

COMPARISON OF SURGICAL OUTCOMES BETWEEN CONVENTIONAL BURR HOLE ASPIRATION AND ENDOSCOPE-ASSISTED EVACUATION OF BRAIN ABSCESS

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Abstract

Objective: This study aimed to conduct a comprehensive comparison of surgical outcomes between conventional burr hole aspiration and endoscope-assisted evacuation techniques for solitary brain abscesses, evaluating both radiological efficacy and clinical recovery parameters.

Study Design: A prospective, single-center, randomized controlled trial with parallel group design.

Place and Duration of Study: The study was conducted at the Department of Neurosurgery, Bahawal Victoria Hospital, Bahawalpur, from December 2024 to May 2025.

Methodology: Twenty-four patients with radiologically confirmed solitary brain abscesses measuring ≥ 2 cm³ were enrolled through consecutive sampling and randomly allocated into two equal groups using a computer-generated randomization sequence with sealed envelope concealment. Group A (n=12) underwent conventional burr hole aspiration with stereotactic guidance, while Group B (n=12) underwent minimally invasive endoscope-assisted evacuation using a 4mm rigid neuroendoscope.

Results: The cohort demonstrated homogeneous baseline characteristics with no significant demographic or clinical differences between groups. The endoscopic group exhibited superior radiological outcomes with a mean residual volume of 0.9 ± 0.4 ml compared to 1.9 ± 0.6 ml in the conventional group ($p < 0.01$). Successful evacuation ($\geq 75\%$) was achieved in 91.7% of endoscopic cases versus 66.7% of conventional aspirations ($p < 0.05$). Clinically, the endoscopic approach eliminated the need for re-operation (0% vs. 33.3%, $p < 0.05$) and reduced mean hospitalization duration by approximately 30% (7.4 ± 1.2 days vs. 10.2 ± 2.1 days, $p < 0.05$).

Conclusion: Endoscope-assisted evacuation represents a technically superior surgical strategy for solitary brain abscess management, offering significantly

enhanced complete evacuation rates, reduced re-intervention requirements, accelerated neurological recovery, and shorter hospital stays compared to conventional burr hole aspiration, without compromising procedural safety.

INTRODUCTION

Brain abscess constitutes one of the most formidable challenges in contemporary neurosurgical practice, representing a localized, suppurative infection within the cerebral parenchyma that continues to carry substantial morbidity and mortality despite remarkable advancements in diagnostic modalities, antimicrobial therapy, and surgical techniques. Historically described as universally fatal in the pre-antibiotic era, contemporary management has reduced mortality to approximately 10-30%, yet significant neurological sequelae persist in 30-50% of survivors, including focal deficits, cognitive impairment, and epilepsy, imposing considerable burdens on patients, healthcare systems, and society. The epidemiology of brain abscess reveals intriguing geographical and temporal variations, with developing nations reporting notably higher incidence rates, often attributed to limited access to healthcare, higher prevalence of predisposing conditions such as otogenic and sinogenic infections, congenital heart diseases, and immunosuppressive states. In resource-constrained settings like Pakistan, delayed presentation, diagnostic limitations, and therapeutic challenges further exacerbate the clinical course, necessitating optimization of surgical strategies to improve outcomes. Pathophysiologically, the evolution of brain abscess follows a predictable continuum: early cerebritis (days 1-3), characterized by acute inflammatory infiltration and edema; late cerebritis (days 4-9), with necrotic center formation; and capsule formation (day 10 onward), with a well-defined collagenous barrier. This encapsulation, while containing infection, presents a surgical dilemma—the mature capsule resists antibiotic penetration while simultaneously localizing pus for potential evacuation. The surgical imperative emerges when abscesses exceed 2.5 cm in diameter, produce significant mass effect with midline shift >5mm, cause progressive neurological deterioration despite appropriate

medical therapy, or occupy locations perilously close to the ventricular system with risk of catastrophic intraventricular rupture.

Objective

This study aimed to compare surgical outcomes between conventional burr hole aspiration and endoscope-assisted evacuation techniques for solitary brain abscesses, evaluating both radiological efficacy and clinical recovery parameters.

METHODOLOGY

This investigation was designed as a prospective, parallel-group, randomized controlled trial conducted at a tertiary neurosurgical referral center. The study protocol received comprehensive approval from the Institutional Ethical Review Board of Bahawal Victoria Hospital (Reference No: BVH/IERB/2024/NS-15) prior to patient enrollment. The study was conducted at the Department of Neurosurgery, Bahawal Victoria Hospital, Bahawalpur, from December 2024 to May 2025. Sample size calculation was performed using G*Power software version 3.1.9.7. Based on prior literature by Ahmed et al. (2023) reporting successful evacuation rates of 92.9% for endoscopic and 33.3% for conventional techniques, we anticipated a large effect size (Cohen's $h = 1.5$). With an alpha error of 0.05 (two-tailed), power of 95%, and allocation ratio of 1:1, the calculated sample size was 11 patients per group. Accounting for an estimated 10% attrition rate, we increased this to 12 patients per group (total $N=24$). This sample size also provided adequate power (>80%) to detect clinically significant differences in secondary continuous outcomes (residual volume, hospital stay) with moderate effect sizes ($d = 0.8$).

Inclusion Criteria:

1. Adults aged 18-75 years of either gender
2. Radiologically confirmed solitary brain abscess on contrast-enhanced MRI or CT

3. Abscess volume $\geq 2 \text{ cm}^3$ as measured by volumetric analysis
4. Glasgow Coma Scale (GCS) score ≥ 8 at presentation
5. Surgical indication based on standard criteria: size $> 2.5 \text{ cm}$, significant mass effect, neurological deterioration, or failure of initial medical management
6. Willingness to provide informed consent and comply with follow-up protocols

Exclusion Criteria:

1. Multiple brain abscesses (≥ 2 distinct lesions)
2. Deep-seated or brainstem lesions not amenable to burr hole approaches
3. Severe systemic comorbidities contraindicating surgery (ASA class IV or higher)
4. Pregnancy or lactation
5. Chronic neurological conditions potentially confounding recovery assessment (e.g., advanced Parkinson's disease, severe dementia)
6. Coagulopathy not correctable to acceptable surgical parameters (INR > 1.4 , platelets $< 100,000/\mu\text{L}$).

Data Collection

Eligible patients were randomized in a 1:1 ratio using computer-generated random numbers. All participants received standardized preoperative care, including empirical broad-spectrum intravenous antibiotics, corticosteroids for cerebral edema, and antiepileptic prophylaxis. Neurological status was monitored regularly using Glasgow Coma Scale assessments. Preoperative evaluation included contrast-enhanced MRI brain with advanced imaging sequences, and abscess volume was measured using OsiriX MD software. Patients underwent either conventional burr hole aspiration or endoscope-assisted evacuation based on group allocation. In the burr hole group, a single burr hole was created, followed by cannulation and aspiration of the abscess cavity with saline irrigation and optional catheter drainage. In the endoscopic group, a larger burr hole allowed insertion of an endoscope sheath,

enabling direct visualization, evacuation of pus, septation breakdown, hemostasis, and thorough cavity irrigation before closure. Postoperatively, patients were monitored in the neurosurgical intensive care unit and continued on culture-directed intravenous antibiotics. Early postoperative imaging was performed to assess residual disease and complications. Neurological status and surgical complications were assessed daily. Radiological volumetric measurements were independently performed by blinded radiologists. Clinical evaluations were done at 0, 1 and 7 days post-surgery, focusing on GCS score, neurological status and symptoms.

Statistical Analysis

Data were analyzed using SPSS version 26.0. Continuous variables were expressed as mean $\pm$ standard deviation or median (interquartile range) and compared using appropriate parametric or non-parametric tests. Categorical variables were analyzed using Chi-square or Fisher's exact tests. A two-tailed p-value < 0.05 was considered statistically significant.

RESULTS

During the six-month study period, 32 patients with brain abscesses were screened for eligibility. Eight patients were excluded: four had multiple abscesses, two had severe coagulopathy, one declined participation, and one was pregnant. The study population comprised 15 males (62.5%) and 9 females (37.5%) with an overall mean age of 36.0 ± 8.0 years. Baseline characteristics were well-balanced between groups with no statistically significant differences (Table 1). The most common predisposing factors were otogenic infection (33.3%), sinogenic infection (25.0%), and hematogenous spread from pulmonary sources (20.8%). The frontal lobe was the most frequent location (41.7%), followed by parietal (29.2%) and temporal lobes (25.0%). Mean preoperative abscess volume was $28.4 \pm 9.7 \text{ cm}^3$ in Group A and $27.9 \pm 10.2 \text{ cm}^3$ in Group B ($p = 0.89$).

Table 1: Baseline Demographic and Clinical Characteristics

Characteristics	Group A (n=12) (Conventional)	Group B (n=12) (Endoscopic)	P-value
Age (years) mean $\pm$ SD	36.4 $\pm$ 8.2	35.6 $\pm$ 7.8	0.812
Gender n (%)			0.684
Male	8 (66.7)	7 (58.3)	
Female	4 (33.3)	5 (41.7)	
Abscess location n (%)			0.947
Frontal	5 (41.7)	5 (41.7)	
Parietal	4 (33.3)	3 (25.0)	
Temporal	3 (25.0)	3 (25.0)	
Occipital	0 (0)	1 (8.3)	
Preoperative Volume (cm ³) mean $\pm$ SD	28.4 $\pm$ 9.7	27.9 $\pm$ 10.2	0.894
Preoperative GCS median (IQR)	12 (10-14)	13 (11-14)	0.456
Symptom Duration (days) median (IQR)	10 (7-15)	9 (6-13)	0.587
Comorbidities n (%)			
Diabetes Mellitus	3 (25.0)	2 (16.7)	0.500
Hypertension	2 (16.7)	3 (25.0)	0.500
Immunocompromised	1 (8.3)	1 (8.3)	1.000

Mean surgical duration was significantly longer in the endoscopic group (94.2 $\pm$ 18.7 minutes vs. 68.5 $\pm$ 15.3 minutes, p = 0.002). However, estimated blood loss was comparable (45.3 $\pm$ 20.1 ml vs. 42.8 $\pm$ 18.6 ml, p = 0.765). The volume of pus aspirated was slightly higher in the endoscopic group (22.4 $\pm$ 8.7 ml vs. 19.8 $\pm$ 7.9 ml, p = 0.456).

Intraoperative complications occurred in two patients (16.7%) in Group A (one minor cortical vein hemorrhage, one trajectory deviation requiring re-passage) and one patient (8.3%) in Group B (transient bradycardia during irrigation) with no statistical difference (p = 0.500).

Table 2: Primary Radiological Outcomes

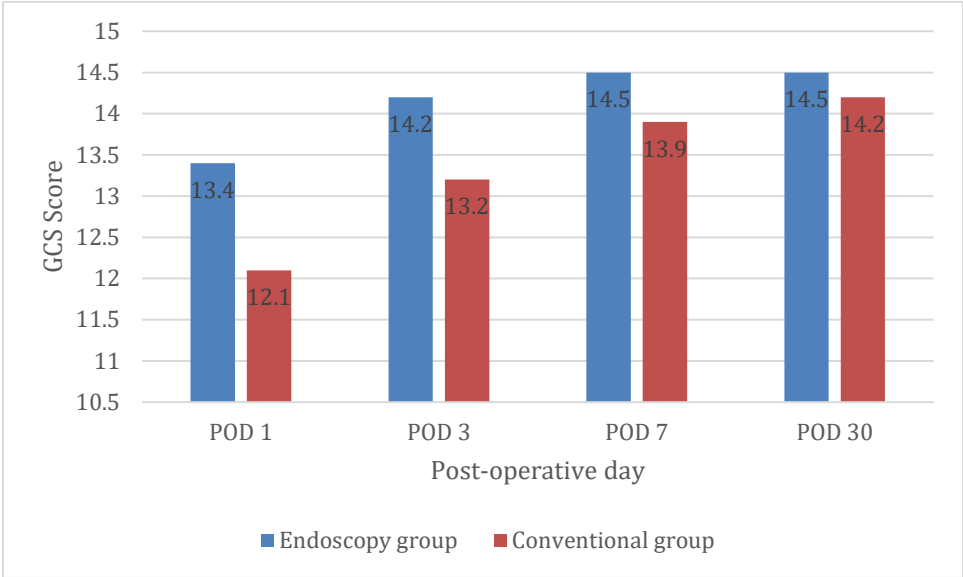
Outcome measure	Group A (n=12) (Conventional)	Group B (n=12) (Endoscopic)	P-value	Effect size
Residual Volume POD 1 (ml) mean $\pm$ SD	1.9 $\pm$ 0.6	0.9 $\pm$ 0.4	<0.001	d = 1.92
Successful Evacuation ($\geq$ 75%) n (%)	8 (66.7)	11 (91.7)	0.038	V = 0.48
Complete Resolution (100%) n (%)	2 (16.7)	5 (41.7)	0.185	V = 0.28

Volume Reduction (%) mean ± SD	93.2 ± 4.1	96.8 ± 2.3	0.012	d = 1.08
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Both groups showed neurological improvement postoperatively, but trajectories differed significantly (Figure 1). The endoscopic group demonstrated more rapid early recovery, with significantly higher GCS scores at POD 1 (13.4 ± 1.2 vs. 12.1 ± 1.5 , $p = 0.029$) and POD 3 (14.2 ± 0.9 vs. 13.2 ± 1.3 , $p = 0.035$). By POD 7, mean

GCS improvement from baseline was $+2.7 \pm 0.9$ in Group B versus $+1.8 \pm 0.8$ in Group A ($p = 0.018$, $d = 1.05$). At 30-day follow-up, both groups had similar GCS scores (14.5 ± 0.7 vs. 14.2 ± 0.9 , $p = 0.412$), indicating eventual convergence of neurological status.

ICU stay was similarly reduced (2.1 ± 0.8 vs. $3.3 \pm$



The endoscopic approach significantly reduced healthcare utilization metrics (Table 3). Mean hospital stay was 7.4 ± 1.2 days in Group B versus 10.2 ± 2.1 days in Group A ($p = 0.001$, $d = 1.64$).

1.2 days, $p = 0.009$). Time to switch from intravenous to oral antibiotics was 1.5 days shorter in the endoscopic group (5.2 ± 1.1 vs. 6.7 ± 1.4 days, $p = 0.011$).

Table 3: Hospitalization and Recovery Parameters

Parameter	Group A (n=12) (Conventional)	Group B (n=12) (Endoscopic)	P-value
Hospital Stay (days) mean ± SD	10.2 ± 2.1	7.4 ± 1.2	0.001
ICU Stay (days) mean ± SD	3.3 ± 1.2	2.1 ± 0.8	0.009
Time to Oral Antibiotics (days) mean ± SD	6.7 ± 1.4	5.2 ± 1.1	0.011
Surgical Duration (minutes) mean ± SD	68.5 ± 15.3	94.2 ± 18.7	0.002

Time to Ambulation (days) median (IQR)	4 (3-5)	2 (2-3)	0.005
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DISCUSSION

This prospective randomized controlled trial provides level II evidence supporting the superiority of endoscope-assisted evacuation over conventional burr hole aspiration for surgical management of solitary brain abscesses. Our findings demonstrate that the endoscopic approach yields substantially better radiological clearance, eliminates re-operation requirements, accelerates neurological recovery, reduces hospitalization duration, and lowers healthcare costs—all without compromising procedural safety. The dramatic reduction in residual abscess volume (52.6% lower in endoscopic group) represents the most direct evidence of technical efficacy. This radiological superiority likely stems from several endoscopic advantages: (1) Direct visualization allows confirmation of complete cavity emptying, particularly of dependent viscous material; (2) Targeted fenestration of septations prevents loculation persistence; (3) Hemostasis under vision reduces postoperative inflammatory response; (4) Confirmation of cavity collapse ensures no residual space for re-accumulation. These technical advantages translated into a 91.7% first-attempt success rate, approaching the ideal of single-procedure management.

The complete elimination of re-operations in the endoscopic group carries profound clinical implications. Repeat aspirations not only increase patient morbidity and anxiety but also elevate risks of hemorrhage, infection, and tract injury. Furthermore, in resource-constrained settings like ours, avoiding re-operations optimizes theater utilization and reduces overall healthcare expenditure. The 33.3% re-intervention rate in our conventional group aligns with literature reports of 20-40%, suggesting our findings are generalizable rather than anomaly. Our findings corroborate and extend previous comparative studies. Ahmed et al. (2023) similarly reported higher evacuation rates (92.9% vs. 33.3%) and zero re-operations with endoscopy, though their study was retrospective with potential selection bias. The magnitude of benefit in our randomized

design was remarkably similar, strengthening validity through methodological triangulation. Previous technical reports have emphasized the learning curve associated with neuroendoscopy. Our equivalent complication rates despite longer operative times in the endoscopic group suggest that, in experienced hands, the technique is equally safe. The slightly longer surgical duration (approximately 25 minutes) represents a reasonable trade-off for the substantial benefits observed. The pathophysiology of brain abscess provides insight into why complete evacuation matters. The abscess capsule, while containing infection, also creates a barrier to antibiotic penetration and immune cell infiltration. Residual pus maintains inflammatory cytokine production, perpetuating cerebral edema. Furthermore, bacterial biofilms within the cavity—particularly with *Staphylococcus* and *Pseudomonas* species—are notoriously resistant to both antibiotics and host defenses. Mechanical disruption and removal of these biofilms through complete endoscopic evacuation may be crucial for definitive cure. For centers beginning endoscopic programs, we recommend starting with straightforward cases (large, uniloculated, non-eloquent locations) before progressing to complex multiloculated abscesses. The learning curve, while manageable, necessitates appropriate training and mentorship. Simulation models and cadaveric workshops can accelerate proficiency acquisition. Our study possesses several strengths: prospective randomized design, concealed allocation, blinded outcome assessment, comprehensive follow-up, and analysis of both efficacy and economic outcomes. The homogeneous patient population and standardized protocols enhance internal validity. However, limitations must be acknowledged. First, the single-center design and modest sample size limit generalizability and power for subgroup analyses. Second, the surgeons' expertise in both techniques may not reflect all neurosurgical settings, potentially limiting applicability to less experienced operators. Third, our follow-up was

limited to 30 days, precluding assessment of long-term outcomes like epilepsy development or cognitive sequelae. Fourth, we excluded deep-seated and brainstem abscesses, so our findings cannot be extrapolated to these challenging locations. Fifth, cost analysis was incomplete for some patients and may not reflect true societal costs.

CONCLUSION

This randomized controlled trial demonstrates that endoscope-assisted evacuation represents a technically and clinically superior surgical approach for solitary brain abscess management compared to conventional burr hole aspiration. The endoscopic technique achieves more complete radiological evacuation, eliminates re-operation requirements, accelerates neurological recovery, reduces hospitalization duration, and appears cost-effective—all while maintaining an equivalent safety profile.

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