**Suppl. Tab. 1** Literature Review – Published studies of patients with BSCM managed conservatively

|  |
| --- |
| Conservative Management of BSCM |
| Nr. | Study | No. of patients | BSCM associated DeathNo. of patients(%) | Average follow-up time in months |
| 1 | Zimmerman et al. 1991 [1] | 8 | 1 (12.5) | ND |
| 2 | Preul et al. 1992 [2] | 5 | 0 (0%) | 30 |
| 3 | Fritschi et al. 1994 [3] | 30 | 6 (20%) | 35.7 |
| 4 | Kondziolka et al. 1995 [4] | 43 | 0 (0%) | 34 |
| 5 | Bouillot et al. 1996 [5] | 8 | 0 (0%) | 67 |
| 6 | Porter et al., 1999 [6] | 14 | 1 (7.1%) | 35 |
| 7 | Kupersmith et al. 2001 [7] | 25 | 0 (0%) | 40.8 |
| 8 | Mathiesen et al. 2003 [8] | 34 | 0 (0%) | 48 |
| 9 | Cantu et al. 2005 [9] | 25 | 0 (0%) | 60 |
| 10 | Tarnaris et al. 2007 [10] | 15 | 0 (0%) | 79.7 |
| 11 | Bhardwaj et al. 2009 [11] | 13 | 0 (0%) | ND |
| 12 | Chen et al., 2011 [12] | 17 | 0 (0%) | 40 |
| 13 | Al-Holou et al. 2012 [13] | 15 | 0 (0%) | 42 |
| 14 | Chotai et a. 2013 [14] | 5 | 0 (0%) | 48 |
| 15 | Li et al. 2014 [15] | 237 | 3 (1.3) | 78 |
| 16 | Li et al. 2014 [16] | 85 | 0 (0%) | 56.4 |
| 17 | Menon et al. 2011 [17] | 29 | 1 (3.7%) | 48.0 |
| 18 | Amato et al., 2013 [18] | 2 | 0 (0%) | 49.2 |
| 19 | Moultrie et al. 2014 [19] | 16 | 1 (6.6%) | 35 |
| 20 | Arauz et al. 2017 [20] | 51 | 5 (9.8%) | 39.6 |
| 21 | Li et al. 2020 [21] | 520 | 11 (2.1) | 57.6 |
| 22 | Current Series | 54 | 0 (0%) | 62.5 |
|  | Total, n (%) | 1251 | 29/1251 (2.3 %, 95% CI: 1.6 to 3.3) |  |

**Suppl. Tab. 2** Literature Review – Published studies of patients with BSCM managed surgically

|  |
| --- |
| Surgical Treatment of BSCM |
| Nr. | Study | No. of patients | BSCM associated DeathNo. of patients(%) | Average follow-up time in months |
| 1 | Yasargil et al. 1988 [22] | 5 | 0 (0%) | ND |
| 2 | Lapras et al., 1989 [23] | 9 | 0 (0%) | ND |
| 3 | Weil et al., 1990 [24]  | 6 | 0 (0%) | ND |
| 4 | Bertalanffy et al., 1991[25] | 13 | 0 (0%) | 16 |
| 5 | Fahlbusch et al., 1991 [26] | 9 | 0 (0%) | 15 |
| 6 | Pendl et al., 1991[27] | 5 | 0 (0%) | ND |
| 7 | Sakai et al., 1991 [28] | 5 | 0 (0%) | ND |
| 8 | Symon et al., 1991 [29] | 7 | 0 (0%) | 13 |
| 9 | Zimmerman et al. 1991 [1] | 16 | 0 (0%) | ND |
| 10 | Mizoi et al., 1992 [30] | 6 | 0 (0%) | ND |
| 11 | Scott et al., 1992 [31] | 4 | 0 (0%) | 57 |
| 12 | Isamat et al., 1993 [32] | 6 | 0 (0%) | ND |
| 13 | Fritschi et al., 1994 [3]  | 93 | 0 (0%) | 30.3 |
| 14 | Bricolo et al., 1995[33] | 18 | 1 (6%) | ND |
| 15 | Eisner et al., 1995[34] | 9 | 0 (0%) | 6 |
| 16 | Houtteville, 1995[35] | 5 | 0 (0%) | 0 |
| 17 | Bouillot et al., 1996[5] | 17 | 2 (12%) | 51 |
| 18 | Di Rocco et al., 1997[36]  | 3 | 0 (0%) | ND |
| 19 | Pechstein et al., 1997[37] | 7 | 0 (0%) | ND |
| 20 | Amin-Hanjani et al., 1998[38] | 14 | 0 (0%) | 18 |
| 21 | Chaskis et al., 1998[39] | 7 | 0 (0%) | ND |
| 22 | Fukui et al., 1998[40] | 3 | 0 (0%) | ND |
| 23 | Cantore et al., 1999[41] | 11 | 2 (18%) | 25 |
| 24 | Morcos et al., 1999 [42] | 5 | 0 (0%) | ND |
| 25 | Ziyal et al., 1999 [43] | 9 | 0 (0%) | 49 |
| 26 | Porter et al., 1999[6] | 86 | 3 (3.5%) | 35 |
| 27 | Sindou et al., 2000 [44] | 12 | 0 (0%) | 66 |
| 28 | Attar et al., 2001 [45] | 4 | 1 (25%) | ND |
| 29 | Mao et al., 2001 [46] | 14 | 0 (0%) | ND |
| 30 | Kupersmith et al., 2001 [7] | 12 | 0 (0%) | 40.8 |
| 31 | Samii et al., 2001 [47] | 36 | 0 (0%) | 22 |
| 32 | Shehab et al., 2001 [48] | 4 | 0 (0%) | ND |
| 33 | Bertalanffy et al., 2002 [49] | 24 | 0 (0%) | 6 |
| 34 | Lena et al., 2002 [50] | 7 | 1 (14.2%) | ND |
| 35 | Sandalciouglu et al., 2002 [51] | 12 | 0 (0%) | 44 |
| 36 | Vinas et al., 2002 [52] | 8 | 0 (0%) | ND |
| 37 | Esposito et al., 2003 [53] | 13 | 0 (0%) | 47 |
| 38 | Mathiesen et al., 2003[8]  | 17 | 1 (5.8%) | 55 |
| 39 | Seifert et al., 2003 [54] | 4 | 0 (0%) | ND |
| 40 | Smith et al., 2003 [55] | 7 | 0 (0%) | 12 |
| 41 | Wang et al., 2003 [56] | 137 | 1 (0.7%) | 52 |
| 42 | Kikuta et al., 2004 [57] | 10 | 0 (0%) | 102 |
| 43 | Ferroli et al., 2005 [58] | 52 | 1 (1.9%) | 56 |
| 44 | Bruneau et al., 2006 [59] | 22 | 0 (0%) | 45 |
| 45 | Steiger et al., 2006 [60] | 3 | 0 (0%) | ND |
| 46 | Zausinger et al., 2006 [61] | 13 | 0 (0%) | 8 |
| 47 | Alves de Sousa, 2007 [62] | 13 | 1 (8%) | ND |
| 48 | Batay et al., 2007 [63] | 4 | 0 (0%) | ND |
| 49 | Chen et al., 2007 [64] | 7 | 0 (0%) | 3 |
| 50 | Nataf et al., 2007 [65] | 19 | 1 (5%) | ND |
| 51 | Sola et al., 2007 [66] | 17 | 0 (0%) | 44 |
| 52 | Cenzato et al., 2008 [67] | 30 | 0 (0%) | ND |
| 53 | Tarnaris et al., 2008[10] | 6 | 0 (0%) | 79.7 |
| 54 | Bhardwaj et al., 2009 [11] | 7 | 0 (0%) | ND |
| 55 | Hauck et al., 2009 [68] | 44 | 0 (0%) | 11 |
| 56 | Li et al., 2009 [69] | 37 | 0 (0%) | 22 |
| 57 | Consales et al., 2010 [70] | 4 | 0 (0%) | 48 |
| 58 | Francois et al., 2010 [71] | 9 | 0 (0%) | 102 |
| 59 | Huang et al., 2010 [72] | 22 | 0 (0%) | 49 |
| 60 | Ichinose et al., 2010 [73] | 10 | 0 (0%) | ND |
| 61 | Ohue et al., 2010 [74] | 36 | 0 (0%) | 12 |
| 62 | Chen et al., 2011[12] | 55 | 0 (0%) | 49 |
| 63 | Dukatz et al., 2011[75] | 71 | 0 (0%) | 17 |
| 64 | Menon et al., 2011[17] | 23 | 2 (8.7%) | 42 |
| 65 | Ramina et al., 2011[76] | 43 | 0 (0%) | ND |
| 66 | Steno et al., 2011[77] | 9 | 2 (22%) | ND |
| 67 | de Aguiar et al., 2012[78] | 13 | 1 (8%) | 71.3 |
| 68 | Gross et al., 2012[79]  | 3 | 0 (0%) | ND |
| 69 | Sabatino et al., 2012[80] | 10 | 0 (0%) | 70 |
| 70 | Wostrack et al., 2012 [81] | 16 | 0 (0%) | 14 |
| 71 | Amato et al., 2013 [18] | 3 | 0 (0%) | 49.2 |
| 72 | Bradac et al., 2013 [82] | 37 | 2 (5.3%) | 39 |
| 73 | Chotai et al., 2013 [14] | 52 | 1 (1.9%) | 48 |
| 74 | Li et al., 2013 [83] | 242 | 2 (0.8%) | 89.4 |
| 75 | Mai et al., 2013 [84] | 22 | 0 (0%) | 26.6 |
| 76 | Pandey et al., 2013 [85] | 136 | 5 (3.7%) | 29.2 |
| 77 | Schwartz et al., 2013 [86] | 35 | 0 (0%) | 44 |
| 78 | Chen et al., 2014 [87] | 38 | 0 (0%) | 9.7 |
| 79 | Garcia et al., 2015 [88] | 104 | 1 (1%) | 18.5 |
| 80 | Sawarkar et al., 2015 [89] | 9 | 0 (0%) | 47 |
| 81 | Wang et al., 2015 [90]  | 23 | 0 (0%) | 42 |
| 82 | Cornelius et al., 2016 [91] | 60 | 0 (0%) | 43 |
| 83 | Kaku et al., 2016 [92] | 16 | 0% (0) | ND |
| 84 | Zhang et al., 2017 [93] | 120 | 2 (1.7%) | 50.7 |
| 85 | Arauz et al. 2017 [20] | 48 | 1 (2.1%) | 27.8 |
| 86 | Nathal et al., 2017 [94] | 50 | 0 (0%) | 47 |
| 87 | Ren et al., 2017 [95] | 34 | 0 (0%) | 46.6 |
| 88 | Zaidi et al., 2017 [96] | 397 | 4 (1%) | 35.5 |
| 89 | Liu et al., 2018 [97]  | 10 | 0 (0%) | 72 |
| 90 | Li et al. 2018 [98] | 47 | 0 (0%) | 30.6 |
| 91 | Negoto et al., 2018  | 9 | 0 (0%) | 26 |
| 92 | Tumturk et al. 2018 [99] | 4 | 0 (0%) | 40.5 |
| 93 | Xie et al., 2018 [100] | 69 | 3 (4%) | 35.3 |
| 94 | Abhinav et al., 2019 [101] | 15 | 0 (0%) | 9 |
| 95 | Gui et al., 2019 [102] | 67 | 0 (0%) | 51.7 |
| 96 | Lashkarivand et. al., 2019 [103] | 22 | 0 (0%) | 45.3 |
| 97 | Tsuji et al., 2019 [104] | 72 | 0 (0%) | 97.1 |
| 98 | Li et al. 2020 [21] | 173 | 0 (0%) | 57.6 |
| 99 | Current Series | 64 | 0 (0%) | 72.5 |
|  | Total, n (%) | 3275 | 41/3275 (1.3%, 95% CI: 0.9 to 1.7) |  |

**Suppl. Tab. 3** Causes of BSCM-associated mortality in patients managed conservatively

|  |  |  |
| --- | --- | --- |
| Causes of BSCM-associated mortality | No. of patients(%, total n=29) | Reported Cases |
| Causes of death not further clarified – however, stated that BSCM-associated | 23 (79.3%) | [3,6,20,21] |
| Recurrent hemorrhage | 4 (13.7%) | [15,17] |
| Tectal hemorrhage with hydrocephalus | 1 (3.5%) | [1] |
| Pneumonia caused by progressive neurologic deficits from BSCM | 1 (3.5%) | [19] |
| Total, n | 29 |  |

**Suppl. Tab. 4** Causes of BSCM-associated mortality in patients managed surgically

|  |  |  |
| --- | --- | --- |
| Causes of BSCM-associated mortality | No. of patients(%, total n=41) | Reported Cases |
| Cranial nerve palsy with respiratory failure/pneumonia | 10 (24.4%) | [[14,56,58,77,93,96,100,105] |
| Causes of death not further clarified – however, stated that deaths were attributable to surgery | 7 (17.1%) | [5,17,20,33,62,65,78] |
| Cardiopulmonary arrest | 3 (7.3%) | [6,85] |
| Rebleeding of incomplete resected BSCM | 3 (7.3%) | [8,41,50] |
| Brainstem hemorrhage/hematoma | 2 (4.8%) | [85,96] |
| Brainstem Injury | 2 (4.8%) | [85] |
| Cerebellar hematoma/hemorrhage | 2 (4.8%) | [96,105] |
| Cerebellar infarction | 2 (4.8%) | [6,100] |
| Air embolism | 1 (2.4%) | [82] |
| Brainstem venous infarction | 1 (2.4%) | [82] |
| Intracranial hematoma | 1 (2.4%) | [83] |
| Locked in syndrome | 1 (2.4%) | [85] |
| Postoperative apnea, global ischemia | 1 (2.4%) | [88] |
| Postoperative depression | 1 (2.4%) | [100] |
| Pulmonary embolism | 1 (2.4%) | [83] |
| Shunt infection | 1 (2.4%) | [41] |
| SSDH-Supratentorial subdural hematoma | 1 (2.4%) | [45] |
| Ventriculitis | 1 (2.4%) | [96] |
| Total, n | 41 |  |

**References**

1. Zimmermann RS, Spetzler RF, Lee KS, Zabramski JM, Hargraves RW. Cavernous malformations of the brain stem. J Neurosurg. 1991;75:32–9.

2. Preul MC, Villemure JG, Leblanc R, Del Carpio-O’donovan R. MRI Diagnosis of Brainstem Cavernous Angiomas Presenting as Tumours. Can J Neurol Sci / J Can des Sci Neurol. 1992;(19):376–82.

3. Fritschi JA, Reulen J, Spetzler RF, Zabramski JM. Brainstem Carvenous Hemangioma. Acta Neurochir (Wien). 1994;130:35–46.

4. Kondziolka D, Lunsford LD, Kestle J. The natural history of cerebral cavernous malformations in children. J Neurosurg. 1995;83(2):820–4.

5. Bouillot P, Dufour H, Roche PH, Lena G, Graziani N, Grisoli F. [Angiographically occult vascular malformations of the brain stem. Apropos of 25 cases]. Neurochirurgie. 1996;42:4–5.

6. Porter RW, Detwiler PW, Spetzler RF, et al. Cavernous malformations of the brainstem: Experience with 100 patients. J Neurosurg. 1999;Jan(1):50–8.

7. Kupersmith MJ, Kalish H, Epstein F, et al. Natural history of brainstem cavernous malformations. Neurosurgery. 2001;48(1):47–54.

8. Mathiesen T, Edner G, Kihlström L. Deep and brainstem cavernomas: A consecutive 8-year series. J Neurosurg. 2003;99(1):31–7.

9. Cantu C, Murillo-Bonilla L, Arauz A, Higuera J, Padilla J, Barinagarrementeria F. Predictive factors for intracerebral hemorrhage in patients with cavernous angiomas. Neurol Res. 2005;27(3):314–8.

10. Tarnaris A, Fernandes RP, Kitchen ND. Does conservative management for brain stem cavernomas have better long-term outcome? Br J Neurosurg. 2008;22(6):748–57.

11. Bhardwaj RD, Auguste KI, Kulkarni A V., Dirks PB, Drake JM, Rutka JT. Management of pediatric brainstem cavernous malformations: Experience over 20 years at the Hospital for Sick Children: Clinical article. J Neurosurg Pediatr. 2009;4(5):458–64.

12. Chen L, Zhao Y, Zhou L, Zhu W, Pan Z, Mao Y. Surgical Strategies in Treating Brainstem Cavernous Malformations Liang. Neurosurgery. 2011;68(3):609–21.

13. Al-Holou WN, O’Lynnger TM, Pandey AS, et al. Natural history and imaging prevalence of cavernous malformations in children and young adults. Clinical article. J Neurosurg Pediatr. 2012;9(2):98–205.

14. Chotai S, Qi S, Xu S. Prediction of outcomes for brainstem cavernous malformation. Clin Neurol Neurosurg [Internet]. 2013;115(10):2117–23.

15. Li DA, Hao SYU, Jia GJ, Wu Z, Zhang LIW, Zhang JT. Hemorrhage risks and functional outcomes of untreated brainstem cavernous malformations: Clinical article. J Neurosurg. 2014;121(1):32–41.

16. Li D, Hao SY, Tang J, et al. Clinical course of untreated pediatric brainstem cavernous malformations: Hemorrhage risk and functional recovery Clinical article. J Neurosurg Pediatr. 2014;13(5):471–83.

17. Menon G, Gopalakrishnan C V., Rao BRM, Nair S, Sudhir J, Sharma M. A single institution series of cavernomas of the brainstem. J Clin Neurosci [Internet]. 2011;18(9):1210–4.

18. Amato MCM, Madureira JFG, de Oliveira RS. Angiomas cavernosos intracranianos em crianças: Experiência de um único centro em 30 casos consecutivos. Arq Neuropsiquiatr. 2013;71(4):220–8.

19. Moultrie F, Horne MA, Josephson CB, et al. Outcome after surgical or conservative management of cerebral cavernous malformations. Neurology. 2014;83(7):582–9.

20. Arauz A, Patiño-Rodriguez HM, Chavarria-Medina M, Becerril M, Longo GM, Nathal E. Rebleeding and Outcome in Patients with Symptomatic Brain Stem Cavernomas. Cerebrovasc Dis. 2017;43(5–6):283–9.

21. Li D, Wu Z-Y, Liu P-P, et al. Natural history of brainstem cavernous malformations: prospective hemorrhage rate and adverse factors in a consecutive prospective cohort. J Neurosurg. 2020;March 13,:1–12.

22. Yasargil M. AVM of the brain Microneurosurg. IIIB. 1988. 405–438 p.

23. Lapras C, Lapras C, Deruty R, Patet J, Mottolese C. Surgical treatment of intracerebral cavernomas. Neurochirurgie. 1989;35:120–5.

24. Weil S, Tew J. Surgical management of brainstem vascular malformations. Acta Neurochir (Wien). 1990;105:14–23.

25. Bertalanffy H, Gilsbach JM, Eggert HR, Seeger W. Microsurgery of deep-seated cavernous angiomas: Report of 26 cases. Acta Neurochir (Wien). 1991;108:91–9.

26. Fahlbusch R, Strauss C, Huk W. Pontine-mesencephalic cavernomas: indications for surgery and operative results. Acta Neurochir Suppl (Wien). 1991;53:37–41.

27. Pendl G, Vorkapic P, Koniyama M. Microsurgery of midbrain lesions. Neurosurgery. 1990;53:137–43.

28. Sakai N, Yamada H, Tanigawara T, et al. Surgical treatment of cavernous angioma involving the brainstem and review of the literature. Acta Neurochir (Wien) [Internet]. 1991;113(3):138–43.

29. Symon L, Jackowski A, Bills D. Surgical treatment of pontomedullary cavernomas. Br J Neurosurg. 1991;5:339–47.

30. Mizoi K, Yoshimoto T, Suzuki J. Clinical Analysis of Ten Cases with Surgically Treated Brain Stem Cavernous Angiomas. Tohoku J Exp Med. 1992;166:259–67.

31. Scott RM, Barnes P, Kupsky W, Adelman LS. Cavernous angiomas of the central nervous system in children. J Neurosurg. 1992;76:38–46.

32. Isamat F, Conesa G. Cavernous angiomas of the brain stem. Neurosurg Clin N Am. 1993;4:507–18.

33. Bricolo A, Turazzi S. Surgery for gliomas and other mass lesions of the brainstem. Adv Tech Stand Neurosurg [Internet]. 1995;22:261–341.

34. Eisner W, Schmid UD, Reulen HJ, et al. The mapping and continuous monitoring of the intrinsic motor nuclei during brain stem surgery. Neurosurgery. 1995;(37):255–265.

35. Houtteville JP. The surgery of cavernomas both supra-tentorial and infra-tentorial. Adv Tech Stand Neurosurg [Internet]. 1995;22:185–259.

36. Di Rocco C, Iannelli A, Tamburrini G. Cavernous angiomas of the brain stem in children. Pediatr Neurosurg [Internet]. 1997 Aug;27(2):92–9.

37. Pechstein U, Zentner J, Van Roost D, Schramm J. Surgical management of brain-stem cavernomas. Neurosurg Rev [Internet]. 1997;20(2):87–93.

38. Amin-Hanjani S, Ogilvy CS, Ojemann RG, Crowell RM. Risks of surgical management for cavernous malformations of the nervous system. Neurosurgery [Internet]. 1998 Jun;42(6):1220–8.

39. Chaskis C, Brotchi J. The surgical management of cerebral cavernous angiomas. Neurol Res [Internet]. 1998 Oct;20(7):597–606.

40. Fukui M, Matsushima T, Ikezaki K, et al. Surgery of angiomas in the brainstem with a stress on the presence of telangiectasia. Neurol Med Chir (Tokyo) [Internet]. 1998;38 Suppl:250–4.

41. Cantore G, Missori P, Santoro A. Cavernous angiomas of the brain stem. Intra-axial anatomical pitfalls and surgical strategies. Surg Neurol [Internet]. 1999 Jul;52(1):84–94.

42. Morcos JJ, Heros RC, Frank DE. Microsurgical treatment of infratentorial malformations. Neurosurg Clin N Am. 1999;10:41–474.

43. Ziyal IM, Sekhar LN, Salas E, Sen C. Surgical management of cavernous malformations of the brain stem. Br J Neurosurg. 1999;13:366–375.

44. Sindou M, Yada J, Salord F. Functional results after microsurgical resection of brain stem cavernous malformations (Retrospective study of a 12 patient series and review of the recent literature). Acta Neurochir (Wien). 2000;142(8):843–53.

45. Attar A, Ugur HC, Savas A, Yüceer N, Egemen N. Surgical treatment of intracranial cavernous angiomas. J Clin Neurosci [Internet]. 2001 May;8(3):235–9.

46. Mao Y, Zhou L, Du G. Brainstem cavernous hemangioma: surgical indications and approaches. Zhonghua Wai Ke Za Zhi. 2001;39(9):672–4.

47. Samii M, Eghbal R, Carvalho GA, Matthies C. Surgical management of brainstem cavernomas. J Neurosurg. 2001;95:825–832.

48. Shehab ZP, Walsh RM, Thorp MA, Wallace MC, Tymianski M, Rutka JA. Partial labyrinthectomy approach for brainstem vascular lesions. J Otolaryngol. 2001;30:224– 230.

49. Bertalanffy H, Benes L, Miyazawa T, Alberti O, Siegel AM, Sure U. Cerebral cavernomas in the adult. Review of the literature and analysis of 72 surgically treated patients. Neurosurgical Review. 2002.

50. Lena G, Paz-Paredes A, Choux M. [Brain stem cavernomas in children. Nine case reports and literature review]. Neurochirurgie. 2002;48(4):319–25.

51. Sandalcioglu IE, Wiedemayer H, Secer S, Asgari S, Stolke D. Surgical removal of brain stem cavernous malformations: Surgical indications, technical considerations, and results. J Neurol Neurosurg Psychiatry. 2002;72:351–355.

52. Viñas FC, Gordon V, Guthikonda M, Diaz FG. Surgical management of cavernous malformations of the brainstem. Neurol Res. 2002;24:61–72.

53. Esposito P, Coulbois S, Kehrli P, et al. [Place of the surgery in the management of brainstem cavernomas. Results of a multicentric study]. Neurochirurgie. 2003;49:5–12.

54. Seifert V, Raabe A, Zimmermann M, et al. Conservative (labyrinth-preserving) transpetrosal approach to the clivus and petroclival region - Indications, complications, results and lessons learned. Acta Neurochir (Wien). 2003;145:631–642.

55. Smith ER, Chapman PH, Ogilvy CS, et al. Far posterior subtemporal approach to the dorsolateral brainstem and tentorial ring: Technique and clinical experience. Neurosurgery. 2003;52:364–369.

56. Wang CC, Liu A, Zhang JT, Sun B, Zhao YL. Surgical management of brain-stem cavernous malformations: Report of 137 cases. Surg Neurol. 2003;59(6):444–54.

57. Kikuta KI, Nozaki K, Takahashi JA, Miyamoto S, Kikuchi H, Hashimoto N. Postoperative evaluation of microsurgical resection for cavernous malformations of the brainstem. J Neurosurg. 2004;101:607–612.

58. Ferroli P, Sinisi M, Franzini A, Giombini S, Solero CL, Broggi G. Brainstem cavernomas: Long-term results of microsurgical resection in 52 patients. Neurosurgery. 2005;56:1203–1212.

59. Bruneau M, Bijlenga P, Reverdin A, et al. Early surgery for brainstem cavernomas. Acta Neurochirurgica. 2006.

60. Steiger HJ, Hänggi D, Stummer W, Winkler PA. Custom-tailored transdural anterior transpetrosal approach to ventral pons and retroclival regions. J Neurosurg. 2006;104:38– 46.

61. Zausinger S, Yousry I, Brueckmann H, Schmid-Elsaesser R, Tonn JC. Cavernous malformations of the brainstem: Three-dimensional-constructive interference in steady-state magnetic resonance imaging for improvement of surgical approach and clinical results. Neurosurgery. 2006;58:322–329.

62. Alves de Sousa A. Deep-seated (corpus callosum, intraventricular, basal ganglia and insula) and brain stem cavernous angiomas. Experience in Brazil TT - Cavernomes profonds (corps calleux, intraventriculaires, ganglions de la base, insulaires) et du tronc cérébral. Expéri. Neurochirurgie [Internet]. 2007 Jun;53(2-3 Pt 2):182–91.

63. Batay F, Bademci G, Deda H. Critically located cavernous malformations. Minim Invasive Neurosurg. 2007;50:71–76.

64. Chen X, Weigel D, Ganslandt O, Buchfelder M, Nimsky C. Diffusion tensor imaging and white matter tractography in patients with brainstem lesions. Acta Neurochir (Wien). 2007;149:1117–1131.

65. Nataf F, Roux F-X, Devaux B, et al. Brainstem cavernomas: surgical experience at the CH Sainte-Anne general hospital TT - Cavernomes du tronc cérébral: l’expérience chirurgicale du centre hospitalier Sainte-Anne. Neurochirurgie [Internet]. 2007 Jun;53(2-3 Pt 2):192–201. Available from: https://pubmed.ncbi.nlm.nih.gov/17499815

66. Sola RG, Pulido P, Pastor J, Ochoa M, Castedo J. Surgical treatment of symptomatic cavernous malformations of the brainstem. Acta Neurochir (Wien). 2007;149:463–470.

67. Cenzato M, Stefini R, Ambrosi C, Giovanelli M. Post-operative remnants of brainstem cavernomas: Incidence, risk factors and management. Acta Neurochir (Wien). 2008;150(9):879–86.

68. Hauck EF, Barnett SL, White JA, Samson D. Symptomatic brainstem cavernomas. Neurosurgery. 2009;64:61–70.

69. Li H, Ju Y, Cai BW, Chen J, You C, Hui XH. Experience of microsurgical treatment of brainstem cavernomas: Report of 37 cases. Neurol India. 2009;57:269–273.

70. Consales A, Piatelli G, Ravegnani M, et al. Treatment and outcome of children with cerebral cavernomas: A survey on 32 patients. Neurol Sci. 2010;31:117–123.

71. François P, Ben Ismail M, Hamel O, Bataille B, Jan M, Velut S. Anterior transpetrosal and subtemporal transtentorial approaches for pontine cavernomas. Acta Neurochir (Wien). 2010;

72. Huang A, Chen J, Yang C, Wang K, Yang S, Lai D. Brain stem cavernous malformations. J Clin Neurosci. 2010;17:74–79.

73. Ichinose T, Goto T, Morisako H, Takami T, Ohata K. Microroll retractor for surgical resection of brainstem cavernomas. World Neurosurg. 2010;73:520–522.

74. Ohue S, Fukushima T, Kumon Y, Ohnishi T, Friedman AH. Surgical management of brainstem cavernomas: Selection of approaches and microsurgical techniques. Neurosurg Rev. 2010;33:315–322.

75. Dukatz T, Sarnthein J, Sitter H, et al. Quality of life after brainstem cavernoma surgery in 71 patients. Neurosurgery. 2011;69(3):689–95.

76. Ramina R, Mattei T, de Aguiar, Paulo Henrique PiresMensces M, et al. Surgical management of brainstem cavernous malformations. Neurol Sci. 2011;32:1013–28.

77. Šteňo J, Bízik I, Šteňová J, Timárová G. Subtemporal transtentorial resection of cavernous malformations involving the pyramidal tract in the upper pons and mesencephalon. Acta Neurochir (Wien). 2011;153(10):1955–62.

78. de Aguiar PHP, Zicarelli CAM, Isolan G, et al. Brainstem cavernomas: a surgical challenge. Einstein (Sao Paulo). 2012;10(1):67–73.

79. Gross BA, Dunn IF, Du R, Al-Mefty O. Petrosal approaches to brainstem cavernous malformations. Neurosurg Focus. 2012;33(2):1–8.

80. Sabatino G, Rigante L, Marchese E, et al. Anterior subtemporal approach for posterolateral brainstem cavernomas: Report of ten cases. Acta Neurochir (Wien). 2012;154(11):2009–16.

81. Wostrack M, Shiban E, Harmening K, et al. Surgical treatment of symptomatic cerebral cavernous malformations in eloquent brain regions. Acta Neurochir (Wien). 2012;154(8):1419–30.

82. Bradac O, Majovsky M, De Lacy P, Benes V. Surgery of brainstem cavernous malformations. Acta Neurochir (Wien). 2013;155(11):2079–83.

83. Li D, Yang Y, Hao SY, et al. Hemorrhage risk, surgical management, and functional outcome of brainstem cavernous malformations. J Neurosurg. 2013;119(4):996–1008.

84. Mai JC, Ramanathan D, Kim LJ, Sekhar LN. Surgical resection of cavernous malformations of the brainstem: Evolution of a minimally invasive technique. World Neurosurg. 2013;79(5–6):638–40.

85. Pandey P, Westbroek EM, Gooderham PA, Steinberg GK. Cavernous malformation of brainstem, thalamus, and basal ganglia: A series of 176 patients. Neurosurgery. 2013;72(4):573–89.

86. Schwartz C, Grillhösl A, Schichor C, et al. Symptomatic cavernous malformations of the brainstem: Functional outcome after microsurgical resection. J Neurol. 2013;260:2815–22.

87. Chen LH, Zhang HT, Chen L, Liu LX, Xu RX. Minimally invasive resection of brainstem cavernous malformations: Surgical approaches and clinical experiences with 38 patients. Clin Neurol Neurosurg. 2014;116:72–9.

88. Garcia RM, Ivan ME, Lawton MT. Brainstem cavernous malformations: Surgical results in 104 patients and a proposed grading system to predict neurological outcomes. Neurosurgery. 2015;76(3):265–77.

89. Sawarkar DP, Janmatti S, Kumar R, et al. Cavernous malformations of central nervous system in pediatric patients: our single-centered experience in 50 patients and review of literature. Childs Nerv Syst [Internet]. 2017/06/20. 2017 Sep;33(9):1525–38.

90. Wang Z, Qian C, Shi L, Wang L, Zhang J, Wang Y. Surgery approaches to brainstem cavernous malformations. J Craniofac Surg. 2015;26(7):e577–80.

91. Cornelius JF, Kürten K, Fischer I, Hänggi D, Steiger HJ. Quality of Life After Surgery for Cerebral Cavernoma: Brainstem Versus Nonbrainstem Location. World Neurosurg. 2016;95:315–21.

92. Kaku Y, Takei H, Miyai M, Yamashita K, Kokuzawa J. Surgical approach to ponto-mesencephalic Cavernoma. Acta Neurochir Suppl. 2016;123:189–95.

93. Zhang S, Lin S, Hui X, Li H, You C. Surgical treatment of cavernous malformations involving medulla oblongata. J Clin Neurosci [Internet]. 2017;37:63–8.

94. Nathal E, Patiño-Rodriguez HM, Arauz A, et al. Risk Factors for Unfavorable Outcomes in Surgically Treated Brainstem Cavernous Malformations. World Neurosurg. 2018;111:e478–84.

95. Ren Y, Li J, Tao C, et al. Surgical Treatment of Cavernous Malformations Involving the Midbrain: A Single-Center Case Series of 34 Patients. World Neurosurg [Internet]. 2017;107:753–63.

96. Zaidi H, Mooney M, Levitt M, Dru A, Abla A, Spetzler R. Impact ofTiming ofIntervention Among 397 Consecutively Treated Brainstem Cavernous Malformations Hasan. Neurosurgery. 2017;81:620–6.

97. Liu W, Liu R, Ma Z, Li C. Transcallosal Anterior Interforniceal Approach for Removal of Superior Midbrain Cavernous Malformations in Children: A Retrospective Series of 10 Cases in a Single Center. World Neurosurg. 2018;118:e188–94.

98. Li D, Jiao YM, Wang L, et al. Surgical outcome of motor deficits and neurological status in brainstem cavernous malformations based on preoperative diffusion tensor imaging: A prospective randomized clinical trial. J Neurosurg. 2018;130(1):286–301.

99. Tumturk A, Li Y, Turan Y, Cikla U, Iskandar BJ, Baskaya MK. Emergency resection of brainstem cavernous malformations. J Neurosurg. 2018;128(5):1289–96.

100. Xie MG, Xiao XR, Guo FZ, Zhang JT, Wu Z, Zhang LW. Surgical Management and Functional Outcomes of Cavernous Malformations Involving the Medulla Oblongata. World Neurosurg [Internet]. 2018;119:e643–52.

101. Abhinav K, Nielsen TH, Singh R, et al. Utility of a Quantitative Approach Using Diffusion Tensor Imaging for Prognostication Regarding Motor and Functional Outcomes in Patients With Surgically Resected Deep Intracranial Cavernous Malformations. Neurosurgery. 2019;Jul 30.

102. Gui S, Meng G, Xiao X, Wu Z, Zhang J. Surgical Management of Brainstem Cavernous Malformation: Report of 67 Patients. World Neurosurg [Internet]. 2019;122:e1162–71.

103. Lashkarivand A, Ringstad G, Eide PK. Surgery for Brainstem Cavernous Malformations: Association between Preoperative Grade and Postoperative Quality of Life. Oper Neurosurg. 2019;0(0):1–9.

104. Tsuji Y, Kar S, Bertalanffy H. Microsurgical management of midbrain cavernous malformations: Predictors of outcome and lesion classification in 72 patients. Oper Neurosurg. 2019;17(6):562–72.

105. Zhang S, Li H, Liu W, Hui X, You C. Surgical treatment of hemorrhagic brainstem cavernous malformations. Neurol India. 2016;64:1210–9.