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The Evolving Landscape of Intracerebral Hemorrhage Surgery: 3 An Evidence-Based Review of Minimally Invasive Evacuation, 4 Technology, and Integrated Care

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ADMINISTRATIVE INFORMATION

Support - No support.

Review Stage at time of this submission - Completed but not published.

Conflicts of interest - None declared.

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Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 31 August 2026 and was last updated on 31 August 2026.

INTRODUCTION

Review question / Objective To evaluate the evolving technological and clinical landscape of intracerebral hemorrhage (ICH) management, with an emphasis on how technical advances translate into meaningful patient outcomes. The review focuses on minimally invasive evacuation, device innovation, image guidance and navigation, intraoperative visualization and hemostasis, perioperative workflow, and critical care and recovery.

Rationale Intracerebral hemorrhage remains associated with high mortality and disability, while the role of surgery has historically been limited by neutral randomized trials. Recent advances in minimally invasive evacuation, image guidance, visualization, and perioperative care have renewed interest in intervention. The review synthesizes contemporary evidence across minimally invasive evacuation and device innovation, image guidance and navigation, intraoperative visualization and

hemostasis, perioperative workflow, and critical care and recovery.

Condition being studied Spontaneous, nontraumatic intracerebral hemorrhage (ICH).

METHODS

Search strategy PubMed/MEDLINE, Embase, Scopus, Web of Science, Cochrane CENTRAL, ClinicalTrials.gov, and IEEE Xplore were searched using terms related to spontaneous ICH, minimally invasive evacuation, surgical technology, image guidance, perioperative care, and recovery. Reference lists of relevant articles were also screened. The final search was conducted on August 10, 2026. Records were screened in Rayyan after duplicate removal.

Participant or population adults (≥18 years) with spontaneous, nontraumatic ICH.

Intervention Minimally invasive evacuation, catheter-based or stereotactic aspiration, thrombolytic-assisted evacuation, endoscopic or exoscopic techniques, transsulcal/parafascicular access, image guidance, intraoperative imaging, and perioperative or recovery interventions.

Comparator Comparators will include best medical management or conservative management, conventional surgical evacuation, and alternative minimally invasive, device-based, image-guided, or perioperative approaches, where applicable.

Study designs to be included Randomized trials, comparative studies, cohorts, registries, technical/feasibility studies, and selected case series were included. Reviews, guidelines, and protocols were used for contextual evidence.

Eligibility criteria Studies of adults (≥ 18 years) with spontaneous, nontraumatic ICH were eligible. Interventions included were, minimally invasive evacuation, catheter-based or stereotactic aspiration, thrombolytic assisted evacuation, endoscopic or exoscopic techniques, transsulcal/parafascicular access, image guidance, intraoperative imaging, and perioperative or recovery interventions. Randomized trials, comparative studies, cohorts, registries, technical/feasibility studies, and selected case series were included; reviews, guidelines, and protocols were used for contextual evidence.

Information sources PubMed/MEDLINE, Embase, Scopus, Web of Science, Cochrane CENTRAL, ClinicalTrials.gov, and IEEE Xplore. Reference lists of relevant articles were also screened.

Main outcome(s) The main outcome will be functional outcome following treatment of spontaneous intracerebral hemorrhage, assessed using validated measures such as the modified Rankin Scale (mRS), at the longest follow-up reported by each study. Mortality will also be considered a major clinical outcome.

Additional outcome(s) Additional outcomes will include technical and safety outcomes, including hematoma evacuation efficacy, residual hematoma volume, procedural and neurological complications, mortality, and other patient-centered outcomes. Where reported, outcomes related to functional recovery, quality of life, cognition, rehabilitation needs, and long-term survival will also be considered.

Data management Extracted data included study design, patient and hematoma characteristics, intervention, timing, technical and safety outcomes, and patient-centered outcomes. Publications from the same underlying study were treated as a single study to avoid duplication of data.

Quality assessment / Risk of bias analysis Risk of bias will be assessed independently by three reviewers using study-design-appropriate methodological assessment tools. Randomized controlled trials will be assessed using the Cochrane risk-of-bias framework, while observational comparative studies will be assessed using an appropriate validated tool for nonrandomized studies. Technical, feasibility, and case-series studies will be evaluated using appropriate methodological assessment criteria for their respective designs. Disagreements will be resolved through discussion and consensus.

Strategy of data synthesis The findings were synthesized narratively because of substantial heterogeneity in patient selection, hematoma characteristics, interventions, and outcome measures. Evidence was synthesized across five domains, namely:- Minimally invasive evacuation and device innovation, Image guidance and navigation, Intraoperative visualization and hemostasis, Perioperative workflow, Critical care and recovery.

Subgroup analysis Where sufficient data are available, findings will be examined according to clinically relevant and technically relevant characteristics, including hematoma location, hematoma volume, timing of intervention, baseline neurological severity, and type of surgical or minimally invasive approach. Particular consideration will be given to differences in outcomes according to hematoma phenotype and intervention characteristics.

Sensitivity analysis Where sufficient data are available, sensitivity analyses will be undertaken to assess whether the overall conclusions are influenced by study design, methodological quality, or other important sources of clinical or methodological heterogeneity.

Language restriction Restricted to english.

Country(ies) involved India.

Keywords Intracerebral hemorrhage; minimally invasive surgery; hematoma evacuation; 83 image-guided surgery; neurocritical care.

Dissemination plans The findings of this systematic review will be submitted for publication in a peer-reviewed scientific journal and may be presented at relevant scientific conferences.

Contributions of each author

Author 1 - Monirah Zeya - Conceptualization, methodology, supervision, interpretation of findings, and manuscript preparation and revision.

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