://doi.org/10.1016/j.medcli.2012.04.010
123. Bayona-Ortiz H, Useche JN, Yanez N, Velasco SC. Availability of stroke units in Colombia. Lancet Neurol [Internet]. 2019 Nov;18(11):988. Available from: https://doi.org/10.1016/s1474-4422(19)30332-1
124. Pagan E, Chatenoud L, Rodriguez T, Bosetti C, Levi F, Malvezzi M, et al. Comparison of Trends in Mortality from Coronary Heart and Cerebrovascular Diseases in North and South America: 1980 to 2013. Am J Cardiol [Internet]. 2017 Mar;119(6):862–71. Available from: https://doi.org/10.1016/j.amjcard.2016.11.040
125. Fay MP, Kim S. Confidence intervals for directly standardized rates using mid-p gamma intervals. Biometrical J [Internet]. 2017 Mar 23;59(2):377–87. Available from: https://doi.org/10.1002/bimj.201600111
126. Yanez N, Useche JN, Bayona H, Porras A, Carrasquilla G. Analyses of Mortality and Prevalence of Cerebrovascular Disease in Colombia, South America (2014-2016): A Cross-Sectional and Ecological Study. J Stroke Cerebrovasc Dis [Internet]. 2020 May;29(5):104699. Available from: https://doi.org/10.1016/j.jstrokecerebrovasdis.2020.104699
127. Figueroa Casanova R, Patiño Rodríguez HM, Téllez Villa JA, Torrado Varón MA, Figueroa Legarda JS, Saavedra Henao JD. Experiencia en el manejo del ataque cerebrovascular isquémico en dos centros de tercer nivel de la ciudad de Ibagué (Colombia) entre junio del 2019 y junio del 2020. Acta Neurológica Colomb [Internet]. 2022 Apr 26;38(1):12–22. Available from: https://doi.org/10.22379/24224022396
128. Claassen JAHR, Thijssen DHJ, Panerai RB, Faraci FM. Regulation of cerebral blood flow in humans: physiology and clinical implications of autoregulation. Physiol Rev [Internet]. 2021 Oct 1;101(4):1487–559. Available from:

https://doi.org/10.1152/physrev.00022.2020
129. Fantini S, Sassaroli A, Tgavalekos KT, Kornbluth J. Cerebral blood flow and autoregulation: current measurement techniques and prospects for noninvasive optical methods. Neurophotonics [Internet]. 2016 Jun 21;3(3):31411. Available from: https://doi.org/10.1117/1.NPh.3.3.031411
130. Bélanger M, Allaman I, Magistretti PJ. Brain Energy Metabolism: Focus on Astrocyte-Neuron Metabolic Cooperation. Cell Metab [Internet]. 2011 Dec;14(6):724–38. Available from: https://doi.org/10.1016/j.cmet.2011.08.016
131. FOG M. CEREBRAL CIRCULATION. Arch Neurol Psychiatry [Internet]. 1939 Feb 1;41(2):260. Available from: https://doi.org/10.1001/archneurpsyc.1939.02270140046003
132. Ouriel K, Shortell CK, Illig KA, Greenberg RK, Green RM. Intracerebral hemorrhage after carotid endarterectomy: Incidence, contribution to neurologic morbidity, and predictive factors. J Vasc Surg [Internet]. 1999 Jan;29(1):82–9. Available from: https://doi.org/10.1016/s0741-5214(99)70362-9
133. Rostami E, Engquist H, Enblad P. Imaging of Cerebral Blood Flow in Patients with Severe Traumatic Brain Injury in the Neurointensive Care. Front Neurol [Internet]. 2014 Jul 7;5. Available from: https://doi.org/10.3389/fneur.2014.00114
134. Fantini S. Dynamic model for the tissue concentration and oxygen saturation of hemoglobin in relation to blood volume, flow velocity, and oxygen consumption: Implications for functional neuroimaging and coherent hemodynamics spectroscopy (CHS). Neuroimage [Internet]. 2014 Jan;85:202–21. Available from: https://doi.org/10.1016/j.neuroimage.2013.03.065
135. Vavilala MS, Lee LA, Lam AM. Cerebral blood flow and vascular physiology. Anesthesiol Clin North America [Internet]. 2002 Jun;20(2):247–64. Available from: https://doi.org/10.1016/s0889-8537(01)00012-8
136. Lassen NA. Normal Average Value of Cerebral Blood Flow in Younger Adults is 50 ml/100 g/min. J Cereb Blood Flow Metab [Internet]. 1985 Sep 1;5(3):347–9. Available from: https://doi.org/10.1038/jcbfm.1985.48
137. Vu EL, Brown CH, Brady KM, Hogue CW. Monitoring of cerebral blood flow autoregulation: physiologic basis, measurement, and clinical implications. Br J Anaesth [Internet]. 2024 Jun;132(6):1260–73. Available from: https://doi.org/10.1016/j.bja.2024.01.043
138. Tzeng Y-C, Ainslie PN. Blood pressure regulation IX: cerebral autoregulation under blood pressure challenges. Eur J Appl Physiol [Internet]. 2014 Mar 5;114(3):545–59. Available from: https://doi.org/10.1007/s00421-013-2667-y
139. Willie CK, Tzeng Y, Fisher JA, Ainslie PN. Integrative regulation of human brain blood flow. J Physiol [Internet]. 2014 Mar 28;592(5):841–59. Available from: https://doi.org/10.1113/jphysiol.2013.268953
140. Girouard H, Iadecola C. Neurovascular coupling in the normal brain and in hypertension, stroke, and Alzheimer disease. J Appl Physiol [Internet]. 2006 Jan;100(1):328–35. Available from:

https://doi.org/10.1152/japplphysiol.00966.2005https://doi.org/10.1152/japplphysiol.00966.2005
141. Koehler RC, Roman RJ, Harder DR. Astrocytes and the regulation of cerebral blood flow. Trends Neurosci [Internet]. 2009 Mar;32(3):160–9. Available from: https://doi.org/10.1016/j.tins.2008.11.005
142. Ashby JW, Mack JJ. Endothelial Control of Cerebral Blood Flow. Am J Pathol [Internet]. 2021 Nov;191(11):1906–16. Available from: https://doi.org/10.1016/j.ajpath.2021.02.023
143. Hannawi Y. Cerebral Small Vessel Disease: a Review of the Pathophysiological Mechanisms. Transl Stroke Res [Internet]. 2024 Dec 21;15(6):1050–69. Available from: https://doi.org/10.1007/s12975-023-01195-9
144. Payne SJ. A model of the interaction between autoregulation and neural activation in the brain. Math Biosci [Internet]. 2006 Dec;204(2):260–81. Available from: https://doi.org/10.1016/j.mbs.2006.08.006
145. Fan J-L, Brassard P, Rickards CA, Nogueira RC, Nasr N, McBryde FD, et al. Integrative cerebral blood flow regulation in ischemic stroke. J Cereb Blood Flow Metab [Internet]. 2022 Mar 14;42(3):387–403. Available from: https://doi.org/10.1177/0271678x211032029
146. Tan CO, Taylor JA. Integrative physiological and computational approaches to understand autonomic control of cerebral autoregulation. Exp Physiol [Internet]. 2014 Jan 4;99(1):3–15. Available from: https://doi.org/10.1113/expphysiol.2013.072355
147. Simpson DM, Payne SJ, Panerai RB. The INfoMATAS project: Methods for assessing cerebral autoregulation in stroke. J Cereb Blood Flow Metab [Internet]. 2022 Mar 19;42(3):411–29. Available from: https://doi.org/10.1177/0271678X211029049
148. Armstead WM. Cerebral Blood Flow Autoregulation and Dysautoregulation. Anesthesiol Clin [Internet]. 2016 Sep;34(3):465–77. Available from: https://doi.org/10.1016/j.anclin.2016.04.002
149. Knot HJ, Nelson MT. Regulation of arterial diameter and wall [Ca 2+] in cerebral arteries of rat by membrane potential and intravascular pressure. J Physiol [Internet]. 1998 Apr 22;508(1):199–209. Available from: https://doi.org/10.1111/j.1469-7793.1998.199br.x
150. Kontos HA. Regulation of the Cerebral Circulation. Annu Rev Physiol [Internet]. 1981 Oct;43(1):397–407. Available from: https://doi.org/10.1146/annurev.ph.43.030181.002145
151. Mishra A, Gordon GR, MacVicar BA, Newman EA. Astrocyte Regulation of Cerebral Blood Flow in Health and Disease. Cold Spring Harb Perspect Biol [Internet]. 2024 Feb 5;a041354. Available from: https://doi.org/10.1101/cshperspect.a041354
152. Payne SJ, Mohammad J, Tisdall MM, Tachtsidis I. Effects of arterial blood gas levels on cerebral blood flow and oxygen transport. Biomed Opt Express [Internet]. 2011 Apr 1;2(4):966. Available from: https://doi.org/10.1364/BOE.2.000966

153. Schmidt B, Klingelhöfer J, Perkes I, Czosnyka M. Cerebral Autoregulatory Response Depends on the Direction of Change in Perfusion Pressure. J Neurotrauma [Internet]. 2009 May;26(5):651–6. Available from: https://doi.org/10.1089/neu.2008.0784
154. Castle-Kirszbaum M, Parkin WG, Goldschlager T, Lewis PM. Cardiac Output and Cerebral Blood Flow: A Systematic Review of Cardio-Cerebral Coupling. J Neurosurg Anesthesiol [Internet]. 2022 Oct;34(4):352–63. Available from: https://doi.org/10.1097/ana.0000000000000768
155. Petrovčič R, Rakusa M, Markota A. Monitoring of Cerebral Blood Flow Autoregulation after Cardiac Arrest. Medicina (B Aires) [Internet]. 2024 Aug 23;60(9):1381. Available from: https://doi.org/10.3390/medicina60091381
156. Lu J, Mamun KA, Chau T. Online transcranial Doppler ultrasonographic control of an onscreen keyboard. Front Hum Neurosci [Internet]. 2014 Apr 22;8. Available from: https://doi.org/10.3389/fnhum.2014.00199
157. Webb AJS, Klerman EB, Mandeville ET. Circadian and Diurnal Regulation of Cerebral Blood Flow. Circ Res [Internet]. 2024 Mar 15;134(6):695–710. Available from: https://doi.org/10.1161/circresaha.123.323049
158. Toda N, Ayajiki K, Okamura T. Cerebral Blood Flow Regulation by Nitric Oxide: Recent Advances. Pharmacol Rev [Internet]. 2009 Mar;61(1):62–97. Available from: https://doi.org/10.1124/pr.108.000547
159. Bhatia A, Gupta AK. Neuromonitoring in the intensive care unit. I. Intracranial pressure and cerebral blood flow monitoring. Intensive Care Med [Internet]. 2007 Jul 24;33(7):1263–71. Available from: https://doi.org/10.1007/s00134-007-0678-z
160. Paulson OB, Hasselbalch SG, Rostrup E, Knudsen GM, Pelligrino D. Cerebral blood flow response to functional activation. J Cereb Blood Flow Metab [Internet]. 2010 Jan;30(1):2–14. Available from: https://doi.org/10.1038/jcbfm.2009.188
161. Ogoh S. Interaction between the respiratory system and cerebral blood flow regulation. J Appl Physiol [Internet]. 2019 Nov 1;127(5):1197–205. Available from: https://doi.org/10.1152/japplphysiol.00057.2019
162. Wang D, Baker WB, He H, Gao P, Zhu L, Peng Q, et al. Influence of probe pressure on the pulsatile diffuse correlation spectroscopy blood flow signal on the forearm and forehead regions. Neurophotonics [Internet]. 2019 Sep 23;6(3):1. Available from: https://doi.org/10.1117/1.NPh.6.3.035013
163. Tisdall MM, Tachtsidis I, Leung TS, Elwell CE, Smith M. Increase in cerebral aerobic metabolism by normobaric hyperoxia after traumatic brain injury. J Neurosurg [Internet]. 2008 Sep;109(3):424–32. Available from: https://doi.org/10.3171/JNS/2008/109/9/0424
164. Leal-Noval SR, Cayuela A, Arellano-Orden V, Marín-Caballos A, Padilla V, Ferrándiz-Millón C, et al. Invasive and noninvasive assessment of cerebral oxygenation in patients with severe traumatic brain injury. Intensive Care Med [Internet]. 2010 Aug 26;36(8):1309–17. Available from: https://doi.org/10.1007/s00134-010-1920-7
165. Fantini S. A new hemodynamic model shows that temporal perturbations of

cerebral blood flow and metabolic rate of oxygen cannot be measured individually using functional near-infrared spectroscopy. Physiol Meas [Internet]. 2014 Jan 1;35(1):N1–9. Available from: https://doi.org/10.1088/0967-3334/35/1/N1
166. Toda N, Ayajiki K, Okamura T. Cerebral blood flow regulation by nitric oxide in neurological disorders. Can J Physiol Pharmacol [Internet]. 2009 Aug;87(8):581–94. Available from: https://doi.org/10.1139/y09-048
167. Strandgaard S. Cerebral blood flow in untreated and treated hypertension. Neth J Med [Internet]. 1995 Oct;47(4):180–4. Available from: https://doi.org/10.1016/0300-2977(95)00065-u
168. Attwell D, Buchan AM, Charpak S, Lauritzen M, MacVicar BA, Newman EA. Glial and neuronal control of brain blood flow. Nature [Internet]. 2010 Nov 11;468(7321):232–43. Available from: https://doi.org/10.1038/nature09613
169. Dewey RC, Hunt WE. Cerebral hemodynamic crisis. Am J Surg [Internet]. 1976 Mar;131(3):338–49. Available from: https://doi.org/10.1016/0002-9610(76)90128-8
170. Hall CN, Reynell C, Gesslein B, Hamilton NB, Mishra A, Sutherland BA, et al. Capillary pericytes regulate cerebral blood flow in health and disease. Nature [Internet]. 2014 Apr 26;508(7494):55–60. Available from: https://doi.org/10.1038/nature13165
171. Webb AJS, Werring DJ. New Insights Into Cerebrovascular Pathophysiology and Hypertension. Stroke [Internet]. 2022 Apr;53(4):1054–64. Available from: https://doi.org/10.1161/strokeaha.121.035850
172. Rickards CA. Cerebral Blood-Flow Regulation During Hemorrhage. In: Comprehensive Physiology [Internet]. Wiley; 2015. p. 1585–621. Available from: https://doi.org/10.1002/cphy.c140058
173. Karbowski J. Scaling of Brain Metabolism and Blood Flow in Relation to Capillary and Neural Scaling. Ermentrout B, editor. PLoS One [Internet]. 2011 Oct 28;6(10):e26709. Available from: https://doi.org/10.1371/journal.pone.0026709
174. Salma A. Normal pressure hydrocephalus as a failure of ICP homeostasis mechanism: the hidden role of Monro–Kellie doctrine in the genesis of NPH. Child's Nerv Syst [Internet]. 2014 May 28;30(5):825–30. Available from: https://doi.org/10.1007/s00381-014-2385-8
175. Rabelo NN, da Silva Brito J, da Silva JS, de Souza NB, Coelho G, Brasil S, et al. The historic evolution of intracranial pressure and cerebrospinal fluid pulse pressure concepts: Two centuries of challenges. Surg Neurol Int [Internet]. 2021 Jun 14;12:274. Available from: https://doi.org/10.25259/sni_53_2021
176. Benson JC, Madhavan AA, Cutsforth-Gregory JK, Johnson DR, Carr CM. The Monro-Kellie Doctrine: A Review and Call for Revision. Am J Neuroradiol [Internet]. 2023 Jan;44(1):2–6. Available from: https://doi.org/10.3174/ajnr.a7721
177. Wilson MH. Monro-Kellie 2.0: The dynamic vascular and venous pathophysiological components of intracranial pressure. J Cereb Blood Flow Metab [Internet]. 2016 Aug 12;36(8):1338–50. Available from:

https://doi.org/10.1177/0271678x16648711
178. Gopalakrishnan MS, Shanbhag NC, Shukla DP, Konar SK, Bhat DI, Devi BI. Complications of Decompressive Craniectomy. Front Neurol [Internet]. 2018 Nov 20;9. Available from: https://doi.org/10.3389/fneur.2018.00977
179. Kawoos U, McCarron R, Auker C, Chavko M. Advances in Intracranial Pressure Monitoring and Its Significance in Managing Traumatic Brain Injury. Int J Mol Sci [Internet]. 2015 Dec 4;16(12):28979–97. Available from: https://doi.org/10.3390/ijms161226146
180. Galindo-Velasquez H. AUTORREGULACIÓN CEREBRAL: FISIOLOGÍA Y FISIOPATOLOGÍA ESENCIALES PARA EL MANEJO NEUROCRÍTICO. Rev Argentina Med [Internet]. 2020;8(4). Available from: https://www.revistasam.com.ar/index.php/RAM/article/view/524
181. Stocchetti N, Longhi L, Magnoni S, Roncati Zanier E, Canavesi K. Head injury, subarachnoid hemorrhage and intracranial pressure monitoring in Italy. Acta Neurochir (Wien) [Internet]. 2003 Jan 1;145(9):761–5. Available from: https://doi.org/10.1007/s00701-003-0092-4
182. Gyawali P, Lillicrap TP, Esperon CG, Bhattarai A, Bivard A, Spratt N. Whole Blood Viscosity and Cerebral Blood Flow in Acute Ischemic Stroke. Semin Thromb Hemost [Internet]. 2024 Jun 9;50(4):580–91. Available from: https://doi.org/10.1055/s-0043-1775858
183. Tikhomirova IA, Oslyakova AO, Mikhailova SG. Microcirculation and blood rheology in patients with cerebrovascular disorders. Clin Hemorheol Microcirc [Internet]. 2011 Dec 26;49(1–4):295–305. Available from: https://doi.org/10.3233/ch-2011-1480
184. Donnelly J, Budohoski KP, Smielewski P, Czosnyka M. Regulation of the cerebral circulation: bedside assessment and clinical implications. Crit Care [Internet]. 2016 Dec 5;20(1):129. Available from: https://doi.org/10.1186/s13054-016-1293-6
185. Czosnyka M, Brady K, Reinhard M, Smielewski P, Steiner LA. Monitoring of Cerebrovascular Autoregulation: Facts, Myths, and Missing Links. Neurocrit Care [Internet]. 2009 Jun 6;10(3):373–86. Available from: https://doi.org/10.1007/s12028-008-9175-7
186. Zweifel C, Lavinio A, Steiner LA, Radolovich D, Smielewski P, Timofeev I, et al. Continuous monitoring of cerebrovascular pressure reactivity in patients with head injury. Neurosurg Focus [Internet]. 2008 Oct;25(4):E2. Available from: https://doi.org/10.3171/foc.2008.25.10.e2
187. McBryde FD, Malpas SC, Paton JFR. Intracranial mechanisms for preserving brain blood flow in health and disease. Acta Physiol [Internet]. 2017 Jan;219(1):274–87. Available from: https://doi.org/10.1111/apha.12706
188. Guild S-J, Saxena UA, McBryde FD, Malpas SC, Ramchandra R. Intracranial pressure influences the level of sympathetic tone. Am J Physiol Integr Comp Physiol [Internet]. 2018 Nov 1;315(5):R1049–53. Available from: https://doi.org/10.1152/ajpregu.00183.2018
189. Artru F. Évaluation du retentissement ischémique de l’hypertension intracrânienne. Ann Fr Anesth Reanim [Internet]. 1997 Jan;16(4):410–4.

Available from: https://doi.org/10.1016/s0750-7658(97)81472-4
190. De Georgia MA, Deogaonkar A. Multimodal Monitoring in the Neurological Intensive Care Unit. Neurologist [Internet]. 2005 Jan;11(1):45–54. Available from: https://doi.org/10.1097/01.nrl.0000149993.99956.09
191. Mazzeo AT, Bullock R. Monitoring brain tissue oxymetry: Will it change management of critically ill neurologic patients? J Neurol Sci [Internet]. 2007 Oct;261(1–2):1–9. Available from: https://doi.org/10.1016/j.jns.2007.04.026
192. Wright WL. Multimodal monitoring in the ICU: When could it be useful? J Neurol Sci [Internet]. 2007 Oct;261(1–2):10–5. Available from: https://doi.org/10.1016/j.jns.2007.04.027
193. Mitchell PH, Kirkness C, Blissitt PA. Cerebral Perfusion Pressure and Intracranial Pressure in Traumatic Brain Injury. Annu Rev Nurs Res [Internet]. 2015 May;33(1):111–83. Available from: https://doi.org/10.1891/0739-6686.33.111
194. Vella MA, Crandall ML, Patel MB. Acute Management of Traumatic Brain Injury. Surg Clin North Am [Internet]. 2017 Oct;97(5):1015–30. Available from: https://doi.org/10.1016/j.suc.2017.06.003
195. Schizodimos T, Soulountsi V, Iasonidou C, Kapravelos N. An overview of management of intracranial hypertension in the intensive care unit. J Anesth [Internet]. 2020 Oct 21;34(5):741–57. Available from: https://doi.org/10.1007/s00540-020-02795-7
196. Raoof N, Hoffmann J. Diagnosis and treatment of idiopathic intracranial hypertension. Cephalalgia [Internet]. 2021 Apr 25;41(4):472–8. Available from: https://doi.org/10.1177/0333102421997093
197. Wang MTM, Bhatti MT, Danesh-Meyer H V. Idiopathic intracranial hypertension: Pathophysiology, diagnosis and management. J Clin Neurosci [Internet]. 2022 Jan;95:172–9. Available from: https://doi.org/10.1016/j.jocn.2021.11.029
198. Daley ML, Pasupathy H, Griffith M, Robertson JT, Leffler CW. Detection of loss of cerebral vascular tone by correlation of arterial and intracranial pressure signals. IEEE Trans Biomed Eng [Internet]. 1995 Apr;42(4):420–4. Available from: https://doi.org/10.1109/10.376137
199. Portella G, Cormio M, Citerio G, Contant C, Kiening K, Enblad P, et al. Continuous cerebral compliance monitoring in severe head injury: its relationship with intracranial pressure and cerebral perfusion pressure. Acta Neurochir (Wien) [Internet]. 2005 Jul 30;147(7):707–13. Available from: https://doi.org/10.1007/s00701-005-0537-z
200. Mollan SP, Davies B, Silver NC, Shaw S, Mallucci CL, Wakerley BR, et al. Idiopathic intracranial hypertension: consensus guidelines on management. J Neurol Neurosurg Psychiatry [Internet]. 2018 Oct;89(10):1088–100. Available from: https://doi.org/10.1136/jnnp-2017-317440
201. Rohit W, Rajesh A, Mridula R, Jabeen SA. Idiopathic Intracranial Hypertension - Challenges and Pearls. Neurol India [Internet]. 2021 Nov;69(Suppl 2):S434–42. Available from: https://doi.org/10.4103/0028-3886.332276
202. de-Lima-Oliveira M, Salinet ASM, Nogueira RC, de Azevedo DS, Paiva WS,

Teixeira MJ, et al. Intracranial Hypertension and Cerebral Autoregulation: A Systematic Review and Meta-Analysis. World Neurosurg [Internet]. 2018 May;113:110–24. Available from: https://doi.org/10.1016/j.wneu.2018.01.194

203. Oshorov AV, Polupan AA, Sychev AA, Baranich AI, Kurdyumova NV, Abramov TA, et al. Influence of cerebral hyperthermia on intracranial pressure and autoregulation of cerebral circulation in patients with acute brain injury. Vopr neirokhirurgii Im NN Burdenko [Internet]. 2021;85(1):68. Available from: https://doi.org/10.17116/neiro20218501168
204. Ekizoglu E. An update on the pathophysiology of idiopathic intracranial hypertension alias pseudotumor cerebri. Ağrı - J Turkish Soc Algol [Internet]. 2015; Available from: https://doi.org/10.5505/agri.2015.22599
205. Pesek M, Kibler K, Easley RB, Mytar J, Rhee C, Andropolous D, et al. The Upper Limit of Cerebral Blood Flow Autoregulation Is Decreased with Elevations in Intracranial Pressure. In 2016. p. 229–31. Available from: https://doi.org/10.1007/978-3-319-22533-3_46
206. Rangel-Castilla L, Gasco J, Nauta HJW, Okonkwo DO, Robertson CS. Cerebral pressure autoregulation in traumatic brain injury. Neurosurg Focus [Internet]. 2008 Oct;25(4):E7. Available from: https://doi.org/10.3171/foc.2008.25.10.e7
207. Pesek M, Kibler K, Easley RB, Mytar J, Rhee C, Andropoulos D, et al. The Upper Limit of Cerebral Blood Flow Autoregulation Is Decreased With Elevations in Intracranial Pressure. Neurosurgery [Internet]. 2014 Aug;75(2):163–70. Available from: https://doi.org/10.1227/neu.0000000000000367
208. Czosnyka M, Miller C. Monitoring of Cerebral Autoregulation. Neurocrit Care [Internet]. 2014 Dec 11;21(S2):95–102. Available from: https://doi.org/10.1007/s12028-014-0046-0
209. Robelin F, Lenfant M, Ricolfi F, Béjot Y, Comby P-O. Hypertension intracrânienne idiopathique : des mécanismes physiopathologiques à la décision thérapeutique. La Rev Médecine Interne [Internet]. 2022 Nov;43(11):661–8. Available from: https://doi.org/10.1016/j.revmed.2022.08.012
210. Rodríguez-Boto G, Rivero-Garvía M, Gutiérrez-González R, Márquez-Rivas J. Conceptos básicos sobre la fisiopatología cerebral y la monitorización de la presión intracraneal. Neurología [Internet]. 2015 Jan;30(1):16–22. Available from: https://doi.org/10.1016/j.nrl.2012.09.002
211. Schimpf MM. Diagnosing Increased Intracranial Pressure. J Trauma Nurs [Internet]. 2012 Jul;19(3):160–7. Available from: https://doi.org/10.1097/jtn.0b013e318261cfb4
212. Murillo-Cabezas F, Godoy DA. Monitorización de la presión intracraneal en el traumatismo craneoencefálico grave: otra visión del Best Trip trial. Med Intensiva [Internet]. 2014 May;38(4):237–9. Available from: https://doi.org/10.1016/j.medin.2013.07.011https://doi.org/10.1016/j.medin.2013.07.011
213. Dawes AJ, Sacks GD, Cryer HG, Gruen JP, Preston C, Gorospe D, et al.

Intracranial pressure monitoring and inpatient mortality in severe traumatic brain injury. J Trauma Acute Care Surg [Internet]. 2015 Mar;78(3):492–502. Available from: https://doi.org/10.1097/ta.0000000000000559
214. Le Roux P. Intracranial pressure after the BEST TRIP trial. Curr Opin Crit Care [Internet]. 2014 Apr;20(2):141–7. Available from: https://doi.org/10.1097/mcc.0000000000000078
215. Shafi S, Diaz-Arrastia R, Madden C, Gentilello L. Intracranial Pressure Monitoring in Brain-Injured Patients is Associated With Worsening of Survival. J Trauma Inj Infect Crit Care [Internet]. 2008 Feb;64(2):335–40. Available from: https://doi.org/10.1097/ta.0b013e31815dd017
216. Han J, Yang S, Zhang C, Zhao M, Li A. Impact of Intracranial Pressure Monitoring on Prognosis of Patients With Severe Traumatic Brain Injury. Medicine (Baltimore) [Internet]. 2016 Feb;95(7):e2827. Available from: https://doi.org/10.1097/md.0000000000002827
217. Donnelly J, Czosnyka M, Harland S, Varsos G V., Cardim D, Robba C, et al. Increased ICP and Its Cerebral Haemodynamic Sequelae. In 2018. p. 47–50. Available from: https://doi.org/10.1007/978-3-319-65798-1_10https://doi.org/10.1007/978-3-319-65798-1_10
218. Bragin DE, Statom G, Nemoto EM. Dynamic Cerebrovascular and Intracranial Pressure Reactivity Assessment of Impaired Cerebrovascular Autoregulation in Intracranial Hypertension. In 2016. p. 255–60. Available from: https://doi.org/10.1007/978-3-319-22533-3_51
219. Derdeyn CP, Grubb RL, Powers WJ. Cerebral hemodynamic impairment. Neurology [Internet]. 1999 Jul;53(2):251–251. Available from: https://doi.org/10.1212/WNL.53.2.251
220. Perez-Barcena J, Llompart-Pou JA, O'Phelan KH. Intracranial Pressure Monitoring and Management of Intracranial Hypertension. Crit Care Clin [Internet]. 2014 Oct;30(4):735–50. Available from: https://doi.org/10.1016/j.ccc.2014.06.005
221. Hinzman JM, Andaluz N, Shutter LA, Okonkwo DO, Pahl C, Strong AJ, et al. Inverse neurovascular coupling to cortical spreading depolarizations in severe brain trauma. Brain [Internet]. 2014 Nov;137(11):2960–72. Available from: https://doi.org/10.1093/brain/awu241
222. Turner DA. Neurovascular regulation is critical for metabolic recovery from spreading depression. Brain [Internet]. 2014 Nov;137(11):2877–8. Available from: https://doi.org/10.1093/brain/awu263
223. Kinoshita K. Traumatic brain injury: pathophysiology for neurocritical care. J Intensive Care [Internet]. 2016 Dec 27;4(1):29. Available from: https://doi.org/10.1186/s40560-016-0138-3
224. Faltermeier R, Proescholdt MA, Bele S, Brawanski A. Parameter Optimization for Selected Correlation Analysis of Intracranial Pathophysiology. Comput Math Methods Med [Internet]. 2015;2015:1–7. Available from: https://doi.org/10.1155/2015/652030
225. Saqqur M, Zygun D, Demchuk A. Role of transcranial Doppler in neurocritical care. Crit Care Med [Internet]. 2007 May;35(Suppl):S216–23. Available from:

https://doi.org/10.1097/01.ccm.0000260633.66384.fb
226. Alexandrov A V., Sloan MA, Wong LKS, Douville C, Razumovsky AY, Koroshetz WJ, et al. Practice Standards for Transcranial Doppler Ultrasound: Part I—Test Performance. J Neuroimaging [Internet]. 2007 Jan 10;17(1):11–8. Available from: https://doi.org/10.1111/j.1552-6569.2006.00088.x
227. Hilz MJ, Stemper B, Heckmann JG, Neundörfer B. Mechanismen der zerebralen Autoregulation, Untersuchungsverfahren und Beurteilung mittels transkranieller Doppler-Sonographie. Fortschritte der Neurol · Psychiatr [Internet]. 2000 Sep;68(9):398–412. Available from: https://doi.org/10.1055/s-2000-11798
228. D′Andrea A, Conte M, Scarafile R, Riegler L, Cocchia R, Pezzullo E, et al. Transcranial Doppler ultrasound: Physical principles and principal applications in Neurocritical care unit. J Cardiovasc Echogr [Internet]. 2016;26(2):28. Available from: https://doi.org/10.4103/2211-4122.183746
229. D'Andrea A, Conte M, Cavallaro M, Scarafile R, Riegler L, Cocchia R, et al. Transcranial Doppler ultrasonography: From methodology to major clinical applications. World J Cardiol [Internet]. 2016;8(7):383. Available from: https://doi.org/10.4330/wjc.v8.i7.383
230. Bonow RH, Young CC, Bass DI, Moore A, Levitt MR. Transcranial Doppler ultrasonography in neurological surgery and neurocritical care. Neurosurg Focus [Internet]. 2019 Dec;47(6):E2. Available from: https://doi.org/10.3171/2019.9.focus19611
231. Kanan R, Sarna R, Bharti N, Panda NB, Chauhan R, Singh N, et al. Evaluation of the changes in middle cerebral artery flow velocity related to different positions of patients during posterior fossa surgery. Surg Neurol Int [Internet]. 2022 Nov 18;13:541. Available from: https://doi.org/10.25259/sni_874_2022
232. Naqvi J, Yap KH, Ahmad G, Ghosh J. Transcranial Doppler Ultrasound: A Review of the Physical Principles and Major Applications in Critical Care. Int J Vasc Med [Internet]. 2013;2013:1–13. Available from: https://doi.org/10.1155/2013/629378
233. White H, Venkatesh B. Applications of transcranial Doppler in the ICU: a review. Intensive Care Med [Internet]. 2006 Jul 10;32(7):981–94. Available from: https://doi.org/10.1007/s00134-006-0173-y
234. Willie CK, Colino FL, Bailey DM, Tzeng YC, Binsted G, Jones LW, et al. Utility of transcranial Doppler ultrasound for the integrative assessment of cerebrovascular function. J Neurosci Methods [Internet]. 2011 Mar;196(2):221–37. Available from: https://doi.org/10.1016/j.jneumeth.2011.01.011
235. Purkayastha S, Sorond F. Transcranial Doppler Ultrasound: Technique and Application. Semin Neurol [Internet]. 2013 Jan 29;32(4):411–20. Available from: https://doi.org/10.1055/s-0032-1331812
236. Lohmann H, Ringelstein EB, Knecht S. Functional Transcranial Doppler Sonography. In: Handbook on Neurovascular Ultrasound [Internet]. Basel: KARGER; 2006. p. 251–60. Available from: https://doi.org/10.1159/000092437

237. Moppett IK, Mahajan RP. Transcranial Doppler ultrasonography in anaesthesia and intensive care. Br J Anaesth [Internet]. 2004 Nov;93(5):710–24. Available from: https://doi.org/10.1093/bja/aeh205
238. Gunda ST, Ng TKV, Liu T-Y, Chen Z, Han X, Chen X, et al. A Comparative Study of Transcranial Color-Coded Doppler (TCCD) and Transcranial Doppler (TCD) Ultrasonography Techniques in Assessing the Intracranial Cerebral Arteries Haemodynamics. Diagnostics [Internet]. 2024 Feb 10;14(4):387. Available from: https://doi.org/10.3390/diagnostics14040387
239. Rabut C, Yoo S, Hurt RC, Jin Z, Li H, Guo H, et al. Ultrasound Technologies for Imaging and Modulating Neural Activity. Neuron [Internet]. 2020 Oct;108(1):93–110. Available from: https://doi.org/10.1016/j.neuron.2020.09.003
240. Ren J, Li J, Chen S, Liu Y, Ta D. Unveiling the potential of ultrasound in brain imaging: Innovations, challenges, and prospects. Ultrasonics [Internet]. 2025 Jan;145:107465. Available from: https://doi.org/10.1016/j.ultras.2024.107465
241. Školoudík D, Walter U. Method and Validity of Transcranial Sonography in Movement Disorders. In 2010. p. 7–34. Available from: https://doi.org/10.1016/s0074-7742(10)90002-0
242. Rigamonti A, Ackery A, Baker AJ. Transcranial Doppler monitoring in subarachnoid hemorrhage: a critical tool in critical care. Can J Anesth Can d'anesthésie [Internet]. 2008 Feb;55(2):112–23. Available from: https://doi.org/10.1007/bf03016323
243. Chacón-Lozsán F, Rodríguez-Torres M, Pacheco C. Neuromonitorización hemodinámica por ultrasonido en el paciente crítico: ultrasonido transcraneal. Acta Colomb Cuid Intensivo [Internet]. 2018 Jul;18(3):164–74. Available from: https://doi.org/10.1016/j.acci.2018.01.002
244. MIYAZAKI M, KATO K. Measurement of Cerebral Blood Flow by Ultrasonic Doppler Technique : THEORY. Jpn Circ J [Internet]. 1965;29(4):375–82. Available from: https://doi.org/10.1253/jcj.29.375
245. D'Andrea A, Conte M, Cavallaro M, Scarafile R, Riegler L, Cocchia R, et al. Transcranial Doppler ultrasonography: From methodology to major clinical applications. World J Cardiol [Internet]. 2016;8(7):383. Available from: http://dx.doi.org/10.4330/wjc.v8.i7.383
246. Sharma VK, Wong KS, Alexandrov A V. Transcranial Doppler. In 2016. p. 124–40. Available from: https://doi.org/10.1159/000448309
247. Ringelstein EB, Kahlscheuer B, Niggemeyer E, Otis SM. Transcranial doppler sonography: Anatomical landmarks and normal velocity values. Ultrasound Med Biol [Internet]. 1990 Jan;16(8):745–61. Available from: https://doi.org/10.1016/0301-5629(90)90039-F
248. Tegeler CH, Crutchfield K, Katsnelson M, Kim J, Tang R, Passmore Griffin L, et al. Transcranial Doppler Velocities in a Large, Healthy Population. J Neuroimaging [Internet]. 2013 Jul 15;23(3):466–72. Available from: https://doi.org/10.1111/j.1552-6569.2012.00711.x
249. Barbosa MF, Abdala N, Carrete Jr. H, Nogueira RG, Nalli DR, Fonseca JRF, et al. Doppler transcraniano convencional em voluntários assintomáticos:

variabilidade e valores de referência para parâmetros de fluxo sanguíneo. Arq Neuropsiquiatr [Internet]. 2006 Sep;64(3b):829–38. Available from: https://doi.org/10.1590/S0004-282X2006000500023

250. Franco M, Ariza-Araújo Y, Mejía-Mantilla JH. Estimación de valores hemodinámicos mediante el uso del doppler transcraneal en un grupo de voluntarios habitantes de Cali (Colombia), una ciudad a 995 m sobre el nivel del mar. Imagen Diagnóstica [Internet]. 2015 Jul;6(2):49–56. Available from: http://dx.doi.org/10.1016/j.imadi.2015.06.003
251. Lau VI, Jaidka A, Wiskar K, Packer N, Tang JE, Koenig S, et al. Better With Ultrasound. Chest [Internet]. 2020 Jan;157(1):142–50. Available from: https://doi.org/10.1016/j.chest.2019.08.2204
252. Brouwers PJAM, Vriens EM, Musbach M, Wieneke GH, Van Huffelen AC. Transcranial pulsed doppler measurements of blood flow velocity in the middle cerebral artery: reference values at rest and during hyperventilation in healthy children and adolescents in relation to age and sex. Ultrasound Med Biol [Internet]. 1990 Jan;16(1):1–8. Available from: https://doi.org/10.1016/0301-5629(90)90079-R
253. Velázquez Gutiérrez OD, Vázquez Aguilar A, Ortega Pérez AQ, Sarmiento Castillo VA, Gaona Valle LS, Negrete Peña A. Uso del Doppler transcraneal en la titulación de la presión de perfusión cerebral en pacientes con traumatismo craneoencefálico severo. Med Crítica [Internet]. 2024;38(8):636–43. Available from: https://doi.org/10.35366/120009
254. Tsivgoulis G, Alexandrov A V., Sloan MA. Advances in transcranial doppler ultrasonography. Curr Neurol Neurosci Rep [Internet]. 2009 Jan 16;9(1):46–54. Available from: https://doi.org/10.1007/s11910-009-0008-7
255. Brasil S, Cardim D, Caldas J, Robba C, Taccone FS, De-Lima-Oliveira M, et al. Predicting short-term outcomes in brain-injured patients: a comprehensive approach with transcranial Doppler and intracranial compliance assessment. J Clin Monit Comput [Internet]. 2024 Dec 6;38(6):1237–47. Available from: https://doi.org/10.1007/s10877-024-01181-y
256. Yeo L, Sharma V. Role of Transcranial Doppler Ultrasonography in Cerebrovascular Disease. Recent Pat CNS Drug Discov [Internet]. 2010 Jan 1;5(1):1–13. Available from: https://doi.org/10.2174/157488910789753576
257. Sharma VK, Tsivgoulis G, Lao AY, Alexandrov A V. Role of transcranial Doppler ultrasonography in evaluation of patients with cerebrovascular disease. Curr Neurol Neurosci Rep [Internet]. 2007 Jan 16;7(1):8–20. Available from: https://doi.org/10.1007/s11910-007-0016-4
258. Pan Y, Wan W, Xiang M, Guan Y. Transcranial Doppler Ultrasonography as a Diagnostic Tool for Cerebrovascular Disorders. Front Hum Neurosci [Internet]. 2022 Apr 29;16. Available from: https://doi.org/10.3389/fnhum.2022.841809
259. Neill MG, Burma JS, Miutz LN, Kennedy CM, Penner LC, Newel KT, et al. Transcranial Doppler Ultrasound and Concussion–Supplemental Symptoms with Physiology: A Systematic Review. J Neurotrauma [Internet]. 2024 Jul 1;41(13–14):1509–23. Available from: https://doi.org/10.1089/neu.2023.0421
260. Finnsdóttir H, Szegedi I, Oláh L, Csiba L. The applications of transcranial

doppler in ischemic stroke. Ideggyogy Sz [Internet]. 2020;73(11–12):367–78. Available from: https://doi.org/10.18071/isz.73.0367
261. Markus HS. Transcranial Doppler ultrasound. Br Med Bull [Internet]. 2000 Jan 1;56(2):378–88. Available from: https://doi.org/10.1258/0007142001903021
262. Akif Topcuoglu M. Transcranial Doppler ultrasound in neurovascular diseases: diagnostic and therapeutic aspects. J Neurochem [Internet]. 2012 Nov 11;123(s2):39–51. Available from: https://doi.org/10.1111/j.1471-4159.2012.07942.x
263. Bertuetti R, Gritti P, Pelosi P, Robba C. How to use cerebral ultrasound in the ICU. Minerva Anestesiol [Internet]. 2020 Mar;86(3). Available from: https://doi.org/10.23736/s0375-9393.19.13852-7
264. Robba C, Goffi A, Geeraerts T, Cardim D, Via G, Czosnyka M, et al. Brain ultrasonography: methodology, basic and advanced principles and clinical applications. A narrative review. Intensive Care Med [Internet]. 2019 Jul 25;45(7):913–27. Available from: https://doi.org/10.1007/s00134-019-05610-4
265. Krishna V, Sammartino F, Rezai A. A Review of the Current Therapies, Challenges, and Future Directions of Transcranial Focused Ultrasound Technology. JAMA Neurol [Internet]. 2018 Feb 1;75(2):246. Available from: https://doi.org/10.1001/jamaneurol.2017.3129
266. Hakimi R, Alexandrov A V., Garami Z. Neuro-ultrasonography. Neurol Clin [Internet]. 2020 Feb;38(1):215–29. Available from: https://doi.org/10.1016/j.ncl.2019.09.006
267. Rajajee V. Transcranial Ultrasound in the Neurocritical Care Unit. Neuroimaging Clin N Am [Internet]. 2024 May;34(2):191–202. Available from: https://doi.org/10.1016/j.nic.2023.11.001
268. Hashemilar M, Partovi A, Forghani N, Sharifipour E. Comparison of transcranial doppler ultrasound indices in large and small vessel disease cerebral infarction. Curr J Neurol [Internet]. 2022 Jan 12; Available from: https://doi.org/10.18502/cjn.v20i4.8349
269. Baumgartner R, Baumgartner I. Transkranielle Doppler- und Farbduplexsonographie. Ultraschall der Medizin [Internet]. 2008 Mar 7;17(2):50–4. Available from: https://doi.org/10.1055/s-2007-1003146
270. Lau VI, Arntfield RT. Point-of-care transcranial Doppler by intensivists. Crit Ultrasound J [Internet]. 2017 Dec 13;9(1):21. Available from: https://doi.org/10.1186/s13089-017-0077-9
271. Montrief T, Alerhand S, Jewell C, Scott J. Incorporation of Transcranial Doppler into the ED for the neurocritical care patient. Am J Emerg Med [Internet]. 2019 Jun;37(6):1144–52. Available from: https://doi.org/10.1016/j.ajem.2019.03.003
272. Tarzi FP, Bulic S, Ho S, Saini P, Alexandrov A, Bronshteyn YS. Point of Care Transcranial Color-Coded Duplex Ultrasound of the Middle Cerebral Artery. J Vis Exp [Internet]. 2024 Aug 9;(210). Available from: https://doi.org/10.3791/67288
273. Gröschel K, Harrer JU, Schminke U, Stegemann E, Allendörfer J. Ultrasound assessment of brain supplying arteries (transcranial). Ultraschall der Medizin

- Eur J Ultrasound [Internet]. 2023 Oct 13;44(5):468–86. Available from: https://doi.org/10.1055/a-2103-4981
274. Garami Z, Alexandrov A V. Neurosonology. Neurol Clin [Internet]. 2009 Feb;27(1):89–108. Available from: https://doi.org/10.1016/j.ncl.2008.09.010
275. Widder B. Transkranielle Doppler- und Duplexsonographie - Wo ist die Methode hilfreich?*. Ultraschall der Medizin [Internet]. 2008 Mar 7;15(4):174–7. Available from: https://doi.org/10.1055/s-2007-1003960
276. Georgiadis D, Siebler M. Detection of Microembolic Signals with Transcranial Doppler Ultrasound. In: Handbook on Neurovascular Ultrasound [Internet]. Basel: KARGER; 2006. p. 194–205. Available from: https://doi.org/10.1159/000092401
277. Pérez-Calatayud ÁA, Carrillo-Esper R, Gasca-Aldama JC, Linarte-Basilio ME, Anica-Malagón ED, Briones-Garduño JC. Neuromonitoreo ultrasonográfico en el perioperatorio: diámetro de la vaina del nervio óptico y Doppler transcraneal. Cir Cir [Internet]. 2019 Aug 5;87(5). Available from: https://doi.org/10.24875/ciru.18000501
278. Burstein B, Tabi M, Barsness GW, Bell MR, Kashani K, Jentzer JC. Association between mean arterial pressure during the first 24 hours and hospital mortality in patients with cardiogenic shock. Crit Care [Internet]. 2020 Dec 20;24(1):513. Available from: https://doi.org/10.1186/s13054-020-03217-6
279. Gutierrez J, Esenwa C. Secondary stroke prevention: challenges and solutions. Vasc Health Risk Manag [Internet]. 2015 Aug;437. Available from: https://doi.org/10.2147/vhrm.s63791
280. Fatima N, Shuaib A, Chughtai T, Ayyad A, Saqqur M. The role of transcranial doppler in traumatic brain injury: A systemic review and meta-analysis. Asian J Neurosurg [Internet]. 2019 Sep 9;14(3):626–33. Available from: https://doi.org/10.4103/ajns.ajns_42_19
281. Ziegler D, Cravens G, Poche G, Gandhi R, Tellez M. Use of Transcranial Doppler in Patients with Severe Traumatic Brain Injuries. J Neurotrauma [Internet]. 2017 Jan;34(1):121–7. Available from: https://doi.org/10.1089/neu.2015.3967
282. Murillo-Cabezas F, Arteta-Arteta D, Flores-Cordero JM, Muñoz-Sánchez MA, Rincón-Ferrari MD, Rivera-Fernández MV, et al. Utilidad del doppler transcraneal en la fase precoz del traumatismo craneoencefálico. Neurocirugia [Internet]. 2002;13(3):196–208. Available from: https://doi.org/10.1016/s1130-1473(02)70617-9
283. Álvarez-Fernández JA, Martín-Velasco MM, Igeño-Cano JC, Pérez-Quintero R. Utilidad del Doppler transcraneal en la resucitación de la parada cardíaca. Med Intensiva [Internet]. 2010 Nov;34(8):550–8. Available from: https://doi.org/10.1016/j.medin.2009.12.007
284. Moreno JA, Mesalles E, Gener J, Tomasa A, Ley A, Roca J, et al. Evaluating the outcome of severe head injury with transcranial Doppler ultrasonography. Neurosurg Focus [Internet]. 2000 Jan;8(1):1–7. Available from: https://doi.org/10.3171/foc.2000.8.1.1702

285. Thilak S, Brown P, Whitehouse T, Gautam N, Lawrence E, Ahmed Z, et al. Diagnosis and management of subarachnoid haemorrhage. Nat Commun [Internet]. 2024 Feb 29;15(1):1850. Available from: https://doi.org/10.1038/s41467-024-46015-2
286. Abdulazim A, Heilig M, Rinkel G, Etminan N. Diagnosis of Delayed Cerebral Ischemia in Patients with Aneurysmal Subarachnoid Hemorrhage and Triggers for Intervention. Neurocrit Care [Internet]. 2023 Oct 3;39(2):311–9. Available from: https://doi.org/10.1007/s12028-023-01812-3
287. Gura M, Elmaci I, Sari R, Coskun N. Correlation of pulsatility index with intracranial pressure in traumatic brain injury. Turk Neurosurg [Internet]. 2010; Available from: https://doi.org/10.5137/1019-5149.jtn.3574-10.1
288. Ryu J, Ko N, Hu X, Shadden SC. Numerical Investigation of Vasospasm Detection by Extracranial Blood Velocity Ratios. Cerebrovasc Dis [Internet]. 2017;43(5–6):214–22. Available from: https://doi.org/10.1159/000454992
289. Kook Kang J, Kalra A, Ameen Ahmad S, Kumar Menta A, Rando HJ, Chinedozi I, et al. A recommended preclinical extracorporeal cardiopulmonary resuscitation model for neurological outcomes: A scoping review. Resusc Plus [Internet]. 2023 Sep;15:100424. Available from: https://doi.org/10.1016/j.resplu.2023.100424
290. Said AS, Guilliams KP, Bembea MM. Neurological Monitoring and Complications of Pediatric Extracorporeal Membrane Oxygenation Support. Pediatr Neurol [Internet]. 2020 Jul;108:31–9. Available from: https://doi.org/10.1016/j.pediatrneurol.2020.03.014
291. Ract C, Le Moigno S, Bruder N, Vigué B. Transcranial Doppler ultrasound goal-directed therapy for the early management of severe traumatic brain injury. Intensive Care Med [Internet]. 2007 Apr 27;33(4):645–51. Available from: https://doi.org/10.1007/s00134-007-0558-6
292. Robba C, Cardim D, Tajsic T, Pietersen J, Bulman M, Donnelly J, et al. Ultrasound non-invasive measurement of intracranial pressure in neurointensive care: A prospective observational study. Schreiber M, editor. PLOS Med [Internet]. 2017 Jul 25;14(7):e1002356. Available from: https://doi.org/10.1371/journal.pmed.1002356
293. Fischer M, Böttiger BW, Hossmann K-A, Popov-Cenic S. Thrombolysis using plasminogen activator and heparin reduces cerebral no-reflow after resuscitation from cardiac arrest: An experimental study in the cat. Intensive Care Med [Internet]. 1996 Nov;22(11):1214–23. Available from: https://doi.org/10.1007/bf01709339
294. Latin American Consensus on the use of transcranial Doppler in the diagnosis of brain death. Rev Bras Ter Intensiva [Internet]. 2014;26(3). Available from: https://doi.org/10.5935/0103-507x.20140035
295. Donnelly J, Aries MJ, Czosnyka M. Further understanding of cerebral autoregulation at the bedside: possible implications for future therapy. Expert Rev Neurother [Internet]. 2015 Feb 23;15(2):169–85. Available from: https://doi.org/10.1586/14737175.2015.996552
296. Czosnyka M, Smielewski P, Piechnik S, Steiner LA, Pickard JD. Cerebral

autoregulation following head injury. J Neurosurg [Internet]. 2001 Nov;95(5):756–63. Available from: https://doi.org/10.3171/jns.2001.95.5.0756
297. Buunk G. Cerebral blood flow after cardiac arrest. Neth J Med [Internet]. 2000 Sep;57(3):106–12. Available from: https://doi.org/10.1016/s0300-2977(00)00059-0
298. Rodríguez Vargas ML, Godínez García F, Gómez González N, Jiménez Correa C, González Carrillo PL. Concordancia en la detección de vasoespasmo en pacientes críticos con hemorragia subaracnoidea por médicos residentes vs especialistas. Med Crítica [Internet]. 2024;38(6):490–6. Available from: https://dx.doi.org/10.35366/119238
299. Rasulo FA, Calza S, Robba C, Taccone FS, Biasucci DG, Badenes R, et al. Transcranial Doppler as a screening test to exclude intracranial hypertension in brain-injured patients: the IMPRESSIT-2 prospective multicenter international study. Crit Care [Internet]. 2022 Dec 15;26(1):110. Available from: https://dx.doi.org/10.1186/s13054-022-03978-2
300. Fatima N, Shuaib A, Chughtai TS, Ayyad A, Saqqur M. The role of transcranial Doppler in traumatic brain injury: A systemic review and meta-analysis. Asian J Neurosurg. 2019;14(3):626-633. doi:10.4103/ajns.AJNS_42_19.
301. Reichenbach A, Alteheld L, Henriksen J, Nakstad ER, Andersen GØ, Sunde K, et al. Transcranial Doppler during the first week after cardiac arrest and association with 6-month outcomes. Front Neurol. 2023;14:1222401. doi:10.3389/fneur.2023.1222401.
302. Ziegler D, Cravens G, Poche G, Gandhi R, Tellez M. Use of Transcranial Doppler in Patients with Severe Traumatic Brain Injuries. J Neurotrauma. 2016. doi:10.1089/neu.2015.3967.