




# Therapy Options in the Management of Brain Abscess. Literature Review

## *Opções de terapia no tratamento de abscesso cerebral. Revisão da literatura*

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### Abstract

**Introduction** Despite the advancements in modern neurosurgical techniques, new antibiotics, neuroimaging technologies, anesthesia practices, and microbial isolation methods, cerebral abscess remains a potentially fatal infection of the central nervous system. Its treatment remains controversial to this day. The combination of clinical and surgical interventions has been widely accepted, yielding satisfactory outcomes.

**Methods** The literature review process primarily relied on data obtained from the Pubmed database, Bireme (Lilacs, Medline, Scielo, Medicaribe, Cochrane). Key search terms included: central nervous system infection, cerebral abscess, and treatment. After a thorough selection analysis, 103 articles covering the period from 1980 to 2023 were included in this work.

**Results** The ideal treatment is surgical; however, clinical treatment has been employed in selected cases. Simple aspiration, stereotactic-guided aspiration, and endoscopy have been performed with efficient results. The outcomes of clinical or surgical treatment depend on factors such as the patient's age, neurological status, microbial isolation, primary cause of the abscess, number of infectious foci, location, and stage of abscess development. Corticosteroids have been recommended for cases of vasogenic cerebral edema, while anticonvulsants are indicated for supratentorial abscesses.

**Conclusion** The combination of aspiration or excision, tailored to the specific cause, number, location, and developmental stage, and intravenous antibiotics has consistently yielded satisfactory results.

### Keywords

- ▶ brain abscess
- ▶ treatment
- ▶ outcome

### Resumo

**Introdução** Apesar do advento de modernas técnicas neurocirúrgicas, novos antibióticos, das tecnologias em neuroimagens, avanços no campo da anestesia, novas técnicas de isolamento de microorganismos, o abscesso cerebral permanece como uma infecção potencialmente fatal do sistema nervoso central. Seu tratamento é ainda

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hoje controverso. A combinação do tratamento clínico e cirúrgico tem sido largamente aceita e com resultados satisfatórios.

**Métodos** O processo de revisão da literatura baseou-se principalmente em dados obtidos da Pubmed database, Bireme (Lilacs, Medline, Scielo, Medcaribe, Cochrane). Para as buscas foram usadas as palavras-chave: infecção do sistema nervoso central, abscesso cerebral, tratamento. Ao final da análise de seleção, obtiveram-se um total de 103 artigos que compuseram essa obra, com um recorte temporal de 1980 a 2023.

**Resultados** O tratamento ideal é cirúrgico, porém, o tratamento clínico é realizado em casos selecionados. A aspiração simples, aspiração guiada por estereotaxia e endoscopia são realizadas com resultados eficientes. Os resultados do tratamento clínico ou cirúrgico, vão depender da idade, estado neurológico do paciente, isolamento do microorganismo, causa primária do abscesso, número de focos infecciosos, localização e fase de evolução do abscesso. Corticosteróides é indicado em casos de edema cerebral vasogênico. Anticonvulsivante nos casos de abscesso supratentorial.

**Conclusão** A combinação de aspiração ou excisão conforme sua causa, número, localização e fase de evolução, associado com antibióticos por via venosa tem apresentado resultados satisfatórios.

### Palavras-chave

- ▶ abscesso cerebral
- ▶ tratamento
- ▶ prognóstico

## Introduction

A cerebral abscess (CA) is a collection of pus located within its respective site.<sup>1-5</sup> CA typically presents with focal neurological deficit, seizures, or symptoms of increased intracranial pressure, and less commonly as a focal or systemic infection.<sup>6,7</sup> The main causes and risk factors for the development of CA include meningitis, sinusitis, otitis, dental infection, open cranioccephalic trauma, cyanotic congenital heart disease, and previous craniotomy.<sup>8,9</sup>

Neuroimaging studies are employed to determine the location, extent, characteristics of lesions, and course of action.<sup>10,11</sup> Depending on the radiological pattern and stage of lesion development, a differential diagnosis should be considered, ranging from infection to tumor.<sup>12</sup> The combination of clinical treatment (oral, intravenous, intrathecal) and surgical intervention (drainage, aspiration, excision, stereotactic aspiration) is the standard for the curative resolution of CA.<sup>2,13-24</sup> Clinical treatment has been used in cases of cerebritis-phase CA, multiple abscesses, or those located in eloquent areas.<sup>8,9,25</sup> Various surgical procedures have been employed, such as simple aspiration, stereotactic aspiration, ultrasound-guided aspiration, neuronavigation-guided aspiration, or neuroendoscopy,<sup>12,26,27</sup> and primary excision.<sup>22,26,28-33</sup>

Despite advances in medicine through neuroimaging, microbial isolation, antibiotic therapy, and modern neurosurgical techniques (stereotaxy, neuronavigation), the morbidity and mortality rates remain high, particularly in developing countries.<sup>34</sup>

The authors provide a review of CA treatment options and discuss their advantages and disadvantages.

## Methods

This is a literature review conducted through searches on the following databases: Pubmed database, Bireme (Lilacs,

Medline, Scielo, Medcaribe, Cochrane). The descriptors used were: Central Nervous System Infection, Cerebral Abscess, and Treatment. Articles were selected with a time frame from 1980 to 2023, resulting in a total of 103 articles that met the inclusion criteria based on their citations, respective impacts, and content relevant to the theme.

## Pharmacological Treatment

Heineman et al.<sup>35</sup> reported the first successful case of clinical treatment for CA. Pharmacological treatment of CA has been indicated in cases of a single abscess < 1.5 cm, cerebritis phase, multiple abscesses measuring < 1.5 cm in diameter, located in eloquent areas, presence of concomitant infection (meningitis, ependymitis), and patients in the terminal phase.<sup>8,9,14,19,24,25,36-46</sup>

Literature reports the effectiveness of clinical treatment in cases where the causative agent is known through blood culture, cerebrospinal fluid, or drainage from otitis or sinusitis.<sup>10,19,47</sup> According to Armornpojnimman et al.,<sup>38</sup> the success rate for pharmacological treatment is high when initiated during the early cerebritis phase, with lesions measuring < 1.5 cm in diameter, in patients with an evolution time of < 2 weeks. Lu et al.<sup>10</sup> recommend clinical treatment when the diagnosis is uncertain or unconfirmed. According to Xiao et al.,<sup>8</sup> clinical treatment is not effective in patients with risk factors, poor level of consciousness, or immunodeficiency.

It is recommended to initiate empirical antibiotic therapy while samples are being analyzed for microbiological study.<sup>19,21,36,37,48,49</sup> Broad-spectrum empirical antibiotic therapy should be maintained for 6 to 8 weeks, and modified according to the microbiological test results for possible effective therapy. Treatment duration of less than 6-8 weeks is associated with an increased risk of recurrence.<sup>50</sup> When the microorganism is unknown, the empirical antimicrobial therapy used is third-generation cephalosporin (cefotaxime,

ceftriaxone) and metronidazole in the treatment of AC originating from otitis, mastoiditis, or sinusitis, showing good results.<sup>14,20,51</sup> In cases secondary to open cranial trauma or post-craniotomy, a combination of third-generation cephalosporin with vancomycin or oxacillin is recommended. There is no consensus on the duration of antimicrobial therapy, with most authors recommending intravenous therapy for 6 to 8 weeks.<sup>10,44,52-56</sup> Patients undergoing clinical treatment should be monitored clinically, laboratorially, and radiologically<sup>55</sup>; if there is no clinical and/or radiological improvement, immediate surgical treatment should be instituted.<sup>8</sup>

The effectiveness of pharmacological treatment can be observed through clinical improvement<sup>3,36</sup> and laboratory tests such as PCR; when elevated, it indicates that pharmacological treatment is ineffective.<sup>19,57,58</sup>

The use of corticosteroids in CA is controversial.<sup>19,20,59</sup> It has been indicated in cases of CA with local vasogenic edema, causing increased intracranial pressure and significantly increasing morbidity and mortality.<sup>8,24,44</sup> It has been recommended in the perioperative period to reduce intracranial pressure and prevent internal brain herniation.<sup>10,20,21,40,47,59,60</sup> Prolonged use of corticosteroids can decrease antibiotic penetration into the abscess and reduce abscess capsule formation, especially in the cerebritis phase.<sup>8,24,44,61-63</sup>

Seizure is one of the main complications of CA, occurring at the onset of the disease or even after its treatment.<sup>64</sup> Anticonvulsant prophylaxis has been recommended.<sup>10,20,44</sup> The most commonly used anticonvulsant is phenytoin, and for an extended period.

### Surgical Treatment

The nature of CA, anatomical location, number of abscesses, size, stage of the lesion, age, and neurological status of the patient all influence the strategy for its treatment.<sup>10</sup> In the historical evolution of CA treatment, in 1924, King<sup>65</sup> introduced the marsupialization technique. Dandy<sup>66</sup> introduced aspiration in 1926. Sargent<sup>67</sup> considered the excision of an encapsulated CA in 1928, but it was Vincent<sup>68</sup> who popularized complete excision and demonstrated its therapeutic value in 1936. The decision on the surgical technique should be made on an individual basis in each case, considering the size, location, overall condition of the patient, and the neurosurgeon's experience.<sup>5,58,69</sup>

### Simple Aspiration

There is a consensus that surgical treatment through puncture and aspiration is indicated for abscesses > 2 cm, located in non-eloquent areas, and with a significant mass effect, yielding excellent results.<sup>10,14,20,21,24,42,44,55,70-73</sup> Large abscesses can be aspirated through a trephine hole, leading to an immediate reduction in mass effect and intracranial pressure, facilitating the collection of material for culture and antibiotic sensitivity testing.<sup>10</sup> Simple aspiration has limitations in cases of multiloculated and recurrent abscesses.<sup>63</sup> A disadvantage of this procedure is the need to repeat it in 70% of cases and the risk of abscess rupture into the ventricular cavity or subarachnoid space, which can lead to

complications such as meningitis and ventriculitis.<sup>13</sup> Contraindications include the presence of coagulopathies.<sup>20</sup>

### Stereotactic-Guided Aspiration

Stereotactic-guided CT or MRI-guided aspiration and puncture in the treatment of CA have been considered the gold standard due to being a minimally invasive procedure and having a low rate of complications compared with excision.<sup>22,26,30,71,74,75</sup> Advantages of this approach over other procedures include its use in cases of deeply located abscesses, eloquent areas, the brainstem, multiple abscesses, and when excision is deemed inappropriate.<sup>20,22,24,25,42,54,57,74,76-86</sup> In stereotactic-guided aspiration, a biopsy of the abscess capsule can be performed.<sup>54</sup> According to Kondziola et al,<sup>77</sup> this technique is optimal for abscesses larger than 3 cm. Stapleton et al<sup>87</sup> suggest it as the method of choice for cases of superficial and large abscesses. Stereotactic surgery with neuronavigation allows for aspiration to be indicated without considering the phases of the abscess and enables the collection of material for laboratory study.<sup>10,18,36,88</sup>

### Endoscopic Aspiration

The treatment of CA through endoscopy has been infrequently performed.<sup>27,89</sup> In comparison with stereotactic-guided aspiration, neuroendoscopy offers some advantages such as direct visual control, the possibility of treating cases with multiseptated CA, addressing intraventricular purulent collections, cases of associated subdural empyema, and control of intraoperative bleeding.<sup>6,12,27,31,32,53</sup> Endoscopic instruments can be flexible or rigid.<sup>6,12,27</sup> Longatti et al<sup>6</sup> used a flexible endoscope as it proved more effective in certain treatment scenarios, such as aspiration and inspection of the abscess in all spaces and directions. In cases where the capsule membrane is firm or elastic, its perforation may sometimes require the use of scissors or other instruments to facilitate the procedure.<sup>12,31</sup>

### Surgical Excision

Excision is generally recommended in cases of cerebellar abscess.<sup>19,20,44,54,90-93</sup> Primary excision of the abscess and its capsule has also been performed in cases of multiloculated abscesses, cases due to more resistant pathogens that do not respond to multiple aspirations.<sup>20,39,54,62,63,94</sup> Abscesses containing gas are resistant to antibiotics and are best treated through excision.<sup>95</sup> Post-traumatic abscesses containing foreign bodies or contaminated bone fragments are indicated for excision to prevent recurrence.<sup>19,44,71,91,96,97</sup> Abscesses resulting from communicating fistulas, such as in cases of trauma or congenital dermal sinuses, require excision of the infected granulation tissue and closure of the fistula.<sup>10</sup> Abscesses located in a lobe and contiguous to the primary source of infection show better results when subjected to excision along with the primary focus. Other authors indicate excision during the late stage of capsule formation or after unsuccessful aspiration.<sup>22,23</sup> Primary excision is contraindicated in cases of cerebritis, deep abscesses, those located in eloquent areas, multiple abscesses, and patients at high surgical risk.<sup>10,13,98</sup>

Complete excision of the CA is indicated in the following cases: 1. superficially located abscess in a non-eloquent area; 2. abscess suspected of fungal, *Mycobacterium tuberculosis*, *Actinomyces* spp, or *Nocardia* spp infection; 3. abscess resulting from congenital diseases or acquired fistula; 4. multiloculated abscesses; 5. abscess caused by a parameningeal septic focus; and 6. failure of previous treatment.<sup>10,58</sup>

### Intraventricular Abscesses

Cerebral abscesses located deep, multiloculated, and close to the ventricular wall increase the chances of intraventricular rupture in 10% of cases.<sup>99</sup> There is no efficient treatment of choice, and it presents a high mortality rate.<sup>100–102</sup> Yang and Zhao<sup>103</sup> propose urgent craniotomy with abscess drainage. Other authors<sup>39,101</sup> suggest craniotomy followed by drainage of the abscess cavity, washing of the ventricular system, along intravenous and intrathecal antibiotic therapy for six weeks.

### Conclusion

The synergistic approach of aspiration or excision, tailored to the specific cause, number, location, and developmental stage of cerebral abscess, coupled with intravenous antibiotic therapy, has demonstrated consistently satisfactory outcomes. Furthermore, the effective management of cerebral abscesses necessitates a comprehensive, multidisciplinary team, comprising neuroradiologists, neurologists, pediatric neurologists, infectious disease specialists, and neurosurgeons.

### Conflicts of Interest

The authors report no conflicts of interest.

### References

- Corsini Campioli C, Castillo Almeida NE, O'Horo JC, et al. Bacterial brain abscess: An outline for diagnosis and management. *Am J Med* 2021;134(10):1210–1217.e2
- Brook I. Microbiology and treatment of brain abscess. *J Clin Neurosci* 2017;38:8–12
- Brouwer MC, Coutinho JM, van de Beek D. Clinical characteristics and outcome of brain abscess: systematic review and meta-analysis. *Neurology* 2014;82(09):806–813
- Kural C, Kirmizigöz S, Ezgu MC, Bedir O, Kutlay M, Izci Y. Intracranial infections: lessons learned from 52 surgically treated cases. *Neurosurg Focus* 2019;47(02):E10
- Ali BHS, Ahmed ADS, Elzain MA, Abdelradi FEM. Brain abscess surgery outcome: A comparison between craniotomy with membrane excision versus burr hole aspiration. *Open J Mod Neurosurg* 2023;13:74–93
- Longatti P, Perin A, Ettorre F, Fiorindi A, Baratto V. Endoscopic treatment of brain abscesses. *Childs Nerv Syst* 2006;22(11):1447–1450
- Lange N, Berndt M, Jörgler AK, et al. Clinical characteristics and course of primary brain abscess. *Acta Neurochir (Wien)* 2018;160(10):2055–2062
- Xiao F, Tseng MY, Teng LJ, Tseng HM, Tsai JC. Brain abscess: clinical experience and analysis of prognostic factors. *Surg Neurol* 2005;63(05):442–449, discussion 449–450
- Bernardini GL. Diagnosis and management of brain abscess and subdural empyema. *Curr Neurol Neurosci Rep* 2004;4(06):448–456
- Lu CH, Chang WN, Lui CC. Strategies for the management of bacterial brain abscess. *J Clin Neurosci* 2006;13(10):979–985
- Kastrup O, Wanke I, Maschke M. Neuroimaging of infections. *NeuroRx* 2005;2(02):324–332
- Hellwig D, Bauer BL, Dauch WA. Endoscopic stereotactic treatment of brain abscesses. *Acta Neurochir Suppl (Wien)* 1994;61:102–105
- Hall WA, Truwit CL. The surgical management of infections involving the cerebrum. *Neurosurgery* 2008;62(Suppl 2):519–530, discussion 530–531
- Carpenter J, Stapleton S, Holliman R. Retrospective analysis of 49 cases of brain abscess and review of the literature. *Eur J Clin Microbiol Infect Dis* 2007;26(01):1–11
- Bodilsen J, Brouwer MC, Nielsen H, Van De Beek D. Anti-infective treatment of brain abscess. *Expert Rev Anti Infect Ther* 2018;16(07):565–578
- Tehli GY, Kirmizigöz S, Durmaz MO, Ezgu MC, Tehli O. Risk factors and surgical treatment options for intracranial infections. *Turk Neurosurg* 2023;33(02):308–317
- Nguyen I, Urbanczyk K, Mtui E, Li S. Intracranial CNS infections: A literature review and radiology case studies. *Semin Ultrasound CT MR* 2020;41(01):106–120
- Zhang C, Liuhua H, et al. GH XW. A retrospective study on the aetiology, management, and outcome of brain abscess in an 11-year, single-centre study from China. *BMC Infect Dis* 2014;14(311):1–7
- Erdoğan E, Cansever T. Pyogenic brain abscess. *Neurosurg Focus* 2008;24(06):E2
- Hakan T. Management of bacterial brain abscesses. *Neurosurg Focus* 2008;24(06):E4
- Mampalam TJ, Rosenblum ML. Trends in the management of bacterial brain abscesses: a review of 102 cases over 17 years. *Neurosurgery* 1988;23(04):451–458
- Sharma BS, Gupta SK, Khosla VK. Current concepts in the management of pyogenic brain abscess. *Neurol India* 2000;48(02):105–111
- Stephanov S. Surgical treatment of brain abscess. *Neurosurgery* 1988;22(04):724–730
- Tseng JH, Tseng MY. Brain abscess in 142 patients: factors influencing outcome and mortality. *Surg Neurol* 2006;65(06):557–562, discussion 562
- Suzer T, Coskun E, Cirak B, Yagci B, Tahta K. Brain stem abscesses in childhood. *Childs Nerv Syst* 2005;21(01):27–31
- Boviatsis EJ, Kouyialis AT, Stranjalis G, Korfiatis S, Sakas DE. CT-guided stereotactic aspiration of brain abscesses. *Neurosurg Rev* 2003;26(03):206–209
- Kamikawa S, Inui A, Miyake S, et al. Neuroendoscopic surgery for brain abscess. *Eur J Paediatr Neurol* 1997;1(04):121–122
- Bhand AA. Brain abscess—diagnosis and management. *J Coll Physicians Surg Pak* 2004;14(07):407–410
- Ortega-Martínez M, Cabezudo JM, Fernández-Portales I, et al. [Pyogenic brain abscesses: experience with 60 consecutive cases]. *Neurocirugia (Astur)* 2006;17(01):23–33, discussion 33
- Nakajima H, Iwai Y, Yamanaka K, Kishi H. Successful treatment of brainstem abscess with stereotactic aspiration. *Surg Neurol* 1999;52(05):445–448
- Fritsch M, Manwaring KH. Endoscopic treatment of brain abscess in children. *Minim Invasive Neurosurg* 1997;40(03):103–106
- Gajdhar M, Yadav YR. A case of thalamic abscess treated by endoscopic surgery. *Neurol India* 2005;53(03):345–346
- Hellwig D, Benes L, Bertalanffy H, Bauer BL. Endoscopic stereotaxy—an eight year's experience. *Stereotact Funct Neurosurg* 1997;68(1–4 Pt 1):90–97
- Menon S, Bharadwaj R, Chowdhary A, Kaundinya DV, Palande DA. Current epidemiology of intracranial abscesses: a prospective 5 year study. *J Med Microbiol* 2008;57(Pt 10):1259–1268
- Heineman HS, Braude AI, Osterholm JL. Intracranial suppurative disease. Early presumptive diagnosis and successful treatment without surgery. *JAMA* 1971;218(10):1542–1547



- 36 Radoi M, Ciubotaru V, Tataranu L. Brain abscesses: clinical experience and outcome of 52 consecutive cases. *Chirurgia (Bucur)* 2013;108(02):215–225
- 37 Lee HS, Kim JH, Kim YH, Lee S. Surgically treated community-acquired brain abscess: bacteriological analysis based on predisposing infections. *Jpn J Infect Dis* 2018;71(03):191–196
- 38 Amornpojnimman T, Korathanakhun P. Predictors of clinical outcomes among patients with brain abscess in Thailand. *J Clin Neurosci* 2018;53:135–139
- 39 Ciurea AV, Stoica F, Vasilescu G, Nuteanu L. Neurosurgical management of brain abscesses in children. *Childs Nerv Syst* 1999;15(6-7):309–317
- 40 Kao PT, Tseng HK, Liu CP, Su SC, Lee CM. Brain abscess: clinical analysis of 53 cases. *J Microbiol Immunol Infect* 2003;36(02):129–136
- 41 Kastenbauer S, Pfister HW, Wispelwey B, Scheld WM. Brain abscess. In: Scheld WM, Whitley RJ, Marra CM, (eds): *Infections of the Central Nervous System*, ed 3. Philadelphia: Lippincott, Williams & Wilkins; 2004:479–507
- 42 Kocherry XG, Hegde T, Sastry KVR, Mohanty A. Efficacy of stereotactic aspiration in deep-seated and eloquent-region intracranial pyogenic abscesses. *Neurosurg Focus* 2008;24(06):E13
- 43 Liston TE, Tomasovic JJ, Stevens EA. Early diagnosis and management of cerebritis in a child. *Pediatrics* 1980;65(03):484–486
- 44 Mamelak AN, Mampalam TJ, Obana WG, Rosenblum ML. Improved management of multiple brain abscesses: a combined surgical and medical approach. *Neurosurgery* 1995;36(01):76–85, discussion 85–86
- 45 Rosenblum ML, Hoff JT, Norman D, Edwards MS, Berg BO. Nonoperative treatment of brain abscesses in selected high-risk patients. *J Neurosurg* 1980;52(02):217–225
- 46 Wong TT, Lee LS, Wang HS, et al. Brain abscesses in children—a cooperative study of 83 cases. *Childs Nerv Syst* 1989;5(01):19–24
- 47 Obana WG, Rosenblum ML. Nonoperative treatment of neurosurgical infections. *Neurosurg Clin N Am* 1992;3(02):359–373
- 48 Sonnevile R, Ruimy R, Benzonana N, et al; ESCMID Study Group for Infectious Diseases of the Brain (ESGIB) An update on bacterial brain abscess in immunocompetent patients. *Clin Microbiol Infect* 2017;23(09):614–620
- 49 Honda H, Warren DK. Central nervous system infections: meningitis and brain abscess. *Infect Dis Clin North Am* 2009;23(03):609–623
- 50 Chow F. Brain and spinal epidural abscess. *Continuum (Minneapolis)* 2018;24(5, Neuroinfectious Disease):1327–1348
- 51 Jansson AK, Enblad P, Sjölin J. Efficacy and safety of cefotaxime in combination with metronidazole for empirical treatment of brain abscess in clinical practice: a retrospective study of 66 consecutive cases. *Eur J Clin Microbiol Infect Dis* 2004;23(01):7–14
- 52 Calfee DP, Wispelwey B. Brain abscess. *Semin Neurol* 2000;20(03):353–360
- 53 Frazier JL, Ahn ES, Jallo GI. Management of brain abscesses in children. *Neurosurg Focus* 2008;24(06):E8
- 54 Moorthy RK, Rajshekhar V. Management of brain abscess: an overview. *Neurosurg Focus* 2008;24(06):E3
- 55 Osenbach RK, Loftus CM. Diagnosis and management of brain abscess. *Neurosurg Clin N Am* 1992;3(02):403–420
- 56 Yang KY, Chang WN, Ho JT, Wang HC, Lu CH. Postneurosurgical nosocomial bacterial brain abscess in adults. *Infection* 2006;34(05):247–251
- 57 Jamjoom AB. Short course antimicrobial therapy in intracranial abscess. *Acta Neurochir (Wien)* 1996;138(07):835–839
- 58 Neidert MC, Karlin K, Actor B, Regli L, Bozinov O, Burkhardt JK. Preoperative C-reactive protein predicts the need for repeated intracerebral brain abscess drainage. *Clin Neurol Neurosurg* 2015;131:26–30
- 59 Rosenblum ML, Mampalam TJ, Pons VG. Controversies in the management of brain abscesses. *Clin Neurosurg* 1986;33:603–632
- 60 Tekkök IH, Erbenli A. Management of brain abscess in children: review of 130 cases over a period of 21 years. *Childs Nerv Syst* 1992;8(07):411–416
- 61 Quartey GR, Johnston JA, Rozdilsky B. Decadron in the treatment of cerebral abscess. An experimental study. *J Neurosurg* 1976;45(03):301–310
- 62 Mathisen GE, Johnson JP. Brain abscess. *Clin Infect Dis* 1997;25(04):763–779, quiz 780–781
- 63 Su TM, Lan CM, Tsai YD, Lee TC, Lu CH, Chang WN. Multiloculated pyogenic brain abscess: experience in 25 patients. *Neurosurgery* 2003;52(05):1075–1079, discussion 1079–1080
- 64 Legg NJ, Gupta PC, Scott DF. Epilepsy following cerebral abscess. A clinical and EEG study of 70 patients. *Brain* 1973;96(02):259–268
- 65 King JEJ. The treatment of the brain abscess by unroofing and temporary herniation of abscess cavity with avoidance of unusual drainage methods, with notes on the management of hernia cerebral general. *Surg Gynecol Obstet* 1924;39:554–568
- 66 Dandy WE. Treatment of chronic abscesses of the brain by tapping. Preliminary note. *JAMA* 1926;87:1477–1487
- 67 Sargent P. Remarks on DRAINAGE OF BRAIN ABSCESS. *BMJ* 1928;2(3543):971–972
- 68 Vincent C. Su rune méthode de traitement des abcès subaigus des hémisphères cérébraux: large décompression, puis ablation en masse sans drainage. *Gaz Med Fr* 1936;43:93–96
- 69 Ratnaike TE, Das S, Gregson BA, Mendelow AD. A review of brain abscess surgical treatment—78 years: aspiration versus excision. *World Neurosurg* 2011;76(05):431–436
- 70 Auvichayapat N, Auvichayapat P, Aungwarawong S. Brain abscess in infants and children: a retrospective study of 107 patients in northeast Thailand. *J Med Assoc Thai* 2007;90(08):1601–1607
- 71 Sheehan JP, Jane JA Jr, Ray DK, Goodkin HP. Brain abscess in children. *Neurosurg Focus* 2008;24(06):E6
- 72 Miller ES, Dias PS, Uttley D. CT scanning in the management of intracranial abscess: a review of 100 cases. *Br J Neurosurg* 1988;2(04):439–446
- 73 Prasad KN, Mishra AM, Gupta D, Husain N, Husain M, Gupta RK. Analysis of microbial etiology and mortality in patients with brain abscess. *J Infect* 2006;53(04):221–227
- 74 Barlas O, Sencer A, Erkan K, Eraksoy H, Sencer S, Bayindir C. Stereotactic surgery in the management of brain abscess. *Surg Neurol* 1999;52(04):404–410, discussion 411
- 75 Kutlay M, Colak A, Yildiz S, Demircan N, Akin ON. Stereotactic aspiration and antibiotic treatment combined with hyperbaric oxygen therapy in the management of bacterial brain abscesses. *Neurosurgery* 2005;57(06):1140–1146, discussion 1140–1146
- 76 Dyste GN, Hitchon PW, Menezes AH, VanGilder JC, Greene GM. Stereotactic surgery in the treatment of multiple brain abscesses. *J Neurosurg* 1988;69(02):188–194
- 77 Kondziolka D, Duma CM, Lunsford LD. Factors that enhance the likelihood of successful stereotactic treatment of brain abscesses. *Acta Neurochir (Wien)* 1994;127(1-2):85–90
- 78 Fuentes S, Bouillot P, Regis J, Lena G, Choux M. Management of brain stem abscess. *Br J Neurosurg* 2001;15(01):57–62
- 79 Nauta HJ, Contreras FL, Weiner RL, Crofford MJ. Brain stem abscess managed with computed tomography-guided stereotactic aspiration. *Neurosurgery* 1987;20(03):476–480
- 80 Imai H, Ono N, Zama A, Tamura M. Diagnosis and treatment of brainstem abscess using magnetic resonance imaging and microsurgical aspiration—case report. *Neurol Med Chir (Tokyo)* 1995;35(03):160–164
- 81 Kashiwagi S, Abiko S, Aoki H. Brainstem abscess. *Surg Neurol* 1987;28(01):63–66
- 82 Lunsford LD. Stereotactic drainage of brain abscesses. *J Neurosurg* 1989;71(01):154

- 83 Ebeling U, Hasdemir MG. Stereotactic guided microsurgery of cerebral lesions. *Minim Invasive Neurosurg* 1995;38(01):10–15
- 84 Wang HS, Kuo MF, Huang SC. Medical cure of a brainstem abscess and serial brainstem auditory evoked potentials. *Dev Med Child Neurol* 1992;34(10):911–915
- 85 Rajshekhar V, Chandy MJ. Successful stereotactic management of a large cardiogenic brain stem abscess. *Neurosurgery* 1994;34(02):368–371, discussion 371
- 86 Skrap M, Melatini A, Vassallo A, Sidoti C. Stereotactic aspiration and drainage of brain abscesses. Experience with 9 cases. *Minim Invasive Neurosurg* 1996;39(04):108–112
- 87 Stapleton SR, Bell BA, Uttley D. Stereotactic aspiration of brain abscesses: is this the treatment of choice? *Acta Neurochir (Wien)* 1993;121(1-2):15–19
- 88 Höhne J, Brawanski A, Schebesch KM. Fluorescence-guided surgery of brain abscesses. *Clin Neurol Neurosurg* 2017;155:36–39
- 89 Kalbarczyk A, Krauss JK, Seiler RW. Endoscopic stereotactic surgery for intraventricular loculated empyema: case report. *Surg Neurol* 1999;52(04):412–417
- 90 Agrawal D, Suri A, Mahapatra AK. Primary excision of pediatric posterior fossa abscesses—towards zero mortality? A series of nine cases and review. *Pediatr Neurosurg* 2003;38(02):63–67
- 91 Pereira CU, Silva AD, Leão JDB. Abscesso cerebral pós-traumático. Considerações sobre nove casos. *J Bras Neurocir* 2001;12:122–125
- 92 Pandey P, Umesh S, Bhat D, et al. Cerebellar abscesses in children: excision or aspiration? *J Neurosurg Pediatr* 2008;1(01):31–34
- 93 Shaw MD, Russell JA. Cerebellar abscess. A review of 47 cases. *J Neurol Neurosurg Psychiatry* 1975;38(05):429–435
- 94 Abdullah J. Clinical presentation and outcome of brain abscess over the last 6 years in community based neurological service. *J Clin Neurosci* 2001;8(01):18–22
- 95 Cohen BS, Belsler EH, Keeler SP, Yabsley MJ, Miller KV. A headache from our past? Intracranial abscess disease, virulence factors of *Trueperella pyogenes*, and a legacy of translocating white-tailed deer (*Odocoileus virginianus*). *J Wildl Dis* 2018;54(04):671–679
- 96 Bhatia R, Tandon PN, Banerji AK. Brain abscess—an analysis of 55 cases. *Int Surg* 1973;58(08):565–568
- 97 Black P, Graybill JR, Charache P. Penetration of brain abscess by systemically administered antibiotics. *J Neurosurg* 1973;38(06):705–709
- 98 Samson DS, Clark K. A current review of brain abscess. *Am J Med* 1973;54(02):201–210
- 99 Lee TH, Chang WN, Su TM, et al. Clinical features and predictive factors of intraventricular rupture in patients who have bacterial brain abscesses. *J Neurol Neurosurg Psychiatry* 2007;78(03):303–309
- 100 Isono M, Wakabayashi Y, Nakano T, Fujiki M, Mori T, Hori S. Treatment of brain abscess associated with ventricular rupture—three case reports. *Neurol Med Chir (Tokyo)* 1997;37(08):630–636
- 101 Zeidman SM, Geisler FH, Olivi A. Intraventricular rupture of a purulent brain abscess: case report. *Neurosurgery* 1995;36(01):189–193, discussion 193
- 102 Pereira CU, Santos EAS. Ruptura intraventricular de abscesso cerebral. Relato de caso. *Braz Neurosurg* 2005;24(04):1163–1165
- 103 Yang SY, Zhao CS. Review of 140 patients with brain abscess. *Surg Neurol* 1993;39(04):290–296