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Brain abscesses caused by anaerobic microorganisms: a systematic review

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ABSTRACT

The objective of this study was to perform a systematic review of the characteristics, causative microorganisms and outcome of brain abscesses caused by anaerobic bacteria over the past 25 years. We reviewed studies on brain abscesses which included infection due to anaerobic microorganisms published between 1998 and 2022. We excluded reports with polymicrobial infections (more than 2 anaerobic bacteria isolated) and those that do not provide enough information to make comparisons, the reports with only one case of brain abscess due to anaerobes, as well as those focused on an only anaerobic bacterium. Also, we have excluded the cases in pediatric population. We searched the scientific literature through the Cochrane Library, EMBASE and PubMed/MEDLINE databases for studies of this condition. We finally included 28 studies with 6,167 patients, of which 715 (11.5%) were cases caused by anaerobic bacteria. There was a male predominance (70%) and mean age of 40.3 years. Most infections were monomicrobial (59.4%). The most common anaerobic microorganisms isolated were *Bacteroides* spp (43.4%) and Gram-positive anaerobic cocci (35.1%). Cases of brain abscesses caused by anaerobic bacteria were most frequent in Asia and Europe. The source of infection most frequent was otogenic in 84.6% followed by a neurosurgery procedure infection in 23% of patients. The main symptom observed was headache in 95.6% of patients followed by fever (69.5%). Surgical treatment was performed in 48 % of patients and the percentage of patients in whom antibiotic treatment was applied range 88.8% to 100%. The main limitation of this review is the non-inclusion of studies published before of 1998 in which MALDI-TOF MS system had not been introduced in the majority of laboratories for routine identification.

The patient rate with isolation of anaerobic bacteria in brain abscesses is low, but these data could be underestimated mainly due to the fastidious nature of these microorganisms and the difficulties in the identification of some anaerobes.

Keywords: Anaerobic bacteria; brain abscesses; *Bacteroides* spp; Gram-positive anaerobic cocci; neurosurgery; antibiotics

Abscesos cerebrales causados por microorganismos anaerobios: una revisión sistemática

RESUMEN

El objetivo de este estudio fue realizar una revisión sistemática de las características, los microorganismos causantes y evolución de los abscesos cerebrales causados por bacterias anaerobias en los últimos 25 años. Revisamos los estudios sobre abscesos cerebrales que incluyeron infección por microorganismos anaerobios publicados entre 1998 y 2022. Se excluyeron estudios con infecciones polimicrobianas (más de 2 bacterias anaerobias aisladas) y aquellos que no proporcionaban suficiente información para realizar comparaciones, los estudios con solo un caso de absceso por anaerobios así como aquellos focalizados solo en una bacteria anaerobia. También se excluyeron los casos en población pediátrica. Se realizó búsqueda de la literatura científica a través de la librería Cochrane y base de datos EMBASE y PubMed/MEDLINE para estudios con esas características. Se incluyeron finalmente 28 estudios con 6167 pacientes, de los cuales 715 (11,5%) fueron casos causados por bacterias anaerobias. Hubo predominio masculino (70%) y edad media de 40,3 años. La mayoría de las infecciones fueron monomicrobianas (59,4%). Los microorganismos anaerobios más comunes aislados fueron *Bacteroides* spp (43,4%) y cocos anaerobios grampositivos (35,1%). Los casos de abscesos cerebrales causados por bacterias anaerobias fueron más frecuentes en Asia y Europa. La fuente de infección más frecuente fue la otogénica en un 84,6% seguida de una infección por

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procedimiento de neurocirugía en un 23% de los pacientes. El principal síntoma observado fue la cefalea en el 95,6% de los pacientes seguido de fiebre (69,5%). Se realizó tratamiento quirúrgico en el 48 % de los pacientes y el porcentaje de pacientes en los que se aplicó tratamiento antibiótico oscila entre el 88,8 % y el 100 %. La principal limitación de esta revisión fue la no inclusión de estudios anteriores a 1998 en los que todavía no se había introducido MALDI-TOF MS en la mayoría de los laboratorios para el diagnóstico rutinario.

La tasa de pacientes con aislamiento de bacterias anaerobias en abscesos cerebrales es baja, pero estos datos podrían estar subestimados debido principalmente a la naturaleza fastidiosa de estos microorganismos y las dificultades en la identificación de algunos anaerobios.

Palabras clave: bacterias anaerobias; abscesos cerebrales; *Bacteroides* spp; cocos anaerobios grampositivos; neurocirugía; antibióticos

INTRODUCTION

Brain abscesses continue to remain a potentially fatal central nervous system infection [1]. This entity can be produced by several kinds of microorganisms such as bacteria, fungi, mycobacteria and parasites and the reported incidence ranges from 0.4 to 0.9 cases per 100,000 inhabitants [2,3]. This infection is usually described to be of polymicrobial nature involving both aerobic and anaerobic microorganisms [4]. The most important predisposing conditions resulting in the formation of brain abscesses are some underlying diseases (e.g. HIV infection), immunosuppressive treatments, disruption of the natural brain protective barriers or a systemic source of infection [5]. Brain abscesses caused by anaerobic bacteria can be mainly due to contiguous spread from parameningeal foci of infection as a consequence of paranasal, odontogenic and middle ear sources [6]. These microorganisms are not well routinely isolated in the majority of laboratories due to the difficulties in the isolation procedures. This circumstance has contributed to the fact that few studies are focused on brain abscesses caused only by anaerobic pathogens [4, 7-12]. Thus, the literature has provided only limited guidance with respect to the patients diagnosed with this condition, so the main objective of this study was to review the scientific literature containing cases of brain abscesses caused by anaerobic bacteria.

METHODS

Sources of information and selection of studies. Using the key words "brain abscesses", "brain abscess anaerobes" "cerebral abscesses" and "brain abscess anaerobic bacteria" we searched the medical literature through the Cochrane Library, EMBASE and PubMed/MEDLINE databases for studies of this condition. We also checked the references cited in the papers for additional reports searching patients with brain abscesses caused by anaerobes and that were described in sufficient detail to allow for comparison.

Inclusion and exclusion criteria. We have included studies with brain abscesses caused by anaerobic bacteria published in the scientific literature between 1998 and 2022, since during this period more and more laboratories use the MALDI-TOF MS or sequencing for identification of anaerobes isolated from serious infections. Our series included adult patients with brain abscesses in which anaerobic bacteria were isolated. Some reports have been excluded because they do not provide enough information to make comparisons, as well as the case reports with only one case of brain abscess due to anaerobes or those focused on an only anaerobic bacterium. Also, we have excluded the cases included exclusively in pediatric studies. We have excluded those in which more than three bacteria were isolated considering as mixed cultures [12].

Extracting of data and synthesis of information. Data were extracted reading these articles and recording them in a file. Later, these data were analyzed, synthetized and compared for establish conclusions.

RESULTS

A review of the literature identified 28 published large reports of brain abscesses whose etiology included anaerobic bacteria presenting data from 1998 to 2022 (Figure 1).

General characteristics. Clinical and microbiologic features of all patients included in this review are displayed in Table 1 and Table 2. Overall number of cases of brain abscesses included in this review was 6,167 and those with anaerobic microorganisms were 715 (11.5%) cases. The number of patients included per study varies between 4 and 2,219 patients, and the number of patients included per study with anaerobic bacteria varies between 2 and 190. There were 70% men (data not reported in 3 studies) and the mean age of patients was 40.3 years (data not reported in 5 studies). The cases were distributed as follows: 9 from India [4,8,9,11,13-17], 4 from Taiwan [18-21], 3 from Spain [12,22,23], 3 from France [7,24,25], 2 from UK [26,27], and one each from USA [28], Italy [29], Finland [30], Hungary [10], South Africa [31], Denmark [3] and Pakistan [32].

No underlying risk factors for anaerobic infection were reported in the majority of studies, although some factors such as immunosuppression, diabetes mellitus, surgery and cancer were observed in some works [3,12,23,24,26,31]. Regarding to the location of abscesses, it was not reported in three studies. From the remaining 25, the main location was the frontal lobe (84%), followed by temporal lobe (60%) and parietal lobe (40%).

Clinical features and source of infection. The most common predisposing conditions found were the presence of a contiguous focus of infection, especially an otogenic focus (84.6%). Other sources of infection also seen were the presence of a previous neurosurgery procedure (23%), a thoracogenic focus (16.9%), and a hematogenous focus (19.2%).

The clinical features in the patients included here were

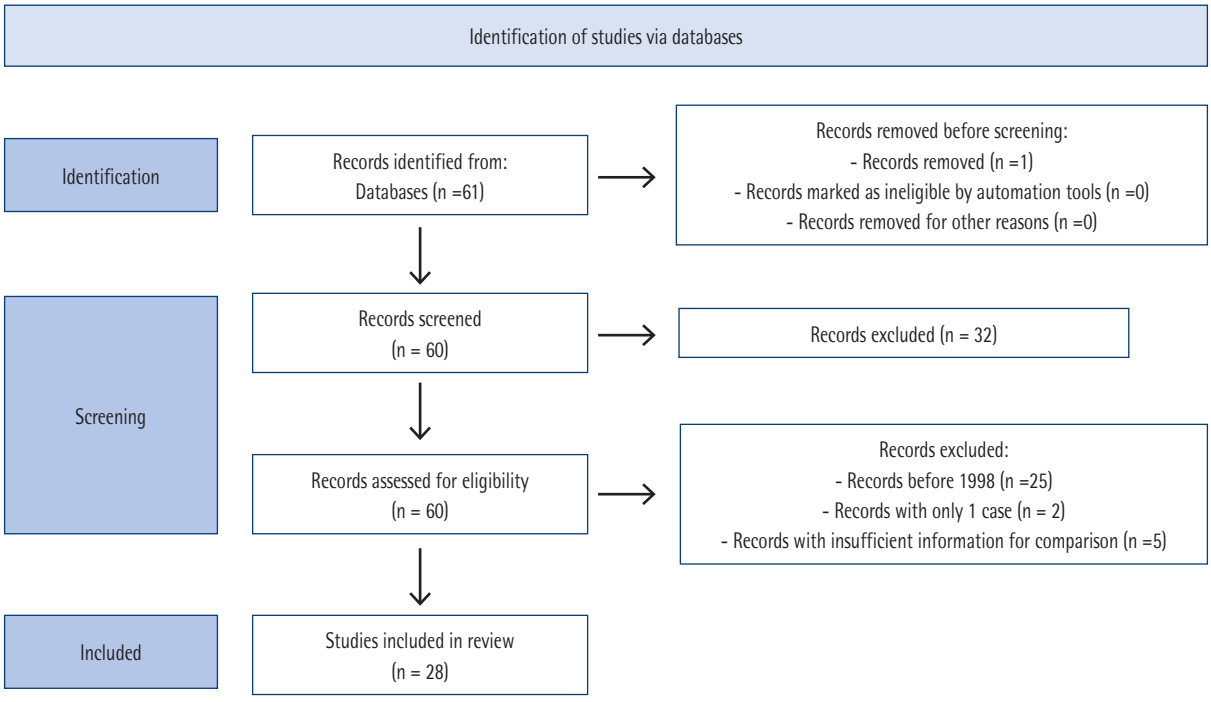

Figure 1 | **Flow diagram of cases of brain abscess included in this systematic review.**

calculated from 23 studies including 3,092 patients. The classic symptoms and signs were seen in many patients: headache was the most frequent and it was reported in 95.6% of cases, fever in 69.5% and neurologic deficit in 17.3%; vomiting only was detected in 8.6% of patients. Headache plus fever was detected in 65.2% of patients.

The relationship between the source of infection and the anaerobic microorganisms causing the brain abscesses was analyzed only in 3 studies [10,12,28]. They included only 74 patients. The most important finding in these cases is that the presence of a previous neurosurgery procedure was related with infection by *C. acnes* [10,12], and a relationship between the presence of sinuses infection and *Fusobacterium* spp was found [30].

Microbiology: type of infection and main anaerobic bacteria isolated. From 6,167 patients, at least one anaerobic bacteria was isolated in 715 (11.5%) of them. All cultures were performed from samples obtained by different surgical techniques such as aspiration/drainage and excision. Detailed microbiological methods related to the culture procedure and the identification of pathogens were only reported in 14 (50%) studies [4,7,8-15,18,21,22,28], and there were so many differences in the microbiological methodologies used. Overall results of the cultures yielded a total of 546 anaerobic bacteria isolated from the brain abscesses. The most frequently cultured microorganisms belonged to the *Bacteroides* genus (237 isolates, 43.4%), followed by Gram-positive anaerobic cocci (GPAC)/anaerobic *streptococci* (192 isolates, 35.1%). The third most common group of bacteria identified was *Fusobacterium* species (68 isolates, 12.4%). Table 3 shows all group of anaerobic bacteria isolated in the studies included in this review.

Regarding to the presence of monomicrobial or polymicrobial infection, this item was not reported in 12 studies; from the remaining 16 works, the infection was considered monomicrobial in 273 (59.4%) patients whereas it was considered polymicrobial in 186 (40.5%) cases.

Treatment and outcome. Initial antimicrobial therapy strategies were reported for 24 studies which included 3,362 patients. The percentage of patients in whom antibiotic treatment was applied range 89% to 100%. Treatment with antibiotics was very diverse, so no interesting conclusions could be drawn. On the other hand, data on surgical treatment were provided in 24 studies of those included here. Of them, 2,701 (43.7%) of patients were treated surgically by means of different techniques. Regarding to neurosurgical treatment modality, abscess aspiration and drainage was performed in 2,203 (81.5%) patients whereas primary abscess excision was done in 498 (18.4%) patients.

A total of 391 from 6,167 patients (6.3%) with brain abscesses died (ranging to 0% to 32%).

Table 1 Data of brain abscesses caused by anaerobic bacteria.

Author/year [reference]	Country	Total cases	Number of cases with anaerobes (%)	Men/women	Mean age (years)	Monomicrobial vs. polymicrobial (anaerobic brain abscesses)	Main anaerobic microorganisms isolated (n)	Main abscess's location	Source of infection
Chaudhry R/1998 [4]	India	18	6 (33.3)	14/4	23	2/4	*Prevotella* spp (4) *Bacteroides* spp (3)	Temporal and parietal	Thoracogenic and otogenic
Lu CH/2002 [18]	Taiwan	123	17 (13.8)	92/31	42	NR	*Bacteroides* spp (7) *Fusobacterium* spp (3)	Frontal and temporal	Hematogenous and neurosurgery
Kao PT/2003 [19]	Taiwan	53	5 (9.4)	34/19	41	2/3	*Bacteroides fragilis* (2) *Peptostreptococcus* spp (2)	Frontal and temporal	Otogenic and neurosurgery
Tattevin P/2003 [24]	France	94	15 (15.9)	74/20	47	NR	*Bacteroides* spp (5) *Anaerobic streptococci* (10)	NR	Dental abscess and thoracogenic
Le Moal G/2003 [7]	France	42	22 (52.3)	28/14	55	13/9	*Fusobacterium nucleatum* (14) *Prevotella* spp (8)	Temporal and frontal	Contiguous infection and trauma
Su TM/2003 [20]	Taiwan	124	18 (14.5)	93/31	40.7	NR	*Bacteroides* spp (7) *Fusobacerium* spp (3)	Frontal and temporal	Hematogenous and contiguous
Ni YH/2004 [21]	Taiwan	24	2 (8.3)	17/7	41	1/1	*Bacteroides fragilis* (1) *Peptostreptococcus* spp (1)	Frontal and parietal	Liver abscess and otogenic
Brook I/2005 [28]	USA	10	9 (90)	6/4	30	2/7	*Fusobacterium* spp (6) *Prevotella* spp (3)	Frontal	Contiguous infection
Prasad KN/2006 [13]	India	118	27 (22.8)	95/23	28	19/8	*Bacteroides fragilis group* (11) *Peptostreptococcus* spp (11)	Temporal, frontal and parietal	Otogenic
Tseng JH/2006 [26]	UK	142	24 (16.9)	98/44	41.5	NR	Anaerobes (24)	Frontal and temporal	Hematogenous and contiguous
Tonon E/2006 [29]	Italy	100	4 (4)	NR	49	4/0	*Peptostreptococcus* spp (2)	Frontal and parietal	Hematogenous and otogenic
Gómez J/2008 [22]	Spain	108	13 (12)	66/42	45	NR	*Bacteroides fragilis* (6) *Peptococcus* spp (5)	Temporal and frontal	Otogenic
Menon S/2008 [14]	India	75	16 (21.3)	55/20	NR	12/4	*Prevotella* spp (5) *Bacteroides* spp (9)	Temporal and frontal	Otogenic
Gutiérrez-Cuadra M/2009 [23]	Spain	71	5 (7)	52/19	45	5/0	*Peptostreptococcus* spp (2)	Frontal	Otogenic and neurosurgery
Lakshmi V/2011 [15]	India	352	39 (11)	2.7:1 ratio	28	22/17	*Peptostreptococcus* spp (17) *Bacteroides* spp (4)	Parietal and frontal	Otogenic
Nathoo N/2011 [31]	South Africa	973	37 (3.8)	722/251	24	NR	*Bacteroides* spp (31)	Frontal and parietal	Otogenic and traumatic
Manzar N/2011 [32]	Pakistan	53	8 (15.1)	41/12	NR	NR	Anaerobes (8)	Frontal and temporal	Sinus and neurosurgery
Mathis S/2012 [25]	France	81	25 (30.8)**	46/35	47	NR	*Fusobacterium* spp (NR) *Peptostreptococcus* spp (NR)	Frontal and parietal	NR
Helweg-Larsen J/2012 [3]	Denmark	102	14 (13.7)	66/36	47	NR	*Fusobacterium* spp (4)	Frontal and parietal	Contiguous and hematogenous
Das SK/2013 [16]	India	104	8 (7.6)	79/25	NR	6/2	*Bacteroides* spp (4)	Temporal and parietal	Otogenic
Vishwanath S/2016 [8]	India	4	4 (100)	2/2	32.5	1/3	*Bacteroides* spp (2) *Fusobacterium* spp (2)	Frontal	Otogenic
Sudhaharan S/2016 [9]	India	430	48 (11.1)	2.7:1 ratio	NR	31/17	*Peptostreptococcus* spp (30) *Bacteroides* spp (18)	Temporal	Otogenic

Table 1 Data of brain abscesses caused by anaerobic bacteria (cont.)

Author/year [reference]	Country	Total cases	Number of cases with anaerobes (%)	Men/women	Mean age (years)	Monomicrobial vs. polymicrobial (anaerobic brain abscesses)	Main anaerobic microorganisms isolated (n)	Main abscess's location	Source of infection
Laulajainen-Hongisto A/2016 [30]	Finland	166	45 (27.1)	117/49	42	NR	*Fusobacterium* spp (23)	Frontal and temporal	Contiguous
Singh N/2017 [17]	India	104	6 (5.7)	78/26	NR	NR	*Bacteroides* spp (6)	Temporal and cerebellar	Otogenic
Widdrington JD/2018 [27]	UK	113	43 (38)	73/40	53	11/32	*Fusobacterium* spp (10) *Prevotella* spp (7)	Frontal and temporal	Contiguous and neurosurgery
Gajdács M/2019 [10]	Hungary	64	34 (52.7)	32/32	52	NR	GPACs (16) *Cutibacterium acnes* (9)	NR	NR
Shruthi U/2019 [11]	India	2219	190 (8.5)	138/52*	22	127/63	*Bacteroides* spp (121) GPACs (97)	NR	Otogenic
Cobo F/2022 [12]	Spain	300	31 (10.3)	175/125	53	15/16	*Cutibacterium acnes* (13) *Parvimonas micra* (8)	Frontal and parietal	Neurosurgery and unknown

USA: United States of America; UK: United Kingdom; NR: not reported; GPAC: Gram-positive anaerobic cocci; * Referred to anaerobic microorganisms; ** Referred to overall patients.

DISCUSSION

Overall, data on brain abscesses caused specifically by anaerobic bacteria are currently limited. Searching the medical literature, only 7 studies described in detail the characteristics of brain abscesses caused by anaerobes [4, 7-12]. Taken into account the 28 studies focused on brain abscesses included in this review, the presence of anaerobes in these infections occurs in 11.5% on average (715 patients from 6,167). However, these data could be underestimated due to several facts such as the fastidious nature of these microorganisms, the special growth conditions required for the isolation of anaerobic pathogens and the difficulties in the identification. In the data reviewed here, it can see that this infection was more frequent in males (70%, n= 3,066 patients) and the mean age of the patients was 40.3 years. From 28 studies, in 21 (84%) the main location of these abscesses was the frontal region, followed by the temporal region (n= 15, 60%) and the parietal area (n= 10, 40%). The area less affected by brain abscesses was the occipital region. *Bacteroides* species were the most common anaerobic microorganisms isolated (237 strains), followed by GPACs (192 isolates). The majority of studies were published in Asia (n= 14), followed by Europe (n=12). There were no significant differences regarding the etiology according to the different regions. The relationship between the etiologic microorganism and the source of infection was only analyzed in 2 studies, including ours. In these published investigations a relationship between the presence of *Fusobacterium* spp and a sinusal focus seems that it could be demonstrated [28]. Also, our data showed a clear relationship between the presence of *Cutibacterium acnes* isolated in pure culture in patients with brain abscess that suffered a previous neurosurgery procedure [12]. Another study recently published also showed *C. acnes* as the second most frequent isolate in that series, although the authors cannot establish any relationship with a possible source of infection [10]. It is important to know the relationship between the source of infection and the causal microorganism in order to establish the empirical therapy of choice in these patients. However, further studies focused on this matter will be necessary to draw some conclusions. Taken together the data above mentioned, the empirical treatment should include effective drugs against *Bacteroides* spp and GPACs, taking into account the patterns of resistance in each area. In this sense, routine antimicrobial susceptibility testing for anaerobic bacteria could provide some interesting data and highlights the need to the resistance analysis for anaerobic isolates, especially in order to establish an adequate empirical therapy according to the local microbiological patterns and to modify the treatment when resistant strains appears.

The etiology of brain abscesses has been usually considered of polymicrobial nature, involving a great variety of aerobic and anaerobic microorganisms. However, from 715 anaerobic microorganisms corresponding to 28 studies, the majority of them were isolated as monomicrobial infections (n= 273, 59.4%) *vs* 186 isolates (40.5%) obtained as polymicrobial infections.

Regarding to the clinical features, none of the signs or symptoms presented in these patients are diagnostic of brain abscess. This symptomatology is only indicative because it can also be present in other diseases such as brain tumors and other central nervous system infections. In fact, in 5 studies the symptomatology was not reported; from the remaining 23

Table 2 **Data of brain abscesses caused by anaerobic bacteria related to clinical features, antimicrobial therapy, surgical treatment and mortality.**

Author/year [reference]	Main clinical features	Antimicrobial therapy n (%)	Surgical treatment n (%)	Overall mortality n (%)
Chaudhry R/1998 [4]	Headache, fever	NR	NR	1 (5.5)
Lu CH/2002 [18]	Headache, fever	123 (100)	106 (86); 72 excision; 40 aspiration and drainage	21 (17)
Kao PT/2003 [19]	Headache, fever	53 (100); 20 only antibiotics	33 (62.2); 25 aspiration and drainage; 8 excision	17 (32)
Tattevin P/2003 [24]	Headache, fever	88 (89)	60 (63.8); 47 aspiration and drainage; 7 excision	24 (26)
Le Moal G/2003 [7]	Headache, neurologic deficit	42 (100); 7 only antibiotics	42 (100)	6 (14)
Su TM/2003 [20]	Headache, fever	124 (100)	105 (84.6); 38 aspiration and drainage; 67 excision	21 (16.9)
Ni YH/2004 [21]	Headache, fever	24 (100)	20 (83.3); 19 excision	4 (16.6)
Brook I/2005 [28]	NR	10 (100)	10 (100)	NR
Prasad KN/2006 [13]	Headache, fever	118 (100)	118 (100); 84 aspiration and drainage; 34 excision	17 (14.4)
Tseng JH/2006 [26]	Headache, neurologic deficit	142 (100)	122 (85.9); 108 aspiration and drainage; 14 excision	24 (16.9)
Tonon E/2006 [29]	Fever, neurologic deficit	100 (100) 28 only antibiotics	72 (72); 64 aspiration and drainage; 8 excision	8 (8.3)
Gómez J/2008 [22]	Headache, fever	108 (100)	NR	17 (15.7)
Menon S/2008 [14]	Headache, fever	75 (100)	75 (100)	7 (9.5)
Gutiérrez-Cuadra M/2009 [23]	Headache, fever	71 (100)	26 (36.6); 19 excision; 7 aspiration and drainage	15 (21.4)
Lakshmi V/2011 [15]	NR	NR	NR	NR
Nathoo N/2011 [31]	Headache, fever	NR	954 (97.1); 927 aspiration and drainage; 18 excision	130 (13.4)
Manzar N/2011 [32]	Headache, fever	53 (100)	53 (100); 29 aspiration and drainage; 24 excision	6 (11.3)
Mathis S/2012 [25]	Headache, fever	24 (92.3)*	12 (46.1); 4 aspiration and drainage; 6 excision	5 (9)
Helweg-Larsen J/2012 [3]	Headache, fever	102 (100); 13 only antibiotics	91 (89); 61 aspiration and drainage; 18 excision	19 (19)
Das SK/2013 [16]	Headache, vomiting	104 (100)	99 (95.1); 78 excision; 21 aspiration and drainage	11 (10.5)
Vishwanath S/2016 [8]	Headache	4 (100)	2 (100); 2 aspiration and drainage	0
Sudhaharan S/2016 [9]	NR	430 (100)	430 (100); aspiration and drainage	1 (0.2)
Laulajainen-Hongisto A/2016 [30]	Headache, fever	164 (98.7)	164 (99); 117 aspiration and drainage; 54 excision	12 (7)
Singh N/2017 [17]	Headache, vomiting	104 (100)	99 (95.1); 78 excision; 12 aspiration and drainage	11 (10.5)
Widdrington JD/2018 [27]	Headache, neurologic deficit	113 (100)	103 (91); 95 aspiration and drainage; 8 excision	6 (5)
Gajdács M/2019 [10]	NR	NR	NR	NR
Shruthi U/2019 [11]	NR	190 (100)	190 (100); 88 aspiration and drainage	8 (4.2) **
Cobo F/ 2022 [12]	Headache	31 (100)**	31 (100)** ; 27 excision; 4 aspiration and drainage	0 **

*** Referred to patients with hereditary haemorrhagic telangiectasia; ** Referred only to anaerobes**

reports, headache was the main symptom present in these patients (95.6%), fever (41%) and fever (69.5%) and neurologic deficit (17.3%). Analyzing the association of these symptoms, headache plus fever was present in 65.2% of patients whereas headache plus focal neurologic deficit was present in only 13% of them. The classic triad of headache, focal neurologic deficits and fever was very unusual.

The outcome of patients with brain abscesses was reported in 391 patients and the average death rate was 6.8% ranging from 0% to 32%. With few exceptions, this mortality rate has clearly improved over the years. Several factors have influenced in this fact such as improvement in both diagnostic and neurosurgical techniques and antimicrobial treatments as well. The most frequent neurosurgical treatment modality was the aspiration of the abscess following the drainage in 40% of patients. The use of modern stereotactic neurosurgical techniques CT or MRI-guided permits both the sampling for diagnostic purposes and the decrease of the brain pressure with fewer complications than before. Also, the improvement in the antimicrobial treatment regimens has contributed to the decrease in mortality in these patients. Different treatment guidelines have been used along these years but, before the

Table 3 **Anaerobic microorganisms isolated from brain abscesses in 28 studies.**

Group of microorganisms	Number (%)
Bacteroides spp	237 (43.4)
GPACs/Anaerobic streptococci	192 (35.1)
Fusobacterium spp	68 (12.4)
Prevotella spp	27 (4.9)
Cutibacterium acnes	22 (4)

GPAC: Gram-positive anaerobic cocci

80's, antimicrobial anaerobicides were not normally included as empiric treatment of these infections; however, metronidazole along with third generation cephalosporins (cefotaxime/ceftriaxone) was considered to be the most frequent empiric treatment in brain abscesses, according to some studies [3, 8, 9, 11].

This study has some limitations: firstly, reporting of data was highly diverse among studies due to their heterogeneity which makes comparisons difficult of some items. Secondly, most data here included were referred to overall brain abscesses, unable to distinguish between abscesses caused by aerobic pathogens from those caused by anaerobic microorganisms. Third, in some studies it is difficult to exclude both the cases located in the extra-axial CNS (e.g. subdural empyema,..) and the cases produced in children.

In conclusion, *Bacteroides* species and GPACs seem to be the globally the most frequent anaerobic bacteria isolated in brain abscesses. Few data about the relationship between source of infection and etiological microorganisms were provided, but in some studies a relationship between *Fusobacterium* spp and sinusal source and *C. acnes* and neurosurgical procedure could be established. Unlike what was previously published, brain abscesses are most frequent of monomicrobial nature and they occurred most frequently in males. The new neurosurgical techniques along with a better empiric antimicrobial coverage have currently improved the global outcome of these patients.

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None to declare.

CONFLICT OF INTEREST

Author declares no conflict of interest.

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