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Acute stroke in adult inpatients: An Updated Review for Radiologists, Pharmacists, and Nursing

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Abstract

Background: Acute stroke is a leading global cause of death and long-term disability, representing a critical medical emergency where "time is brain." It is primarily classified into ischemic stroke, caused by arterial occlusion, and hemorrhagic stroke, which includes intracerebral hemorrhage (ICH) and subarachnoid hemorrhage (SAH). Each subtype has distinct pathophysiological mechanisms, risk factors, and management requirements, placing a premium on rapid diagnosis and intervention.

Aim: This updated review aims to synthesize current knowledge on acute stroke for a multidisciplinary audience of radiologists, pharmacists, and nursing staff, emphasizing their collaborative roles in the timely evaluation, treatment, and management of adult inpatients.

Methods: The article is a comprehensive narrative review of stroke etiology, epidemiology, pathophysiology, clinical presentation, diagnostic evaluation, and evidence-based management strategies, referencing established guidelines from bodies like the American Heart Association/American Stroke Association.

Results: Key findings highlight the effectiveness of rapid neuroimaging (CT, CTA, MRI) for diagnosis and treatment selection. For ischemic stroke, intravenous thrombolysis and endovascular thrombectomy are cornerstone reperfusion therapies. Management of ICH focuses on blood pressure control and reversal of coagulopathy, while SAH care centers on securing aneurysms and preventing complications like vasospasm. The review underscores that structured, protocol-driven care involving an interprofessional team significantly improves patient outcomes.

Conclusion: Optimal acute stroke care is multidisciplinary and time-sensitive. Collaboration between radiologists, pharmacists, and nursing specialists across the care continuum—from emergency intervention to rehabilitation and secondary prevention—is essential to reduce mortality, minimize disability, and improve long-term functional recovery.

Keywords: Acute Stroke, Ischemic Stroke, Intracerebral Hemorrhage, Subarachnoid Hemorrhage, Thrombolysis, Thrombectomy, Neuroimaging, Multidisciplinary Team, Inpatient Care.

Introduction

Acute stroke, often labeled in clinical language as a cerebrovascular accident, does not represent a random or accidental occurrence. The process reflects a predictable consequence of underlying vascular and systemic risk factors. Many experts now prefer the term brain attack because it parallels the concept of heart attack and highlights the urgent nature of the event and the need for rapid intervention. Stroke, however, includes a wider spectrum of pathophysiological patterns than coronary disease and manifests through heterogeneous mechanisms and clinical presentations. From a broad etiological perspective, clinicians classify stroke into two principal groups, ischemic and hemorrhagic. Hemorrhagic stroke includes intracerebral hemorrhage and subarachnoid hemorrhage, most often described as nontraumatic spontaneous intracerebral hemorrhage and nontraumatic spontaneous aneurysmal subarachnoid hemorrhage [1]. Ischemic stroke develops when an arterial occlusion restricts cerebral blood flow and deprives brain tissue of

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oxygen and glucose. This process triggers a cascade of metabolic failure, ionic imbalance, and cell death within the ischemic core and penumbra. In contrast, hemorrhagic stroke results from rupture of a cerebral vessel and the subsequent extravasation of blood into the brain parenchyma or subarachnoid space. This event causes direct tissue injury, mass effect, and secondary ischemia. These distinctions are fundamental for diagnosis, acute imaging strategies, and therapeutic decision making, including eligibility for thrombolysis, endovascular therapy, or neurosurgical intervention.

The American Heart Association and the American Stroke Association provide an operational definition that supports clinical practice and research [1]. In its most concise form, stroke represents an acute episode of focal neurological dysfunction that lasts for more than 24 hours and arises from a vascular cause. This definition helps differentiate stroke from transient ischemic attack and from nonvascular neurological disorders. Stroke currently ranks as the second most common cause of death worldwide and remains a leading cause of long term disability in adults [2][3][4]. The condition generates a substantial economic burden that extends across the prehospital phase, emergency and inpatient care, rehabilitation, and community based follow up [5][6][7]. Direct medical expenditures, indirect productivity loss, and informal caregiving demands collectively amplify its societal impact. The concept that time is brain summarizes the critical relationship between treatment delay and irreversible neuronal loss. Every minute without reperfusion or appropriate management reduces the probability of full neurological recovery in patients with acute stroke. This understanding underpins modern systems of stroke care that prioritize rapid recognition, prehospital triage, early neuroimaging, and protocol driven acute interventions. Timely use of reperfusion therapies structured multidisciplinary rehabilitation, and sustained lifestyle and risk factor modification can improve functional outcomes, reduce recurrence, and lessen the global burden of stroke [8].

Etiology

Ischemic stroke represents a broad and heterogeneous group of disorders with more than one hundred distinct underlying pathological processes identified in the literature [9]. To facilitate clinical classification and research, the Trial of Org 10172 in Acute Stroke Treatment system defines three principal etiological categories. These are large vessel disease, small vessel or lacunar disease, and cardioembolic stroke [10]. Each group reflects different mechanisms of vascular injury, different anatomic targets, and different implications for prevention and long term management. Understanding these mechanisms is central for accurate diagnosis, tailored investigation, and the development of individualized secondary prevention strategies. Large vessel disease includes atherosclerotic stenosis or occlusion, arterial dissection, and artery to artery embolism [11][12]. In this context, thrombotic or embolic obstruction of major extracranial or intracranial arteries leads to focal reductions in cerebral blood flow that correspond to specific vascular territories. The resulting clinical syndromes often match the anatomical distribution of the affected vessel. Large intracranial arteries include the circle of Willis and its proximal branches, while extracranial large vessels include the common carotid, internal carotid, and vertebral arteries [11][12]. Atherosclerotic plaques may gradually narrow the lumen or rupture and generate emboli that occlude distal branches. Arterial dissections produce intramural hematoma and luminal compromise. Artery to artery embolism transmits thrombotic material from one diseased large artery into downstream cerebral branches. These mechanisms often coexist in patients with diffuse vascular disease and shared systemic risk factors.

Small vessel disease is the predominant substrate for lacunar strokes, which characteristically involve the deep perforating arteries that supply subcortical structures [13][14]. Two main pathological processes are usually described. Lipohyalinosis causes concentric hyaline thickening of small penetrating vessels and progressive luminal narrowing, eventually resulting in occlusion. This process is strongly associated with chronic hypertension and other vascular risk factors. In addition, atherosclerotic plaques in larger parent arteries can extend to involve the ostia of small perforating branches and block flow at the vessel origin. Microatheromas, which are small focal atherosclerotic lesions, can also obstruct these penetrating arteries [13][14]. The outcome is a small, deep infarct that produces classic lacunar syndromes. Despite their size, these lesions may cause substantial long term disability when they affect critical motor or sensory pathways. Cardioembolism constitutes another major cause of ischemic stroke and arises when thrombi or other embolic material form in the heart and migrate to the cerebral circulation [10][11][12]. A range of cardiac conditions increases this risk. Atrial fibrillation and other atrial arrhythmias promote blood stasis and thrombus formation in the atria. Valvular heart disease alters normal flow patterns and can cause local thrombus development or endothelial damage. Bioprosthetic and mechanical heart valves, particularly in the absence of adequate anticoagulation, are also established sources of emboli. Various cardiomyopathies can create regions of low flow or akinetic myocardium where mural thrombi can develop [10][11][12]. The clinical consequence is often a sudden and severe stroke, frequently cortical, with a high risk of early recurrence if the underlying cardiac condition is not addressed.

Across these mechanistic categories, ischemic stroke shares a set of common risk factors that modify vascular biology and accelerate

atherothrombotic processes. Advanced age, hypertension, diabetes mellitus, hyperlipidemia, cigarette smoking, cardiac disease, and arrhythmias are consistently associated with higher incidence and poorer outcomes [11][12][14]. These factors contribute to endothelial dysfunction, arterial stiffness, and prothrombotic states. Comprehensive management of these risks through blood pressure control, glycemic optimization, lipid lowering therapy, smoking cessation, and effective cardiac rhythm management is central to primary and secondary prevention. Intracerebral hemorrhage represents the second most frequent subtype of stroke and is characterized by bleeding into the brain parenchyma [15]. In most cases, ICH results from rupture of small penetrating arteries that have been structurally weakened by chronic vascular pathology. Hypertensive vasculopathy and cerebral amyloid angiopathy are the most prominent causes, alongside coagulopathies and other less common vasculopathies [15]. Hypertensive vasculopathy is typically linked to non lobar ICH that affects deep brain structures such as the basal ganglia, thalamus, brainstem, and cerebellum. Chronic exposure to elevated blood pressure leads to lipohyalinosis, fibrinoid necrosis, and formation of microaneurysms in small arteries. These changes increase the likelihood of spontaneous rupture. In contrast, cerebral amyloid angiopathy involves deposition of amyloid beta protein in the walls of cortical and leptomeningeal vessels. This process weakens vessel integrity and predisposes to lobar hemorrhages, often recurrent, in older adults [15].

A range of modifiable and nonmodifiable risk factors further influence the probability of ICH [16][17]. Advancing age and hypertension remain the most powerful predictors. Additional contributors include smoking, high alcohol intake, and use of sympathomimetic drugs that acutely raise blood pressure and vascular stress [16][17]. Therapeutic anticoagulants, including vitamin K antagonists and direct oral anticoagulants, increase bleeding risk, especially in the presence of uncontrolled hypertension, renal impairment, or drug interactions. Antiplatelet agents also contribute, particularly when combined with other risk factors [16][17]. Recognition and careful management of these exposures are vital in patients at risk and in those with a history of prior ICH. Subarachnoid hemorrhage constitutes a smaller proportion of overall strokes yet carries high morbidity and mortality [18]. Spontaneous SAH accounts for approximately five percent of all strokes, and in about eighty five percent of these cases the cause is rupture of an intracranial aneurysm [18]. Aneurysms most commonly arise at arterial bifurcations within the circle of Willis and its major branches. Hemodynamic stress and underlying vessel wall abnormalities contribute to aneurysm formation and growth. When rupture occurs, blood enters the subarachnoid space and can lead to sudden severe headache, rapid neurological deterioration, and life threatening complications such as vasospasm and hydrocephalus. Not all spontaneous SAH is aneurysmal. Other causes include drug use, especially amphetamines and cocaine, which acutely elevate blood pressure and induce vascular injury, coagulopathy that impairs normal hemostasis, ruptured arteriovenous malformations, and vessel rupture secondary to dural venous sinus thrombosis [18][19][20][21]. The risk profile for SAH overlaps partly with that of other stroke types but also has specific features. Smoking and hypertension are major modifiable risks. Excessive alcohol consumption further increases susceptibility. Age related changes in vessel integrity raise risk with advancing age. A personal history of another intracranial aneurysm or prior SAH and a family history of intracranial aneurysm also confer higher probability of aneurysm presence and rupture [18][19][20][21]. These observations support targeted screening and aggressive risk factor management in selected high risk groups.

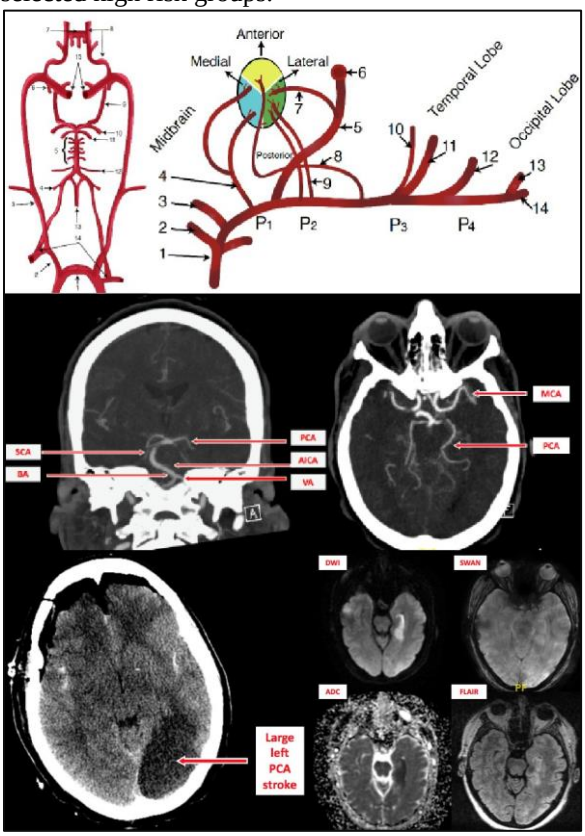

Fig. 1: Stroke, Posterior Cerebral Artery.

Epidemiology

Stroke remains one of the most significant global health challenges, ranking as the second leading cause of death and a major source of long term disability in many populations. Patterns of stroke incidence demonstrate clear differences across subtypes. Ischemic stroke represents the majority of cases and accounts for roughly sixty two percent of all strokes, while intracerebral hemorrhage contributes twenty eight percent and subarachnoid hemorrhage accounts for about ten percent [2][3][4]. Although

ischemic stroke occurs more frequently, hemorrhagic forms are associated with greater mortality and result in a higher number of disabilities adjusted life years lost, reflecting their more severe clinical course [3]. Global epidemiological trends show measurable progress in reducing the burden of stroke. From 1990 to 2019, intracerebral and subarachnoid hemorrhage demonstrated larger annual reductions in age standardized incidence, prevalence, mortality, and disability adjusted life years compared with ischemic stroke [22]. These improvements may reflect better hypertension control, broader access to acute care services, and increased public awareness of stroke symptoms in many regions. However, the benefits have not been uniform, and significant disparities persist across income levels and geographic areas. Current estimates indicate that both men and women face an approximate lifetime stroke risk of twenty five percent beginning at age twenty five [23]. This substantial figure underscores the cumulative effect of vascular risk over the lifespan and highlights the importance of early prevention strategies. Certain regions show particularly high risk profiles, including East Asia and Central and Eastern Europe, where demographic factors, lifestyle patterns, and differences in health care access contribute to elevated stroke rates [23]. These observations reinforce the need for targeted prevention and population based interventions to mitigate the global burden of stroke [23].

Pathophysiology

Ischemic Stroke

Ischemic stroke develops when a defined region of brain tissue is exposed to critically reduced blood flow. The process starts with a sudden decline in perfusion that deprives neurons and glial cells of oxygen and glucose. Within minutes, a central core of severely hypoperfused tissue undergoes irreversible injury and evolves into the infarcted area. Surrounding this core lies the ischemic penumbra. In this zone, blood flow is reduced but not completely interrupted. Cellular function is impaired, yet structural integrity initially remains. This penumbral tissue is potentially salvageable if blood flow is restored rapidly through effective reperfusion therapies [24]. The energy crisis that follows reduced perfusion is a central feature of ischemic pathophysiology. In the ischemic territory, the mismatch between ATP production and ATP consumption leads to progressive depletion of high energy reserves. Failure of ATP dependent ion pumps disrupts normal transmembrane gradients. Sodium and calcium accumulate intracellularly. Potassium diffuses out of cells. These ionic shifts trigger membrane depolarization and electrical instability, which promote further injury. The ischemic cascade also enhances the generation of reactive oxygen species and nitric oxide [25]. Excessive ROS and NO interact with lipids, proteins, and nucleic acids. This causes oxidative damage, mitochondrial dysfunction, and activation of cell death pathways. Over time, these processes compromise cell membranes, induce cell lysis, and drive both necrotic and apoptotic cell death [25].

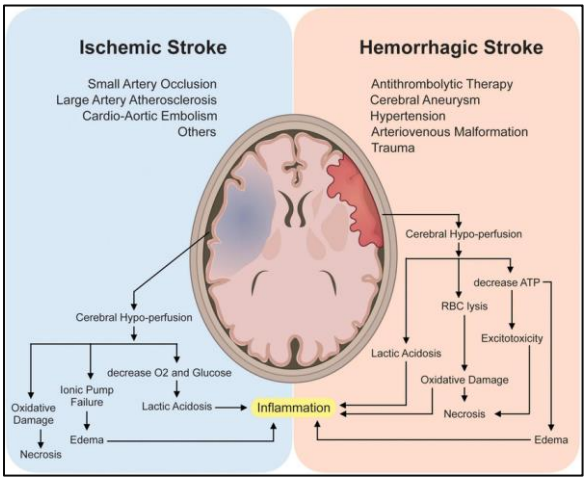

Fig. 2: Pathogenesis of stroke.

Neuroinflammation is another important component of ischemic stroke pathophysiology. Microglia, the resident immune cells of the central nervous system, become rapidly activated within the ischemic core and penumbra. Their activation starts early after vessel occlusion, reaches a peak between 48 and 72 hours, and may persist for several weeks [26][27]. Activated microglia secrete a wide range of mediators. On one hand, they release proinflammatory factors such as ROS, NO, interleukin-1β, and tumor necrosis factor-α. These mediators amplify local inflammation, increase neuronal vulnerability, and damage the blood brain barrier. On the other hand, microglia also produce anti-inflammatory cytokines and neurotrophic molecules, including brain-derived neurotrophic factor, glial cell-line-derived neurotrophic factor, and basic fibroblast growth factor [28][27][29][30][31]. These factors can support neuronal survival, promote tissue repair, and facilitate plasticity. The net effect depends on the timing, magnitude, and balance of these opposing responses. The overall ischemic cascade is complex and dynamic. It involves bioenergetic failure, ionic and neurotransmitter imbalance, oxidative stress, excitotoxicity, inflammation, endothelial dysfunction, and microvascular collapse. Together, these mechanisms lead to the progressive loss of neurons, glia, and vascular elements within the affected territory. The extent of damage is determined by duration and severity of ischemia, collateral circulation, and the speed and success of reperfusion interventions.

Intracerebral Hemorrhage (ICH)

In intracerebral hemorrhage, the primary injury starts at the moment of vessel rupture. Small arteries damaged by hypertensive vasculopathy, cerebral amyloid angiopathy, coagulopathies, or other vasculopathies break and release blood directly into the brain parenchyma [32][16][17]. The extravasated

blood accumulates and forms a hematoma. Expansion of the hematoma produces a mass effect that compresses surrounding tissue. Perihematomal edema develops in parallel. The combination of hematoma volume and edema raises intracranial pressure. This can reduce cerebral perfusion pressure and precipitate secondary ischemic injury in adjacent and remote regions. As intracranial pressure rises further, patients become vulnerable to intraventricular hemorrhage, obstructive hydrocephalus, and herniation syndromes [32][16][17]. Secondary injury mechanisms in ICH share several features with ischemic stroke. Blood and its breakdown products exert direct cytotoxic effects on neurons and glia. Hemoglobin, iron, and other components promote oxidative stress and excitotoxicity. Inflammatory pathways activate and disrupt the blood brain barrier. This disruption permits additional plasma proteins and inflammatory cells to enter the brain, which increases edema and tissue damage [32][33]. The result is extensive brain cell death in the perihematomal region and the development of potentially life threatening brain swelling.

Subarachnoid Hemorrhage (SAH)

Subarachnoid hemorrhage most often arises from rupture of an intracranial aneurysm located on a major cerebral artery. Yet aneurysms can injure the brain even in the absence of rupture. Progressive enlargement can compress neighboring parenchyma, cranial nerves, or vascular structures, leading to local dysfunction and compromised distal blood supply. When rupture occurs, arterial blood is suddenly released into the subarachnoid space. This blood rapidly mixes with cerebrospinal fluid and disseminates over the surface of the brain and spinal cord. The acute influx of blood increases intracranial pressure, sometimes to levels that transiently equal or exceed mean arterial pressure. This can produce a brief global cerebral ischemia. Blood may also track into the ventricular system and, in some cases, into the brain parenchyma, creating a mixed pattern of SAH and ICH. Secondary brain injury after SAH develops through multiple pathways. Elevated intracranial pressure, intraventricular hemorrhage, and acute hydrocephalus can impair cerebral perfusion and cause further ischemic damage. Blood products in the subarachnoid space trigger inflammation and contribute to delayed cerebral ischemia, which may occur days after the initial bleed [34]. Additional complications include subdural hematoma and recurrent bleeding. Together, these processes can result in widespread neuronal loss, diffuse brain swelling, and long term neurological impairment.

History and Physical

The evaluation of a patient with sudden onset focal neurological deficit begins with a rapid and structured history and physical examination. These initial steps are pivotal in distinguishing true acute stroke from a range of stroke mimics and in guiding early classification of the event as ischemic or hemorrhagic, together with its specific subtype. Careful clinical assessment helps avoid misdiagnosis in conditions that may closely resemble stroke such as hypoglycemia, seizures, and migraine which represent among the most frequent ischemic stroke mimics in emergency practice [35]. Prompt recognition of the underlying mechanism supports timely selection of appropriate imaging, acute therapy, and secondary prevention strategies.

Ischemic Stroke

For suspected ischemic stroke, a precise temporal history carries critical importance. The clinician should determine the exact time the patient was last known to be at their baseline neurological status and clarify whether symptom onset was sudden or progressive. This information defines eligibility windows for reperfusion therapies and supports decision making regarding intravenous thrombolysis and endovascular treatment. The history should also explore established vascular and cardiac risk factors, previous cerebrovascular events, current and recent medications including anticoagulants and antiplatelets, and any intercurrent illnesses that may predispose to thromboembolism or systemic hypotension. In parallel with a full set of vital signs, a focused neurological examination should be performed using a standardized and validated instrument. The National Institutes of Health Stroke Scale is widely used for this purpose and provides a reproducible quantitative measure of stroke severity that informs acute management, prognosis, and research classification [12].

Intracerebral Hemorrhage

In intracerebral hemorrhage, clinical presentation is influenced by the site and size of bleeding and by the speed with which the hematoma expands. ICH most often arises during ordinary daily activity although it may also occur during exertional episodes including sexual activity or other physical effort [16][36]. Neurological symptoms typically evolve over minutes to several hours rather than seconds. Many patients experience a progressive decline due to ongoing hematoma enlargement and the development of mass effect and raised intracranial pressure. During hospitalization further neurological deterioration is common as hematoma expansion, perihematomal edema, and secondary complications evolve. The symptom profile of ICH is variable but frequently includes headache, nausea, and vomiting. These manifestations reflect acute increases in intracranial pressure and irritation of pain sensitive structures [16][36]. Focal neurological deficits correspond to the anatomical location of the hemorrhage. Involvement of deep structures such as the basal ganglia or thalamus may produce contralateral motor and sensory deficits whereas cerebellar hemorrhage can present with ataxia and vertigo. Seizures represent another important clinical feature. They occur most often at the time of bleeding onset or within the first 24 hours and the reported

incidence of acute seizures during the first 24 to 72 hours ranges between 4% and 42% [37][38]. Despite these characteristic patterns no purely clinical decision rule can reliably differentiate ICH from other causes of acute neurological dysfunction with sufficient sensitivity or specificity. Neuroimaging remains indispensable for definitive diagnosis and subtype classification [39].

Subarachnoid Hemorrhage

Aneurysmal subarachnoid hemorrhage shares certain contextual features with ICH while presenting with distinctive clinical hallmarks. It usually occurs during routine activities including rest or sleep although it may also be precipitated by physical exertion [40][41]. The classic presentation is an abrupt severe headache that reaches maximal intensity within a very short period. Many patients describe this as the worst headache of their life. This headache often appears with associated symptoms such as neck pain or stiffness, photophobia, vomiting, altered level of consciousness, or transient loss of consciousness. A subset of individuals report a preceding sentinel headache day or weeks before the major event which may reflect a minor leak or structural change in the aneurysm wall [34]. Seizures may arise at the time of rupture during subsequent hospitalization or as a later complication of aneurysmal subarachnoid hemorrhage [34]. The neurological examination in SAH can reveal both generalized and focal findings. Meningeal irritation may be evident through neck stiffness and photophobia while focal deficits depend on the location of the aneurysm and the extent of associated brain injury. Potential focal signs include unilateral visual loss, visuospatial neglect, ophthalmoplegia, and intraocular hemorrhages involving the retina, subhyaloid space, or vitreous body. Cranial nerve involvement may manifest as third or sixth nerve palsy and parenchymal or ischemic injury may lead to hemiparesis, aphasia, or abulia [42]. These findings assist in localizing the lesion and anticipating complications such as vasospasm or hydrocephalus. The overall assessment of patients with SAH and ICH requires not only description of focal deficits but also grading of global neurological status. Standardized scales have been developed to categorize severity and predict outcome. In the context of aneurysmal SAH the Hunt Hess scale and the World Federation of Neurological Surgeons scale are widely applied to classify patients based on clinical presentation and level of consciousness [34]. These grading systems help guide treatment decisions, facilitate communication among clinicians, and provide a framework for prognostic counseling and research comparisons.

Evaluation

Neuroimaging represents a central element in the diagnostic and therapeutic pathway for patients with suspected stroke. Computed tomography and magnetic resonance imaging are the principal modalities used in the acute setting and form the basis for differentiating ischemic from hemorrhagic events and for guiding early management decisions [43]. The 2019 American Heart Association and American Stroke Association guidelines for the management of acute ischemic stroke emphasize that every patient with suspected acute stroke should undergo emergent brain imaging immediately upon arrival to the hospital and before the initiation of any specific therapy directed at acute ischemic stroke [44]. For this purpose, noncontrast computed tomography and magnetic resonance imaging are both considered suitable options to exclude intracerebral hemorrhage prior to the administration of intravenous alteplase [44]. In the subgroup of patients with acute ischemic stroke who present within six hours from the onset of symptoms and who demonstrate a small infarct core on noncontrast computed tomography, advanced vascular imaging is strongly recommended. In such cases, computed tomography angiography or magnetic resonance angiography should be performed to identify large vessel occlusion and to support selection of candidates for mechanical thrombectomy [45][46]. These techniques allow visualization of the intracranial and extracranial arterial circulation, enabling rapid identification of proximal occlusions amenable to endovascular therapy. For patients arriving later, within a six to twenty four hour window after symptom onset, and who have evidence of a large vessel occlusion in the anterior circulation, more detailed tissue based imaging is preferred. Diffusion weighted magnetic resonance imaging with or without perfusion studies or computed tomography perfusion can be used to characterize the size of the irreversibly damaged core and the extent of salvageable penumbral tissue [45][46]. This perfusion mismatch framework has been incorporated into patient selection criteria in key clinical trials and is now embedded in guideline recommendations for extended window thrombectomy.

In patients with wake up stroke or with an uncertain time of symptom onset, magnetic resonance imaging plays a particularly important role. The identification of lesions that are diffusion positive but fluid attenuated inversion recovery negative provides a surrogate marker of relatively recent ischemia and helps determine whether the patient falls within a timeframe in which intravenous thrombolysis may still offer benefit [47]. This approach allows treatment of selected patients who would otherwise be excluded on the basis of an unknown onset time. In intracerebral hemorrhage, imaging strategies have complementary goals. Once the diagnosis of hemorrhage is established, computed tomography angiography performed within the first hours from symptom onset can help identify individuals who are at heightened risk for hematoma expansion, for example through recognition of the radiographic spot sign [39]. In

addition, serial noncontrast head computed tomography during the first twenty four hours allows clinicians to monitor hematoma size and detect early expansion, which has prognostic and therapeutic implications [39]. For suspected subarachnoid hemorrhage, noncontrast computed tomography remains the cornerstone of initial diagnosis. When clinical suspicion is high but computed tomography is negative, lumbar puncture is recommended to assess for xanthochromia and red blood cells in the cerebrospinal fluid [48]. A recent evaluation of the Ottawa subarachnoid hemorrhage rule applied to patients undergoing computed tomography within six hours of headache onset reported a sensitivity of 95.5 percent and specificity of 100 percent for the diagnosis of subarachnoid hemorrhage [48]. These data support the use of structured clinical decision rules in conjunction with early imaging to optimize diagnostic accuracy.

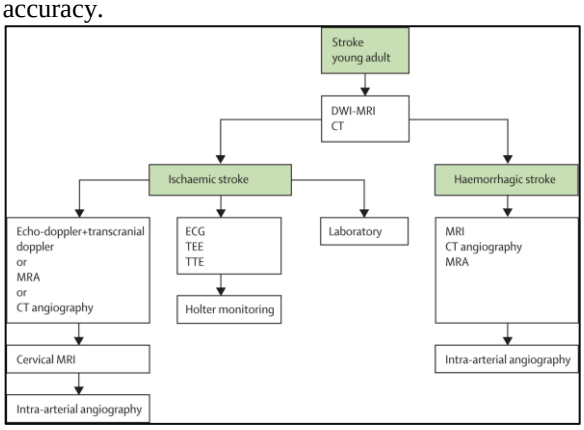

Fig. 3: Stroke diagnosis in Adults.

Computed tomography angiography is frequently used in the evaluation of subarachnoid hemorrhage to identify and characterize aneurysms and other vascular lesions [49][50]. When computed tomography angiography results are equivocal or when detailed anatomical definition is required for treatment planning, digital subtraction catheter angiography with three dimensional reconstruction remains the reference standard for aneurysm detection and characterization [49][50]. This invasive technique offers high spatial resolution and dynamic visualization of the cerebral vasculature and guides decisions regarding microsurgical clipping or endovascular coiling. Beyond imaging, the 2019 American Heart Association and American Stroke Association guidelines underscore several essential laboratory and cardiac assessments in the acute evaluation of ischemic stroke [44]. Measurement of blood glucose is mandated in all patients before the administration of intravenous alteplase, because both hypoglycemia and hyperglycemia can present with focal neurological deficits that mimic acute ischemic stroke [44]. A baseline electrocardiogram is also recommended to screen for arrhythmias and other cardiac abnormalities that may have etiological or prognostic relevance. However, this investigation must not delay the initiation of intravenous alteplase when the patient is otherwise eligible [44]. Similarly, baseline cardiac troponin testing is advised because myocardial injury commonly coexists with acute stroke and has prognostic importance, yet this evaluation should not interfere with timely delivery of thrombolytic therapy or mechanical thrombectomy [44]. Through integration of rapid neuroimaging, focused laboratory testing, and concurrent cardiovascular assessment, clinicians can optimize diagnostic precision while preserving the narrow therapeutic windows that define modern acute stroke care.

Treatment / Management

The probability of achieving full neurological recovery after an acute stroke decline with each passing minute in which reperfusion and definitive treatment are delayed. This concept, widely summarized as time is brain, underpins contemporary acute stroke systems of care and justifies the emphasis on rapid triage, imaging, and evidence based intervention across all major stroke subtypes. Early recognition expedited transport to an appropriate facility, and protocol driven in hospital management together shape clinical outcomes more than any single therapeutic maneuver. In acute ischemic stroke, initial management focuses on stabilization of vital physiological parameters and rapid determination of eligibility for reperfusion therapies in accordance with guideline based criteria. Airway protection, adequate ventilation, and oxygenation are immediate priorities. Supplemental oxygen is indicated in patients with hypoxemia in order to maintain arterial oxygen saturation above ninety four percent, whereas routine oxygen administration in nonhypoxic individuals is not recommended because it has not demonstrated benefit and may carry potential harms [44]. Parallel assessment of blood pressure, circulation, and level of consciousness informs decisions regarding airway support and hemodynamic management. Blood pressure control requires careful titration because both excessive hypertension and aggressive reduction can exacerbate brain injury. For patients considered for intravenous fibrinolysis, the 2019 AHA and ASA guidelines recommend lowering elevated blood pressure to below one hundred eighty five millimeters of mercury systolic and below one hundred ten millimeters of mercury diastolic before alteplase administration, with subsequent maintenance of values below one hundred eighty over one hundred five millimeters of mercury for at least twenty four hours [44]. When mechanical thrombectomy is planned in patients who have not received intravenous fibrinolysis, it is reasonable to maintain systolic blood pressure at or below one hundred eighty five and diastolic pressure at or below one hundred ten millimeters of mercury before the procedure, and at or below one hundred eighty over one hundred five millimeters of mercury during and for twenty four hours after the intervention [44]. These thresholds aim

to reduce the risk of hemorrhagic transformation and other complications while preserving perfusion to the ischemic penumbra.

Body temperature and glucose levels are additional modifiable physiological variables that influence neuronal survival. In patients with acute ischemic stroke, hyperthermia defined as body temperature greater than thirty eight degrees Celsius or one hundred point four degrees Fahrenheit should be treated with antipyretic agents, since fever is associated with worse outcomes and may amplify ischemic injury [44]. Glycemic control must address both hypoglycemia and hyperglycemia. Blood glucose levels below sixty milligrams per deciliter can mimic stroke and can directly harm the brain, and should be corrected promptly. Marked hyperglycemia is also detrimental and therapy is recommended to maintain glucose in a target range, commonly between one hundred forty and one hundred eighty milligrams per deciliter, while avoiding rapid swings that could induce further metabolic stress [44]. Intravenous alteplase remains the cornerstone pharmacological reperfusion therapy for eligible patients with acute ischemic stroke. The recommended dosing regimen is zero point nine milligrams per kilogram, with ten percent of the total dose given as an initial bolus over one minute and the remainder infused over sixty minutes, up to a maximum total dose of ninety milligrams [44]. Candidates include patients who satisfy standard inclusion and exclusion criteria and who can be treated within three hours of witnessed symptom onset or of the time they were last known to be well or at their neurological baseline. Selected patients may also benefit within a three to four and a half hour window, according to established trial based criteria [44]. Advances in neuroimaging have expanded the group of patients potentially eligible for thrombolysis beyond those with precisely known onset times. Individuals who awaken with stroke symptoms or who have an unknown onset time that is more than four and a half hours from when they were last known well may still receive intravenous alteplase if magnetic resonance imaging demonstrates a diffusion weighted lesion smaller than one third of the middle cerebral artery territory and no corresponding signal change on fluid attenuated inversion recovery sequences [44]. This diffusion fluid attenuated inversion recovery mismatch suggests relatively recent ischemia and provides a tissue based rather than purely time based therapeutic window. To reduce the risk of serious bleeding complications, several combinations are specifically discouraged. Abciximab should not be given concurrently with intravenous alteplase, intravenous aspirin should not be administered within ninety minutes after alteplase initiation, and alteplase should not be given within twenty four hours following a full treatment dose of low molecular weight heparin [44].

Tenecteplase offers an alternative fibrinolytic agent in certain clinical scenarios. For patients who are eligible for mechanical thrombectomy and have no contraindications, a single intravenous bolus of tenecteplase at a dose of zero point twenty five milligrams per kilogram, up to a maximum of twenty five milligrams, can be used instead of alteplase [44]. In contrast, other intravenous defibrinogenating or fibrinolytic agents beyond alteplase and tenecteplase are not recommended for acute ischemic stroke because of insufficient evidence of benefit and concerns regarding safety [44]. Endovascular mechanical thrombectomy has become a standard of care for selected patients with large vessel occlusion in the anterior circulation. Guidelines state that patients otherwise eligible for intravenous alteplase should receive it even when mechanical thrombectomy is also planned, since combined treatment has demonstrated improved outcomes in multiple trials [44]. Mechanical thrombectomy with a stent retriever or direct aspiration technique is recommended when six key criteria are met. These are a pre stroke modified Rankin Scale score of zero to one, acute ischemic stroke due to occlusion of the internal carotid artery or the first segment of the middle cerebral artery, age at least eighteen years, National Institutes of Health Stroke Scale score of six or higher, Alberta Stroke Program Early CT Score of six or higher, and the ability to initiate endovascular treatment within six hours of symptom onset [44]. Evidence from the DAWN and DEFUSE 3 trials has extended the time window for thrombectomy in carefully selected patients. Mechanical thrombectomy is recommended in individuals who present between six and sixteen hours from the time they were last known well, and reasonable in those presenting between sixteen and twenty four hours, provided they have large vessel occlusion in the anterior circulation and meet the additional imaging and clinical criteria defined in these trials [45]51. This extended window relies on advanced imaging to demonstrate a small infarct core and substantial salvageable tissue.

Antiplatelet therapy constitutes an essential component of early secondary prevention after ischemic stroke. Aspirin should be administered within twenty four to forty eight hours after symptom onset in most patients, although in those treated with intravenous alteplase it is customary to delay aspirin until twenty four hours after thrombolysis and after follow up imaging has excluded hemorrhagic transformation [44]. For patients with minor noncardioembolic ischemic stroke who have not received intravenous alteplase, early initiation of dual antiplatelet therapy with aspirin and clopidogrel within twenty four hours of symptom onset is appropriate and supported by clinical trial data for short term use to reduce recurrent events [44]. Management strategies for intracerebral hemorrhage differ fundamentally from those for ischemic stroke

and focus on limiting hematoma expansion, controlling intracranial pressure, reversing coagulopathy, and addressing structural complications. Elevated blood pressure plays a pivotal role in ongoing bleeding and hematoma growth. Evidence suggests that initiating antihypertensive treatment within two hours of ICH onset and achieving the target blood pressure within one hour can reduce the risk of hematoma expansion and improve functional outcomes [39]. In patients with mild to moderate ICH and an initial systolic blood pressure between one hundred fifty and two hundred twenty millimeters of mercury, current recommendations target a systolic level of approximately one hundred forty millimeters of mercury, aiming to maintain systolic blood pressure between one hundred thirty and one hundred fifty millimeters of mercury [39]. Conversely, in patients who present with initial systolic blood pressure above one hundred fifty millimeters of mercury, very rapid lowering to values below one hundred thirty millimeters of mercury may be harmful, underscoring the need for moderate rather than extreme blood pressure reduction [39].

In cases of anticoagulant associated intracerebral hemorrhage, immediate discontinuation of the offending anticoagulant is mandatory, and rapid reversal of its pharmacological effect should be undertaken as soon as possible [39]. Specific reversal strategies depend on the agent involved and may include vitamin K and prothrombin complex concentrates for vitamin K antagonists or targeted antidotes for certain direct oral anticoagulants. Platelet transfusion has a more limited and nuanced role. It may be considered in patients who have been treated with aspirin and require emergency neurosurgical intervention, where restoration of platelet function may facilitate hemostasis [39][53]. However, platelet transfusion should not be given to aspirin treated patients with intracerebral hemorrhage who are not undergoing urgent neurosurgery because clinical trial data indicate potential harm in this context [39]. Surgical management represents an important adjunct or alternative to medical therapy in selected patients with intracerebral hemorrhage and can reduce mortality when applied to appropriate subgroups. Options include minimally invasive hematoma evacuation using endoscopic or stereotactic aspiration techniques, which aim to decompress the brain while minimizing additional injury, insertion of an external ventricular drain to alleviate hydrocephalus and control intracranial pressure, and open craniotomy for clot evacuation in cases with superficial lobar hematomas or life threatening mass effect [39]. Patient selection depends on factors such as hematoma location and volume, neurological status, age, comorbidities, and timing from onset.

Management of aneurysmal subarachnoid hemorrhage rests on prompt securing of the ruptured aneurysm, prevention of rebleeding, mitigation of secondary ischemic injury, and treatment of complications such as hydrocephalus and seizures. Both the European Stroke Organization and the AHA and ASA guidelines recommend early aneurysm treatment in order to reduce the risk of recurrent hemorrhage, with the European Stroke Organization suggesting intervention within seventy two hours of symptom onset whenever feasible [50][55]. Despite this general consensus, a recent meta-analysis examining the timing of endovascular treatment in subarachnoid hemorrhage indicated that robust evidence defining an optimal time frame is lacking, which leaves some room for individualized decision making based on clinical stability, logistical factors, and aneurysm characteristics [56]. Short term antifibrinolytic therapy with agents such as tranexamic acid has been explored as a method to reduce the risk of early rebleeding before aneurysm obliteration. However, current evidence does not support routine use of tranexamic acid after subarachnoid hemorrhage, and guidelines therefore do not recommend its widespread application [57]. Between the onset of subarachnoid hemorrhage symptoms and definitive obliteration of the aneurysm, blood pressure management seeks to minimize rebleeding risk while preserving cerebral perfusion. The AHA and ASA recommend maintaining systolic blood pressure below one hundred sixty millimeters of mercury in this period, whereas the European Stroke Organization suggests a slightly higher upper limit of one hundred eighty millimeters of mercury until the ruptured aneurysm has been coiled or clipped [34][50][55].

Complete and durable obliteration of the aneurysm is the central therapeutic goal. When a ruptured aneurysm is technically suitable for both microsurgical clipping and endovascular coiling, current guidelines favor endovascular coiling as the preferred modality because of its association with lower immediate morbidity in many patients [34][50][55]. Choice of technique must nevertheless account for aneurysm morphology, location, patient age, comorbidities, and local expertise. Seizure management forms another important dimension of care. For patients who experience seizures in association with subarachnoid hemorrhage, treatment with antiepileptic drugs is recommended [55]. Short term seizure prophylaxis can also be considered in the immediate post hemorrhagic period in selected high risk patients, although universal long term prophylaxis is not supported [50]. Hydrocephalus is a frequent and potentially reversible cause of neurological deterioration after subarachnoid hemorrhage. Depending on the clinical scenario and radiological findings, cerebrospinal fluid diversion may be achieved through external ventricular drain placement or lumbar drainage [34][50][55]. These interventions relieve pressure, improve cerebral perfusion, and may facilitate recovery. Nimodipine is a cornerstone pharmacological therapy in aneurysmal subarachnoid hemorrhage and should be administered to all patients to reduce the incidence of delayed cerebral ischemia,

which is a major contributor to poor outcome [34][50][55]. Oral administration is preferred over intravenous routes because of a more favorable safety profile and ease of use [34][50][55]. Alongside these disease specific measures, comprehensive supportive care is essential. Key goals include adequate pain control, maintenance of euvolemia, avoidance of fever, and stabilization of blood glucose within normal or near normal ranges. Together, these strategies aim to optimize the biological environment for brain recovery and to minimize secondary neurological injury across the continuum of acute stroke care.

Differential Diagnosis

The evaluation of patients presenting with suspected acute stroke requires careful consideration of a broad range of alternative diagnoses, as a significant proportion of individuals ultimately do not have a confirmed transient ischemic attack or stroke. A systematic review examining the differential diagnosis of suspected stroke identified the twenty most frequently encountered non-stroke conditions, which together account for nearly all cases initially suspected of stroke but later ruled out [58]. Among these, seizure represents the most common mimic, affecting approximately nineteen point six percent of patients, reflecting the fact that postictal deficits or ongoing seizure activity can closely resemble focal neurological deficits of acute stroke. Syncope, accounting for twelve point two percent of cases, may present with transient loss of consciousness and brief neurological impairment, further complicating early evaluation. Systemic infections such as sepsis contribute to nine point six percent of non-stroke diagnoses, often through encephalopathy or metabolic disturbances that mimic stroke symptoms. Benign headache disorders, including migraine with aura, are implicated in nine percent of presentations, highlighting the need for detailed history taking. Finally, structural brain lesions, most commonly tumors, comprise eight point two percent of alternative diagnoses, underscoring the importance of neuroimaging in distinguishing acute cerebrovascular events from mass effect or other intracranial pathology [58]. This evidence emphasizes the necessity of a structured, systematic approach to differential diagnosis in acute stroke evaluation to avoid misdiagnosis and ensure timely, appropriate management.

Prognosis

Acute stroke remains a leading cause of mortality and long-term disability worldwide, and its prognosis varies according to the type, subtype, and timeliness of treatment. The global burden of stroke continues to rise, as evidenced by the 2019 systematic analysis conducted as part of the Global Burden of Diseases, Injuries, and Risk Factors Study. This analysis demonstrated a significant increase in both the annual incidence of all stroke types—including ischemic stroke, intracerebral hemorrhage (ICH), and subarachnoid hemorrhage (SAH)—and the number of deaths attributable to stroke between 1990 and 2019 [22]. This trend underscores the persistent challenge that stroke poses to public health systems and highlights the necessity for effective acute care strategies and secondary prevention measures to reduce mortality and disability. Long-term outcomes following stroke remain sobering. A population-based cohort study conducted in the United Kingdom found that within five years of a first stroke, 47% of patients had died, and 39% continued to live with functional disabilities [59]. These findings indicate that nearly half of patients do not survive beyond the first five years post-stroke, while a substantial proportion of survivors experience significant limitations in daily activities, reinforcing the need for comprehensive rehabilitation programs. Variations in prognosis are particularly evident when comparing ischemic stroke to ICH. Analysis of the Swedish Stroke Register (Riksstroke) revealed that 30-day survival after a first ischemic stroke was 89.9%, compared to only 69.3% following ICH, reflecting the higher early mortality associated with hemorrhagic events. Beyond the initial month, survival declined at a similar trajectory for both groups; however, patients with ICH exhibited consistently higher rates of functional dependency at all measured time points. At five years, survival rates were 49.4% for ischemic stroke and 37.8% for ICH, suggesting that more than 65% of ischemic stroke survivors and over 75% of ICH survivors were either deceased or functionally dependent [60]. These findings emphasize that hemorrhagic strokes carry not only higher acute mortality but also greater long-term functional impairment.

Data from large national cohorts in Australia and New Zealand provide additional insight into the long-term prognosis of first-time stroke survivors. Among these patients, the five-year and ten-year survival rates were 52.8% and 36.4%, respectively. Moreover, the cumulative incidence of recurrent stroke was reported at 19.8% at five years and 26.8% at ten years, highlighting the persistent risk of recurrence and the importance of secondary prevention interventions [61]. Similarly, a population-based study in the Netherlands focusing on young adults aged 18 to 49 who survived at least 30 days post-stroke demonstrated that mortality risk remained elevated compared to the general population for up to fifteen years, indicating that stroke confers long-term excess mortality even in younger patients [62]. Temporal trends in stroke recurrence reveal modest improvements over time. A UK cohort study found that five-year recurrence rates decreased from 18% among patients who experienced a stroke between 1995 and 1999 to 12% among those who experienced a stroke between 2000 and 2005. However, there has been little reduction in recurrence rates since 2005, indicating a plateau in the effectiveness of current preventive strategies [63]. Data from Danish

nationwide health registries provide further granularity. Following a first ischemic stroke, recurrence risks were 4% at one year and 13% at ten years, while for ICH, the corresponding risks were 3% and 12%, respectively. All-cause mortality after a first ischemic stroke was 17% at one year and 56% at ten years, increasing to 25% and 70% after recurrent events. For ICH, mortality reached 37% at one year and 70% at ten years following a first event, rising to 31% at one year and 75% at ten years after recurrence [64]. Collectively, these data underscore the profound long-term impact of stroke on both survival and functional outcomes. The findings emphasize the necessity for timely acute interventions, structured rehabilitation, vigilant secondary prevention, and targeted strategies to reduce recurrence and improve overall quality of life. Collaborative, multidisciplinary approaches remain essential to mitigate the enduring global burden of stroke and optimize long-term prognoses for affected patients.

Complications

Medical complications following stroke are a major contributor to morbidity and mortality and require proactive identification, prevention, and management to optimize patient outcomes. The spectrum and severity of these complications vary depending on stroke type, size, and associated comorbidities. Early recognition and structured care protocols are essential in mitigating the adverse effects of these complications. In ischemic stroke, treatment-related complications are particularly relevant in patients receiving intravenous (IV) alteplase. Symptomatic intracranial hemorrhage occurs in approximately six percent of patients, while major systemic hemorrhage affects around two percent. Angioedema has also been reported in five percent of patients [11]. These potential adverse events necessitate preparedness for emergent interventions prior to initiating fibrinolytic therapy. Beyond pharmacologic complications, patients with large territorial infarcts are at risk of developing brain edema, which can significantly increase intracranial pressure and result in life-threatening herniation. Decompressive surgery has been demonstrated to reduce mortality in patients with malignant cerebral edema, emphasizing the importance of early recognition and timely surgical intervention [65]. Seizures can also complicate the course of ischemic stroke, occurring either in the acute phase or during recovery. While recurrent seizures should be managed according to standard protocols for acute neurological conditions, prophylactic administration of antiseizure medications is not recommended unless clinically indicated [44].

In patients with intracerebral hemorrhage (ICH), the early hours and days following stroke onset are critical, as the risk of secondary medical complications is high. Standardized protocols and structured order sets have been shown to reduce both mortality and long-term disability [39]. Early identification of dysphagia through formal screening prior to oral intake is strongly recommended to decrease the risk of aspiration pneumonia, which is a major contributor to morbidity [39]. Management of hyperpyrexia is crucial and can be achieved using antipyretics, standard cooling blankets, water-circulating surface cooling devices, or catheter-based cooling systems. Simultaneously, close glucose monitoring is necessary to prevent hypoglycemia and hyperglycemia, both of which can exacerbate neuronal injury and worsen outcomes [39][66][67][68]. Complications in subarachnoid hemorrhage (SAH) are often related to secondary brain injury and can arise from intracerebral hemorrhage, intraventricular hemorrhage, increased intracranial pressure, hydrocephalus, subdural hematoma, or delayed cerebral ischemia. Medical complications are common and profoundly impact patient outcomes. Frequent complications include pyrexia, sepsis, aspiration pneumonia, cardiac dysfunction, anemia, hyponatremia, hyperglycemia, and deep venous thrombosis [34][69]. Critical care management for SAH must focus on early detection, prevention, and targeted treatment of these complications. Maintaining normothermia and normoglycemia is particularly important, as these measures reduce secondary neurological injury and improve functional recovery. Multidisciplinary coordination between neurology, neurosurgery, critical care, and rehabilitation teams is essential to address these complications efficiently and to minimize their long-term sequelae. Overall, the management of complications following stroke demands a proactive, structured, and multidisciplinary approach. The implementation of standardized protocols, close monitoring, and early intervention are key strategies that can reduce mortality, limit secondary injury, and improve long-term functional outcomes for patients across all stroke subtypes.

Postoperative and Rehabilitation Care

Rehabilitation is a cornerstone in post-stroke management, aiming to restore functional independence and improve quality of life. Effective rehabilitation requires an interdisciplinary approach that integrates neurologists, physiatrists, therapists, nurses, and social support systems to address the multifaceted deficits resulting from stroke. The timing and intensity of rehabilitation interventions remain subjects of active investigation, as evidence continues to evolve regarding the most effective strategies for optimizing recovery [70][71][72]. While early mobilization is generally advocated to prevent complications associated with immobility, evidence suggests that initiating very early mobilization—within 24 hours of stroke onset—may paradoxically lead to adverse outcomes, including hemodynamic instability, increased risk of falls, and potential exacerbation of neurological injury. Consequently, the precise window for initiating rehabilitation must balance the benefits of early activity against the potential for harm, highlighting the need for

individualized assessment and careful monitoring of each patient's clinical status [70][71][72]. Current guidelines recommend commencing structured therapy within two weeks of stroke onset, once the patient is medically stable and acute complications have been addressed.

Rehabilitation services encompass physical, occupational, and speech therapies, tailored to the patient's specific impairments. Physical therapy focuses on enhancing gait, balance, and overall mobility, reducing the risk of falls, and preventing musculoskeletal complications such as contractures. Techniques such as task-specific training, proprioceptive neuromuscular facilitation, mirror therapy, and neuromuscular electrical stimulation are frequently employed to stimulate motor recovery and promote neuroplasticity. Occupational therapy emphasizes the restoration of activities of daily living, including self-care, domestic tasks, and community reintegration, while speech therapy addresses dysarthria, aphasia, and other communication deficits [70][71][72][73]. Management of post-stroke pain, particularly shoulder pain, is an integral component of rehabilitation. Strategies include transcutaneous electrical nerve stimulation, taping, and strapping techniques designed to reduce discomfort and facilitate active engagement in therapy. Additionally, cognitive therapeutic exercises are increasingly incorporated to target attention, memory, and executive function deficits, which often impede functional recovery and independence. These interventions aim to maximize neurorehabilitation outcomes by promoting adaptive neuroplasticity and restoring functional networks disrupted by ischemic or hemorrhagic injury [70][71][72][73][74].

Despite the growing repertoire of rehabilitation modalities, there remains a lack of high-quality, large-scale evidence to definitively guide the optimal intensity, timing, and combination of therapies across the continuum of post-stroke recovery. Most existing studies are limited by small sample sizes, heterogeneous patient populations, and variations in outcome measures, making it challenging to generalize findings or establish standardized protocols. Consequently, ongoing research is necessary to refine rehabilitation strategies, identify patient-specific predictors of recovery, and determine the most effective combination of interventions for enhancing motor, cognitive, and functional outcomes [70][71][72][73][74]. In summary, postoperative and rehabilitation care is critical for improving functional outcomes, promoting independence, and enhancing the quality of life of stroke survivors. Rehabilitation should be initiated promptly within the appropriate clinical context, tailored to individual deficits, and delivered by a multidisciplinary team employing evidence-based techniques. Continuous research and clinical innovation remain essential to optimize rehabilitation strategies, mitigate post-stroke complications, and facilitate maximal recovery for patients across all stages of stroke convalescence.

Patient Education

Patient education plays a pivotal role in both the prevention and management of acute stroke. Stroke is a largely preventable and treatable condition, yet its burden remains substantial worldwide. Effective education focuses on increasing awareness of risk factors, recognizing early warning signs, and promoting timely medical intervention. Public health initiatives targeting diverse populations have demonstrated measurable success in reducing delays in stroke diagnosis and treatment. Educational campaigns that emphasize the urgency of acute stroke and encourage immediate access to emergency care are essential components of stroke prevention strategies [39][75][76]. Modifiable risk factors are central to patient-centered stroke prevention efforts. Physical inactivity, poor diet, dyslipidemia, obesity, diabetes mellitus, hypertension, cigarette smoking, and atrial fibrillation are among the most well-established contributors to stroke risk. Hypertension, in particular, represents the single most significant and well-documented modifiable factor. Patient education should therefore emphasize the adoption of healthy lifestyle behaviors, including regular physical activity, adherence to a balanced diet, and the avoidance of tobacco products. In addition, pharmacological management of hypertension, dyslipidemia, and diabetes mellitus is crucial, and patients should receive guidance on medication adherence and monitoring [77]. For individuals with atrial fibrillation, risk stratification using the CHA2DS2-VASc score is recommended to guide the initiation of anticoagulant therapy for primary stroke prevention, and patients should be educated regarding the rationale, benefits, and potential risks of such therapy [77][78].

Special populations require targeted educational interventions. Sickle cell disease (SCD) is associated with a particularly high risk of stroke, especially in early childhood. Most strokes in SCD occur in patients with homozygous disease, making this subgroup a primary target for preventive strategies. Education for caregivers and patients should include guidance on monitoring for neurological symptoms, adherence to disease-modifying treatments such as hydroxyurea, and timely engagement with healthcare services [77]. Following an acute stroke, comprehensive patient education extends beyond prevention to post-stroke recovery and rehabilitation. Patients should receive structured counseling that addresses the impact of stroke on physical, cognitive, and emotional functioning. Clear explanations regarding treatment plans, rehabilitation goals, expected outcomes, and strategies to prevent recurrence are essential to empower patients in their recovery process [44]. Education should also encompass potential complications, strategies for self-monitoring, and instructions for emergency situations.

Caregiver education is equally important, as caregivers play a central role in the daily support and long-term well-being of stroke survivors. Training should include safe mobility techniques, recognition of complications, management of cognitive and speech deficits, and emotional support strategies. Providing caregivers with knowledge, practical skills, and psychological support enhances the patient's recovery trajectory and improves quality of life for both patients and their families [39]. In summary, patient education is a foundational component of acute stroke management, addressing both prevention and post-stroke care. By targeting modifiable risk factors, promoting timely recognition and treatment, and supporting post-stroke rehabilitation, education empowers patients and caregivers, reduces morbidity and mortality, and contributes to improved long-term outcomes. Effective education requires a coordinated approach involving healthcare professionals, caregivers, and public health systems to ensure that knowledge translates into meaningful action and behavioral change.

Enhancing Healthcare Team Outcomes

Effective management of acute stroke necessitates interprofessional and multidisciplinary collaboration to ensure timely identification, intervention, and comprehensive care throughout the recovery process. Clinical guidelines for ischemic stroke, intracerebral hemorrhage (ICH), and subarachnoid hemorrhage (SAH) underscore the critical importance of coordinated healthcare teams in both prehospital and hospital settings to improve patient outcomes. Multidisciplinary rehabilitation services, initiated during hospitalization and continued post-discharge, are essential for promoting functional recovery and supporting patient independence following an acute stroke [70][79]. Prehospital stroke care is typically led by Emergency Medical Services (EMS) personnel and paramedics, who play a pivotal role in early recognition, stabilization, and rapid transport of patients to definitive care. In the emergency department (ED), collaboration with clinicians is crucial to facilitate immediate evaluation and triage. During the hyperacute phase of stroke, defined as the first 72 hours post-onset, a specialized team including a stroke clinician, stroke specialist nurse, and radiology personnel—led by a radiologist or neuroradiologist—is essential for accurate diagnosis and timely intervention [80]. Pharmacists are integral members of this interprofessional team, providing critical expertise in the selection, dosing, preparation, and administration of thrombolytic agents. Their role extends to medication reconciliation, monitoring for potential drug interactions, and offering patient counseling to ensure adherence and safety throughout the treatment process. Upon activation of a Code: Stroke, rapid mobilization of the stroke team within the ED is essential. Prompt admission to a dedicated stroke inpatient unit has been shown to reduce mortality, improve functional outcomes, and enhance patient independence. The continuity of care within these specialized units ensures that stroke survivors receive coordinated, evidence-based interventions that optimize recovery potential [80].

Rehabilitation services should commence as early as clinically feasible. Inpatient rehabilitation teams generally consist of stroke clinicians, nurses, physiotherapists, occupational therapists, speech and language therapists, and therapy assistants. Early initiation of rehabilitation fosters improved motor function, cognitive recovery, and patient confidence, while supporting the development of self-care capabilities and facilitating a smoother transition to post-discharge care [70][79][80]. Stroke coordinators function as key facilitators within the multidisciplinary team, supporting patients and their families throughout hospitalization and beyond. Their responsibilities include coordinating care, providing education on secondary stroke prevention, and ensuring seamless communication among team members. This role is critical in optimizing continuity of care and reinforcing adherence to rehabilitation and prevention strategies [80]. Early supported discharge (ESD) is an evidence-based interprofessional intervention designed to transition patients from hospital to home while continuing specialized rehabilitation services. ESD programs initiate therapy within 24 hours of hospital discharge, delivering patient-centered care in the home environment and promoting earlier functional independence. International stroke guidelines advocate for ESD as a core component of comprehensive stroke care due to its demonstrated efficacy in improving long-term outcomes [81]. The interprofessional care model relies on open communication, shared decision-making, and clearly defined roles to achieve optimal outcomes for stroke patients. Collaborative practice across disciplines not only enhances acute management but also supports rehabilitation, secondary prevention, and long-term functional recovery, ultimately improving quality of life for individuals affected by stroke. This model represents a holistic approach, integrating acute care, rehabilitation, and patient education into a continuous care pathway tailored to the needs of each patient.

Conclusion:

In conclusion, acute stroke remains a formidable global health challenge, but its impact can be mitigated through a highly coordinated and evidence-based approach. The critical principle underpinning all effective intervention is the urgency of time, where rapid diagnosis and the immediate initiation of treatment are paramount to preserving neurological function. The management pathways for ischemic and hemorrhagic strokes are distinct yet equally reliant on precision and speed, from administering thrombolytics and performing thrombectomy to controlling hematoma expansion and securing ruptured aneurysms. The success of these

interventions is fundamentally dependent on a seamless, interprofessional healthcare team. Radiologists are indispensable for providing rapid and accurate neuroimaging to guide therapeutic decisions. Pharmacists ensure the safe and effective use of high-risk medications, from thrombolytics to anticoagulant reversal agents. Nursing staff provide continuous monitoring, execute protocols, manage complications, and offer essential patient and family education. This collaborative model must extend from the hyperacute phase in the emergency department through specialized inpatient stroke units and into post-discharge rehabilitation and secondary prevention. Ultimately, enhancing communication and defined roles within this multidisciplinary framework is the key to reducing mortality, minimizing long-term disability, and improving the overall quality of life for stroke survivors. The enduring burden of stroke necessitates that healthcare systems continue to prioritize and refine this integrated, team-based approach to care.

References:

1. Sacco RL, Kasner SE, Broderick JP, Caplan LR, Connors JJ, Culebras A, Elkind MS, George MG, Hamdan AD, Higashida RT, Hoh BL, Janis LS, Kase CS, Kleindorfer DO, Lee JM, Moseley ME, Peterson ED, Turan TN, Valderrama AL, Vinters HV, American Heart Association Stroke Council, Council on Cardiovascular Surgery and Anesthesia, Council on Cardiovascular Radiology and Intervention, Council on Cardiovascular and Stroke Nursing, Council on Epidemiology and Prevention, Council on Peripheral Vascular Disease, Council on Nutrition, Physical Activity and Metabolism. An updated definition of stroke for the 21st century: a statement for healthcare professionals from the American Heart Association/American Stroke Association. Stroke. 2013 Jul:44(7):2064-89. doi: 10.1161/STR.0b013e318296aeca.
2. George MG, Fischer L, Koroshetz W, Bushnell C, Frankel M, Foltz J, Thorpe PG. CDC Grand Rounds: Public Health Strategies to Prevent and Treat Strokes. MMWR. Morbidity and mortality weekly report. 2017 May 12:66(18):479-481. doi: 10.15585/mmwr.mm6618a5.
3. Katan M, Luft A. Global Burden of Stroke. Seminars in neurology. 2018 Apr:38(2):208-211. doi: 10.1055/s-0038-1649503.
4. Ding C, Wu Y, Chen X, Chen Y, Wu Z, Lin Z, Kang D, Fang W, Chen F. Global, regional, and national burden and attributable risk factors of neurological disorders: The Global Burden of Disease study 1990-2019. Frontiers in public health. 2022:10():952161. doi: 10.3389/fpubh.2022.952161.
5. Struijs JN, van Genugten ML, Evers SM, Ament AJ, Baan CA, van den Bos GA. Future costs of stroke in the Netherlands: the impact of stroke services. International journal of technology assessment in health care. 2006 Fall:22(4):518-24
6. Luengo-Fernandez R, Violato M, Candio P, Leal J. Economic burden of stroke across Europe: A population-based cost analysis. European stroke journal. 2020 Mar:5(1):17-25. doi: 10.1177/2396987319883160.
7. Rochmah TN, Rahmawati IT, Dahlui M, Budiarto W, Bilqis N. Economic Burden of Stroke Disease: A Systematic Review. International journal of environmental research and public health. 2021 Jul 15:18(14):. doi: 10.3390/ijerph18147552.
8. Hankey GJ. Stroke. Lancet (London, England). 2017 Feb 11:389(10069):641-654. doi: 10.1016/S0140-6736(16)30962-X.
9. Radu RA, Terecoasă EO, Băjenaru OA, Tiu C. Etiologic classification of ischemic stroke: Where do we stand? Clinical neurology and neurosurgery. 2017 Aug:159():93-106. doi: 10.1016/j.clineuro.2017.05.019.
10. Adams HP Jr, Bendixen BH, Kappelle LJ, Biller J, Love BB, Gordon DL, Marsh EE 3rd. Classification of subtype of acute ischemic stroke. Definitions for use in a multicenter clinical trial. TOAST. Trial of Org 10172 in Acute Stroke Treatment. Stroke. 1993 Jan:24(1):35-41
11. Chugh C. Acute Ischemic Stroke: Management Approach. Indian journal of critical care medicine : peer-reviewed, official publication of Indian Society of Critical Care Medicine. 2019 Jun:23(Suppl 2):S140-S146. doi: 10.5005/jp-journals-10071-23192.
12. Feske SK. Ischemic Stroke. The American journal of medicine. 2021 Dec:134(12):1457-1464. doi: 10.1016/j.amjmed.2021.07.027.
13. Yamamoto Y, Ohara T, Hamanaka M, Hosomi A, Tamura A, Akiguchi I. Characteristics of intracranial branch atheromatous disease and its association with progressive motor deficits. Journal of the neurological sciences. 2011 May 15:304(1-2):78-82. doi: 10.1016/j.jns.2011.02.006.
14. Yaghi S, Raz E, Yang D, Cutting S, Mac Grory B, Elkind MS, de Havenon A. Lacunar stroke: mechanisms and therapeutic implications. Journal of neurology, neurosurgery, and psychiatry. 2021 May 26:():. pii: jnnp-2021-326308. doi: 10.1136/jnnp-2021-326308.
15. Kremer PH, Jolink WM, Kappelle LJ, Algra A, Klijn CJ, SMART and ESPRIT Study Groups. Risk Factors for Lobar and Non-Lobar Intracerebral Hemorrhage in Patients with Vascular Disease. PloS one. 2015:10(11):e0142338. doi: 10.1371/journal.pone.0142338.
16. An SJ, Kim TJ, Yoon BW. Epidemiology, Risk Factors, and Clinical Features of Intracerebral Hemorrhage: An Update. Journal of stroke. 2017

Jan:19(1):3-10. doi: 10.5853/jos.2016.00864. Epub 2017
17. Magid-Bernstein J, Girard R, Polster S, Srinath A, Romanos S, Awad IA, Sansing LH. Cerebral Hemorrhage: Pathophysiology, Treatment, and Future Directions. Circulation research. 2022 Apr 15:130(8):1204-1229. doi: 10.1161/CIRCRESAHA.121.319949. Epub 2022 Apr 14
18. Martin CO, Rymer MM. Hemorrhagic stroke: aneurysmal subarachnoid hemorrhage. Missouri medicine. 2011 Mar-Apr:108(2):124-7
19. Sweeney K, Silver N, Javadpour M. Subarachnoid haemorrhage (spontaneous aneurysmal). BMJ clinical evidence. 2016 Mar 17:2016():. pii: 1213.
20. Maher M, Schweizer TA, Macdonald RL. Treatment of Spontaneous Subarachnoid Hemorrhage: Guidelines and Gaps. Stroke. 2020 Apr:51(4):1326-1332. doi: 10.1161/STROKEAHA.119.025997.
21. Treadwell SD, Robinson TG. Cocaine use and stroke. Postgraduate medical journal. 2007 Jun:83(980):389-94
22. GBD 2019 Stroke Collaborators. Global, regional, and national burden of stroke and its risk factors, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019. The Lancet. Neurology. 2021 Oct:20(10):795-820. doi: 10.1016/S1474-4422(21)00252-0. Epub 2021 Sep 3
23. GBD 2016 Lifetime Risk of Stroke Collaborators, Feigin VL, Nguyen G, Cercy K, Johnson CO, Alam T, Parmar PG, Abajobir AA, Abate KH, Abd-Allah F, Abejie AN, Abyu GY, Ademi Z, Agarwal G, Ahmed MB, Akinyemi RO, Al-Raddadi R, Aminde LN, Amlie-Lefond C, Ansari H, Asayesh H, Asgedom SW, Atey TM, Ayele HT, Banach M, Banerjee A, Barac A, Barker-Collo SL, Bärnighausen T, Barregard L, Basu S, Bedi N, Behzadifar M, Béjot Y, Bennett DA, Bensenor IM, Berhe DF, Boneya DJ, Brainin M, Campos-Nonato IR, Caso V, Castañeda-Orjuela CA, Rivas JC, Catalá-López F, Christensen H, Criqui MH, Damasceno A, Dandona L, Dandona R, Davletov K, de Courten B, deVeber G, Dokova K, Edessa D, Endres M, Faraon EJA, Farvid MS, Fischer F, Foreman K, Forouzanfar MH, Gall SL, Gebrehiwot TT, Geleijnse JM, Gillum RF, Giroud M, Goulart AC, Gupta R, Gupta R, Hachinski V, Hamadeh RR, Hankey GJ, Hareri HA, Havmoeller R, Hay SI, Hegazy MI, Hibstu DT, James SL, Jeemon P, John D, Jonas JB, Jóźwiak J, Kalani R, Kandel A, Kasaeian A, Kengne AP, Khader YS, Khan AR, Khang YH, Khubchandani J, Kim D, Kim YJ, Kivimaki M, Kokubo Y, Kolte D, Kopec JA, Kosen S, Kravchenko M, Krishnamurthi R, Kumar GA, Lafranconi A, Lavados PM, Legesse Y, Li Y, Liang X, Lo WD, Lorkowski S, Lotufo PA, Loy CT, Mackay MT, Abd El Razek HM, Mahdavi M, Majeed A, Malekzadeh R, Malta DC, Mamun AA, Mantovani LG, Martins SCO, Mate KK, Mazidi M, Mehata S, Meier T, Melaku YA, Mendoza W, Mensah GA, Meretoja A, Mezgebe HB, Miazgowski T, Miller TR, Ibrahim NM, Mohammed S, Mokdad AH, Moosazadeh M, Moran AE, Musa KI, Negoi RI, Nguyen M, Nguyen QL, Nguyen TH, Tran TT, Nguyen TT, Anggraini Ningrum DN, Norrving B, Noubiap JJ, O'Donnell MJ, Olagunju AT, Onuma OK, Owolabi MO, Parsaeian M, Patton GC, Piradov M, Pletcher MA, Pourmalek F, Prakash V, Qorbani M, Rahman M, Rahman MA, Rai RK, Ranta A, Rawaf D, Rawaf S, Renzaho AM, Robinson SR, Sahathevan R, Sahebkar A, Salomon JA, Santalucia P, Santos IS, Sartorius B, Schutte AE, Sepanlou SG, Shafieesabet A, Shaikh MA, Shamsizadeh M, Sheth KN, Sisay M, Shin MJ, Shiue I, Silva DAS, Sobngwi E, Soljak M, Sorensen RJD, Sposato LA, Stranges S, Suliankatchi RA, Tabarés-Seisdedos R, Tanne D, Nguyen CT, Thakur JS, Thrift AG, Tirschwell DL, Topor-Madry R, Tran BX, Nguyen LT, Truelsen T, Tsilimparis N, Tyrovolas S, Ukwaja KN, Uthman OA, Varakin Y, Vasankari T, Venketasubramanian N, Vlassov VV, Wang W, Werdecker A, Wolfe CDA, Xu G, Yano Y, Yonemoto N, Yu C, Zaidi Z, El Sayed Zaki M, Zhou M, Ziaeian B, Zipkin B, Vos T, Naghavi M, Murray CJL, Roth GA. Global, Regional, and Country-Specific Lifetime Risks of Stroke, 1990 and 2016. The New England journal of medicine. 2018 Dec 20:379(25):2429-2437. doi: 10.1056/NEJMoa1804492.
24. Saver JL. Penumbral salvage and thrombolysis outcome: a drop of brain, a week of life. Brain : a journal of neurology. 2017 Mar 1:140(3):519-522. doi: 10.1093/brain/awx020.
25. Xing C, Arai K, Lo EH, Hommel M. Pathophysiologic cascades in ischemic stroke. International journal of stroke : official journal of the International Stroke Society. 2012 Jul:7(5):378-85. doi: 10.1111/j.1747-4949.2012.00839.x
26. Lalancette-Hébert M, Gowing G, Simard A, Weng YC, Kriz J. Selective ablation of proliferating microglial cells exacerbates ischemic injury in the brain. The Journal of neuroscience : the official journal of the Society for Neuroscience. 2007 Mar 7:27(10):2596
27. Denes A, Vidyasagar R, Feng J, Narvainen J, McColl BW, Kauppinen RA, Allan SM. Proliferating resident microglia after focal cerebral ischaemia in mice. Journal of cerebral blood flow and metabolism : official journal of the International Society of Cerebral Blood Flow and Metabolism. 2007 Dec:27(12):1941-53
28. Battista D, Ferrari CC, Gage FH, Pitossi FJ. Neurogenic niche modulation by activated

microglia: transforming growth factor beta increases neurogenesis in the adult dentate gyrus. The European journal of neuroscience. 2006 Jan:23(1):83-93
29. Narantuya D, Nagai A, Sheikh AM, Masuda J, Kobayashi S, Yamaguchi S, Kim SU. Human microglia transplanted in rat focal ischemia brain induce neuroprotection and behavioral improvement. PloS one. 2010 Jul 23:5(7):e11746. doi: 10.1371/journal.pone.0011746.
30. Merson TD, Binder MD, Kilpatrick TJ. Role of cytokines as mediators and regulators of microglial activity in inflammatory demyelination of the CNS. Neuromolecular medicine. 2010 Jun:12(2):99-132. doi: 10.1007/s12017-010-8112-z.
31. Kiefer R, Streit WJ, Toyka KV, Kreutzberg GW, Hartung HP. Transforming growth factor-beta 1: a lesion-associated cytokine of the nervous system. International journal of developmental neuroscience : the official journal of the International Society for Developmental Neuroscience. 1995 Jun-Jul:13(3-4):331-9
32. Aronowski J, Zhao X. Molecular pathophysiology of cerebral hemorrhage: secondary brain injury. Stroke. 2011 Jun:42(6):1781-6. doi: 10.1161/STROKEAHA.110.596718. Epub 2011
33. Wilkinson DA, Pandey AS, Thompson BG, Keep RF, Hua Y, Xi G. Injury mechanisms in acute intracerebral hemorrhage. Neuropharmacology. 2018 May 15:134(Pt B):240-248. doi: 10.1016/j.neuropharm.2017.09.033.
34. Claassen J, Park S. Spontaneous subarachnoid haemorrhage. Lancet (London, England). 2022 Sep 10:400(10355):846-862. doi: 10.1016/S0140-6736(22)00938-2. Epub 2022 Aug 16
35. H Buck B, Akhtar N, Alrohimi A, Khan K, Shuaib A. Stroke mimics: incidence, aetiology, clinical features and treatment. Annals of medicine. 2021 Dec:53(1):420-436. doi: 10.1080/07853890.2021.1890205.
36. Qureshi AI, Mendelow AD, Hanley DF. Intracerebral haemorrhage. Lancet (London, England). 2009 May 9:373(9675):1632-44. doi: 10.1016/S0140-6736(09)60371-8.
37. Vespa PM, O'Phelan K, Shah M, Mirabelli J, Starkman S, Kidwell C, Saver J, Nuwer MR, Frazee JG, McArthur DA, Martin NA. Acute seizures after intracerebral hemorrhage: a factor in progressive midline shift and outcome. Neurology. 2003 May 13:60(9):1441-6
38. De Herdt V, Dumont F, Hénon H, Derambure P, Vonck K, Leys D, Cordonnier C. Early seizures in intracerebral hemorrhage: incidence, associated factors, and outcome. Neurology. 2011 Nov 15:77(20):1794-800. doi: 10.1212/WNL.0b013e31823648a6. Epub 2011 Oct 5
39. Greenberg SM, Ziai WC, Cordonnier C, Dowlatshahi D, Francis B, Goldstein JN, Hemphill JC 3rd, Johnson R, Keigher KM, Mack WJ, Mocco J, Newton EJ, Ruff IM, Sansing LH, Schulman S, Selim MH, Sheth KN, Sprigg N, Sunnerhagen KS, American Heart Association/American Stroke Association. 2022 Guideline for the Management of Patients With Spontaneous Intracerebral Hemorrhage: A Guideline From the American Heart Association/American Stroke Association. Stroke. 2022 Jul:53(7):e282-e361. doi: 10.1161/STR.0000000000000407.
40. MacMahon S, Peto R, Cutler J, Collins R, Sorlie P, Neaton J, Abbott R, Godwin J, Dyer A, Stamler J. Blood pressure, stroke, and coronary heart disease. Part 1, Prolonged differences in blood pressure: prospective observational studies corrected for the regression dilution bias. Lancet (London, England). 1990 Mar 31:335(8692):765-74
41. Lewington S, Clarke R, Qizilbash N, Peto R, Collins R, Prospective Studies Collaboration. Age-specific relevance of usual blood pressure to vascular mortality: a meta-analysis of individual data for one million adults in 61 prospective studies. Lancet (London, England). 2002 Dec 14:360(9349):1903-13
42. Suarez JI. Diagnosis and Management of Subarachnoid Hemorrhage. Continuum (Minneapolis, Minn.). 2015 Oct:21(5 Neurocritical Care):1263-87. doi: 10.1212/CON.0000000000000217.
43. Lövblad KO, Altrichter S, Mendes Pereira V, Vargas M, Marcos Gonzalez A, Haller S, Sztajzel R. Imaging of acute stroke: CT and/or MRI. Journal of neuroradiology = Journal de neuroradiologie. 2015 Feb:42(1):55-64. doi: 10.1016/j.neurad.2014.10.005.
44. Powers WJ, Rabinstein AA, Ackerson T, Adeoye OM, Bambakidis NC, Becker K, Biller J, Brown M, Demaerschalk BM, Hoh B, Jauch EC, Kidwell CS, Leslie-Mazwi TM, Ovbiagele B, Scott PA, Sheth KN, Southerland AM, Summers DV, Tirschwell DL. Guidelines for the Early Management of Patients With Acute Ischemic Stroke: 2019 Update to the 2018 Guidelines for the Early Management of Acute Ischemic Stroke: A Guideline for Healthcare Professionals From the American Heart Association/American Stroke Association. Stroke. 2019 Dec:50(12):e344-e418. doi: 10.1161/STR.0000000000000211.
45. Nogueira RG, Jadhav AP, Haussen DC, Bonafe A, Budzik RF, Bhuva P, Yavagal DR, Ribo M, Cognard C, Hanel RA, Sila CA, Hassan AE, Millan M, Levy EI, Mitchell P, Chen M, English JD, Shah QA, Silver FL, Pereira VM, Mehta BP,

Baxter BW, Abraham MG, Cardona P, Veznedaroglu E, Hellinger FR, Feng L, Kirmani JF, Lopes DK, Jankowitz BT, Frankel MR, Costalat V, Vora NA, Yoo AJ, Malik AM, Furlan AJ, Rubiera M, Aghaebrahim A, Olivot JM, Tekle WG, Shields R, Graves T, Lewis RJ, Smith WS, Liebeskind DS, Saver JL, Jovin TG, DAWN Trial Investigators. Thrombectomy 6 to 24 Hours after Stroke with a Mismatch between Deficit and Infarct. The New England journal of medicine. 2018 Jan 4:378(1):11-21. doi: 10.1056/NEJMoa1706442.

46. Albers GW, Marks MP, Kemp S, Christensen S, Tsai JP, Ortega-Gutierrez S, McTaggart RA, Torbey MT, Kim-Tenser M, Leslie-Mazwi T, Sarraj A, Kasner SE, Ansari SA, Yeatts SD, Hamilton S, Mlynash M, Heit JJ, Zaharchuk G, Kim S, Carrozzella J, Palesch YY, Demchuk AM, Bammer R, Lavori PW, Broderick JP, Lansberg MG, DEFUSE 3 Investigators. Thrombectomy for Stroke at 6 to 16 Hours with Selection by Perfusion Imaging. The New England journal of medicine. 2018 Feb 22:378(8):708-718. doi: 10.1056/NEJMoa1713973.
47. Thomalla G, Simonsen CZ, Boutitie F, Andersen G, Berthezene Y, Cheng B, Cheripelli B, Cho TH, Fazekas F, Fiehler J, Ford I, Galinovic I, Gellissen S, Golsari A, Gregori J, Günther M, Guibernau J, Häusler KG, Hennerici M, Kemmling A, Marstrand J, Modrau B, Neeb L, Perez de la Ossa N, Puig J, Ringleb P, Roy P, Scheel E, Schonewille W, Serena J, Sunaert S, Villringer K, Wouters A, Thijs V, Ebinger M, Endres M, Fiebach JB, Lemmens R, Muir KW, Nighoghossian N, Pedraza S, Gerloff C, WAKE-UP Investigators. MRI-Guided Thrombolysis for Stroke with Unknown Time of Onset. The New England journal of medicine. 2018 Aug 16:379(7):611-622. doi: 10.1056/NEJMoa1804355.
48. Perry JJ, Sivilotti MLA, Émond M, Hohl CM, Khan M, Lesiuk H, Abdulaziz K, Wells GA, Stiell IG. Prospective Implementation of the Ottawa Subarachnoid Hemorrhage Rule and 6-Hour Computed Tomography Rule. Stroke. 2020 Feb:51(2):424-430. doi: 10.1161/STROKEAHA.119.026969.
49. Cho WS, Kim JE, Park SQ, Ko JK, Kim DW, Park JC, Yeon JY, Chung SY, Chung J, Joo SP, Hwang G, Kim DY, Chang WH, Choi KS, Lee SH, Sheen SH, Kang HS, Kim BM, Bae HJ, Oh CW, Park HS, Quality Control Committees from the Korean Society of Cerebrovascular Surgeons, Society of Korean Endovascular Neurosurgeons, Korean Society of Interventional Neuroradiology, Korean Stroke Society and Korean Academy of Rehabilitation Medicine. Korean Clinical Practice Guidelines for Aneurysmal Subarachnoid Hemorrhage. Journal of Korean Neurosurgical Society. 2018 Mar:61(2):127-166. doi: 10.3340/jkns.2017.0404.005.
50. Connolly ES Jr, Rabinstein AA, Carhuapoma JR, Derdeyn CP, Dion J, Higashida RT, Hoh BL, Kirkness CJ, Naidech AM, Ogilvy CS, Patel AB, Thompson BG, Vespa P, American Heart Association Stroke Council, Council on Cardiovascular Radiology and Intervention, Council on Cardiovascular Nursing, Council on Cardiovascular Surgery and Anesthesia, Council on Clinical Cardiology. Guidelines for the management of aneurysmal subarachnoid hemorrhage: a guideline for healthcare professionals from the American Heart Association/american Stroke Association. Stroke. 2012 Jun:43(6):1711-37. doi: 10.1161/STR.0b013e3182587839.
51. Thomalla G, Gerloff C. Acute imaging for evidence-based treatment of ischemic stroke. Current opinion in neurology. 2019 Aug:32(4):521-529. doi: 10.1097/WCO.0000000000000716.
52. Hanger HC, Geddes JA, Wilkinson TJ, Lee M, Baker AE. Warfarin-related intracerebral haemorrhage: better outcomes when reversal includes prothrombin complex concentrates. Internal medicine journal. 2013 Mar:43(3):308-16. doi: 10.1111/imj.12034.
53. Li X, Sun Z, Zhao W, Zhang J, Chen J, Li Y, Ye Y, Zhao J, Yang X, Xiang Y, Li G, Mao J, Zhang W, Zhang M, Zhang W. Effect of acetylsalicylic acid usage and platelet transfusion on postoperative hemorrhage and activities of daily living in patients with acute intracerebral hemorrhage. Journal of neurosurgery. 2013 Jan:118(1):94-103. doi: 10.3171/2012.9.JNS112286.
54. Baharoglu MI, Cordonnier C, Al-Shahi Salman R, de Gans K, Koopman MM, Brand A, Majoie CB, Beenen LF, Marquering HA, Vermeulen M, Nederkoorn PJ, de Haan RJ, Roos YB, PATCH Investigators. Platelet transfusion versus standard care after acute stroke due to spontaneous cerebral haemorrhage associated with antiplatelet therapy (PATCH): a randomised, open-label, phase 3 trial. Lancet (London, England). 2016 Jun 25:387(10038):2605-2613. doi: 10.1016/S0140-6736(16)30392-0.
55. Steiner T, Juvela S, Unterberg A, Jung C, Forsting M, Rinkel G, European Stroke Organization. European Stroke Organization guidelines for the management of intracranial aneurysms and subarachnoid haemorrhage. Cerebrovascular diseases (Basel, Switzerland). 2013:35(2):93-112. doi: 10.1159/000346087.
56. Rawal S, Alcaide-Leon P, Macdonald RL, Rinkel GJ, Victor JC, Krings T, Kapral MK, Laupacis A. Meta-analysis of timing of endovascular aneurysm treatment in subarachnoid haemorrhage: inconsistent results of early treatment within 1 day. Journal of neurology,

neurosurgery, and psychiatry. 2017 Mar:88(3):241-248. doi: 10.1136/jnnp-2016-314596.
57. Shi M, Yang C, Chen ZH, Xiao LF, Zhao WY. Efficacy and Safety of Tranexamic Acid in Aneurysmal Subarachnoid Hemorrhage: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. Frontiers in surgery. 2021:8():790149. doi: 10.3389/fsurg.2021.790149.
58. Gibson LM, Whiteley W. The differential diagnosis of suspected stroke: a systematic review. The journal of the Royal College of Physicians of Edinburgh. 2013:43(2):114-8. doi: 10.4997/JRCPE.2013.205.
59. Luengo-Fernandez R, Paul NL, Gray AM, Pendlebury ST, Bull LM, Welch SJ, Cuthbertson FC, Rothwell PM, Oxford Vascular Study. Population-based study of disability and institutionalization after transient ischemic attack and stroke: 10-year results of the Oxford Vascular Study. Stroke. 2013 Oct:44(10):2854-61. doi: 10.1161/STROKEAHA.113.001584.
60. Sennfält S, Norrving B, Petersson J, Ullberg T. Long-Term Survival and Function After Stroke: A Longitudinal Observational Study From the Swedish Stroke Register. Stroke. 2019 Jan:50(1):53-61. doi: 10.1161/STROKEAHA.118.022913.
61. Peng Y, Ngo L, Hay K, Alghamry A, Colebourne K, Ranasinghe I. Long-Term Survival, Stroke Recurrence, and Life Expectancy After an Acute Stroke in Australia and New Zealand From 2008-2017: A Population-Wide Cohort Study. Stroke. 2022 Aug:53(8):2538-2548. doi: 10.1161/STROKEAHA.121.038155.
62. Ekker MS, Verhoeven JI, Vaartjes I, Jolink WMT, Klijn CJM, de Leeuw FE. Association of Stroke Among Adults Aged 18 to 49 Years With Long-term Mortality. JAMA. 2019 Jun 4:321(21):2113-2123. doi: 10.1001/jama.2019.6560.
63. Flach C, Muruet W, Wolfe CDA, Bhalla A, Douiri A. Risk and Secondary Prevention of Stroke Recurrence: A Population-Base Cohort Study. Stroke. 2020 Aug:51(8):2435-2444. doi: 10.1161/STROKEAHA.120.028992.
64. Skajaa N, Adelborg K, Horváth-Puhó E, Rothman KJ, Henderson VW, Thygesen LC, Sørensen HT. Risks of Stroke Recurrence and Mortality After First and Recurrent Strokes in Denmark: A Nationwide Registry Study. Neurology. 2022 Jan 24:98(4):e329-e342. doi: 10.1212/WNL.0000000000013118.
65. Vahedi K, Hofmeijer J, Juettler E, Vicaut E, George B, Algra A, Amelink GJ, Schmiedeck P, Schwab S, Rothwell PM, Bousser MG, van der Worp HB, Hacke W, DECIMAL, DESTINY, and HAMLET investigators. Early decompressive surgery in malignant infarction of the middle cerebral artery: a pooled analysis of three randomised controlled trials. The Lancet. Neurology. 2007 Mar:6(3):215-22
66. Rincon F, Mayer SA. Clinical review: Critical care management of spontaneous intracerebral hemorrhage. Critical care (London, England). 2008:12(6):237. doi: 10.1186/cc7092.
67. Diringer MN, Neurocritical Care Fever Reduction Trial Group. Treatment of fever in the neurologic intensive care unit with a catheter-based heat exchange system. Critical care medicine. 2004 Feb:32(2):559-64
68. Mayer SA, Kowalski RG, Presciutti M, Ostapkovich ND, McGann E, Fitzsimmons BF, Yavagal DR, Du YE, Naidech AM, Janjua NA, Claassen J, Kreiter KT, Parra A, Commichau C. Clinical trial of a novel surface cooling system for fever control in neurocritical care patients. Critical care medicine. 2004 Dec:32(12):2508-15
69. Hammer A, Ranaie G, Erbguth F, Hohenhaus M, Wenzl M, Killer-Oberpfalzer M, Steiner HH, Janssen H. Impact of Complications and Comorbidities on the Intensive Care Length of Stay after Aneurysmal Subarachnoid Haemorrhage. Scientific reports. 2020 Apr 10:10(1):6228. doi: 10.1038/s41598-020-63298-9.
70. Winstein CJ, Stein J, Arena R, Bates B, Cherney LR, Cramer SC, Deruyter F, Eng JJ, Fisher B, Harvey RL, Lang CE, MacKay-Lyons M, Ottenbacher KJ, Pugh S, Reeves MJ, Richards LG, Stiers W, Zorowitz RD, American Heart Association Stroke Council, Council on Cardiovascular and Stroke Nursing, Council on Clinical Cardiology, and Council on Quality of Care and Outcomes Research. Guidelines for Adult Stroke Rehabilitation and Recovery: A Guideline for Healthcare Professionals From the American Heart Association/American Stroke Association. Stroke. 2016 Jun:47(6):e98-e169. doi: 10.1161/STR.0000000000000098.
71. Coleman ER, Moudgal R, Lang K, Hyacinth HI, Awosika OO, Kissela BM, Feng W. Early Rehabilitation After Stroke: a Narrative Review. Current atherosclerosis reports. 2017 Nov 7:19(12):59. doi: 10.1007/s11883-017-0686-6.
72. National Collaborating Centre for Chronic Conditions (UK). Stroke: National Clinical Guideline for Diagnosis and Initial Management of Acute Stroke and Transient Ischaemic Attack (TIA). 2008
73. Almhdawi KA, Mathiowetz VG, White M, delMas RC. Efficacy of Occupational Therapy Task-oriented Approach in Upper Extremity Post-stroke Rehabilitation. Occupational therapy international. 2016 Dec:23(4):444-456. doi: 10.1002/oti.1447.
74. Gandhi DB, Sterba A, Khatter H, Pandian JD. Mirror Therapy in Stroke Rehabilitation: Current

Perspectives. Therapeutics and clinical risk management. 2020:16():75-85. doi: 10.2147/TCRM.S206883.
75. Patel A, Fang J, Gillespie C, Odom E, King SC, Luncheon C, Ayala C. Awareness of Stroke Signs and Symptoms and Calling 9-1-1 Among US Adults: National Health Interview Survey, 2009 and 2014. Preventing chronic disease. 2019 Jun 20:16():E78. doi: 10.5888/pcd16.180564.
76. Sirisha S, Jala S, Vooturi S, Yada PK, Kaul S. Awareness, Recognition, and Response to Stroke among the General Public-An Observational Study. Journal of neurosciences in rural practice. 2021 Oct:12(4):704-710. doi: 10.1055/s-0041-1735822. Epub 2021 Sep 23
77. Meschia JF, Bushnell C, Boden-Albala B, Braun LT, Bravata DM, Chaturvedi S, Creager MA, Eckel RH, Elkind MS, Fornage M, Goldstein LB, Greenberg SM, Horvath SE, Iadecola C, Jauch EC, Moore WS, Wilson JA, American Heart Association Stroke Council, Council on Cardiovascular and Stroke Nursing, Council on Clinical Cardiology, Council on Functional Genomics and Translational Biology, Council on Hypertension. Guidelines for the primary prevention of stroke: a statement for healthcare professionals from the American Heart Association/American Stroke Association. Stroke. 2014 Dec:45(12):3754-832. doi: 10.1161/STR.0000000000000046.
78. Kirchhof P, Benussi S, Kotecha D, Ahlsson A, Atar D, Casadei B, Castella M, Diener HC, Heidbuchel H, Hendriks J, Hindricks G, Manolis AS, Oldgren J, Popescu BA, Schotten U, Van Putte B, Vardas P, Agewall S, Camm J, Baron Esquivias G, Budts W, Carerj S, Casselman F, Coca A, De Caterina R, Deftereos S, Dobrev D, Ferro JM, Filippatos G, Fitzsimons D, Gorenek B, Guenoun M, Hohnloser SH, Kolh P, Lip GY, Manolis A, McMurray J, Ponikowski P, Rosenhek R, Ruschitzka F, Savelieva I, Sharma S, Suwalski P, Tamargo JL, Taylor CJ, Van Gelder IC, Voors AA, Windecker S, Zamorano JL, Zeppenfeld K. 2016 ESC Guidelines for the management of atrial fibrillation developed in collaboration with EACTS. Europace : European pacing, arrhythmias, and cardiac electrophysiology : journal of the working groups on cardiac pacing, arrhythmias, and cardiac cellular electrophysiology of the European Society of Cardiology. 2016 Nov:18(11):1609-1678
79. Chiu CC, Lin HF, Lin CH, Chang HT, Hsien HH, Hung KW, Tung SL, Shi HY. Multidisciplinary Care after Acute Care for Stroke: A Prospective Comparison between a Multidisciplinary Post-Acute Care Group and a Standard Group Matched by Propensity Score. International journal of environmental research and public health. 2021 Jul 20:18(14):. doi: 10.3390/ijerph18147696.
80. Clarke DJ, Forster A. Improving post-stroke recovery: the role of the multidisciplinary health care team. Journal of multidisciplinary healthcare. 2015:8():433-42. doi: 10.2147/JMDH.S68764.
81. Fisher RJ, Byrne A, Chouliara N, Lewis S, Paley L, Hoffman A, Rudd A, Robinson T, Langhorne P, Walker MF. Effectiveness of Stroke Early Supported Discharge: Analysis From a National Stroke Registry. Circulation. Cardiovascular quality and outcomes. 2020 Aug:13(8):e006395. doi: 10.1161/CIRCOUTCOMES.119.006395