Critical Care Management of Intracerebral Hemorrhage

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- Antihypertensive agents/therapeutic use
- Blood coagulation disorders
- Intracerebral hemorrhage
- Hypertensive/diagnosis/cause/therapy
- Neurocritical care
- Neurosurgical procedures

KEY POINTS
- Acute care of patients with intracerebral hemorrhage should prioritize stabilization of airway, breathing, and circulation; making a quick diagnosis; triage to an appropriate hospital unit; and measures to reduce risk of hematoma expansion, secondary neurologic deterioration, and complications of prolonged neurologic dysfunction.
- Physicians caring for patients with ICH should anticipate the need for emergent blood pressure reduction, coagulopathy reversal, cerebral edema management, and surgical interventions including ventriculostomy and hematoma evacuation.
- Neurologic aspects of critical care management extend to ventilation, cardiac monitoring, early feeding, infection surveillance, fever and hyperglycemia management, and venous thromboembolism prophylaxis.
- Early outcome prediction models are limited by the influence of elective withdrawal of care, do-not-resuscitate orders, and evolving effectiveness of new treatments.

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INTRODUCTION

Primary, spontaneous intracerebral hemorrhage (ICH) confers significant early mortality and long-term morbidity worldwide. The overall incidence is estimated at 24.6 cases per 100,000 person years, with a case fatality rate approximately 40% at 1 month and 54% at 1 year, and only 12% to 39% of patients achieving long-term functional independence. A meta-analysis of ICH outcomes between 1980 and 2008 showed no appreciable change in case fatality rate over that time period, although retrospective studies of large cohorts in the United Kingdom and United States have shown a significant decrease in early mortality since 2000. Decreases in 30-day and in-hospital mortality are possibly related to the introduction of improved investigative, diagnostic, and management strategies including bedside neuromonitoring, as well as ascertainment of less severe cases that may previously have been misdiagnosed as ischemic stroke. Example guidelines for the diagnosis and management of spontaneous ICH include those from the American Heart Association (American Stroke Association) and the Neurocritical Care Society (part of the Emergency Neurological Life Support [ENLS] program). This article briefly reviews the pathogenesis and diagnosis of ICH, then details the acute management of spontaneous ICH in the critical care setting based on existing evidence and these published guidelines.

PATHOGENESIS

Spontaneous ICH results from the bursting of small intracerebral arteries, most commonly because of increased susceptibility to rupture caused by chronic vasculopathy. Long-standing high blood pressure commonly leads to lipohyalinosis of tiny perforating arteries serving the thalamus, basal ganglia, and pons, causing deep hemorrhages that often extend into the ventricles. In contrast, cerebral amyloid angiopathy (CAA) typically involves cortical perforators, and is the leading cause of lobar hemorrhage in patients more than 70 years of age. Genetic alleles associated with high blood pressure and cerebral amyloid correlate with higher ICH risk, larger hematoma volume, and poor outcome. Other common risk factors for spontaneous ICH include older age, history of stroke, history of heavy alcohol use, and education attainment at less than a high school level. Table 1 lists various primary and secondary causes of ICH.

Table 1
Causes of nontraumatic intracerebral hemorrhage

<table>
<thead>
<tr>
<th>Primary ICH</th>
<th>Secondary ICH</th>
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<tbody>
<tr>
<td>Hypertension</td>
<td>Vascular malformations</td>
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<tr>
<td>CAA</td>
<td>Arteriovenous malformation</td>
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<tr>
<td>Sympathomimetic drugs of abuse</td>
<td>Cavernous malformation</td>
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<tr>
<td>Cocaine</td>
<td>Saccular aneurysm</td>
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<tr>
<td>Methamphetamine</td>
<td>Mycotic aneurysm</td>
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<td>Coagulopathy</td>
<td>Dural arteriovenous fistula</td>
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<td></td>
<td>Moyamoya</td>
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<tr>
<td></td>
<td>Ischemic stroke (hemorrhagic conversion)</td>
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<td></td>
<td>Cerebral venous sinus thrombosis (hemorrhagic conversion)</td>
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<tr>
<td></td>
<td>Tumor (primary or metastatic)</td>
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<td></td>
<td>Cerebral vasculitis</td>
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</table>

Medications contribute significantly to the risk of ICH, larger hematoma volume, and ICH mortality. Warfarin use was associated with approximately 6.6% of ICH cases in the United States from 2005 to 2008, and this association is expected to increase as the population ages and more patients are placed on anticoagulants for a variety of cardiovascular indications. Supratherapeutic warfarin use as measured by high International Normalized Ratio (INR) correlates with case rate and poor outcome. Newer oral anticoagulants with lower potential for unpredictable therapeutic levels may confer less risk than warfarin. Daily low-dose antiplatelet use, including clopidogrel use, confers a small increase in ICH risk, even when combined with warfarin. Although premorbid statin use has not been related to ICH outcome, low-low-density lipoprotein is associated with in-hospital mortality, and high-dose atorvastatin may be associated with recurrent ICH.

ICH commonly occurs in the putamen (46%), followed by thalamic (18%), lobar (9%), caudate (4%), pontine (13%), cerebellar (4%), and primary ventricular (2%) locations. Lobar hemorrhage has a predilection for the occipital lobes, followed by frontal, temporal, and parietal lobes. Lobar hemorrhage is more often associated with recurrent ICH than deep hemorrhage.

The initial neurologic damage to tissue at the epicenter of ICH formation is unlikely to be salvaged because of blood dissection causing direct and rapid tissue destruction. The first few days after acute ICH confer additional threat of neurologic worsening caused by hematoma expansion, edema, and resultant secondary brain injury. Secondary injury from inflammation, red cell lysis, and disruption of the blood-brain barrier can compromise the surrounding brain parenchyma. Perihematoma edema develops early after ICH, can double within the first 7 to 11 days, and may persist for 4 weeks, even with small-volume ICH. The degree of edema is associated with poor outcome.

DIAGNOSIS

The diagnosis of ICH is suspected on the sudden onset of acute focal neurologic symptoms. The constellation of findings typically relates to the location of the hematoma and its impact on the surrounding brain parenchyma, and is indistinguishable from acute ischemic stroke or other paroxysmal neurologic disorders without neuroimaging. The clinical presentation of ICH may also include acute severe headache, vomiting, seizure, high systolic blood pressure (SBP) greater than 220 mm Hg, and rapid deterioration in consciousness, although none of these are specific for ICH. A brief medical history should also include inquiry for anticoagulant use, recent head trauma, prior stroke, and other hemorrhage.

In addition to an expeditious clinical history and neurologic examination, a swift neuroimaging test is necessary to diagnosis primary ICH quickly and to initiate appropriate acute management. Time from symptom onset to scan is associated with long-term mortality. A computed tomography (CT) study of the head performed without contrast is usually the most efficient study for diagnosis, and may provide further information helpful for clinical decision making. The presence of an intra-axial, hyperdense consolidated lesion is extremely sensitive (89%) and specific (100%) for acute ICH. Hematoma volume is easily estimated using the ABC/2 method (A, maximum hematoma diameter of a reference axial slice that appears largest in hematoma area; B, maximum hematoma diameter perpendicular to A; and C, number of slices in vertical plane with hematoma multiplied by slice thickness [with slices <25% in hematoma volume of the reference slice being ignored, those 25% to 75% of the reference slice considered as a half slice, and those >75% considered a full slice]).
Although highly variable, the ABC/2 method is reliable for most clinical decision making.\textsuperscript{26,27} Large hematoma volumes and the presence of heterogeneous ICH attenuation are predictive of subsequent hematoma expansion.\textsuperscript{28,29} Gradient echo and T2\textsuperscript{*} susceptibility magnetic resonance imaging (MRI) may be equivalent to CT in the diagnosis of acute ICH, although availability of MRI and the clinical condition of many acute patients with ICH often limit the use of MRI as the primary imaging modality (Fig. 1).

The addition of contrast to the head CT may show a spot sign, which represents active contrast extravasation into the hematoma and has a 60% association with hematoma expansion (Fig. 2).\textsuperscript{30} The spot-and-tail sign, a linear density extending from the first segment of the middle cerebral artery into the hematoma and coursing toward the spot sign, may be even more sensitive for predicting hematoma expansion and acute deterioration.\textsuperscript{31} CT angiogram/venogram performed with contrast during the acute phase has an overall sensitivity of 97.0% and specificity of 98.9% for causal vascular abnormalities, compared with digital subtraction angiography (DSA) as the gold standard.\textsuperscript{32} Other CT findings, such as the presence of subarachnoid

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Fig. 1. Typical locations for ICH. ICH caused by chronic hypertension is usually caused by rupture of small penetrating arterioles and typically occurs in the basal ganglia (A), thalamus (B), cerebellum (D), and pons (E). ICH from CAA and sympathomimetic drugs of abuse such as cocaine or methamphetamine often occurs in lobar regions such as the temporal lobe (C). Supratentorial ICH is considered as basal ganglia, thalamic, or lobar (A–C), whereas ICH originating in the cerebellum or pons is considered infratentorial (D and E). Intraventricular hemorrhage (IVH) can also be seen (A–C, E). (Reproduced from Andrews CM, Jauch EC, Hemphill JC 3rd, et al. Emergency neurological life support: intracerebral hemorrhage. Neurocrit Care 2012;17 Suppl 1:S39; with permission.)
hemorrhage, subdural hemorrhage, intraventricular hemorrhage (IVH), and leukoaraisis are associated with early and long-term mortality.\textsuperscript{16,33,34}

MRI performed in the subacute stage of the disease is highly accurate for detecting underlying vascular malformations, and also provides valuable information regarding other causes of intracerebral hemorrhage such as CAA, cavernoma, arterial hypertension, hemorrhagic transformation of ischemic infarct, and malignant brain tumor.\textsuperscript{35} The presence of microbleeds on MRI is associated with increased risk of hematoma expansion, likely from vasculopathy caused by amyloid angiopathy or chronic hypertension (Fig. 3).\textsuperscript{36} Magnetic resonance (MR) angiography is nearly equivalent to DSA for diagnosing vascular abnormalities.\textsuperscript{37} Patients 55 years of age or less, without a history of hypertension, or with lobar hemorrhage should routinely undergo MRI/MR angiography.\textsuperscript{37} Repeat studies at a later date are recommended if there is concern that an underlying lesion cannot be ruled out because of the presence of unresorbed blood. There is no consensus on the ideal timing for MRI, but lesions have been found on imaging performed earlier than 20 days and longer than 100 days from the acute hemorrhage. DSA is considered the gold standard for vascular abnormalities, and should be performed if the clinical suspicion is high and the screening MR or CT is suggestive.

The initial evaluation should also include laboratory studies of coagulopathy, blood count, and toxicology screen to identify additional contributors to ICH, and to assess the need for reversal. Careful review of the clinical history, physical examination, neuroimaging, and laboratory studies may reveal more rare causes of ICH including angiitis, autonomic dysreflexia, connective tissue disease, infection with bacteremia and endocarditis, and moyamoya disease.\textsuperscript{38–42}

Fig. 2. Contrast extravasation (spot sign) in acute ICH. In this postcontrast image obtained after administration of intravenous contrast during a stroke CT scan (noncontrast study, CT angiogram, CT perfusion study), contrast extravasation is present in this acute left temporal lobe ICH. This feature is commonly referred to as a spot sign (arrows) and is associated with increased risk of hematoma expansion. (Reproduced from Andrews CM, Jauch EC, Hemphill JC 3rd, et al. Emergency neurological life support: intracerebral hemorrhage. Neurocrit Care 2012;17 Suppl 1:S40; with permission.)
ACUTE MANAGEMENT

The severe acuity of suspected ICH often necessitates emergent medical assessment before a definitive diagnosis of ICH is made. Acute management protocols such as ENLS prioritize stabilization of airway, breathing, and circulation (ABCs), making a quick diagnosis, triage to an appropriate hospital unit, and measures to reduce risk of hematoma expansion, secondary neurologic deterioration, and complications of prolonged neurologic dysfunction. In addition, certain ICH-specific issues need to be addressed rapidly and these are emphasized in the ENLS checklist for ICH (Box 1).

**ABCs**

Patients who are obtunded or comatose may require immediate airway management before they are stable enough to undergo neuroimaging. Rapid sequence intubation should be undertaken for patients who cannot protect their airway because of poor

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**Box 1**

ENLS ICH checklist for the first hour after diagnosis

- Blood pressure
- PT, PTT, platelet count, INR
- Head CT: measure size of hemorrhage (ABC/2 method)
- Calculate Glasgow Coma Scale score
- Determine ICH score

*Abbreviations: PT, prothrombin time; PTT, partial thromboplastin time.*

mental status, impaired gag and swallow reflexes, or severe vomiting. Barring any significant pulmonary disease, intubated patients can be managed with minimal mechanical ventilator support.

**Blood Pressure**

Prospective studies show that extreme increases in blood pressure in the immediate time period after ICH predict hematoma expansion and early neurologic deterioration.\textsuperscript{43,44} The results of the Intensive Blood Pressure Reduction in Acute Cerebral Hemorrhage Trial 2 (INTERACT2) showed that patients randomized to early intensive lowering of blood pressure to target SBP less than 140 mm Hg (compared with a target SBP of 180 mm Hg) had no difference in death or major disability at 90 days, but significantly better 90-day modified Rankin scores.\textsuperscript{45} Aggressive blood pressure management strategies have not been shown to reduce hematoma volumes or perihematoma cerebral blood flow.\textsuperscript{46} Nevertheless, early aggressive blood pressure management strategies seem to be safe, and targets of SBP less than 140 mm Hg are reasonable to maximize patient outcomes.\textsuperscript{47} Commonly used medications include intravenous \(\beta\)-blockers and calcium channel blockers. Nitrates should be avoided because of potential for cerebral vasodilation, impaired cerebral autoregulation and increased intracranial pressure (ICP). Close blood pressure monitoring and frequent medication titrations are necessary to avoid overshoot and to ensure that cerebral perfusion pressure is maintained in cases of increased ICP.\textsuperscript{5} A blood pressure control protocol initiated in the emergency department with early arterial line placement, continued in an intensive care unit, is encouraged to safely and rapidly achieve target blood pressure parameters.\textsuperscript{48}

**Coagulopathy**

Although coagulopathy is associated with worse outcomes, acute reversal of coagulopathy has not been clearly shown to result in clinical benefit. Even though this area has not been extensively studied in large randomized trials, existing guidelines emphasize rapid correction of coagulopathy in potentially salvageable patients. Options for correction of an INR greater than 1.4 caused by warfarin include fresh-frozen plasma (FFP), vitamin K, prothrombin complex concentrates (PCC), or recombinant activated factor 7 (rFVIIa). Vitamin K is administered slowly in doses of 5 to 10 mg intravenously. It has long-lasting effects and should be given to all eligible patients; however, it is insufficient for rapid INR correction. Monitoring for a severe anaphylactic reaction during infusion is essential. PCCs can be administered more quickly than FFP, correct the INR faster, and require less volume of infusion.\textsuperscript{49} Recombinant factor VIIa is not recommended as a singular agent for warfarin reversal because this may correct the INR value, but not completely correct the coagulopathy. In addition, the Factor Seven for Acute Hemorrhagic Stroke Trial (FAST) in patients with noncoagulopathic ICH showed that rFVIIa in doses of 20 and 80 \(\mu g/kg\) resulted in significant reduction in hematoma expansion at 24 hours, but no significant difference in rate of poor clinical outcome. Although serious thromboembolic events were the same in all treatment groups, arterial events were more frequent in those receiving 80 \(\mu g/kg\) of rFVIIa versus placebo.\textsuperscript{50} Thus, the use of rFVIIa is not routinely recommended for any category of patients with ICH.

Optimal coagulopathy reversal of newer oral anticoagulants remains unclarified. The effect of dabigatran might be partially reversed by PCC, rFVIIa, activated charcoal, and hemodialysis. Rivaroxaban and apixaban are more likely to be partially reversed by PCC.\textsuperscript{51} Practitioners should also be aware of the type of PCC available in their facilities. PCC may include 3 factors (II, IX, and X) or 4 factors (II, VII, IX, and
some 4-factor PCCs include small amounts of heparin and should be avoided in patients with heparin-induced thrombocytopenia. Although patients on clopidogrel, and possibly aspirin, may be at risk for increased hematoma volumes and higher in-hospital mortality, the clinical benefit of platelet transfusions or 1-deamino-8-D-arginine vasopressin (DDAVP), either empirically or targeted using platelet function assays, have not been clearly shown in the limited studies to date.52,53

Neurocritical Care

Retrospective reviews show that more than 20% of patients with ICH deteriorate within the first 2 days of presentation.54,55 Patients with large hematoma volume, IVH, midline shift on head CT, high blood pressure requiring frequent administrations of medications and close blood pressure monitoring, hyperglycemia, and alterations in consciousness are at higher risk of hematoma expansion and neurologic worsening, and should be considered for immediate transfer to a multidisciplinary neurocritical care unit or tertiary care center, if available. Physicians caring for patients with ICH/IVH might anticipate the need for surgical interventions such as ventriculostomy and hematoma evacuation, which are often prompted by findings on repeat neurologic examination in the acute period after hemorrhage.56 Although the evidence on unimodality and multimodality neuromonitoring in ICH is limited, management targets derived from traumatic brain injury research may aid with prevention, early detection, and treatment of secondary brain injury.57 Neurocritical care services have been shown to more effectively perform blood pressure management and dysphagia screening, and may be associated with improved in-hospital mortality.58,59 Stabilization of ABCs, initiation of blood pressure management, and measures to reverse coagulopathy should be initiated before transfer to a higher level of care. Close communication on the clinical status of the patient and plans for care are paramount to effective transfer either within a hospital or to another hospital.

Repeat Imaging

A prospective study of repeat imaging showed that delayed IVH occurred in 21% of patients with ICH without initial IVH, and that these patients did as poorly as those with initial IVH. Furthermore, delayed findings occurred up to 72 hours from the time of symptom onset.60 A protocol for repeat imaging is recommended in anticipation of the need for emergent procedures such as ventriculostomy and management of hydrocephalus and increased ICP. The optimal timing and number of repeat studies is unclear, and should be guided by close monitoring of neurologic signs.

Ventriculostomy and ICP Management

Hydrocephalus complicates up to 50% of ICH cases, and is associated with younger age, lower Glasgow Coma Scale score, deep hemorrhages, intubation, and mortality.61 Patients with ICH with a Glasgow Coma Scale (GCS) score less than 9, those with clinical evidence of transtentorial herniation, or those with significant IVH or hydrocephalus may be considered for ventriculostomy to monitor ICP, titrate ICP treatment, and drain intraventricular blood.4 In a retrospective review, ICP greater than 20 mm Hg occurred in 70% of patients with ICH who had an ICP monitor placed, and was most common in young patients with supratentorial hemorrhage.62 ICP variability with active treatment is associated with poor outcome at 30 days and inpatient mortality, but not 12-month outcome.63 Increased ICP may be treated with hyperosmolar therapy such as intravenous hypertonic saline or mannitol, cerebrospinal fluid drainage, or sedation, although none of these have been shown to improve functional outcome.64,65 A retrospective review of 64 patients with ICH who received
intraventricular recombinant tissue plasminogen activator (rT-PA) in doses of 8 ± 6 mg showed safety, although in-hospital mortality and cerebral edema was unchanged compared with matched controls. The High Dose Deferoxamine in ICH (HI-DEF) trial is underway to follow up a phase I trial that showed that deferoxamine mesylate dosed at 62 mg/kg/d may exert neuroprotective effects, reduce perihematoma edema and neuronal damage, and improve functional recovery without increase in serious adverse event or mortality.

**Surgical Interventions**

Certain patients with ICH may benefit from surgical evacuation of the hematoma, although prospective randomized trials in patients with supratentorial ICH have not shown significant benefit in the patients studied. The International Surgical Trial in Intracerebral Haemorrhage (STICH) did not show benefit on mortality or 6-month functional outcome of a policy of early hematoma evacuation of supratentorial ICH. STICH II studied early hematoma evacuation in a subset of patients with lobar ICH, hematoma volumes 10 to 100 mL, and without IVH. The trial showed no overall significant difference in combined death or disability compared with initial conservative treatment, although a subgroup of patients with an initial poor prognosis may have benefitted.

Because of high morbidity, cerebellar hemorrhages in patients with neurologic deterioration should be evacuated and this is recommended per current guidelines. Preoperative risk stratification using the ICH Score may predict surgical outcome and assist with patient selection. If surgery is indicated, INR should generally be corrected to less than 1.5 and platelet count to greater than 100,000 per microliter with transfusions as needed.

Other surgical procedures may be helpful in reducing hematoma volume, ICP, and midline shift. Small case series have shown the feasibility of decompressive hemicraniectomy, with or without clot evacuation. The transsylvian-transinsular approach is a minimally invasive method that can visualize a bleeding vessel under the microscope, spare functional cortex, and achieve high hematoma clearance rate with adequate decompression. Image-guided needle-based approaches with robot control also debulk hematoma while sparing healthy brain tissue. The ongoing Minimally Invasive Surgery Plus rt-PA for Intracerebral Hemorrhage Evacuation (MISTIE) trial combines stereotactic catheter placement and clot aspiration with injections of rt-PA through the catheter every 8 hours, up to 9 doses or until clot reduction end point. The procedure seems to be safe and the trial is ongoing as of this writing.

**Seizure Monitoring and Anticonvulsant Treatment**

Retrospective reviews report electrographic seizures in up to one-third of patients monitored with continuous electroencephalography (EEG), with about half of seizures being electrographic only and most occurring within the first 24 hours after ICH. Seizures are associated with younger age, hemicraniectomy, ventriculostomy, intubation, tracheostomy, lower in-hospital mortality, and longer hospital length of stay. Evidence is unclear about the effect of seizures on overall outcomes; whether seizures should be treated; and, if so, with which anticonvulsant medications. Retrospective data about anticonvulsant treatment are confounded by indication, disease severity, and do-not-resuscitate (DNR) status. A prospective review of patients given anticonvulsants showed that phenytoin was associated with more fever and worse outcomes. EEG monitoring is probably indicated in patients with ICH with depressed mental status out of proportion to the degree of brain injury. Patients with clinically
significant seizures should be treated with anticonvulsants, but prophylactic medications, especially phenytoin, are not generally recommended.4

**Cardiac Monitoring**

Patients with ICH should receive close cardiac monitoring for the first few days, especially if they are undergoing active management for blood pressure using intravenous medications. In a retrospective review, most electrocardiographic changes occurred in patients with ICH with deep hemorrhage. QTc and ST abnormalities, and bradyarrhythmias/tachyarrhythmias were common. Almost all patients with IVH had QTc prolongation and this has been associated with in-hospital mortality regardless of IVH. ST segment abnormalities were also associated with higher in-hospital mortality.82 Wall motion abnormalities in patients with ICH are frequently seen on transthoracic echocardiogram. They are associated with lower admission SBP, history of ischemic heart disease, but not in-hospital mortality, age, gender, GCS, or hematoma volume. Routine transthoracic echocardiography is unlikely to be helpful for treatment course, but may be helpful in cases of high clinical suspicion or a history of ischemic heart disease.83

**Mechanical Ventilation**

In retrospective reviews, up to 21% of patients with ICH are mechanically ventilated, usually for inability to protect the airway because of poor level of consciousness. Intubated patients with ICH are at risk for pulmonary edema, acute respiratory distress syndrome (ARDS), pneumonia, and long-term need for tracheostomy.84 Ventilated patients have as much as 48% in-hospital mortality, and death rates after discharge are high. However, up to 42% of ventilated patients who survive to discharge have a good functional outcome.85

ARDS has a prevalence of about 27% in intubated patients with ICH and usually occurs by hospital day 2, with a pathophysiology possibly related to neurogenic pulmonary edema. ARDS in patients with ICH is associated with high tidal volumes, male sex, blood transfusions, higher fluid balance, obesity, hypoxemia, acidosis, tobacco use, emergent hematoma evacuation, and vasopressor dependence. Lower GCS is not associated, suggesting that aspiration is not a significant contributor. ARDS is also not independently associated with in-hospital mortality or functional outcome, possibly because the morbidity of ICH is already so high.86,87 Management of ARDS in patients with ICH must balance the risks of hypercapnea with hypoxia as related to secondary brain injury.

Intubated patients should undergo surveillance for ventilator-associated pneumonia along with pneumonia-prevention measures such as minimizing duration of mechanical ventilation, health care personnel hand hygiene, head of bed elevation to 30°, and good oral care.88 Patients progressing to tracheostomy tend to have larger hematoma volumes, IVH, hydrocephalus, low admission GCS, pneumonia, and intubation period longer than 2 weeks. Prediction models for timing of tracheostomy have the potential to reduce complications of endotracheal intubation and decrease hospital length of stay.

**Nutrition**

In a retrospective review of patients with ICH divided into enteral feeding initiated within 48 hours versus delayed feeding, in-hospital mortality was lower in the early feeding group, as were pneumonia, sepsis, discharge morbidity, and intensive care unit length of stay.89 Efforts should be undertaken to feed patients with ICH as early as safely possible.
**Hyperglycemia, Hypothermia**

Blood glucose greater than 140 mg/dL and temperature greater than 37.5°C at hospital admission predict late neurologic deterioration.\(^5^4,^5^5\) Although aggressive treatment of these parameters has not been systematically investigated for ICH, maintenance of normothermia and euglycemia are reasonable strategies for minimizing secondary brain injury.

**Infection**

Infection in patients with ICH is associated with worse clinical status, larger hematoma volumes, IVH, and invasive procedures. Common infections include pneumonia, urinary tract infection, and clinical or laboratory evidence of infection without identified source.\(^9^0\) Patients should undergo active monitoring for infections with aggressive treatment when indicated by clinical status.

**Venous Thromboembolism Prophylaxis**

The incidence of symptomatic venous thromboembolism ranges from 0.5% to 13% of patients with ICH, and pulmonary embolism from 0.7% to 5%. Hemiplegic patients may have rates of asymptomatic thromboembolism as high as 75%. In a pilot study, 97 patients with ICH received low-molecular-weight heparin by 36 hours of admission as long as they were free of clinical or radiological growth of hemorrhage. None developed fatal embolism, 2 patients had moderate hematoma growth, and 2 developed nonsignificant heparin-induced thrombocytopenia.\(^9^1\) Early venous thromboembolism prophylaxis with intermittent pneumatic compression devices, elastic stockings, and low-molecular-weight heparin or unfractionated heparin is probably reasonable and safe for immobile patients.

**Blood Transfusion**

Anemia has a 25% prevalence in patients with ICH, which is much higher than in the general elderly population, and is correlated with poor functional outcome.\(^9^2\) It is not clear whether transfusions are helpful.\(^9^3\)

**Outcome Predictions**

Despite improvements in acute care, ICH continues to be a disease with high morbidity and mortality. Outcome prediction models seek to accurately identify patients who might survive and benefit from acute and long-term care. The ICH Score, ICH Grading Scale, and Modified ICH Score have all been evaluated in multiple retrospective cohorts and are highly predictive of 30-day mortality (Table 2).\(^9^4–^9^6\) However, the point estimates from the original publications of all of these are limited by the influence of elective withdrawal of support and DNR orders.\(^9^7,^9^8\) Even so, the use of a baseline severity score such as one of these or the FUNC score is reasonable because this may help with communication across caregivers and with patient families.\(^9^9\) Patients who progress to brain death may be eligible for organ donation, and loss of brainstem reflexes or the CT swirl sign on admission may aid in early identification.\(^1^0^0\) Longer term functional outcome has also been correlated with neuroimaging cerebral volume loss, transcranial Doppler pulsatility index, hematoma involvement of the inferior parietal lobule or posterior insula, surgical feeding tube placement, and tracheostomy placement, but none of these are individually sensitive or specific.\(^1^0^1–^1^0^4\)

In a prospective registry of 245 patients, 18% had DNR orders instituted within 24 hours of admission. DNR cases did not receive ventricular drainage or surgical hematoma evacuation. By matched analysis, more controls had surgical evacuation and
mechanical ventilation, but there was no difference in functional outcome and survival at 1 year. Current guidelines recommend aggressive full care and avoiding new DNR orders until at least the second day of hospitalization in order to decrease the likelihood of a self-fulfilling prophecy of poor outcome caused by early care limitations.

LONG-TERM MANAGEMENT

Patients who survive to discharge should receive aggressive rehabilitation as tolerated to maximize functional outcome. Long-term management of identified risk factors such as hypertension, alcohol use, and other substance abuse are important to reduce ICH recurrence risk.

For patients who were on anticoagulation or antiplatelet therapy at the time of hemorrhage, the evidence on restarting therapy is limited. Retrospective studies show no differences in strokes among patients who did or did not resume anticoagulation. For patients with lobar hemorrhage and nonvalvular atrial fibrillation, avoidance of long-term anticoagulation is reasonable because of the high risk of ICH recurrence, especially in the setting of CAA. Newer anticoagulants may have advantages but lack effective laboratory testing and availability of reversal agents. Each patient must be assessed individually according to the underlying medical condition, hemorrhagic burden, comorbidities, and complication risks.

Regarding statins, secondary analysis of the Stroke Prevention by Aggressive Reduction in Cholesterol Levels (SPARCL) trial suggested that statins were associated with occurrence of ICH primarily in patients with a history of ICH. Nevertheless, the overall benefit of stroke risk reduction and coronary events with atorvastatin dosed at
80 mg/d likely outweighs the increase in ICH. Another extensive meta-analysis found no association between statins and ICH occurrence. Retrospective reviews show that patients exposed to statins as early as 72 hours after hemorrhage onset have reduced death and disability at 1 year, and those who receive low doses of atorvastatin at 20 mg/d have no increased risk of recurrent ICH. Thus, it is probably safe to restart low-dose statin treatment early after ICH, and increase the dose as clinically appropriate.

**SUMMARY**

Despite the high morbidity and mortality of ICH, advances in acute management have contributed greatly to the improved survival potential of patients with ICH. High-quality care based on evidence and delivered by practitioners familiar with practice guidelines is paramount to maximizing functional outcomes. Acute ICH management will continue to evolve with ongoing research on ICH treatments and neurocritical care.

**REFERENCES**


