# The Non-Neurosurgeon's Guide to Intracerebral Hemorrhage

## PART ONE: THE BASICS

### Introduction

Intracerebral hemorrhage (ICH) accounts for approximately 10-15% of all cases of stroke in the United States. It is usually quite devastating and is associated with a much higher mortality than ischemic stroke. Those patients who do survive are often left with moderate to severe disability. The critical care management of patients who have suffered an ICH can be quite challenging. The purpose of this guide is to help non-neurosurgical clinicians deal with these issues in the ICU.

### Pathophysiology

Hypertension is, by far, the biggest risk factor for ICH. Uncontrolled hypertension leads to arteriolar degeneration and infiltration of the vessel wall with lipids; hyaline changes also occur, and this process is collectively referred to as lipohyalinosis. Charcot-Bouchard aneurysms are discrete microaneurysms in arterioles measuring 100-600 μm in diameter—these are often found in the basal ganglia, pons, deep white matter, and the cerebellum. Risk factors for ICH include heavy alcohol consumption and hypocholesterolemia. Smoking has not been directly correlated with an increased risk of ICH, but it certainly can't help.

Approximately 15% of people who suffer ICH have a condition called amyloid angiopathy—amyloid-ß peptide infiltrates small and medium-diameter arteries in the brain and the leptomeninges. The resulting vascular fragility can lead to multiple episodes of ICH, which can be seen with gradient MR imaging. These patients are often elderly and have lobar ICH that extends to the cortex.

### The Acute Event

Previously, it was felt that ICH was a monophasic event—an acute rupture of the cerebral arterioles, associated with rapid hematoma formation and edema that then slowly resolved. Recent human and animal studies have shown that this is not the case. After the initial rupture, there is a phase of hematoma expansion, followed by an inflammatory process that leads to vasogenic and cytotoxic edema.

Early hematoma growth has been shown to occur even in patients without preexisting coagulopathy. Continued bleeding can occur for 3-6 hours following the initial hemorrhage. Arterial pressure causes much of this ongoing bleeding. Engorgement of the tissue and obstructed venous flow also contributes to expansion. A localized area of coagulopathy related to consumption of clotting factors may also be present.

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Following the ICH and subsequent hematoma formation, an inflammatory process occurs in the perihematomal region. This appears to be due to extravasation of thrombin and other products of coagulation into the brain parenchyma. This inflammation creates a zone of cytotoxic edema, and the disrupted blood-brain barrier leads to vasogenic edema. This can cause mass effect, even herniation, and seems to be the principal mechanism behind the secondary neuronal injury (the primary injury being the initial rupture). Brain edema peaks on the day of the ICH, and declines each day thereafter.

Contrary to what was believed for many years, there is no ischemic penumbra surrounding the hematoma; this is in contrast to what is seen with ischemic stroke. PET and MRI scans performed within 6 hours of ICH have not demonstrated perihematomal tissue ischemia.

## Clinical Presentation

Most patients will present with an abrupt change in mental status, which may range from mild drowsiness to coma. Lateralizing signs are common, as are signs consistent with increased intracranial pressure (nausea, vomiting, blurred vision). 90% of patients will have a blood pressure in excess of 160/100, regardless of any history of hypertension.

Initial management, as always, hinges on the ABC's. Patients with a GCS less than 8, signs of airway compromise or respiratory distress, or a rapidly declining neurologic exam should be intubated. The $PaCO_2$ should be kept normal (35-40) unless there is actual or impending herniation. Hypoxemia should be avoided at ALL COSTS! Blood pressure control is important and will be discussed in more detail later.

## Diagnosis

The best tool for initial diagnosis is noncontrasted CT. 50% of ICH occur in the basal ganglia (caudate, putamen, thalamus), 33% in the cerebral lobes, and the remainder in the pons or cerebellum. 40% of ICH will be associated with intraventricular extension—this can lead to hydrocephalus and an abrupt increase in intracranial pressure.

In previously hypertensive patients over 45 who have a "typical hypertensive bleed" in the basal ganglia, angiography is probably not needed. Cerebral angiography is indicated in lobar or subarachnoid bleeding, young, previously normotensive patients, isolated intraventricular hemorrhage, or ICH related to cocaine abuse. In these cases, a treatable cause (dural sinus thrombosis, vasculitis, neoplasm, aneurysm, AVM) can often be identified. MR imaging may be an acceptable alternative.

## Prognosis

The 1-year mortality from ICH is 50%. Half of all patients who die from an ICH die within the first 2 days; the remainder who die within the next year tend to die from medical complications. Factors associated with 1-month and 1-year mortality include hematoma volume greater than 30 cc, coma, advanced age, intraventricular bleeding, and

infratentorial location. Unfortunately, predicting long-term survival or eventual neurologic outcome is very difficult, and no criteria have yet been shown to accurately accomplish this.

## PART TWO: CRITICAL CARE MANAGEMENT

### Blood Pressure Control

With increased understanding of the pathophysiology of ICH, it is evident that strict blood pressure control is very important. Early hematoma expansion is directly related to the degree of hypertension. The mean arterial pressure (MAP) should be held to 130 mm Hg or less—if the patient doesn't have an arterial line, the systolic blood pressure should be kept between 160 and 180 mm Hg. Nicardipine and Labetalol are commonly used in continuous infusion; alternatively, IV boluses of Labetalol or Enalaprilat can be used. Sodium nitroprusside or nitroglycerin should NOT be used, as venodilation can cause worsening cerebral edema.

The blood pressure should also not be allowed to become too low, because this can lead to cerebral hypoperfusion. The MAP should be kept above 80 mm Hg, with vasopressors if necessary. If the patient has a ventriculostomy or ICP monitor, the cerebral perfusion pressure (CPP – ICP) should be kept above 70 mm Hg.

After 3-4 days, if the patient is otherwise stable, oral antihypertensives can be started. The risk of rebleeding is highest in patients with a diastolic blood pressure over 90, so therapy should be targeted at keeping the DBP below this threshold.

### Reversal of Anticoagulation

Patients with ICH who are coagulopathic require rapid reversal to prevent hematoma expansion.

| Coagulopathy | Reversal Agent |
|---|---|
| Warfarin | FFP—15 mL/kg (typically 4-6 units); may repeat until INR is less than 1.5. Prothrombin concentrates are becoming more available and may be used as well.<br><br>Recombinant Factor VIIa is an option for life-threatening hemorrhage that requires emergency surgery, and the dose is 20-40 mcg/kg IV.<br><br>Vitamin K 10 mg IV daily for 3 days (delayed action) |
| Heparin or LMWH | Protamine sulfate 1 mg per 100 units heparin, or per 1 mg enoxaparin (one dose), to a maximum dose of 50 mg IV. |

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| Platelet dysfunction | Platelet transfusion (keep platelet count > 100K); may also use DDAVP 0.3 μg/kg IV (one dose).<br>Conjugated estrogens (0.6 mg/kg) IV daily for 5 days for prolonged platelet dysfunction. |
| Tissue Plasminogen Activator | 10 units cryoprecipitate, followed by FFP and Vitamin K |

Thromboelastography is quick and is a good way to evaluate the adequacy of the coagulation cascade. Transfusing to normalize TEG parameters, rather than coagulation values, is becoming more common.

## Surgical Intervention

The role of surgical intervention in ICH is limited, and unfortunately recent trials (STICH) have not shown a benefit to early, aggressive surgical intervention. There are some subsets of patients who will benefit from craniotomy, however. These include patients with cerebellar hemorrhage >3 cm, large lobar hemorrhage and mass effect, and ICH due to AVM or aneurysm. Urgent consultation with a neurosurgeon should be done in all cases to determine whether surgery will be of benefit.

Some therapies currently being examined include stereotactic thrombolysis and drainage, intraventricular thrombolysis, and endoscopic drainage. Decompressive craniectomy may also be beneficial for patients with significant edema.

## Anticonvulsants and Seizures

Seizures should be treated with lorazepam (0.05-0.1 mg/kg IV); recurrent seizures should be treated with anticonvulsants such as phenytoin or valproic acid. Status epilepticus should be treated initially as above, and if it persists, midazolam 0.2-2.0 mg/kg/hour or propofol 20-150 μg/kg/min should be given. The role of prophylactic anticonvulsants is controversial.

## Fever

Fever and hyperthermia increase the metabolic activity of the brain and can increase intracranial pressure. Fever should be treated aggressively with acetaminophen and cooling blankets. The temperature should be kept below 100º F.

## Glycemic Control

Hypo- and hyperglycemia are both detrimental to injured brain. All patients, whether or not they are diabetic, should have glucose checks with insulin coverage as needed.

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## Other Measures

Don't forget DVT/stress ulcer prophylaxis, nutritional support, VAP precautions, lung-protective ventilation, infection control measures, and all of the other little things that make a big difference in critically ill patients!

# PART THREE: DEALING WITH INTRACRANIAL PRESSURE

## Monitors

Several types of intracranial pressure monitors are available. Ventriculostomy allows both measurement of ICP and therapeutic drainage, and is therefore the most preferred. Other devices include intraparenchymal fiberoptic monitors and epidural bolts—these measure ICP, but do not allow drainage of CSF. These devices also tend to "drift" and cannot be recalibrated.

## Cerebral Perfusion

The cerebral perfusion pressure (CPP) is defined as the difference between the mean arterial pressure (MAP) and the intracranial pressure (ICP). When the CPP falls below 60 mm Hg, autoregulation is lost and brain ischemia occurs. Excessively high CPP (over 110 mg Hg) can also be detrimental. At this pressure the upper autoregulatory threshold is exceeded and cerebral edema can occur. In general, the CPP should be kept between 70 and 90 mm Hg.

## Intracranial Hypertension

Intracranial hypertension is defined as an ICP exceeding 20 mm Hg. Clinical manifestations of intracranial hypertension include mental status changes, worsening peripheral deficits, vomiting, and autonomic changes. Unilateral pupillary dilatation may signal impending uncal herniation. Cushing's Triad may be present in cases of severely increased intracranial pressure. The components of the triad are:

- Bradycardia
- Respiratory Irregularity
- Systolic Hypertension

Airway protection is essential. Measures should be taken to rapidly lower the ICP. If untreated, herniation may occur.

## Measures to Lower the ICP

When confronted with a sustained increase in ICP, a few basic steps will usually suffice. First, ensure adequate arterial pressure—fluids or vasopressors should be used. If the patient has a ventriculostomy, CSF can be drained in 3-5 cc increments until adequate CPP

is restored. Alternatively, the ventriculostomy can be left open to drain, set at a desired height (usually 20 mm Hg). Repeat CT scanning should be performed to see if there is anything that can be corrected surgically.

If this does not work, or the patient does not have a ventriculostomy, mild hyperventilation should be initiated. Hypocapnia causes cerebral vasoconstriction and reduces intracranial blood flow. The goal $PaCO_2$ is 28-32—lower than this can impair oxygen delivery. Sustained hyperventilation becomes ineffective after 6-12 hours, and there is no role for prophylactic hyperventilation. The patient's head should be kept at 30 degrees elevation and the head should be in a neutral position so venous blood flow is not obstructed.

If the ICP is still elevated, osmotherapy can be used. Mannitol (0.25-1.0 g/kg IV) can be used as an osmotic diuretic to lower the ICP. Mannitol should not be used if the patient does not have adequate intravascular volume, however, as this can cause dangerous hypotension. An alternative, which does not deplete the intravascular volume, is hypertonic saline (7.5%, given in 2 cc/kg boluses). Volume overload and pulmonary edema are possible side effects of hypertonic saline. The serum sodium can be raised to 150-155 mEq/L without adverse effects. Serum osmolarity should be followed when using either of these agents, and should not exceed 320 mEq/L.

If the ICP is still elevated despite hyperventilation, CSF drainage, and osmotherapy, consider reducing cerebral metabolic oxygen consumption with a drug-induced coma. Pentobarbital is the standard agent for this—the dose is 10 mg/kg bolus over 30 minutes, followed by 5 mg/kg q 1 hour for three doses, followed by an infusion of 1-3 mg/kg/hour. Barbiturate coma is usually carried out for 3-5 days before it is withdrawn (slowly!). Propofol is a newer, and possibly better, alternative—it reduces cerebral metabolism and intracranial pressure without the systemic effects of pentobarbital.

Induced hypothermia is currently being studied for this purpose, and decompressive craniectomy may also be of benefit. This should be considered for patients on an individual basis.

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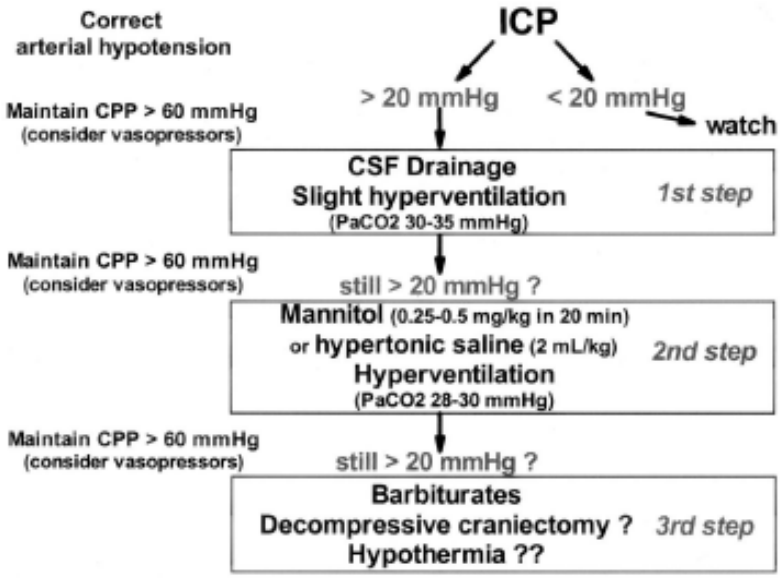


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