Section I

Acute Triage

Bart M. Demaerschalk, Devi P. Patra, Chandan Krishna, Rudy J. Rahme, Andrej Urumov, Mathew E. Welz, and Evelyn L. Turcotte

1 Clinical Presentation and Acute Triage of Ischemic Stroke, Intracranial Hemorrhage, and Subarachnoid Hemorrhage

Devi P. Patra, Onur Açiş, Miles Hudson, Benzion Blech, Gyanendra Kumar, Vanesa K. Vanderhye, Lynda M. Christel, and Bernard R. Bendok

Abstract

Acute stroke management is challenging because patients can have varied presentation and multiple pathologies can present in a similar way. In this regard, it is critical to identify and triage stroke patients as the treatment paradigm can be significantly different. The triage begins in the field by the emergency medical services (EMS) in the prehospital setting and then in the emergency department, where ischemic stroke is primarily differentiated from a hemorrhagic stroke in addition to ruling out other pathologies like tumors, vascular malformations, and even other systemic conditions mimicking a stroke. The triage process starts with careful initial history and examination, and rapid laboratory tests including glucose and oxygen saturation, which in most of the cases gives a global impression regarding the etiology of the stroke. A rapid noncontrast computed tomography (CT) scan is the key differentiating imaging modality to differentiate an ischemic and hemorrhagic stroke. In the absence of hemorrhage or other obvious mass lesion, most patients receive thrombolytic therapy unless contraindicated. Further evaluation includes a CT or magnetic resonance (MR) angiogram with or without perfusion study based on the timing of presentation, which helps in detecting large vessel occlusion. Similarly, most patients with hemorrhagic stroke are further evaluated with an angiographic study to rule out structural lesions like aneurysms, arteriovenous malformations, etc. In an acute setting, a prompt differentiation of type of stroke in the emergency department is essential to institute rapid treatment to prevent irreversible brain damage.

Keywords: acute stroke, ischemic stroke, hemorrhagic stroke, subarachnoid hemorrhage, triage, intracranial hemorrhage, intracerebral hemorrhage, thrombectomy, large vessel occlusion

Pearls

- Acute stroke must be promptly differentiated to ischemic or hemorrhagic as there are significant differences in management. A noncontrast CT scan of the head is usually the first imaging modality differentiating these two, but clinical history nuances are paramount as well. The two entities can also present together.
- Once acute ischemic stroke is confirmed, the next step in management is to determine eligibility for thrombolysis and/or mechanical thrombectomy. A timely intervention is the key to effectively prevent irreversible brain damage.
- The primary management of spontaneous intracerebral hemorrhage is control of blood pressure, reversal of anticoagulation if needed, and monitoring in intensive or intermediate care unit. Procedural intervention may be necessary to prevent deterioration and optimize outcome in select cases.
- Nontraumatic subarachnoid hemorrhage should be evaluated for lesion all causes including brain aneurysms with vascular imaging. Timely microsurgical/endovascular intervention to occlude the aneurysm is essential to prevent rehemorrhage.

1.1 Clinical Case

A 53-year-old gentleman with medical history of atrial fibrillation on Coumadin therapy, renal cell carcinoma treated with radical nephrectomy 8 months ago, and coronary artery disease, who presented with acute onset of left-sided arm weakness, facial weakness, and mild headache. He came to the emergency department within 4 hours of symptom onset. On arrival, the patient is conscious with heart rate of 72/min, blood pressure (BP) 168/92 mm Hg, and respiratory rate of 16/min. His National Institutes of Health Stroke Scale (NIHSS) score is 13.

1. What is the next step in management?
   a) Check arterial blood gas (ABG).
   b) Noncontrast computed tomography (CT) scan of the head.
   c) Magnetic resonance imaging (MRI) of the head.
   d) Computed tomography angiography (CTA) of the head and neck.
2. What are the contraindications to alteplase therapy in this patient?
   a) Age.
   b) History of renal cell carcinoma.
   c) Current Coumadin therapy.
   d) Time of arrival.

The following questions are based on different scenarios of CT scan findings in this patient.

3. What is the next step in management if the CT scan shows the finding as ▶ Fig. 1.1a?
   a) CT perfusion.
   b) CTA of the head.
   c) MRI of the brain.
   d) Admission to intensive care unit (ICU).
4. What is the next step in management if the CT scan shows the finding as ▶ Fig. 1.1b?
   a) MRI of the brain.
   b) Admission in monitored unit for strict BP control and repeat CT scan in 4 hours.
   c) Catheter angiogram.
   d) Decompressive hemicraniectomy.
5. What is the next appropriate imaging/test if the CT scan shows the finding as ▶ Fig. 1.1c?
   a) MRI of the brain.
   b) CT perfusion.
   c) Electroencephalogram (EEG).
   d) Contrast enhanced CT scan.

1.2 Introduction

Acute stroke is a neurological emergency. Different types of stroke and several alternative diagnoses can present in a similar fashion. Treatments that are available for stoke today are often limited by time windows during which they can be beneficial. There is a strong evidence to suggest early interventions can significantly enhance outcomes. Therefore, early recognition of the stroke symptoms is critical so that proper interventions can be deployed. An organized approach should be taken to obtain the key clinical

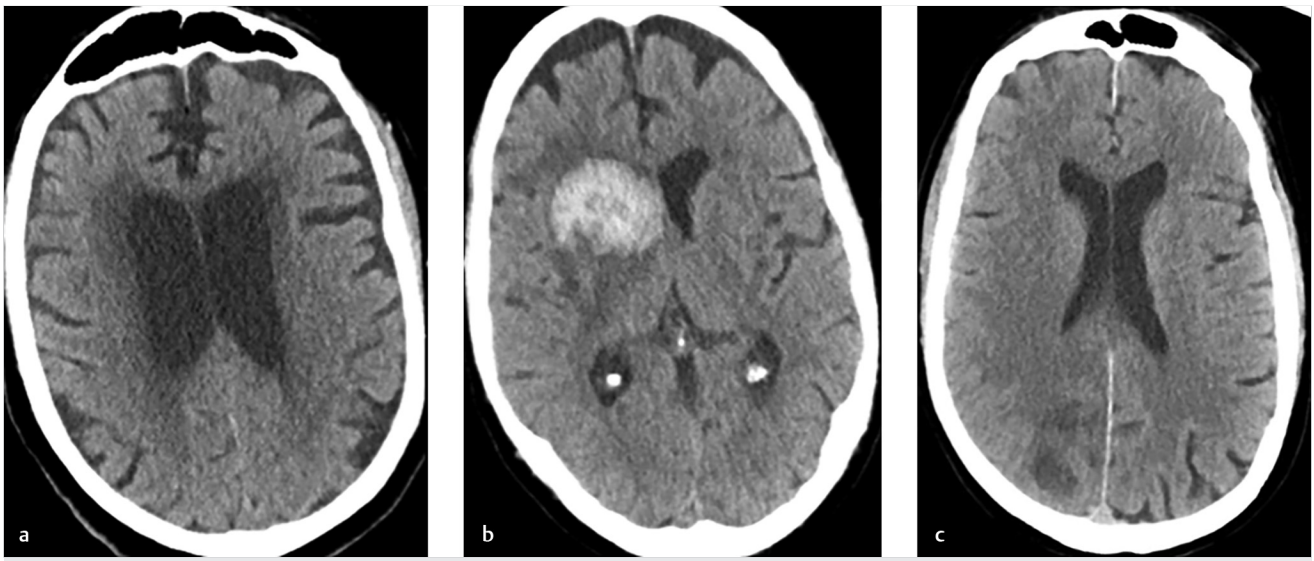

Fig. 1.1 (a–c) Case description.

information needed to determine if stroke is the cause of symptoms, and if it is, determine the type of stroke. The approach must include careful consideration of differential diagnoses and, in cases where stroke cannot be ruled out, concomitant conditions accompanying stroke and possible contraindications to potential treatment methods. This chapter discusses recognition of stroke in the field and the acute hospital and acute management of patients with acute neurological deficits. It summarizes an approach that is tailored toward providing the clinician with the information needed to act and choose among the treatments for acute stroke that are discussed in subsequent chapters.

As treatment strategies largely differ, this chapter focuses on differences in clinical presentation and acute triage of three specific types of acute stroke: acute ischemic stroke (AIS), acute intracerebral hemorrhage (ICH), and subarachnoid hemorrhage (SAH).

1.3 Acute Ischemic Stroke

AIS is defined as abrupt cessation of blood flow to any artery in the brain due thrombus, emboli, local, and/or systemic hypoperfusion. When the brain is deprived of blood supply, neuronal death occurs rapidly, and permanent infarct develops. Clinicians must act promptly as time is vital for saving the salvageable brain tissue that continues to be viable for a short period of time via collateral blood supply (the penumbra). Standardized protocols from initial emergency medical services (EMS) triage to hospital triage can enhance outcomes. Intravenous (IV) tissue plasminogen activator (tPA) has been proven to enhance outcomes in select patients. Multiple clinical trials published recently have provided evidence regarding the efficacy of endovascular therapy (EVT) in AIS.[1,2,3,4,5,6] Time intervals and criteria to select patients for this therapy have been established. Consequently, triaging patients who qualify for EVT to centers equipped to do it in a timely manner has gained tremendous importance.

1.3.1 Prehospital Setting

Stroke remains a condition that can be best evaluated and treated in the hospital setting. American Heart Association (AHA)/American Stroke Association (ASA) guidelines recommend patients call 911 as the most effective and rapid method for dispatching appropriate teams and transporting patients to a center capable of administering IV tPA and/or EVT.[7] Educational stroke programs can educate the general public as to how stroke can be recognized and what is best to do when encountered. Health care facilities and EMS teams should work together with 911 to make stroke calls a dispatch of top priority and diminish delays in transport and communication.

1.3.2 EMS Assessment and Management

EMS teams should ideally receive training in stroke recognition. Adhering to protocols has been shown to decrease errors as well as time to treatment and improve outcomes as a result.[7] EMS teams giving notice to hospitals or stroke centers before arrival of the patient to facilitate availability of appropriate teams and facilities is recommended. Evaluation should include level of consciousness (LOC), possible sensory, motor deficits, and speech. Although NIHSS remains a gold standard in assessing and following up the severity of stroke, it is too complicated for use in the field by EMS personnel. Several simplified screening tools have been developed for rapid recognition of stroke (▶ Table 1.1). Glasgow Coma Scale (GCS) offers a rapid and standardized assessment of LOC, via scoring eye, verbal, and motor responses. Although GCS provides a standardized evaluation tool at the time of presentation, it is much less sensitive for follow-up as it only takes gross changes in patient status into account. NIHSS should be used for follow-up of stroke patients instead.

Table 1.1 Stroke screening scales

Stroke screening scales	
A. Cincinnati Prehospital Stroke Scale (CPSS)	
Facial droop: Have the patient show their teeth or smile. Abnormal if asymmetric	1/3 + CPSS corresponds to 72% stroke possibility while in patients with 3/3 + CPSS possibility increases up to 85%
Arm drift: Have the patient close their eyes and extend both arms straight out, with palms up, for 10 seconds. Positive if one arm or both arms drift down or do not move at all	
Speech: Have the patient say "you can't teach an old dog new tricks." Positive if not able or slurred speech	
B. Los Angeles Prehospital Stroke Screen (LAPSS)	
< 45 y old	Positive if all 6 criteria are met
No seizure history	
Neurologic symptoms presented within the last 24 h	
Nonhospitalized patient	
Blood sugar: 60–400 mg/dL	
Unilateral (and not bilateral) exhibition of facial droop, grip weakness, arm weakness, or other observable motor asymmetries	
C. FAST	
FAST is an acronym for a stroke screening tool that is used to educate the public about stroke recognition and is recommended by the AHA/ASA guidelines. It only requires assessment of abnormalities in the **F**ace, **A**rm, and **S**peech, and stresses the importance of **T**ime in calling 911 as soon as possible	

1.3.3 Rapid Screening for Presence of Large Vessel Occlusion

Between 2015 and 2016, six positive trials were published backing the use of early mechanical thrombectomy in large vessel occlusion (LVO) stroke patients. In patients with stroke suspicion, LVO possibility should be assessed by EMS using one of the following standardized tools of severity (i.e., Cincinnati Stroke Triage Assessment Tool [CSTAT], Field Assessment Stroke Triage for Emergency Destination [FAST-ED], Los Angeles Motor Scale [LAMS], Rapid Arterial Occlusion Evaluation [RACE], and vision, aphasia, and neglect [VAN]) as this can play a vital role in decision to transfer the patient to an EVT-capable facility (▶ Table 1.2). Although it is not clear which of these scales is sufficiently accurate to be the gold standard, they are the best tools we have at hand currently and their use provides standardized data for further stroke research. Time is crucially important when managing patients with a stroke suspicion (▶ Table 1.3). Current guidelines recommend door-to-imaging times ≤ 20 minutes so that candidates for endovascular treatment and IV alteplase can be determined without delay.[7] Patients who are eligible for mechanical thrombectomy should be transferred to an endovascular treatment–capable facility even if pursuing this will increase transfer time up to 30 to 45 minutes. Although AHA guidelines offer 15 minutes of additional transfer time as acceptable, there are reports published demonstrating benefits with up to 30 to 45 minutes of additional transport time.[8]

1.3.4 Hospital Setting

The 2018 AHA/ASA guidelines recommend using standardized stroke protocols in hospitals as there is tremendous amount of data backing use and demonstrating improvement in outcomes in institutions that have protocols in place.[7] Stroke teams that can mobilize effectively should be put together as an acute response to stroke alerts. The goals for these institutions should be to increase tPA use rates and decrease door to needle times to under an hour for more than half of the patients. The 2018 AHA/ASA guidelines suggest that the Food and Drug Administration (FDA) approved teleradiology can be used to decide whether to administer IV tPA treatment. This methodology is as effective as hospital setting imaging and can be used for patients who have restricted access to well-equipped facilities.[7] Institutions should record data on their stroke patients to improve their performance over time.

1.3.5 Initial Stabilization

When a suspected stroke patient is identified, the first steps should be checking vital signs and securing an intact airway. Patients with acute neurological symptoms are likely to have neurologically depressed respiratory function or aspiration due to decreased levels of consciousness. Clinicians should be attentive to possible emesis that might be caused by increased intracranial pressure (ICP) possibly compromising respiration. If the patient is able to ventilate well, monitoring of oxygen status should guide the decision to intubate. Hypoventilation can worsen ICP status due to cerebral vasodilation. Guidelines recommend oxygen supply if saturation is below 94%.[7] If the patient has had a fall following the stroke symptoms, unstable cervical injury must be presumed until proven otherwise and a cervical collar is recommended. Cardiac monitoring should ensure stable cardiac rhythm and BP. Severe hypotension decreases cerebral perfusion pressure that might aggravate the stroke symptoms; therefore, it should be corrected. There are no current standard BP goals, but keeping the BP in a slightly higher range might be helpful in keeping perfusion intact through collaterals. On the other hand, severe hypertension may be associated with increased hemorrhage risk. If the patient is an IV tPA candidate, guidelines recommend keeping BP < 185/110 for at least 24 hours after therapy.[7] Presence of fever may hint toward infective etiology like infective endocarditis, in which case IV

Table 1.2 Stroke severity scales

Stroke severity scales	
A. National Institute of Health Stroke Scale (NIHSS)	
1. Level of consciousness (LOC questions, LOC commands)	The NIHSS is a 15-item neurologic examination stroke scale. Ratings for each item are scored with 3 to 5 grades with 0 as normal, and there is an allowance for untestable items. The single patient assessment requires < 10 min to complete A cutoff value of 7 was shown to be sensitive in predicting LVO
2. Best gaze	
3. Visual field	
4. Facial weakness	
5. Motor arm	
6. Motor leg	
7. Limb ataxia	
8. Sensory impairment	
9. Best language	
10. Dysarthria	
11. Extinction and inattention	
B. Cincinnati Stroke Triage Assessment Tool (CSTAT)	
1. Conjugate gaze deviation (No-0/Yes-2)	A score ≥ 2 corresponds to suspected LVO
2. LOC/following commands (0/1)	
3. Arm weakness (No-0/Yes-1)	
C. Field Assessment Stroke Triage for Emergency Destination (FAST-ED)	
1. Facial palsy (0/1)	A score ≥ 3 corresponds to suspected LVO
2. Arm weakness (0/2)	
3. Speech changes (0/2)	
4. Eye deviation (0/2)	
5. Denial/neglect (0/2)	
D. Los Angeles Motor Scale (LAMS)	
1. Facial droop (Absent-0, Present-1)	LAMS ≥ 4 corresponds to suspected LVO
2. Grip strength (Normal-0, Weak-1, No grip-2)	
3. Arm drift (Absent-0, Drifts down-1, Falls rapidly-2)	
E. Rapid Arterial Occlusion Evaluation (RACE) Scale	
1. Facial palsy (0/2)	A score ≥ 4 shows possible stroke, while a score ≥ 5 corresponds to suspected LVO
2. Arm motor function (0/2)	
3. Leg motor function (0/2)	
4. Head and gaze deviation (0/1)	
5. Aphasia (R side) (0/2)	
6. Agnosia (L side) (0/2)	
F. VAN assessment	
1. Visual field impairment	Positive if any of the following is associated with arm drift
2. Aphasia	
3. Neglect	

Abbreviation: LVO, large vessel occlusion.

Table 1.3 Stroke management time goals recommended by NINDS[a] and ACLS[b]

Time from hospital arrival to	Time goal
ED physician	10 min
Stroke team assessment	25 min
CT scan completion	25 min
CT scan interpretation	45 min
Fibrinolytic therapy	60 min
Admission to stroke unit or ICU	3 h

Abbreviations: CT, computed tomography; ED, emergency department; ICU, intensive care unit.
[a]National Institute of Neurological Disorders and Stroke.
[b]Advanced cardiac life support.

tPA treatment is contraindicated due to increased hemorrhagic transformation risk. Fever itself should be treated. Blood glucose status should be checked and corrected if necessary. Severe hypoglycemia or hyperglycemia is among absolute contraindications to IV tPA administration. Blood glucose level is the only laboratory value that must be available to clinician before administration of IV tPA. The patient must be kept NPO until stabilization due to possibility of emergent surgery and also to avoid the risk of aspiration. Naloxone can be given if history suggests narcotic intoxication. Electrocardiogram (ECG) must be obtained keeping in mind the probability of concomitant cardiac ischemia, which is also a clue for embolic strokes.

1.3.6 Clinical Examination

History

A crucial part of the history obtained from stroke patients is time of symptom onset. Clinicians should confirm this information with witnesses, bystanders, family, EMS personnel, etc. If the exact time of onset cannot be obtained, last witnessed baseline status time must be noted. EVT and thrombolysis treatments can be indicated or contraindicated based on this information. The later any treatment is administered, the worse the prognosis for the patient. While IV thrombolytic therapy has been restricted to 4.5 hours, and mechanical thrombectomy up to 6 hours from symptom onset, recent evidence from DAWN (DWI or CTP Assessment with Clinical Mismatch in the Triage of Wake-Up and Late Presenting Strokes Undergoing Neurointervention with Trevo) and DEFUSE 3 (Endovascular Therapy Following Imaging Evaluation for Ischemic Stroke 3) trials have demonstrated a benefit of mechanical thrombectomy up to 24 hours after onset of symptoms in carefully selected patients.[9,10] Clinicians should be aware of common differential diagnoses such as seizure, migraine, hypertensive encephalopathy, syncope, hypoglycemia, and conversion disorder. Careful observation while taking history can provide priceless information helpful in ruling out alternative diagnoses. How symptoms started and progressed should be clarified when possible. AIS presents with symptoms maximal at onset and may partially resolve over time. ICH symptoms, on the other hand, tend to gradually worsen as a hematoma expands. ICH is more likely to be associated with trauma than AIS. SAH is almost always associated with a severe headache. Presence of vomiting suggests increased ICP and favors ICH or SAH. While seizures can be a cause for traumatic ICH, they can also be associated with cerebral ischemia. Temporal relationship of limb-shaking movements, headaches, and neurological deficits can cause a different diagnosis. A patient with a conversion disorder who is positive for a neurological deficit on examination can spontaneously be observed to resolve that specific deficit. Lack of concern by a patent for a neurological deficit can suggest conversion disorder as well. Transient ischemic attack occurs when stroke symptoms are temporary and not accompanied by infarct on imaging. Patients who describe symptoms that are not present at the time of presentation should

Table 1.4 ABCD^2 score for predicting stroke risk after transient ischemic attack (TIA)

1. Age ≥ 60 y		1 point	0–3 points: low risk 2-d stroke risk: 1.0% 7-d stroke risk: 1.2% 90-d stroke risk: 3.1%
2. Initial BP ≥ 140/90		1 point	
3. Clinical feature of TIA	Unilateral weakness	2 points	
	Speech disturbance without weakness	1 point	
4. Duration of symptoms	10–59 min	1 point	
	≥ 60 min	2 points	
5. History of diabetes mellitus	1 point		

be managed as standard stroke patients as stroke risk following TIA episodes is high and these patients may be eligible for thrombolytic therapy. The ABCD^2 score is used to predict stroke risk following TIA (▶ Table 1.4). Handedness of a patient may be relevant in diagnostic workup. While a dominant-hemisphere middle cerebral artery (MCA) lesion causes contralateral hemiparesis with aphasia, the same lesion in the nondominant side causes hemiparesis with contralateral neglect. Clinicians must note the risk factors for stroke including prior stroke episodes, prior myocardial infraction, hypertension, diabetes mellitus, smoking, atrial fibrillation, and peripheral vascular disease. Complete medication lists must be obtained whenever possible. Special attention must be paid to antithrombotics, anticoagulants, insulin, and oral hypoglycemic medications. Anticoagulant medication use may preclude thrombolytic therapy and medication-induced hypoglycemia can mimic stroke symptoms. Stimulant medication use is a risk factor for ICH. History of illicit drug use, especially cocaine or herbal supplements, should be clarified.

General Examination

Clinicians must focus on signs that give clues regarding the etiology of stroke and therefore should complete a general physical examination in no more than 3 minutes. Obtaining and stabilizing vital signs is crucial. Although there are no recommended standard cutoff values, severe uncontrolled hypertension is an absolute contraindication to thrombolytic therapy. Vital signs might direct the clinical team to consider alternative diagnoses. Cardiac examination should be focused on conditions that predispose to embolism, which include atrial fibrillation, endocarditis, and congestive heart failure. An irregular pulse may point to atrial fibrillation, while cardiac murmurs can be a sign of endocarditis. Congestive heart failure patients who have increased tendency to develop emboli may be detected by peripheral edema. Pulmonary examination demonstrating pulmonary edema signifies left ventricular dysfunction. Skin examination can show a constellation of signs in favor of endocarditis such as Osler's nodes, Janeway's lesions, splinter hemorrhages, or rashes such as livedo reticularis that indicate autoimmune disease or hypercoagulable states. Lacerations, ecchymoses on the hip, knee, or elbow, or a bitten tongue can be markers of trauma or seizures. In cases of suspected increased ICP or herniation, an ophthalmoscopic examination may reveal papilledema.

Neurological Examination

AIS oftentimes presents with focal neurological deficits and initially preserved LOC as opposed to global depression in CNS function. Quick assessment of LOC helps give clues about possible differential diagnoses. A global neurological deficit and decreased LOC may suggest SAH, extensive intracranial hemorrhage (ICH), or LVO AIS. Alertness and orientation of the patient to time, place, and person and ability to perform simple tasks such as handgrip and eye closure must be assessed. Type of stimuli the patient is responsive to should be clearly assessed and documented.

Neurological examination in stroke patients need not be a comprehensive one. Focus should be on anatomically localizing the lesion and determining the need for endovascular therapy. LOC should be determined, and alertness level should be clearly described. If altered mental status is present, the specific response the patient gives to painful stimuli should be noted. LOC examination of NIHSS includes testing the patient's orientation and ability to perform simple tasks such as handgrip. Aphasia can be assessed during this first part of the examination. Asking the patients to name certain items or read sentences aloud helps differentiate receptive aphasia (impaired comprehension, fluent but incoherent speech), expressive aphasia (influent but coherent, relevant speech), or global aphasia (no speech, no signs of comprehension). These deficits can be localized to different areas of the brain. As opposed to aphasic patients, dysarthric patients have no problem understanding language and finding words while speaking, but have trouble with pronouncing words correctly because of facial and lingual involvement. Anosognosia is a patient's lack of awareness of his or her deficit. This can be assessed by asking the patient about the degree of his or her deficit. Whether the patient notices the examiner standing on the opposite side of the patient's dominant hand or not can reveal presence of neglect. Cranial nerve tests that should be performed while scoring the NIHSS scale include dysarthria, extraocular eye movements, gross visual field examination, facial sensation, strength, and symmetry testing. Motor function should be tested in the upper and lower extremities. Grading and documenting motor function according to Medical Research Council (MRC) grading is important as any change in grade of strength may signify improvement or worsening in the clinical status of the patient during follow-up. Use of serial NIHSS score is important in this regard. Sensation should be grossly tested. A positive neglect found in double simultaneous stimulation testing suggests a parietal lobe lesion. A detailed sensory examination and deep tendon reflex testing can be deferred until the patient is stable and gets appropriate treatments. Coordination should be tested in all four extremities to assess ataxia.

If the patient is comatose, brainstem reflexes such as corneal reflex, oculocephalic reflex, pupillary reaction to light, limb response to pain, and level of arousal, must be checked. A patient who is comatose with intact brainstem reflexes and brisk withdrawal to pain in all four extremities suggests

a cortical global insult other than stroke such as infection or hypoglycemia.

Unilateral enlarged, unreactive pupil and contralateral hemiplegia in a comatose patient may suggest an enlarging hematoma and imminent herniation. Emergent surgical decompressive craniectomy may be indicated in these patients. Abnormal eye movements and absent brainstem reflexes in a comatose patient suggest extensive and often irreversible brainstem damage. An important part of the examination to localize the lesion in a comatose patient is to note the posture of the patient. A lesion above the red nucleus of the midbrain would cause disinhibition of the rubrospinal tract, which forces the patient into decorticate posturing in which the upper extremities are flexed. A lesion below the red nucleus of the midbrain, which is frequently caused by pontine strokes, would lead to decerebrate posturing in which the patient involuntarily extends the upper extremities in response to stimuli.

Rapid Laboratory Tests

Following initial stabilization of the patient and focused clinical examination, the cause of the problem must be determined. The character and evolution of the neurological deficit can hint etiology. While AIS patients usually present with focal deficits that are attributable to certain localizations in the central nervous system (CNS), a global deficit that encompasses the whole cerebrum may suggest an etiology other than stroke.

As initial test procedures, all stroke patients must get the following:

- Noncontrast brain CT or brain MRI.
- Finger stick blood glucose.
- Oxygen saturation.

Additional tests that should be performed but are not urgent include ECG and troponin to detect arrhythmia that might be the cause of an emboli or show silent concomitant myocardial infarction, complete blood count (CBC) to check possible hemorrhagic anemia, thrombocytopenia and infectious processes, activated partial thromboplastin time (aPTT), international normalized ratio (INR), and clotting time to check for possible coagulopathies that can cause intracranial bleeding. In patients whose head CT shows extensive hypoattenuation, thrombolytic therapy is not recommended. IV tPA is contraindicated in patients with platelets less than 100,000/mm^3, INR over 1.7, aPTT longer than 40 seconds, or prothrombin time (PT) over 15 seconds.

Remaining potentially useful tests in patients with suspected stroke include liver function tests as liver disease is a cause of coagulopathy. Toxicology and drug screen should be done when intoxication is suspected. Alcoholism can be a cause of seizures, encephalopathy, and coagulopathy, and it is a risk factor for especially hemorrhagic strokes. Blood alcohol content should be checked when alcoholism is suspected. Beta-human chorionic gonadotropin (b-HCG) should be tested in childbearing age women. ABGs are useful in hypoxic patients. Lumbar puncture (LP) is useful where SAH is suspected but CT is nonconclusive. A chest X-ray may show cardiac abnormalities. Patients with suspicion of seizure should get a stat and continuous EEG.

Initial Imaging

The initial imaging modality is a noncontrast CT scan of the head, which is often immediately followed by a CTA with or without perfusion study depending upon the time of onset of symptoms. The noncontrast CT scan is to rule out any ICH or other mass lesion that can mimic an ischemic stroke where the IV thrombolysis therapy with tPA is contraindicated. Once the hemorrhage or mass lesion is ruled out, the next step is to look for ischemic changes in the suspected arterial territory. The ischemic changes are identified as areas of hypodensity corresponding to an arterial territory. In early cases, the changes can be subtle showing edema and/or loss of gray–white matter differentiation. On the other hand, old strokes can show as prominent hypodensities. It is critical to correlate the ischemic changes, if any, to the patient's symptomatology. This localization is extremely important to rule out other potential etiologies from stroke as the cause of symptoms. In strokes involving the MCA territory, the ASPECT score is then calculated based on the presence of hypodensities in 10 defined MCA territories, which helps in decision-making toward mechanical thrombectomy (discussed later). Noncontrast CT also at times hints toward the presence of LVO by showing a hyperdense signal in the M1 segment (hyperdense MCA sign). CTA is the next imaging modality done almost in all patients with suspected stroke to localize the site of occlusion and to rule out LVO. Recent guidelines suggest performing a CT perfusion or MR perfusion study especially in patients within the 6- to 24-hour window to identify any penumbra that can be salvaged with mechanical thrombectomy. The details of the role of these advanced imaging are discussed in Chapter 3, Medical Imaging for Acute Ischemic and Hemorrhagic Stroke.

1.3.7 Determination of Thrombolysis Eligibility

IV tPA is the standard of care in eligible patients with AIS. It should be administered as rapidly as possible even in patients who merit EVT. In acute management of stroke alert patients, early focus should be on contraindications to thrombolysis, most important of which is ICH. The primary motive in imaging patients with noncontrast CT is to rule out ICH or SAH and administer thrombolytic therapy as soon as possible. Past medical history of ICH at any point during lifetime, intracranial or intraspinal surgery, serious head trauma or stroke in previous 3 months, coagulopathy or use of anticoagulants are among contraindications to thrombolytic treatment. Antiplatelet drugs, even when used in combination, are not contraindications to IV tPA use. IV tPA should be administered within 3 hours of onset of symptoms. For patients who are younger than 80 years of age, without a history of diabetes mellitus and prior stroke, NHSS score ≤ 25, without imaging evidence of ischemic injury involving more than one-third of MCA territory, this time interval can be extended up to 4.5 hours. Patients who wake up with stroke or have an unknown time of onset of symptoms should not get IV tPA. Patients who are further out than 4.5 hours since onset should not get IV tPA as hemorrhagic transformation risk is much higher. IV tPA is also contraindicated in patients with gastrointestinal (GI) malignancy or intra-axial intracranial neoplasms. It should not be given to patients who have experienced GI bleeding in the past 21 days and in those whose clinical history suggests acute aortic arch dissection as the cause of stroke.

1.3.8 Assessment of the Presence of LVO and Eligibility for Mechanical Thrombectomy

The importance of recognizing LVO lesions that are treatable via endovascular therapy (EVT) demonstrate cortical signs as opposed to white matter tract signs. A recent study showed the best tool to predict LVO is the NIHSS.[11] Physical examination signs that point toward LVO include aphasia, gaze deviation with contralateral weakness, anosognosia (unawareness of deficit), hemispatial neglect, and visual field cut (Box 1.1). If in the 24-hour clinical window, clinical suspicion or stroke scales point toward eligibility for EVT treatment, mechanical thrombectomy should be performed as quickly as possible. The criteria for eligibility for EVT in different time windows are summarized in Box 1.2. Some patients can present with unilateral severe motor or sensory deficits in the absence of the above-mentioned signs that favor LVO. These patients are usually alert and complain of weakness, sensory loss, or both in the unilateral face, and the upper and lower extremities in differing degrees. Unilateral incoordination may accompany these symptoms (ataxic hemiparesis). This pattern of symptoms is usually associated with lacunar strokes or small hemorrhages in small penetrating arteries of the pons and internal capsule. These arteries are so small and it is not possible to see them via angiography. These patients may benefit from thrombolysis, but EVT is not indicated.

1.4 Intracranial Hemorrhage

ICH or hemorrhagic stroke differs in etiology and slightly in presentation compared to the AIS. ICH is a condition that can arise spontaneously or be associated with an inciting event such as trauma, illicit drug use, or following bleeding into ischemic stroke. There are two types of ICH, which have distinct presentations and differences in management: intraparenchymal hemorrhage (IPH) and SAH. Because these two types differ in acute management, ICH will be used interchangeably with IPH in this section. SAH will be discussed later separately in this chapter.

1.4.1 Presentation

Although differences exist in presentation and management, presentation of a patient with ICH may entail similar features to AIS; it may also be a consequence of AIS. Depending on the size and location of the hemorrhage, ICH may give focal or global signs of neurological deficit. One important point that distinguishes ICH from AIS is that the symptoms typically gradually increase over minutes or hours as hematoma expands, whereas AIS symptomatology is maximal at onset and may improve over time. Symptoms of increased ICP or herniation are more likely to arise in ICH as expanding hematoma leaves less space to brain parenchyma in restricted cranial vault as expansion occurs over time. Headache, nausea, vomiting, and lethargy/decreased LOC are expected. A severe headache ("worst headache of my life") is more likely associated with SAH than IPH. Meningismus symptoms such as nuchal rigidity and neck stiffness are more likely associated with SAH as subarachnoid blood tends to irritate meninx more so than intraparenchymal blood. Risk factors specifically associated with ICH as opposed to AIS include trauma, hypertension, bleeding/clotting disorders, anticoagulant/antithrombotic medication use, drug (specifically cocaine) and alcohol abuse, and smoking. ICH can be a result of

Box 1.1 Clinical signs of large artery occlusion

1. Aphasia
2. Gaze preference with contralateral weakness
3. Unawareness of deficit (anosognosia)
4. Hemispatial neglect
5. Visual field cut
6. Neglect on the affected side to double simultaneous visual or tactile stimulation

Box 1.2 Eligibility for endovascular therapy (EVT) according to time of presentation

EVT eligibility

For the first 6 h

Prestroke mRS score of 0 to 1

Location of occlusion of the internal carotid artery (ICA) or MCA segment 1 (M1)

Age ≥ 18 y

National Institute of Health Stroke Scale (NIHSS) score of ≥ 6

ASPECTS of ≥ 6

6–16 h (DEFUSE3 criteria)

18–90 y

NIHSSS ≥ 6

Pre-morbid mRS2 ≤ 2

ICA or M1 occlusion by MRA or CTA

Target mismatch profile on CT perfusion or MRI

6–24 h (DAWN criteria)

Age ≥ 18 y

Failed or contraindicated for IV tPA

NIHSS ≥ 10

Prestroke mRS 0–1

< 1/3 MCA territory by CT or MRI; ICA-T and/or MCA-M1 occlusion

Clinical imaging mismatch

A. ≥ 80 y/o, NIHSS ≥ 10 + core < 21 mL

B. < 80 y/o, NIHSS ≥ 10 + core < 31 mL

C. < 80 y/o, NIHSS ≥ 20 + core < 51 mL

Abbreviations: ASPECTS, Alberta Stroke Program Early CT Score; CTA, computed tomography angiography; DAWN, DWI or CTP Assessment with Clinical Mismatch in the Triage of Wake-Up and Late Presenting Strokes Undergoing Neurointervention with Trevo; DEFUSE 3, Endovascular Therapy Following Imaging Evaluation for Ischemic Stroke 3; IV, intravenous; MCA, middle cerebral artery; MRA, magnetic resonance angiography; MRI, magnetic resonance imaging; mRS, modified Rankin scale; tPA, tissue plasminogen activator.

bleeding from a vascular lesion like an aneurysm, arteriovenous malformation (AVM), or cavernous malformation. These structural etiologies will be discussed in the subsequent chapters.

1.4.2 Prehospital Setting

Because deterioration of neurological condition is much more common in ICH compared to AIS, rapid aggressive management is vital. Management in the prehospital setting is the same as explained in the AIS section. Stabilizing the patient with ABC interventions, securing airway, cervical collar, and cardiovascular perfusion are imperative. Time of onset of symptoms or last baseline witnessed status must be obtained by EMS as in AIS. Obtaining medication, drug use, and medical history are of increased importance in ICH as anticoagulants, antithrombotic medications, and clotting disorders are risk factors. The patient must be promptly transferred to a stroke center and hospital must be informed of a stroke alert patient en route so that certain stroke teams can be alerted and time to CT can be shortened. No clinical scale exists to differentiate hemorrhagic stroke from ischemic stroke before arrival to hospital. Some studies showed that prehospital in-ambulance CT scanning can be achieved and expedite start of an ICH-specific therapy.[12]

1.4.3 Hospital Setting

History

History taken from the patient who has a radiological diagnosis of ICH should encompass all of the risk factors associated with ICH. Time of onset of symptoms or the time the patient was last witnessed to be at his or her baseline health should be documented. How symptoms started and progressed should be carefully listened either from the patient or either a witness as rapidly worsening status is an indicator of worse prognosis. Medications of all kinds including herbal supplements must be noted as coagulopathy or thrombocytopenia may be influenced by a variety of medications. History of comorbidities, particularly hypertension and cardiac history that requires the use of medications that interfere with platelets, clotting, and BP, must be obtained. Recent trauma history and, if it exists, mechanism of trauma are of critical importance. Trauma caused by seizures may be the cause of ICH and ICH may be the cause of seizures. Recent surgeries, specifically carotid endarterectomy or stenting, are important as hyperperfusion may lead to ICH. Past medical history of strokes must be questioned, as patients may bleed to the infarcted brain parenchyma. Cocaine and sympathomimetic drugs are associated with ICH. Causes of coagulopathy, especially liver disease and cancer and family history of bleeding or clotting disorders, are important. ICH may be the presenting symptom of bleeding disorders especially in young patients and these patients may require additional treatment for reversal of their coagulopathy. Dementia is also a risk factor for bleeding as it may be associated with atrophied fragile brain tissue and amyloid angiopathy. In patients without apparent risk factors like hypertension, smoking, or old age, likelihood of a vascular malformation causing bleeding is increased.

Physical Examination

Physical examination of ICH patients is similar to what was discussed in the AIS section. Initial important part of the physical examination in ICH patients is assessment of vital signs. ICH patients tend to have extremely elevated BP on presentation, contributing to hematoma expansion and worsening neurological status. Tachycardia may be a sign of expanding hematoma or concurrent bleeding elsewhere in the body as patients with bleeding tendency are an important portion of ICH patient population. Bradycardia may be a part of Cushing's reflex and may indicate increasing ICP. Fever is common in ICH patients especially in hematomas with intraventricular component and may be associated with hematoma expansion.[13] General examination should include an examination of the head and extremities especially in the cases associated with trauma looking for scratches or bruises to better understand the mechanism of trauma. LOC should be assessed and specifically recorded as explained before, including the specific patient response to pain because decline is more likely in ICH and may indicate urgent intervention. Signs of brainstem compression and hydrocephalus should arise and coma is more common in patients with ICH than AIS. A focused neurological examination that ideally localizes symptoms to an anatomical location should be performed. Clinicians should be alert for signs and symptoms of increased ICP and herniation.

Imaging

Most important diagnostic tool in differentiating AIS from ICH is CT of the head. Noncontrast CT of the head is the gold standard imaging modality in any type of stroke suspicious patient as it provides a prompt way to rule in or rule out hemorrhage. T2-weighted MRI, on the other hand, although it takes more time than CT, is as sensitive as CT and can provide information about the presence of an old hemorrhagic lesion. Currently, no standardized tools exist to predict hematoma expansion. Yet, contrast-enhanced CT or CTA may be utilized to determine the risk of expansion in selected patients. Spot sign indicates the presence of contrast within a hematoma, and is typically predictive of impending expansion as it shows active bleeding from a vessel into the hematoma region. This corresponds to the swirl sign in noncontrast CT, which is a hypodense area showing active bleeding site, as fresh blood is seen as less dense compared to older hematoma around it. Rapid imaging enables physicians to emergently begin correct treatment course. Standardized frequency of CT utilization in ICH patients do not exist. Although some clinicians recommend routine twice-a-day CT in ICH patients till stability of ICH volume has been established, the usual tendency is to image head once every day and follow patients clinically and image if any deterioration is detected in examination. The location and pattern of hemorrhage should be carefully looked at, if possible along with neuroradiologist, to evaluate if there is a need for an angiogram to rule out vascular pathologies. Noninvasive angiographic like CTA or MRA imaging are superior to noncontrast CT in identifying vascular malformations, which may be the cause of bleeding.[14] If such lesions are suspected, a catheter angiogram should be considered. Although it is not the common practice, some authors recommend routine CTA with noncontrast head CT for stroke-alert patients.[15] Lobar hemorrhages especially in young individuals, ICH with SAH near the sylvian fissure or basal cisterns, anterior interhemispheric fissure hematomas are few examples where it is essential to obtain a vascular imaging like CTA or MRA to rule out aneurysms or AVMs. Any suspicion

regarding abnormalities of cerebral sinuses should prompt MR venography or CT venography to diagnose a possible cerebral venous thrombosis. Similarly, ICH with disproportionate edema and heterogeneous pattern may indicate other structural lesions like tumors as etiology of the hemorrhage. In these cases, it is helpful to obtain an MRI of the brain with and without contrast.

Laboratory Tests

CBC, electrolytes, blood urea nitrogen (BUN), creatinine, glucose, PT, INR, aPTT, cardiac-specific troponin, toxicology screen urinalysis, urine culture, and b-HCG tests are among tests that are potential in all patients with suspected ICH.

Initial Care in Intensive Care Unit

After imaging diagnosis of ICH is made, the next step is to admit the patient to the neuroscience ICU for strict BP management, monitoring of neurological status, monitoring of ICP as indicated, and reversal of coagulopathy/thrombocytopenia as needed. Those who use warfarin should get vitamin K–dependent factor replacement as soon as possible. Neurosurgery consultation should be routine for possible emergent expanding hematoma evacuation, ventricular drainage, or angiographic intervention. As ICH patients are more likely to present with decreased LOC, NIHSS scores are not routinely utilized as they are in AIS. The most commonly used scoring system is the ICH score (▶ Table 1.5).[16]

1.5 Subarachnoid Hemorrhage

SAH is a subtype of ICH that has unique features. It arises more abruptly than IPHs, usually associated with a sudden severe headache and meningeal irritation signs and can be caused by trauma (tSAH) or aneurysm (aSAH). As aneurysms can rebleed, SAH is a neurological emergency that should be evaluated and treated promptly.

1.5.1 Presentation

Most characteristic presenting symptom in SAH patients is suddenly arising severe "thunderclap" headaches. Eighty percent of patients describe this as the "worst headache of my life." The most common cause of spontaneous SAH is ruptured cerebral aneurysm. Other rare causes include rupture of AVM, dural arteriovenous fistula, rupture of bridging veins following minor trauma, etc. Misdiagnosis rates are high in SAH and it is a major cause of mortality and morbidity. Patients presenting with severe headaches should be approached with serious suspicion. Severe presenting headache of the patient may be preceded by "sentinel" warning headaches days in advance. These sentinel headaches represent minor hemorrhages or leaks before rupture of aneurysms. As presence of sentinel headaches dramatically increases rebleeding likelihood, clinicians should recognize it in the history for prompt evaluation and management.[17] Meningeal irritation signs typically appear in a delayed manner after the appearance of headache. Nausea, vomiting, decreased LOC, neck stiffness, and photophobia may accompany. Although the presence of focal neurological deficits is not common after SAH, they might occur including cranial nerve deficits. The presence of neurological deficits suggests onset of vasospasm or mass effect from hematoma. A generalized decreased sensorium and obtundation may indicate multiple possibilities including a global vasospasm, raised ICP due to hydrocephalus, or an expanding hematoma with herniation. A portion of SAH patients also present with seizures or have a seizure in hospital setting.

History

SAH has two main etiologies: Trauma and ruptured aneurysms. History taken from the patient should differ from other stroke patients in these aspects. Clinicians must focus on familial history of aneurysms and brain bleeds, and systemic syndromes that cause aneurysms such as polycystic kidney disease and Ehlers–Danlos syndrome. Trauma history and history of progression of symptoms must be carefully taken to differentiate from other causes of headache and neurological deficits. Risk factors for SAH that must be questioned include history of hypertension, smoking and alcohol abuse, and use of sympathomimetic drugs such as cocaine. Female sex is an additional risk factor for SAH. Presence of an unruptured aneurysm diagnosis and history of previous SAH or similar symptoms should be inquired.

Physical Examination

Apart from the general distinction between focal and global deficits and neurological examination discussed earlier, in patients with SAH, elements of physical examination that differ from other types of strokes are nuchal rigidity, photophobia, and

Table 1.5 Intracerebral hemorrhage (ICH) score

1. Glasgow Coma Scale (GCS) score	3–4	2	Total ICH score: 0–6 *Mortality:* Score 0 = 0% Score 1 = 13% Score 2 = 26% Score 3 = 72% Score 4 = 94% Score 5 = 100% Score 6 = 100%
	5–12	1	
	13–15	0	
2. ICH volume (ABC/2 method)	≥ 30 cm^3	1	
	< 30 cm^3	0	
3. IVH	Yes	1	
	No	0	
4. Infratentorial origin of ICH	Yes	1	
	No	0	
5. Age	≥ 80 y	1	
	< 80 y	0	

Box 1.3 Subarachnoid hemorrhage grading scales

Hunt and Hess grading

Grade 1: asymptomatic or mild headache

Grade 2: cranial nerve palsy or moderate to severe headache/nuchal rigidity

Grade 3: mild focal deficit, lethargy, or confusion

Grade 4: stupor and/or hemiparesis

Grade 5: deep coma, decerebrate posturing, and moribund appearance

World Federation of Neurological Societies (WFNS) grading

Grade 1: Glasgow Coma Scale (GCS) 15, no motor deficit

Grade 2: GCS 13–14 without deficit

Grade 3: GCS 13–14 with focal neurological deficit

Grade 4: GCS 7–12, with or without deficit

Grade 5: GCS < 7, with or without deficit

Modified Fischer grading

Grade 0: no subarachnoid hemorrhage (SAH), no intraventricular hemorrhage (IVH)

Grade 1: focal or diffuse SAH, thin < 1 mm, no IVH

Grade 2: focal or diffuse SAH, thin < 1 mm, with IVH

Grade 3: focal or diffuse SAH, thick > 1 mm, no IVH

Grade 4: focal or diffuse SAH, thick > 1 mm, with IVH

meningeal irritation signs. Vital signs should be obtained. Especially BP is critical in the management of SAH. Signs of cocaine or sympathomimetic use such as tachycardia and hypertension are important to observe. Signs of alcohol withdrawal such as tremor and sympathetic activation can also be appreciated. Several scales are available for use to determine the severity of SAH like Hunt and Hess scale and World Federation of Neurological Societies grading system (Box 1.3). These scales are the main predictor of prognosis in SAH patients.

Initial Workup

Initial workup of SAH includes the standard approach to stroke-alert patients, ABCs, stabilization, and noncontrast head CT. Although noncontrast CT is the main tool in diagnosis, it is not foolproof. The sooner CT can be utilized, the more accurate it becomes. If clinical suspicion is high for SAH and CT is nonconclusive, LP should be performed. LP shows xanthochromia, which is blood-tinged yellowish cerebrospinal fluid (CSF) as opposed to normal clear CSF. Traumatic LP contaminated with blood must be distinguished where CSF analysis will show increased number of red blood cells (RBCs). In patients in whom LP is contraindicated or wished to be avoided, MRI is helpful in aiding diagnosis. CTA to detect aneurysms can be used, but it is not reliable in revealing aneurysms that are smaller than 3 mm.[18] If CTA is negative and suspicion is high, digital subtraction angiography (DSA) must be performed. If initial angiography is negative, repeat delayed DSA is indicated as it can detect missed aneurysms. DSA with three-dimensional rotational angiography is used in treatment planning of aneurysms.

Management

Patients who are found to have aneurysms should be treated as soon as possible as longer time to aneurysm treatment is associated with higher rates of rebleeding. Rebleeding risk is higher in the first hours of presentation and is associated with worse outcome as opposed to late rebleeding. Other risk factors for rebleeding are hypertension (systolic blood pressure [SBP] > 160 mm Hg), worse neurological assessment scores and loss of consciousness on admission, larger size of aneurysm, and sentinel headaches. BP control medications should be administered in all patients presenting with SAH as soon as possible. BP should be kept under control up to aneurysm treatment while maintaining cerebral perfusion pressure. There are no certain BP levels established in guidelines. Although not approved by the FDA, antifibrinolytic medications are frequently used to decrease the risk of rebleeding where the aneurysm treatment is delayed.

Cerebral vasospasm (CVS) is an angiographically visible constriction of cerebral arteries that occurs after SAH. CVS occurs most commonly 7 to 10 days after SAH and resolves around 21 days. Current medical knowledge offers no therapy that is efficacious enough to prevent CVS. Delayed cerebral ischemia (DCI) associated with CVS can give neurological symptoms and may be extensive to the degree that patients develop cerebral infarcts. Consequently, nimodipine is a standard therapy given to all SAH patients. CVS is monitored via serial transcranial Doppler imaging although new data show effectiveness and possible superiority of perfusion MRI. Current guidelines recommend induced hypertension and maintaining euvolemic status rather than conventional triple-H therapy (hypervolemia, hypertension, and hemodilution). When these measures are not effective and DCI develops, balloon angioplasty for vessels that are accessible and intra-arterial vasodilator infusion for vessels that are not are recommended.

1.6 Conclusions

Acute stroke is a medical emergency, and for the purpose of directing effective treatment, triage is necessary. Any acute stroke should be differentiated to ischemic stroke or hemorrhagic stroke as soon as possible, as there is a significant difference in management. The single most important step in differentiating these two categories is getting the non-contrast-enhanced CT scan of the head as soon as possible. The requirement of an emergent intervention is significantly more in ischemic strokes to prevent irreversible brain damage; therefore, recognition and timely selection of appropriate patients for intervention is critical. For hemorrhagic strokes, although prompt treatment is necessary, initial stabilization and identification of etiology is essential before definitive therapy.

1.7 Clinical Case Answers

1. (b) The clinical presentation in this patient is suspicious of acute stroke. After initial stabilization, the most important

step is to get a noncontrast CT scan of the head to differentiate between an ischemic and hemorrhagic stroke. ABG in this patient is not necessary at this moment as the patient and vitals are stable.

2. (c) Anticoagulation therapy is an absolute contraindication to alteplase therapy.
3. (b) The CT shows normal parenchyma without any hemorrhage or hypodensity. Based on the history and clinical findings, there is a suspicion of LVO that may require mechanical thrombectomy. Therefore, urgent CTA is indicated.
4. (b) The CT scan shows a right caudate hemorrhage and the most common cause in this location is likely hypertension. Although he might need CTA to rule out vascular pathology, the suspicion is low. The patient needs urgent admission to the ICU for BP control and monitoring of the neurological status. An interval CT in 4 hours is necessary to monitor hematoma progression.
5. (a) The CT scan shows a hypodense heterogenous lesion in the left parietal region with mild surrounding edema, which raises the suspicion of a structural lesion. Because of his presentation with acute stroke–like symptoms, a CTA of the head is necessary to rule out LVO. In the absence of any LVO, the most important imaging in this patient is an MRI of the brain to characterize the structural lesion.

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