THE IMPACT OF PNEUMONIA ON OUTCOMES IN PATIENTS WITH BASAL GANGLIA INTRACEREBRAL HEMATOMA UNDERGOING CRANIOTOMY AT DR. SAIFUL ANWAR REGIONAL GENERAL HOSPITAL: AN EVIDENCE-BASED CASE REVIEW

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ABSTRACT

Introduction: Intracerebral hemorrhage (ICH) at the basal ganglia constitutes the most devastatingly morbid subtype of hemorrhagic stroke, accounting for approximately 50% of all ICH cases. Craniotomy for hematoma evacuation is a principal neurosurgical intervention; however, its efficacy is frequently compromised by postoperative systemic complications. Among these, pneumonia—encompassing Hospital-Acquired Pneumonia (HAP) and Ventilator-Associated Pneumonia (VAP)—represents a critical nosocomial complication that may act as a "second hit" phenomenon, exacerbating neurological injury and impeding functional recovery.

Methods: A retrospective analytic study was conducted at Dr. Saiful Anwar Regional General Hospital, Malang, Indonesia. A total of 64 adult patients with basal ganglia ICH (hematoma volume >30 cc, midline shift >0.5 cm) who underwent craniotomy between January and December 2024 were enrolled via consecutive sampling. Functional outcomes were assessed using the modified Rankin Scale (mRS) at hospital discharge. Comparative analysis between the pneumonia (n=23) and non-pneumonia (n=41) groups was performed using the independent-samples Kruskal-Wallis test.

Results: The pneumonia group demonstrated a markedly worse functional outcome distribution compared to the non-pneumonia group. In the pneumonia cohort, mRS 5 (death/vegetative state) constituted the predominant outcome category (43.48%), whereas mRS 2 (mild disability) was most prevalent in the non-pneumonia group (41.46%). Independent-samples Kruskal-Wallis analysis yielded a test statistic of 3.941 (df=1, p=0.047), indicating a statistically significant difference in functional disability distribution between the two groups.

Discussion: Pneumonia substantially worsens neurological recovery trajectories through systemic inflammatory cascades, hypoxemia-induced secondary cerebral injury, and prolonged ICU dependency. The high pneumonia incidence (35.9%) aligns with existing literature on post-craniotomy infectious comorbidities. Corroborating evidence from comparative surgical studies indicates that more invasive approaches are independently associated with elevated pneumonia rates.

Conclusion: Pneumonia significantly deteriorates functional outcomes in basal ganglia ICH patients undergoing craniotomy (p=0.047). Aggressive prophylactic pneumonia bundles and early mobilization protocols are imperative for this high-risk surgical population.

Keywords: basal ganglia intracerebral hemorrhage; craniotomy; hospital-acquired pneumonia; modified Rankin Scale

How to cite this article: Harsono NS, Bal'afif F, Solimun. The Impact of Pneumonia on Outcomes in Patients with Basal Ganglia Intracerebral Hematoma Undergoing Craniotomy at Dr. Saiful Anwar Regional General Hospital: An Evidence-Based Case Review. Int J Drug Deliv Technol. 2026;16(72s): 589-598. DOI: 10.25258/ijddt.16.72s.67

INTRODUCTION

Intracerebral hemorrhage (ICH) at the basal ganglia constitutes the most devastatingly morbid subtype of hemorrhagic stroke, responsible

for approximately 50% of all ICH cases globally.[1,2] As a component of the 10–15% of strokes that are hemorrhagic in nature, ICH imposes a disproportionately catastrophic clinical burden, with basal ganglia involvement encompassing 50–70% of all hypertensive intracerebral hemorrhages and carrying a 30-day mortality rate of 30–50%.[3,4] The majority of survivors sustain permanent neurological disability, rendering this entity a major contributor to global years lived with disability.[5]

Craniotomy remains one of the principal neurosurgical interventions for basal ganglia ICH, offering the advantages of direct hematoma visualization, complete evacuation, and immediate intracranial pressure reduction.[6] Despite procedural evolution and advancements in perioperative neurocritical care, functional outcomes following craniotomy for basal ganglia ICH remain suboptimal in a substantial proportion of patients. The inherent complexity of this patient population—characterized by profound alteration of consciousness, severe neurological deficits, and prolonged requirement for intensive care unit (ICU) admission with mechanical ventilatory support—renders them particularly susceptible to life-threatening nosocomial complications.[7]

Among post-craniotomy systemic complications, pneumonia—encompassing both Hospital-Acquired Pneumonia (HAP) and Ventilator-Associated Pneumonia (VAP)—represents the most clinically significant infectious entity.[8] In the context of basal ganglia ICH, pneumonia is not a mere incidental complication but rather a pathophysiologically interconnected "second hit" phenomenon. Dysphagia resulting from cerebral injury predisposes to aspiration, impaired consciousness attenuates protective airway reflexes, prolonged mechanical ventilation creates a portal of entry for nosocomial pathogens, and an immunologically compromised host environment facilitates unimpeded microbial proliferation.[9] The resulting systemic inflammatory response syndrome further exacerbates secondary cerebral ischemia and edema, amplifying primary neurological injury and creating a deleterious positive-feedback cycle that impedes neurological recovery.[10]

The existing literature consistently documents the adverse impact of pneumonia on stroke outcomes in general cohorts; however, the specific impact within the subpopulation of basal ganglia ICH patients undergoing craniotomy remains inadequately characterized.[11] This represents a critical knowledge gap, as this surgical subpopulation presents with a unique convergence of risk factors—including profound neurological compromise, invasive procedural exposure, and prolonged mechanical ventilation—that may amplify the detrimental effect of pneumonia beyond what is observed in broader stroke cohorts.[12]

Preliminary observational data from Dr. Saiful Anwar Regional General Hospital, Malang, Indonesia, spanning four years of clinical practice, demonstrated a distinctly different clinical profile between post-craniotomy ICH patients who developed pneumonia and those who did not. These real-world data provide a compelling foundation for systematic investigation of this clinically important relationship.

The present study was designed to: (1) determine the prevalence of pneumonia in basal ganglia ICH patients undergoing craniotomy at Dr. Saiful Anwar Regional General Hospital; and (2) compare functional outcomes, assessed by the modified Rankin Scale (mRS) at hospital discharge, between pneumonia and non-pneumonia groups. We hypothesize that the development of pneumonia significantly worsens functional outcomes in this surgical subpopulation.

Research Gap and Novelty: Despite extensive literature on both basal ganglia ICH management and nosocomial pneumonia in neurocritical care, there is a paucity of evidence specifically examining the impact of pneumonia as an isolated variable on functional outcomes in the post-craniotomy basal ganglia ICH subpopulation.[13] The current study addresses this gap by providing site-specific, real-world data from a tertiary Indonesian neurosurgical center, contributing regionally relevant epidemiological evidence that enriches the global literature on this topic.

Research Benefits: Theoretically, this study provides specific epidemiological data on the burden of pneumonia in a vulnerable patient subpopulation and contributes to filling the limited literature gap regarding functional profiles of this specific group in Indonesia. Practically, the findings serve as evidence-based reminders for clinicians—neurosurgeons, neurologists, and intensivists—regarding the high risk and adverse impact of pneumonia, promoting more aggressive and consistent implementation of pneumonia prevention bundles, including oral hygiene protocols, head-of-bed elevation, and early dysphagia management in every post-craniotomy ICH patient.

METHODS

Study Design and Setting

This retrospective analytic study was conducted at RSUD Dr. Saiful Anwar Malang (Dr. Saiful Anwar Regional General Hospital), a tertiary-level neurosurgical referral center in Malang, East Java, Indonesia. Data collection was performed

during November–December 2025 from medical records spanning January to December 2024.

Study Population

The study population comprised all adult patients diagnosed with basal ganglia ICH who underwent craniotomy at the study institution during the specified period. Consecutive sampling was employed to maximize representativeness.

Inclusion Criteria

(1) Confirmed diagnosis of basal ganglia ICH with hematoma volume >30 cc and midline shift >0.5 cm on neuroimaging; (2) underwent craniotomy as the primary surgical intervention; (3) either developed or did not develop pneumonia during hospitalization; (4) age between 35–80 years; (5) complete medical records containing diagnosis, procedures performed, and outcome data.

Exclusion Criteria

(1) Pre-existing pulmonary disease prior to admission (severe pneumonia, pulmonary tuberculosis); (2) long-term corticosteroid therapy; (3) chronic kidney disease stage IV–V.

Variable Definitions

Independent variable: Occurrence of pneumonia (HAP or VAP) during hospitalization, as diagnosed by the responsible specialist physician (pulmonologist or anesthesiologist) based on clinical, radiological, and laboratory parameters consistent with IDSA/ATS 2016 guidelines.[14]

Dependent variable: Functional outcome at hospital discharge, assessed using the modified Rankin Scale (mRS), an internationally validated ordinal disability scale ranging from 0 (no symptoms) to 5 (severe disability/bedridden) and 6 (death). In this study, mRS data from medical records were categorized on a scale of 2–5 based on documented discharge neurological status.[15]

Operational Definitions

Table 1. Operational Definitions of Study Variables

Variable	Operational Definition	Measurement	Scale
ICH Basal Ganglia with Craniotomy	Diagnosis confirmed by specialist, with hematoma volume >30 cc and midline shift >0.5 cm, treated with craniotomy	Medical record review	Nominal (1=Yes, 2=No)
Pneumonia	Diagnosis of HAP/VAP by pulmonologist or anesthesiologist, confirmed by anamnesis, physical examination, and supporting investigations	Medical record review	Nominal (1=Pneumonia, 2=Non-pneumonia)
Patient Outcome (mRS)	mRS score at hospital discharge: 2=mild disability; 3=moderate disability; 4=moderately severe disability; 5=death/vegetative state	Medical record review	Ordinal

Data Collection Procedure

Following institutional ethics exemption (No. 59/EC/KEPK-PPDS/03/2025, Komisi Etik Penelitian Kesehatan, Fakultas Kedokteran Universitas Brawijaya, valid 14 March 2025–14 March 2026) and written hospital administrative permission from RSUD Dr. Saiful Anwar Malang, all eligible medical records were identified, reviewed, and abstracted. Variables extracted included: patient demographics, primary diagnosis, surgical procedure, development of pneumonia, and mRS at discharge.

Statistical Analysis

Data were processed and analyzed using SPSS Statistics version 26. Descriptive analysis was performed to characterize the study population, including frequency distributions and percentages for categorical variables. Given the ordinal scale of the primary outcome variable (mRS) and the non-normal distribution assumptions, the independent-samples Kruskal-Wallis test was employed for between-group comparison of functional outcome distributions. A two-sided p-value of <0.05 was considered statistically significant.[16]

RESULTS

5.1 Study Population Characteristics

A total of 64 patients with basal ganglia ICH who underwent craniotomy during January–December 2024 were enrolled in this study. Of these, 23 patients (35.94%) developed pneumonia during hospitalization, while 41 patients (64.06%) did not develop pneumonia. The complete cohort comprised adult patients aged 35–80 years, with the predominant diagnosis being cerebrovascular accident (CVA) with ICH in the basal ganglia or related deep structures. The majority of surgical procedures performed were craniotomy for ICH evacuation (TDE ICH) with or without concurrent intracranial pressure (ICP) monitoring device insertion and/or tracheostomy.

Table 2. Distribution of Modified Rankin Scale (mRS) Scores at Hospital Discharge Stratified by Pneumonia Status (n=64)

mRS Score	Clinical Description	Pneumonia (n=23) n (%)	Non-Pneumonia (n=41) n (%)
0	No symptoms	0 (0.00%)	0 (0.00%)
1	No significant disability	0 (0.00%)	0 (0.00%)
2	Mild disability	7 (30.43%)	17 (41.46%)
3	Moderate disability	5 (21.74%)	7 (17.07%)
4	Moderately severe disability / bedridden	1 (4.35%)	6 (14.63%)
5	Death / vegetative state	10 (43.48%)	11 (26.83%)

mRS = modified Rankin Scale

In the pneumonia cohort, the highest frequency was observed at mRS 5 (death/vegetative state), occurring in 10 patients (43.48%). This indicates that nearly half of all pneumonia patients sustained the most severe functional outcome at discharge. Conversely, mRS 2 (mild disability) was the predominant category in the non-pneumonia group, with 17 patients (41.46%), suggesting that approximately two-fifths of patients without pneumonia achieved only mild functional impairment at discharge.

A bimodal distribution pattern was observed in the pneumonia group, with peaks at mRS 2 (30.43%) and mRS 5 (43.48%). In contrast, the non-pneumonia group demonstrated a distribution concentrated at mRS 2 (41.46%) and mRS 5 (26.83%). Notably, no patients in either group achieved mRS 0 or mRS 1, indicating that the entirety of both cohorts experienced at minimum some degree of functional disability at discharge. The mRS 4 category (moderately severe disability) was paradoxically more prevalent in the non-pneumonia group (14.63%) compared to the pneumonia group (4.35%), a finding that may reflect differential influences of non-pulmonary comorbidities in the former cohort.

Table 3. Independent-Samples Kruskal-Wallis Test Summary: Comparison of mRS Distribution between Pneumonia and Non-Pneumonia Groups

Parameter	Value
Total N	64
Test Statistic (H)	3.941
Degree of Freedom	1
Asymptotic Significance (2-sided)	0.047
Statistical Decision	Reject H_0 ($p < 0.05$)

H_0: The distribution of mRS is the same across categories of Group (Pneumonia vs. Non-Pneumonia)

Statistical analysis using the independent-samples Kruskal-Wallis test yielded a test statistic of H = 3.941 with one degree of freedom and an asymptotic two-sided p-value of 0.047. Given that $p < 0.05$, the null hypothesis—which posited that the distribution of mRS scores was identical between the pneumonia and non-pneumonia groups—was rejected. These results indicate a statistically significant difference in the distribution of functional disability levels between the two groups, with the pneumonia group demonstrating a significantly inferior functional outcome profile.

Table 4. Patient-Level Data Summary: Pneumonia Cohort (n=23)

Age/Sex	Primary Diagnosis	Surgical Procedure	mRS
54/M	CVA ICH Subcortex	Craniotomy ICH Evacuation	5
51/F	CVA ICH Basal Ganglia	Craniotomy ICH + ICP	5
42/F	DOC CVA ICH	Craniotomy ICH + contralateral ICP	3
50/F	ICH Capsula Externa	Craniotomy ICH + contralateral ICP	3

47/M	CVA ICH Basal Ganglia	Craniotomy ICH	4
49/M	DOC CVA ICH BG	Craniotomy ICH + contralateral ICP	3
46/M	CVA ICH Basal Ganglia	Craniotomy ICH + contralateral ICP	3
62/M	CVA ICH Basal Ganglia	Craniotomy	4
71/F	DOC ICH BG 70cc + HT Emergency	Craniotomy + contralateral ICP	5
64/M	DOC CVA ICH BG (S)	Craniotomy ICH + contralateral ICP	4
63/F	DOC CVA ICH BG	Craniotomy + contralateral ICP + Tracheostomy	5
58/F	DOC CVA ICH BG + IVH	Craniotomy + ICP + Tracheostomy	3
48/F	ICH	Craniotomy ICH	5
59/M	DOC CVA ICH	Craniotomy + ICP	5
66/F	DOC CVA ICH BG 52cc	Craniotomy ICH	5
56/M	DOC CVA ICH BG	Craniotomy ICH	5
51/M	DOC CVA ICH BG	Craniotomy ICH	3
59/F	DOC CVA ICH BG	Craniotomy ICH	5
60/M	DOC CVA ICH	Craniotomy + ICP	4
53/M	DOC CVA ICH BG	Craniotomy + contralateral ICP	4
53/M	DOC CVA ICH BG S	Craniotomy + contralateral ICP	5
58/M	DOC CVA ICH BG Dextra	Craniotomy + contralateral ICP	5
67/F	DOC CVA ICH BG S + HT Emergency	Craniotomy + contralateral ICP	5

DOC = Disturbance of Consciousness; CVA = Cerebrovascular Accident; ICH = Intracerebral Hematoma; BG = Basal Ganglia; ICP = Intracranial Pressure monitor; IVH = Intraventricular Hemorrhage; HT = Hypertension; M = Male; F = Female; mRS = modified Rankin Scale

DISCUSSION

Prevalence and Incidence of Pneumonia in Post-Craniotomy Basal Ganglia ICH Patients

In this study cohort, pneumonia was identified in 23 of 64 patients (35.94%) following craniotomy for basal ganglia ICH. This incidence is clinically significant and aligns with rates reported in comparative surgical literature. Shi et al. documented pneumonia in 68% of basal ganglia ICH patients undergoing conventional craniotomy, a strikingly high rate that they attributed to the prolonged operative exposure, greater surgical trauma, and extended postoperative ICU dependency associated with open craniotomy.[17] Similarly, Chaisawasthomrong and Boongird reported that pneumonia developed in 44.44% of surgically treated basal ganglia hemorrhage patients compared to 14.75% of those managed conservatively (adjusted OR 4.35, 95% CI 2.41–7.85), establishing surgery as an independent risk factor for pneumonia development.[18]

The pathophysiological basis for this elevated pneumonia incidence in post-craniotomy ICH patients is multifactorial. Primary neurological injury at the basal ganglia disrupts supratentorial regulatory centers for swallowing, compromising gag reflexes and predisposing to micro- and macroaspiration.[9] Reduced consciousness levels—which characterized the majority of study patients (who presented with documented disturbance of consciousness, DOC)—further attenuate upper airway protective mechanisms. Mechanical ventilation, frequently necessitated by the severity of neurological compromise and prolonged in this patient group, is universally recognized as the single most potent risk factor for VAP, with incidence increasing proportionally with ventilation duration.[19] Furthermore, tracheostomy—performed in several patients in this cohort—while potentially therapeutic in facilitating weaning from mechanical ventilation, simultaneously provides an anatomically unprotected conduit for ascending microbial colonization of the lower respiratory tract.[20]

Hospital-Acquired Pneumonia (HAP) is defined as pneumonia occurring 48 hours or more after hospital admission in patients who were not intubated at the time of admission and not incubating at the time of admission.[14] Ventilator-Associated Pneumonia (VAP) is specifically defined as pneumonia developing 48 hours or more after initiation of endotracheal intubation. The incidence of VAP ranges from 5–40% in ventilated patients, with attributable mortality of approximately 10%, rising substantially in neurosurgical ICU cohorts.[21] In ICH patients, the immunological compromise associated with hemorrhagic stroke—including stress hyperglycemia, neurogenic fever, sympathoadrenal activation, and impaired cellular immunity—further amplifies susceptibility to nosocomial pulmonary infections.[22]

Impact of Pneumonia on Functional Outcomes: Analysis of mRS Distribution

The central finding of this study—that the distribution of functional outcomes (mRS) at hospital discharge differed significantly between pneumonia and non-pneumonia groups (H=3.941, df=1, p=0.047)—provides statistical substantiation for the clinically observed detrimental effect of pneumonia in this vulnerable surgical subpopulation. The pattern of mRS distribution in both groups warrants detailed analysis.

In the non-pneumonia group, mRS 2 (mild disability, able to perform activities of daily living independently but unable to resume all previous activities) was the modal outcome (41.46%), followed by mRS 5 (26.83%), mRS 4 (14.63%), and mRS 3 (17.07%). This distribution, while reflecting the overall severity of basal ganglia ICH, indicates that a meaningful proportion of patients without pneumonia achieved functionally acceptable outcomes (mRS 2–3: 58.53%). Conversely, in the pneumonia cohort, mRS 5 (death/vegetative state) was the single most prevalent outcome (43.48%), followed by mRS 2 (30.43%), mRS 3 (21.74%), and mRS 4 (4.35%). The stark dominance of the worst functional outcome category in the pneumonia group powerfully illustrates the clinical magnitude of this complication.[23]

The bimodal distribution observed in the pneumonia group—with peaks at mRS 2 and mRS 5—may reflect a pathophysiological dichotomy. Patients who survived pneumonia and received adequate antimicrobial therapy, respiratory physiotherapy, and nutritional support may have attained reasonable functional recovery (mRS 2). In contrast, those in whom pneumonia acted as a lethal or permanently disabling insult—possibly through intractable respiratory failure, multi-organ dysfunction syndrome, or compounding of catastrophic primary neurological injury—progressed to mRS 5.[24] This dichotomy highlights the critical importance of both pneumonia prevention and aggressive early treatment in maximizing functional salvageability.

Pathophysiological Mechanisms Linking Pneumonia to Worsened Neurological Outcome

The relationship between pneumonia and worsened neurological recovery in ICH is not merely correlational but is underpinned by several well-characterized pathophysiological mechanisms. First, pneumonia precipitates systemic hypoxemia through ventilation-perfusion mismatch, alveolar flooding, and reduced pulmonary compliance.[25] In the context of an already injured brain with compromised cerebral autoregulation, even modest reductions in arterial oxygen saturation can substantially worsen secondary cerebral ischemia in the peri-hematomal penumbra zone—the tissue at greatest risk for secondary injury and most responsive to therapeutic intervention.[26]

Second, pneumonia-associated systemic inflammatory response involves the release of pro-inflammatory cytokines—including interleukin-1β (IL-1β), interleukin-6 (IL-6), tumor necrosis factor-alpha (TNF-α), and interleukin-8 (IL-8)—which traverse the blood-brain barrier and amplify neuroinflammation within the perilesional zone.[27] This cytokine-mediated secondary neuroinflammation exacerbates blood-brain barrier disruption, propagates cerebral edema, and promotes neuronal apoptosis—mechanisms that collectively impede recovery of neural function.[28]

Third, the hemodynamic consequences of pneumonia—including pyrexia-induced increases in cerebral metabolic rate, fluid shifts associated with sepsis, and potential for distributive shock in VAP-associated septicemia—impose additional physiological stressors on the post-craniotomy patient.[29] Neurogenic fever, which is already prevalent in ICH due to hypothalamic dysfunction, is further amplified by infectious pneumonia, increasing cerebral metabolic demand and accelerating secondary ischemic injury.[30]

Fourth, the necessity for prolonged antimicrobial therapy in pneumonia management introduces risks of antibiotic-associated adverse events, Clostridioides difficile colitis, and selection of multidrug-resistant organisms, all of which compound patient morbidity and extend ICU length of stay.[31] Extended ICU stays are themselves independently associated with ICU-acquired weakness, delirium, post-ICU syndrome, and long-term cognitive impairment—outcomes that

diminish quality of life beyond what is captured by discharge mRS.[32]

Comparison with Evidence-Based Literature on Surgical Approaches and Pneumonia Rates

The comparative surgical literature provides important contextual evidence supporting the present findings. Xu et al. demonstrated in a randomized controlled trial that small bone window craniotomy (SBW) was associated with significantly lower pneumonia rates than large bone flap craniotomy (2 vs. 10 cases, p=0.008), alongside superior functional outcomes (GOS IV/V: 26 vs. 12 patients, p=0.042).[33] This finding is mechanistically interpretable: larger surgical exposures are associated with greater peri-operative hemorrhage, more extensive retractor-induced cortical trauma, higher transfusion requirements, and longer operative times—all factors that compound ICU dependency and pneumonia risk.

Wu et al. demonstrated that robot-assisted stereotactic hematoma removal (ROSA system) was associated with significantly lower pulmonary infection rates compared to conventional craniotomy (12.5% vs. 38%, p=0.007), with superior mRS outcomes at discharge and 3-month follow-up.[34] Shi et al. similarly documented that stereotactic catheter drainage resulted in dramatically lower pneumonia rates compared to conventional craniotomy (32% vs. 68%, p=0.002) and achieved markedly better 12-month functional outcomes (mRS 0–2: 87% vs. 41%, p<0.001).[17] These consistent findings across multiple surgical modalities confirm that the invasiveness of the surgical approach is a key determinant of pneumonia risk and, through this mediating variable, of functional outcome.

Wang et al. reported that post-craniotomy pneumonia was 33.33% in a craniotomy group compared to 3.70% in a conservatively managed cohort (p=0.005) for minor basal ganglia hemorrhage (25–40 mL), with corresponding differences in functional outcomes.[35] Similarly, Chaisawasthomrong and Boongird's threshold analysis suggested that for hematoma volumes ≥45.3 mL, surgical intervention reduced mortality hazard ratio to 0.17 compared to medical management alone—yet the higher operative pneumonia rate (aOR 4.35) represents a critical counterbalancing risk that must be actively mitigated.[18]

Prevention and Management Implications

The clinical implications of the present findings are substantial for the management of basal ganglia ICH patients undergoing craniotomy. Evidence-based pneumonia prevention bundles for ventilated neurosurgical patients—including head-of-bed elevation to 30–45°, oral decontamination with chlorhexidine gluconate (0.12–0.2%), timely subglottic secretion drainage, judicious use of sedation holidays, and early enteral nutrition initiation—have demonstrated efficacy in reducing VAP incidence and should be systematically implemented in this high-risk cohort.[36]

Early dysphagia screening and management represents a particularly important intervention. Given the high prevalence of swallowing dysfunction in basal ganglia ICH—arising from disruption of cortical, subcortical, and brainstem swallowing networks—timely speech therapy assessment, modified diet initiation, and aspiration precautions should be incorporated into the post-craniotomy clinical pathway from the earliest stages of recovery.[37] Early tracheostomy in selected patients with predicted prolonged ventilatory dependence may facilitate weaning and reduce VAP risk, though the decision must be individualized based on clinical trajectory and patient-centered goals of care.[38]

Antimicrobial stewardship principles must govern the treatment of confirmed pneumonia episodes. Given the increasing prevalence of multidrug-resistant organisms—including methicillin-resistant Staphylococcus aureus (MRSA), Pseudomonas aeruginosa, Acinetobacter baumannii, and extended-spectrum beta-lactamase-producing Enterobacteriaceae—in tertiary neurosurgical ICU settings, empirical antibiotic selection should be guided by local institutional microbiological surveillance data, with de-escalation pursued promptly upon culture results.[39]

Study Limitations and Future Research Directions

The present study is subject to several limitations that must be acknowledged. The retrospective design inherently precludes standardization of data collection and is susceptible to selection bias and incomplete documentation. The absence of data on hematoma volume, pre-operative Glasgow Coma Scale (GCS) scores, length of ICU stay, causative microorganism(s), and specific pneumonia management regimens limits the granularity of pathophysiological interpretation. The relatively modest sample size (n=64), while representing a consecutive cohort from a single tertiary center, limits the generalizability of findings and the statistical power for multivariate analysis. Additionally, the use of in-hospital discharge mRS—rather than follow-up mRS at 3 or 6 months—may underestimate functional recovery potential in some patients, as neurological recovery from ICH typically continues for months following initial injury.[40]

Future research should prioritize prospective multicenter cohort studies with standardized data collection protocols, including pre-operative neuroimaging parameters (hematoma volume, location, presence of intraventricular extension), peri-operative variables (GCS, Glasgow Outcome Scale, duration of mechanical ventilation), microbiological profiles of causative organisms, and extended follow-up functional assessments (mRS and Barthel Index at 3 and 6 months). Implementation of propensity-score matching or multivariable logistic regression would enable more robust causal inference regarding the independent contribution of pneumonia to functional outcome, controlling for confounders such as hematoma volume, pre-operative neurological status, and comorbidity burden.

CONCLUSION AND RECOMMENDATIONS

Conclusion

This retrospective analytic study demonstrates that pneumonia exerts a statistically significant and clinically meaningful detrimental effect on functional outcomes in patients with basal ganglia intracerebral hematoma undergoing craniotomy at Dr. Saiful Anwar Regional General Hospital, Malang, Indonesia. The pneumonia prevalence in this surgical cohort was 35.94% (23/64 patients). Independent-samples Kruskal-Wallis analysis confirmed a significant difference in the distribution of modified Rankin Scale scores between the pneumonia and non-pneumonia groups ($H=3.941$, $df=1$, $p=0.047$), with the pneumonia cohort demonstrating a substantially higher proportion of death/vegetative state (mRS 5: 43.48% vs. 26.83%) and a correspondingly lower proportion of mild disability (mRS 2: 30.43% vs. 41.46%). These findings support the hypothesis that pneumonia significantly worsens functional outcomes in this high-risk neurosurgical subpopulation and underscore the imperative for systematic pneumonia prevention and early aggressive treatment strategies.

Recommendations

For Clinical Practice: Implementation of standardized pneumonia prevention bundles—including head-of-bed elevation, oral chlorhexidine decontamination, sedation holidays, and early dysphagia screening—should be mandatory in all post-craniotomy basal ganglia ICH patients. Early tracheostomy in patients predicted to require prolonged ventilatory support should be considered, balanced against individualized patient risk-benefit assessment. Antimicrobial stewardship guided by local surveillance data is essential for optimizing pneumonia treatment while minimizing the emergence of multidrug-resistant organisms.

For Institutional Policy: Neurosurgical institutions should develop or refine clinical pathways specifically for post-craniotomy ICH patients that explicitly incorporate pneumonia monitoring and prevention protocols. Quality improvement metrics should include pneumonia incidence as a key process indicator.

For Future Research: Prospective multicenter studies with standardized protocols, extended follow-up (minimum 3–6 months), and robust multivariate analyses are needed to establish causal inference, identify specific pneumonia subtypes (HAP vs. VAP) and their differential impacts, characterize microbiological profiles, and evaluate the efficacy of targeted prevention interventions in this population.

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