










Original Article

A Canadian National Survey of the Neurosurgical Management of Intracranial Abscesses

Michelle M. Kameda-Smith^{1,2} , Malavan Ragulojan¹, Shannon Hart^{1,2}, Taylor R. Duda^{1,2}, Mark A. MacLean⁴ , Jonathan Chainey⁵, Minoo Aminnejad^{1,3}, Michael Rizzuto⁶ , David Bergeron⁷, Mathew Eagles⁸ , Alan Chalil⁹ , Anne-Mare Langlois¹⁰, Charles Garipey¹¹, Amit Persad¹², Mohammed Hasen¹³, Alick Wang¹⁴ , Lior Elkaim¹⁵ , Sean Christie⁴ , Forough Farrokhyar^{1,3}, Kesava Reddy^{1,2}  and on behalf of the Canadian Neurosurgery Research Collaborative¹

¹McMaster University, Hamilton, Ontario, Canada, ²Department of Surgery, Neurosurgery, London, UK, ³Department of Health Research Methods, Evidence and Impact, McMaster University, Hamilton General Hospital, Hamilton, Ontario, Canada, ⁴Dalhousie University, Department of Surgery, Neurosurgery, QEII Health Sciences Center, Halifax Infirmary, Halifax, Nova Scotia, Canada, ⁵University of Alberta, Department of Surgery, Neurosurgery, Royal Alexandra Hospital, Edmonton, Alberta, Canada, ⁶University of British Columbia, Department of Surgery, Neurosurgery, Vancouver General Hospital, Vancouver, British Columbia, Canada, ⁷Université de Montréal, Department of Surgery, Neurosurgery, Centre Hospitalier de l'Université de Montréal (CHUM), Montréal, Québec, Canada, ⁸University of Calgary, Department of Surgery, Neurosurgery, Foothills Medical Center, Calgary, Alberta, Canada, ⁹University of Western Ontario, Department of Surgery, Neurosurgery, University Hospital, London, Ontario, Canada, ¹⁰Université de Sherbrooke, Department of Surgery, Neurosurgery, Centre de recherche du Centre Hospitalier Universitaire de Sherbrooke, Sherbrooke, Québec, Canada, ¹¹Université de Laval, Department of Surgery, Neurosurgery, Hôpital de l'Enfant-Jésus Québec City, Québec, Canada, ¹²University of Saskatchewan, Department of Surgery, Neurosurgery, Royal University Hospital, Saskatoon, Saskatchewan, Canada, ¹³University of Manitoba, Department of Surgery, Neurosurgery, Health Science Center (HSC), Winnipeg, Manitoba, Canada, ¹⁴University of Ottawa, Department of Surgery, Neurosurgery, Ottawa Hospital, Ottawa, Ontario, Canada and ¹⁵University of McGill, Department of Surgery, Neurosurgery, Montreal Neurological Institute (MNI) Hospital, Montreal, Quebec, Canada

ABSTRACT: Objective: Intracerebral abscess is a life-threatening condition for which there are no current, widely accepted neurosurgical management guidelines. The purpose of this study was to investigate Canadian practice patterns for the medical and surgical management of primary, recurrent, and multiple intracerebral abscesses. **Methods:** A self-administered, cross-sectional, electronic survey was distributed to active staff and resident members of the Canadian Neurosurgical Society and Canadian Neurosurgery Research Collaborative. Responses between subgroups were analyzed using the Chi-square test. **Results:** In total, 101 respondents (57.7%) completed the survey. The majority (60.0%) were staff neurosurgeons working in an academic, adult care setting (80%). We identified a consensus that abscesses >2.5 cm in diameter should be considered for surgical intervention. The majority of respondents were in favor of excising an intracerebral abscess over performing aspiration if located superficially in non-eloquent cortex (60.4%), located in the posterior fossa (65.4%), or causing mass effect leading to herniation (75.3%). The majority of respondents were in favor of reoperation for recurrent abscesses if measuring greater than 2.5 cm, associated with progressive neurological deterioration, the index operation was an aspiration and did not include resection of the abscess capsule, and if the recurrence occurred despite prior surgery combined with maximal antibiotic therapy. There was no consensus on the use of topical intraoperative antibiotics. **Conclusion:** This survey demonstrated heterogeneity in the medical and surgical management of primary, recurrent, and multiple brain abscesses among Canadian neurosurgery attending staff and residents.¹

RÉSUMÉ : Sondage à l'échelle du Canada portant sur le traitement neurochirurgical des abcès intracrâniens. **Objectif :** L'abcès intracérébral est une affection potentiellement mortelle pour laquelle il n'existe pas à l'heure actuelle de lignes directrices largement acceptées en matière de prise en charge neurochirurgicale. L'objectif de cette étude est donc d'examiner les pratiques canadiennes en matière de traitement médical et chirurgical des abcès intracérébraux primaires, récurrents et multiples. **Méthodes :** Un sondage électronique transversal auto-administré a été distribué aux membres actifs et aux résidents de la Société canadienne de neurochirurgie (SCN) et du *Canadian Neurosurgery Research Collaborative* (CNRC). À noter que les réponses des sous-groupes à ce sondage ont été analysées à l'aide du test du khi carré. **Résultats :** Au total, ce sont 101 répondants (57,7 %) qui ont complété ce sondage. La majorité d'entre eux (60,0 %) étaient des neurochirurgiens salariés travaillant dans un établissement universitaire de soins pour adultes (80 %). Nous avons identifié un consensus à l'effet que les abcès de plus de 2,5 cm de diamètre devraient faire l'objet d'une intervention chirurgicale. La majorité des répondants étaient aussi favorables à l'excision d'un abcès intracérébral plutôt qu'à une aspiration s'il était situé superficiellement dans le cortex somatosensoriel « non-sensible » (*non-eloquent cortex*) (60,4 %) mais aussi s'il était situé dans la fosse crânienne postérieure (65,4 %).

Corresponding author: Michelle Kameda-Smith, Clinical Fellow in Paediatric Neurosurgery, Department of Surgery, Division of Neurosurgery, Great Ormond Street Hospital for Children, London, UK. Email: michelle.kameda@medportal.ca

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%) ou s'il provoquait un effet de masse entraînant une hernie (75,3 %). La majorité des répondants étaient par ailleurs en faveur d'une réopération pour les abcès récurrents s'ils mesuraient plus de 2,5 cm, s'ils étaient associés à une détérioration neurologique progressive, si l'opération de référence était une aspiration et ne comprenait pas la résection de la capsule de l'abcès et enfin si la récurrence survenait malgré une chirurgie antérieure combinée à une antibiothérapie maximale. Finalement, aucun consensus n'a émergé quant à l'utilisation d'antibiotiques topiques peropératoires. **Conclusion :** En définitive, ce sondage administré au personnel traitant et aux résidents canadiens en neurochirurgie a démontré une hétérogénéité dans la prise en charge médicale et chirurgicale des abcès cérébraux primaires, récurrents et multiples.

Keywords: Canadian national survey; Intracerebral infection; Intraparenchymal abscess; Resection; Aspiration

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Introduction

Intracerebral abscess is a life-threatening neurosurgical condition.² Advances in neuroimaging, stereotaxy, pathogen isolation/sequencing, and antibiotic therapy have improved care of patients with intracerebral abscess.^{2,3} However, case fatality rates vary from ~10% to 25%.⁴⁻⁸ Abscess development may occur via contiguous spread of local infection or hematogenous spread of systemic infection. Risk factors include immunosuppression, immunodeficiency, disruption of brain protective barriers, and prior cranial neurosurgical intervention.^{1,9} Abscess-associated complications include hydrocephalus, acute ventriculitis, and epilepsy^{1,2,10} and therefore prompt identification of abscesses that will benefit from surgical intervention is crucial.

Two commonly utilized approaches to surgical management include (1) craniotomy for complete excision of abscess contents and capsule and (2) burrhole aspiration with or without stereotactic guidance.^{2,10-14} Many surgeons believe complete excision of the abscess and associated capsule may offer improved source control and penetration of antibiotics (i.e., following resection of collagenous abscess capsule). Prior reports indicate this may lead to lower abscess recurrence rates, decreased length of hospital stay, decreased overall cost, and shorter length of antibiotic requirement.^{2,14-16} In contrast, abscess aspiration alone may provide a microbiological diagnosis, reduce mass effect, and minimize the risk of morbidity (i.e., neurovascular injury, intracerebral hemorrhage, delayed-onset epilepsy.^{5,16-18} However, to date there have been no randomized controlled trials comparing these approaches.³ Furthermore, indications (e.g., lesion size, location, single or multiple, primary or recurrent) and timing for surgery remain unclear.

To date, there are no widely accepted neurosurgical guidelines, and no standard practices have been adopted by the greater neurosurgical community. Here, we investigate Canadian practice patterns for the medical and surgical management of primary, recurrent, and multiple intracerebral abscesses. Identifying heterogeneity or consensus in national practice patterns may inform the development of national standard guidelines.

Methods

Study Design and Population

The Canadian Neurosurgery Research Collaborative (CNRC) is led by resident neurosurgeons, uniquely positioned to capture multicenter data to address the multidimensional knowledge gaps pertaining to the medical and surgical management of neurosurgical entities such as primary, recurrent, and multiple intracerebral abscess. We conducted a self-administered, cross-sectional electronic

survey of Canadian staff and resident neurosurgeons. Board-certified fellows were also eligible. Institutional ethics review board approval was obtained prior to survey development. A local chart review was performed, and anonymized data were utilized during the development of case examples subsequently included in the survey. All data during survey development and administration were collected and stored on a secure REDCap server.

Survey Development

Survey design was iterative and completed by the primary investigators (MKS, TD, and KR). The initial survey draft was assessed for redundancy and clarity by the steering committee of the CNRC.¹⁹ Face and content validity were assessed via board-certified neurosurgeons at multiple sites.

Survey Distribution

The anonymous, voluntary survey was distributed by email to all active members of the Canadian Neurosurgical Society (CNSS) and CNRC over a scheduled 8-month period with several email reminders. A final personal communication via local CNRC member to their colleagues was completed over the 2-month period prior to survey closure. We anticipated 175 potential respondents across both targeted groups.

Statistical Analysis

Descriptive data were tabulated. Responses between subgroups (e.g., adult vs pediatric practice, staff vs. resident, years in practice) were analyzed using the Chi-square test with statistical significance set at $p < 0.05$. A 7-point Likert scale was provided for determining the self-perceived response confidence. Free text responses were analyzed qualitatively. Categorical data were reported as counts and percentages.

Results

Demographics

In total, 101 respondents (57.7%) completed the survey. The majority (60.0%) were attending staff neurosurgeons working in an academic, adult care setting (80%) (Figure 1). Thirty-four percent of respondents were neurosurgical residents. Twenty-seven percent of attending staff reported being in practice for between 11 and 20 years. The majority of respondents (47.5%) reported managing between 26 and 50 patients in consultation per week. Responses were widely distributed across Canadian centers. The majority (63.4%) of respondents reported managing either one or zero intracerebral abscess per month.

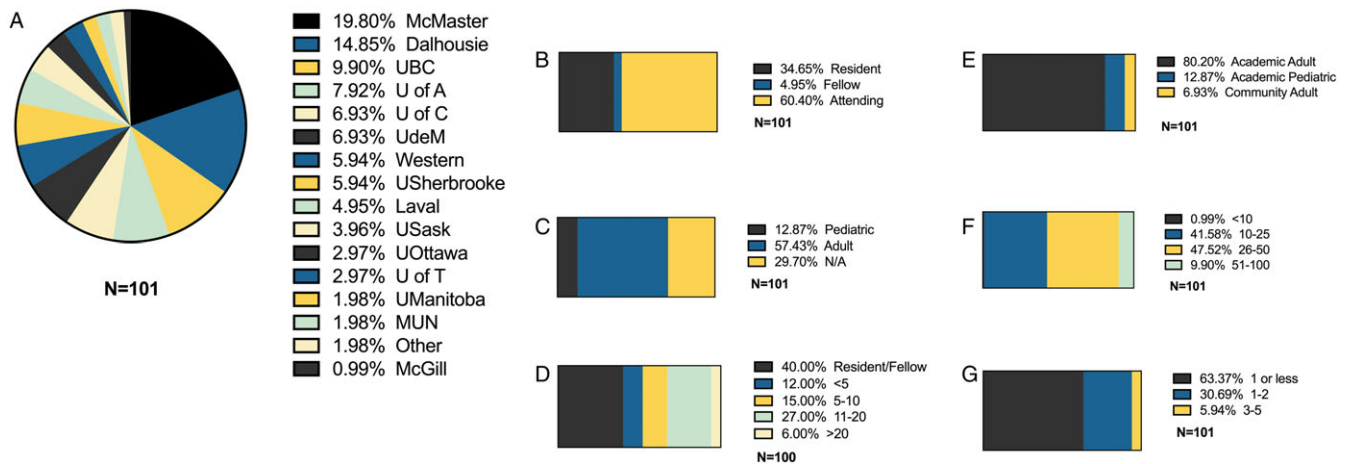


Figure 1: Respondent demographics. (A) Proportion of respondents from each Canadian neurosurgical institution by percentage (%), (B) Distribution of survey respondents by level of training, (C) respondents who identified as an adult or pediatric neurosurgeon, with N/A indicating a mixed practice, (D) years of independent neurosurgical practice respondents reported (excluding residency or fellowship), (E) principal care setting respondents practice in; community pediatric practice not shown as no respondents chose this answer, (F) average number of patients respondents reported seeing in a typical week, for any reason, (G) average number of intracranial abscesses respondents reported seeing as a consultation in a typical month.

Guidelines and Recommendations

A minority of (23.8%) respondents indicated that they are aware of general guidelines for the management of intracerebral abscesses (Table 1). Several respondents further elaborated further that their practice was informed by Infectious Disease Society of America (IDSA) or American Association of Neurosurgery (AANS) guidelines. The majority of respondents (77.2%) agreed (i.e., somewhat, mostly, or entirely) with a theoretical recommendation that neurosurgical management is indicated for *any* brain abscess measuring at least 2.5 cm in diameter. Fifty two (51.5%) recommended this approach for all patients with intracerebral abscess they managed during the 6 months preceding survey completion. Clinicians disagreeing with this indication provided cases in which they would not offer neurosurgical treatment: abscesses in the early cerebritis stage, avoiding aggressive therapy in patients who may not tolerate surgery, abscesses in deep or inaccessible locations, and known microbial etiology with improvement on antibiotic therapy.

Surgical Technique and Indications

Most respondents (67.3%) chose a surgical technique (i.e., aspiration vs evacuation and resection of abscess capsule) based on assessment of clinical and radiological factors (Table 1). The majority of respondents favored of excising an intracerebral abscess over performing aspiration if located superficially in non-eloquent cortex (60.4%), located in the posterior fossa (65.4%), or causing mass effect leading to herniation (75.3%) (Figure 2). Choice of surgical technique was equivocal if there was a high suspicion of nocardia, tuberculous, fungal, or branching bacteria, or when the abscess capsule appears radiologically mature. Fifty-eight percent (57.4%) of respondents were not in favor of open resection to prevent ventriculitis when an abscess is abutting but has not yet ruptured into the ventricular system. The majority of respondents agreed with the published management recommendations in each scenario as visualized in Figure 2B.

Intraoperative Antibiotic Use

Half of our respondents (54.5%) felt there is a role for antibiotics administration directly into the abscess cavity (Figure 3). Although

half (53.5%) believed vancomycin powder should be applied to the cavity following excision, 81.2% had not applied vancomycin powder for any intracerebral abscess excision case during the 6-month period prior to survey completion. While 42 (41.6%) surgeons agreed that synthetic duraplasty should not be used if a craniotomy is performed for evacuation of an intracerebral abscess, 30 (29.7%) respondents were uncertain. The primary exception stated by most respondents was in cases where a watertight closure was needed and pericranium could not be harvested.

Multiple and Recurrent Abscesses

Most respondents (81.2%) reported that in situations involving multiple abscesses the largest one should be aspirated for culture and antibiotic sensitivities (Figure 4). A third of respondents (30.7%) implemented this guideline in more than half of their recent cases. Eighty-nine respondents (88.1%) indicated that choosing to aspirate additional lesions would depend on other factor such as lesion size, maturity, surrounding edema, patient’s symptoms, and prior response to antimicrobials.

Most respondents were in favor of reoperation for recurrent abscesses if the recurrence measured greater than 2.5 cm, there was significant neurological deterioration, the prior operation was an aspiration and did not include resection of the abscess capsule, and if recurrence occurred despite maximal antibiotic therapy after the index surgery (Figure 5). Subtotal resection (85.2%) and goals of care that include “doing everything possible to save a patient’s life” (62.4%) were not considered stand-alone indications for repeat intervention by most respondents.

Clinical Case Scenarios

The most common goal of surgery in all three clinically distinct cases of intracerebral abscesses was identification of the organism (Figure 6). Regarding Case 1 (i.e., multiple intracerebral abscesses), 40.6% of respondents would recommend stereotactic aspiration of any abscesses greater than 2.5 cm in diameter on radiographic imaging. Regarding Case 2 (i.e., intraventricular rupture of abscess), 32% of respondents recommended surgical excision of abscess and insertion of an external ventricular drain (EVD).

Table 1: Respondent expert opinion on the general management of brain abscesses

Survey question		N (%)	
Are you aware of any general guidelines in the management of intracerebral abscesses?			
No		77 (76.2)	
Yes		24 (23.8)	
Neurosurgical management is indicated for any brain abscess (with or without capsule formation) that measures at least 2.5 cm in diameter, irrespective of location.			
How much do you agree with the statement?		How justified do you find the above clinical recommendation?	
7 - Entirely Agree	3 (3.0)	7 - Entirely Agree	3 (3.0)
6 - Mostly Agree	47 (46.5)	6 - Mostly Agree	44 (43.6)
5 - Somewhat Agree	28 (27.7)	5 - Somewhat Agree	29 (28.7)
4 - Neither Agree or Disagree	5 (4.9)	4 - Neither Agree or Disagree	9 (8.9)
3 - Somewhat Disagree	10 (9.9)	3 - Somewhat Disagree	9 (8.9)
2 - Mostly Disagree	7 (6.9)	2 - Mostly Disagree	7(6.9)
1 - Entirely Disagree	1 (1)	1 - Entirely Disagree	0 (0.0)
In what percent of patients in the last 6 months with a suspected intracranial abscess at least 2.5 cm in diameter have you implemented the above recommendation?			
0%		23 (22.8)	
20%		1 (1)	
40%		2 (2.0)	
60%		7 (6.9)	
80%		15 (14.9)	
100%		52 (51.5)	
How do you manage intracerebral abscesses neurosurgically?			
I only aspirate the abscess cavity		31 (30.7)	
I perform either aspiration or resection of the abscess capsule depending on clinical and radiological factors.		68 (67.3)	
I believe the abscess capsule must be fully resected		2 (2.0)	

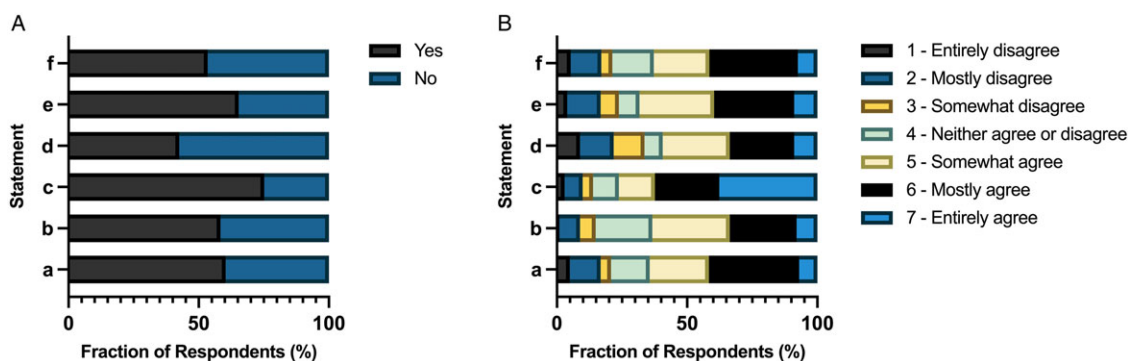


Figure 2: Surgeon opinion regarding excision vs aspiration of intracranial abscesses. Survey responses to the below stem and substatements. (A) Results of yes or no responses regarding excision vs aspiration for the situations detailed below. (B) Level of agreement of published abscess management recommendations on a 7-point Likert scale. Neurosurgical excision via craniotomy over aspiration through burr hole is preferred in the following situations: (A) With superficial lesions NOT located in eloquent areas of the brain. (B) Upon the suspicion of nocardia, fungal, tuberculous, or branching bacteria as an etiology. (C) When the abscess produces mass effect leading to brain herniation. (D) When the abscess is abutting, but has not yet ruptures into, the ventricular system, in order to prevent ventriculitis. (E) When the brain abscess is located in the posterior fossa. (F) When the abscess capsule is considered “thick” and the abscess appears radiologically mature.

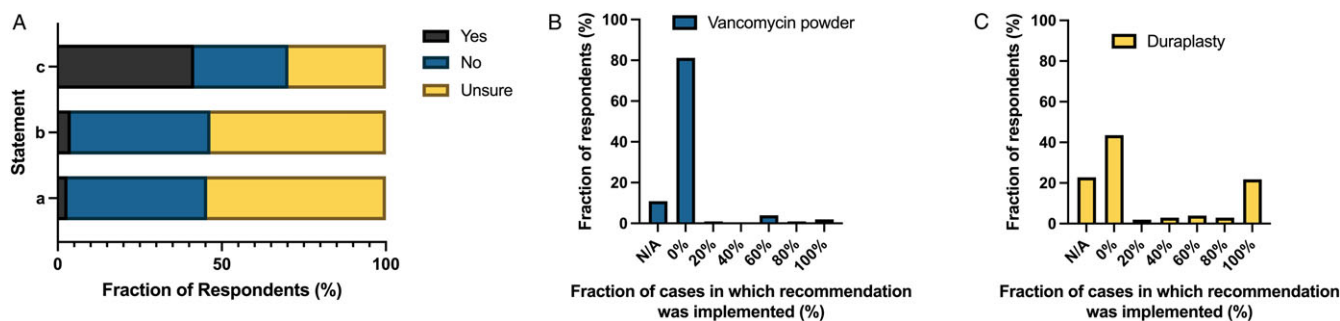


Figure 3: Role of intraoperative antibiotics and synthetic duraplasty following craniotomy for intracranial abscess. Demonstrates responses to statements listed below. (A) Results of respondents answering yes, no, or unsure to below statements. (B) Percentage of abscess cases respondents reported not using synthetic duraplasty in the setting of craniotomy. Statements: (A) Is there any role for antibiotic administration directly into the abscess cavity? (B) When excision is performed, vancomycin powder should be used. (C) Synthetic duraplasty should NOT be used if a craniotomy is performed for evacuation of intracerebral abscess.

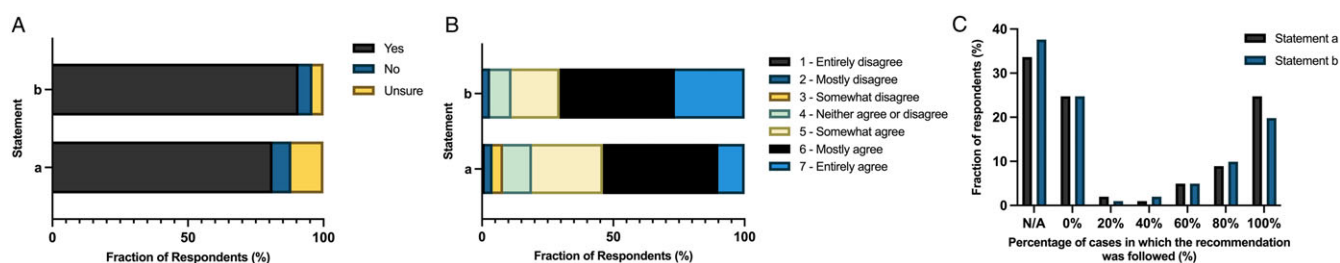


Figure 4: Management decisions of multiple intracerebral abscesses. (A) Results of respondents answering yes, no, or unsure to the statements: (A) When multiple abscesses are present, the largest one should be aspirated for culture and antibiotic sensitivities; (B) aspirating additional lesions will depend on such prognostic factors such as their size, maturity, the extent of surrounding edema, the patient’s symptoms, and the response to antimicrobial treatment. (B) Further breakdown of responses into level of agreement on 7-point Likert scale, (C) proportion of respondents in which answered % of cases in which recommendations followed for statements A and B.

Regarding Case 3 (i.e., pediatric intracerebral abscess from otitis media), 39 (38.6%) respondents recommended stereotactic aspiration of the largest abscess only (Figure 7).

Subgroup Analyses

We compared responses between groups according to type of practice (i.e., pediatric vs adult practice), position (i.e., residents vs attending staff), years in practice (greater or less than 10 years), number of abscesses managed per month (0 or 1 vs greater than 1), and awareness of guidelines (Supplementary Table 1). A greater proportion of respondents with less than 10 years in practice and awareness of guidelines were more likely to recommend abscess excision compared to aspiration alone. A greater proportion of respondents practicing pediatric neurosurgery, residents, and those with less than 10 years in practice were more likely to recommend excision of abscesses in non-eloquent locations. Residents and those in practice with less than 10 years of experience favored excision for situations where abscesses produce a mass effect resulting in herniation. When the abscess capsule was perceived as “thick” and radiologically “mature,” significantly more adult neurosurgeons compared to pediatric surgeons recommended craniotomy and excision over aspiration; whereas a greater proportion of residents and those in practice for less than 10 years in practice recommended excision.

A greater proportion of attending staff felt there was no role for antibiotic administration into the abscess cavity, including using vancomycin in an open excision, compared to residents. Respondents who saw at least one intracerebral abscess a month

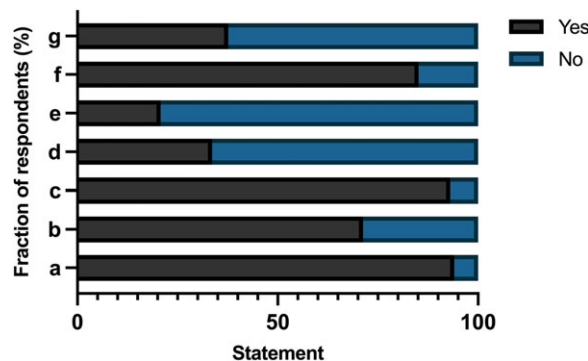


Figure 5: Role of reoperation in recurrent abscesses. Responses of Canadian neurosurgeons considering the following statement: I would consider returning to re-operate on a previously aspirated/resected recurrent abscess if: (A) significant neurological decline in the setting of a patient improving from index surgery and recurrent abscess formation. (B) Recurrent abscess >2.5 cm. (C) Recurrent abscess causing significant mass effect correlating with neurological decline. (D) Previous operation was an aspiration and did not remove abscess capsule. (E) Previous operation subtotalled resected the abscess capsule. (F) Recurrent abscess formed despite maximal antibiotic therapy after the index surgery. (G) The goals of care are to do everything possible to save the patient’s life.

were more likely to rely on additional factors including size, maturity, surrounding edema, and response to antimicrobial treatment when deciding to aspirate additional lesions aside from the largest lesion. Regarding Case 1 (i.e., multiple abscesses) and Case 3 (i.e., pediatric abscess), we did not identify statistically significant

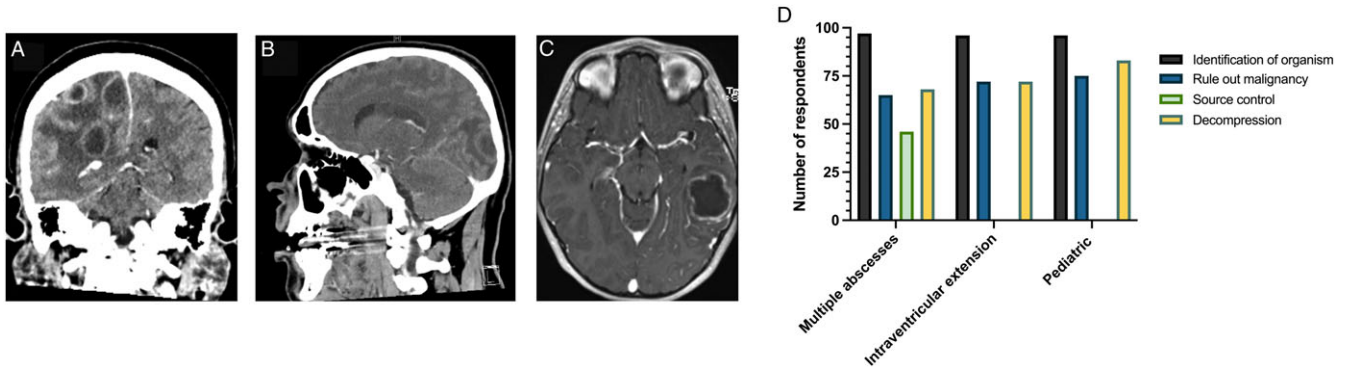


Figure 6: Representative images (Cases 1–3) and proportion of respondents selecting various goals of surgery. (A) Multiple intracerebral abscesses in a 57-year-old female presenting with a 3-week history of left-sided weakness and confusion. Greater than 5 right-sided ring enhancing lesions with 8 mm midline shift. Largest lesion abutting the motor cortex. CT chest: left lung lesion (query of lung malignancy vs abscess), (B) intracerebral abscess ruptured into the occipital horn of the lateral ventricle in a 58-year-old male presenting with 1 week of malaise, nausea, and vomiting and blurry vision with 3.1 x 2.5 cm single right occipital ring enhancing lesion with ventricular enhancement, (C) single left parietal abscess in 6-year-old male presenting with 6 weeks of lethargy, “blocked ears” sensation, mild hearing impairment, and transient upper respiratory tract infection.

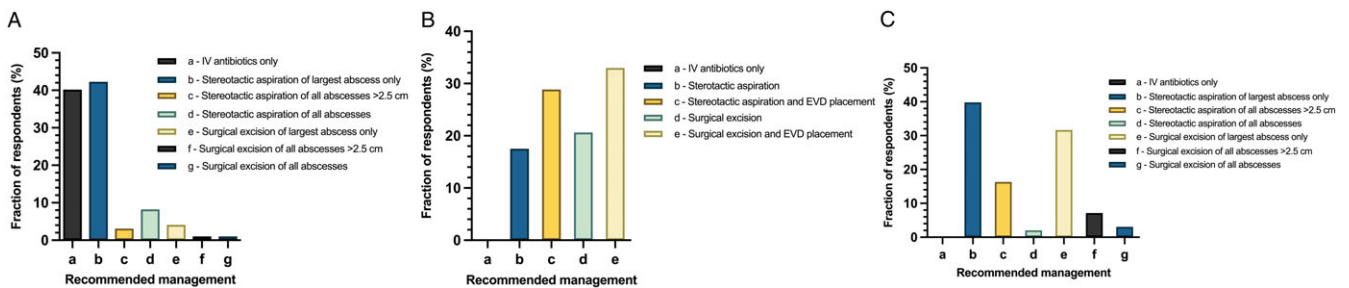


Figure 7: Recommended management for cases described in Figure 6. (A) Multiple intracranial abscesses – (A) IV antibiotics only, (B) stereotactic aspiration of largest abscess only, (C) stereotactic aspiration of all abscesses >2.5 cm, (D) stereotactic aspiration of all abscess, (E) surgical excision of largest abscess only, (F) surgical excision of all abscesses >2.5 cm, (G) surgical excision of all abscesses; (B) intraventricular extension – (A) IV antibiotics only, (B) stereotactic aspiration, (C) stereotactic aspiration and EVD placement, (D) surgical excision, (E) surgical excision and EVD placement; (C) pediatric single abscess – (A) IV antibiotics only, (B) stereotactic aspiration of largest abscess only, (C) stereotactic aspiration of all abscesses >2.5 cm, (D) stereotactic aspiration of all abscess, (E) surgical excision of largest abscess only, (F) surgical excision of all abscesses >2.5 cm, (G) surgical excision of all abscesses.

differences across subgroups (Supplementary Tables 2 and 4). In Case 2 (i.e., intraventricular rupture), a greater proportion of those with > 10 years in practice (compared to <10 years), attending staff (compared to residents), with greater than 1 abscess (compared to 0–1) seen in consultation per month, and perceived awareness of guidelines (Supplementary Table 3) observed significant differences between subgroups ($p < 0.001$). Attendings and those with >10-years experience were more likely to stereotactically aspirate where residents and fellows would surgically excise. Whereas clinicians who manage more than 1 abscess per month were more likely to excise rather than stereotactically aspirate.

Discussion

To date, there are no widely accepted neurosurgical guidelines for management of intracerebral abscess. Despite the lack of standard practices among the greater neurosurgical community, no randomized controlled trials comparing common surgical techniques (e.g., craniotomy for excision of abscess vs. stereotactic aspiration via burr holes) have been completed. This cross-sectional national survey of Canadian neurosurgery attending staff and residents captures practice patterns regarding the medical and surgical management of primary, recurrent, and multiple intracerebral abscesses. We identified few areas of consensus and significant heterogeneity in practice patterns. These results may inform development of national practice guidelines.

Surgical Indications

Indications for neurosurgical intervention include significant mass effect, intracranial hypertension, progressive neurologic deficit, and pathogen identification.²⁰ While surgery is generally considered a mainstay of treatment, medical treatment alone may be appropriate. Such instances include small abscesses (<2.5 cm), good initial neurological status, known pathogen, and when the patient is a poor surgical candidate.^{20,21}

Although there are no current, widely accepted neurosurgical guidelines for the management of intracerebral abscess, approximately a third of respondents indicated they were aware of general guidelines (e.g., IDSA). Most respondents in this study agreed with the theoretical recommendation that *any* abscesses larger than 2.5 cm should be operated on. However, few respondents reported implementing this practice for abscesses they recently managed. A patient with a larger abscess may be a candidate for conservative management if there were significant contraindications to surgery, refusal of surgery, or the abscess is in the early cerebritis stage. On the other hand, select abscesses smaller than 2.5 cm may be also be amenable to surgery. The 2.5 cm size cutoff is commonly cited but unfortunately lacks objective evidence to support an impact on functional outcome and overall survival.^{9,10,20,1,22} Respondents also felt that lesion location (e.g., non-eloquent, eloquent, deep, posterior fossa), high suspicion for fungal or atypical bacterial species (e.g., nocardia or tuberculous disease), radiographic appearance,

and symptomatic mass effect leading to herniation were also important considerations in the surgical management of intracerebral abscesses.

Surgical Techniques

The optimal surgical technique for management of intracerebral abscess is a topic of ongoing debate.^{23,24} Advantages and disadvantages of each technique have been reported including the challenges and experiences in developing countries.²⁵ In the literature, abscess excision has been observed to be associated with decreased recurrence and re-operation rates, decreased duration of antibiotic course, shorter hospital stays, and lower overall cost relative to aspiration.^{2,13–16,18,23} Excision may be preferred in cases of large, superficial, or multiloculated abscesses, when there is significant mass effect, in trauma- and/or foreign body associated abscesses, and those located in the posterior fossa.^{2,18,26} We identified further suggestions for excision over aspiration including abscesses in non-eloquent areas of the brain, with suspicion of more resistant pathogens such as fungi, TB, or branching bacteria.¹ However, excision has been associated with an increased rate of mortality,¹⁸ intracranial hemorrhage,²⁴ and seizures.² Advantages of aspiration include minimally invasive technique, potential to avoid general anesthesia in poor surgical candidates, less potential morbidity and mortality, and use in deep-seated or eloquent areas.^{2,14,18,26} The largest drawback of aspiration is that the abscess capsule remains *in situ* and may lead to higher rates of early recurrence and need for re-operation.^{2,14,23}

Most of our survey respondents agreed that either aspiration or excision may be an acceptable approach depending on specific clinical and radiographic factors. There remained a preference for less invasive techniques, however, as a much larger proportion of surgeons used aspiration (30.7%) compared to excision (2%) exclusively. Choice of procedure was equivocal if the abscess abuts the ventricle, with more resistant pathogens, and a more radiologically mature capsule. Of particular interest was the discordance in responses between experienced surgeons and residents, those < 10 years into practice, and those managing 0–1 abscesses per month. Specifically, while more experienced surgeons were less likely to excise an abscess in a non-eloquent area, they were more likely to resect an abscess that appears radiologically mature with a “thick” capsule and less likely to use topical antibiotics in the abscess cavity following excision (e.g., vancomycin powder) (Supplementary Table 1).

Additional unresolved issues investigated in this study include intraoperative antibiotic administration and use of synthetic duraplasty in the setting of intracerebral abscess. Some experts advised intra- or postoperative administration of antibiotics into the abscess cavity as penetration through the abscess capsule may be limited during an aspiration procedure.⁷ Some authors observed good clinical and radiological outcomes with the use of intracavity antibiotics and suggest their utility in large, poorly resolving abscesses, or those involving more resistant pathogens; however, evidence is limited.^{27–30} In our study, we found that most Canadian neurosurgeons did not routinely utilize intraoperative intracavitary antibiotics unless for repeat procedures.

Approach to Multiple Abscesses

For confirmed intracerebral abscess, the incidence of multiple lesions ranges from 10% to 50%.^{21,31–35} Patient presentation depends on multiple factors: abscess location (i.e., eloquence), size and mass effect, and stage of abscess formation. When there are

multiple small brain abscesses (<2.5 cm), Brouwer et al. advocate for diagnostic aspiration of the largest lesion, with subsequent decision to aspirate other abscesses made based on their size, extent of surrounding edema, patient’s symptoms, and response to broad-spectrum anti-microbial therapy.¹⁰ Given the apparent higher mortality rate with multiple abscesses, more aggressive management may be required to achieve source control.³³ Mamelak et al. suggest an algorithm with aspiration of all abscesses >2.5 cm on an urgent basis with antimicrobials held until surgical specimens are obtained in the patient with no primary source of infection.²² Interestingly, the conservative cutoff of 2.5 cm for surgical intervention in the nonearly cerebritis phase intraparenchymal abscess was first advocated by Mamelak et al. using Rosenblum et al. finding that solitary abscesses that are 3.0 cm were more likely to require surgical intervention to achieve a cure ($p < 0.005$).³⁶

Rupture of the intracerebral abscess into the ventricular system either spontaneously or iatrogenically during a surgical procedure is associated with a case fatality rate reported between 84% and 100%.^{37,38} The spontaneous event is thought to result from a poorly formed abscess capsule on the ventricular wall. The mortality of intraventricular rupture has decreased in recent years with the application of surgical techniques such as intraventricular lavage akin to infective hydrocephalus^{38,39} and broader-spectrum antibiotics that can cross the blood–brain barrier. In this survey, many respondents selected a maximally invasive surgical approach to the management of an intracerebral abscess with imaging suggestive of intraventricular rupture (Figure 7B).

Pediatric Considerations

We identified little discordance between the pediatric and adult trained clinicians in the management of intracerebral abscesses. In a recent review of pediatric brain abscesses, Mamelak et al. outline recommendations for surgical aspiration *versus* excision of intracerebral abscesses in children.²¹ Specifically, these authors recommend aspiration for abscesses >2.5 cm, multiple and deep-seated abscesses that may be in eloquent locations and at high risk of complication with excision. Abscesses in children may be considered for surgical excision if located in the posterior fossa, there are multilobulated lesions, or result from a prior cranial trauma.

Limitations

In the present survey study, given the small number of pediatric neurosurgeon respondents, we were unable to identify differences in pediatric compared to adult practice in the management of intracerebral abscesses. Additionally, despite a long data collection period, the response rate was low including some large high-volume centers, therefore the generalizability of the findings to the practices across the country are limited. Recall bias may have influenced respondents estimates of the number of intracerebral abscesses seen in consultation per month.

Conclusion

This survey demonstrated heterogeneity in the medical and surgical management of primary, recurrent, and multiple brain abscesses. No standardized practices have been proposed or adopted by the Canadian neurosurgical community. These results highlight the clinical benefit of the development of evidence-based national clinical guidelines.

Supplementary Material. To view supplementary material for this article, please visit <https://doi.org/10.1017/cjn.2022.299>.

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