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ROLE OF CONTRAST-ENHANCED COMPUTED TOMOGRAPHY IN THE DIAGNOSIS AND MANAGEMENT OF INTRACRANIAL HAEMORRHAGE: A REVIEW

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ABSTRACT

Intracranial haemorrhage (ICH) is a neurological emergency associated with high rates of mortality and long-term disability. Early and accurate diagnosis is critical for timely intervention and improved patient outcomes. Non-contrast computed tomography (NCCT) is the standard initial imaging modality for detecting acute intracranial bleeding because of its speed, accessibility, and high sensitivity. However, contrast-enhanced computed tomography (CECT), particularly CT angiography (CTA), has become an essential adjunct by identifying the underlying vascular cause of haemorrhage, detecting active bleeding, and predicting haematoma expansion. CTA can demonstrate aneurysms, arteriovenous malformations (AVMs), cerebral venous thrombosis, tumour-related haemorrhage, and the CTA spot sign, which is an important prognostic marker. This review summarizes current evidence regarding the role of contrast-enhanced CT in the diagnosis, evaluation, and management of intracranial haemorrhage. The review also discusses recent advances in multidetector CT technology, artificial intelligence, and imaging biomarkers that have improved diagnostic accuracy and clinical decision-making. Overall, contrast-enhanced CT complements NCCT by providing valuable anatomical and vascular information that guides treatment planning and improves

patient outcomes.

KEYWORDS: Intracranial haemorrhage, Contrast-enhanced CT, CT angiography, Neuroimaging, Stroke, Spot sign.

INTRODUCTION

Intracranial haemorrhage refers to bleeding within the cranial vault and represents one of the most serious neurological emergencies encountered in clinical practice. It accounts for approximately 10–20% of all strokes worldwide and is associated with high morbidity and mortality. The condition may occur spontaneously due to hypertension, cerebral aneurysms, vascular malformations, cerebral amyloid angiopathy, anticoagulant therapy, or coagulation disorders, or may result from traumatic brain injury.

Prompt diagnosis is essential because treatment options and prognosis depend on the type, location, and cause of bleeding. Imaging is therefore central to patient evaluation. Computed tomography has revolutionized emergency neuroimaging because it rapidly identifies intracranial bleeding with excellent sensitivity. Although NCCT remains the first-line investigation, it cannot always determine the underlying source of haemorrhage. Consequently, contrast-enhanced CT, particularly CTA, has become increasingly important for evaluating vascular lesions and guiding treatment.

Classification of Intracranial Haemorrhage

Intracranial haemorrhage is classified according to the location of bleeding:

- **Intracerebral haemorrhage (ICH):** Bleeding into the brain parenchyma, commonly
- associated with hypertension and cerebral amyloid angiopathy.
- **Subarachnoid haemorrhage (SAH):** Bleeding into the subarachnoid space, most often caused by rupture of an intracranial aneurysm.
- **Subdural haematoma (SDH):** Venous bleeding between the dura and arachnoid mater, frequently resulting from trauma.
- **Epidural haematoma (EDH):** Arterial bleeding between the skull and dura mater, usually caused by injury to the middle meningeal artery.
- **Intraventricular haemorrhage (IVH):** Bleeding into the ventricular system, either primary or secondary to another haemorrhage.

Each subtype has distinct radiological features and clinical implications, making accurate imaging crucial for diagnosis and management.

Role of Non-Contrast CT

NCCT is the preferred initial imaging modality in suspected intracranial haemorrhage because it is rapid, widely available, and highly sensitive for detecting acute blood. Fresh haemorrhage appears hyperdense owing to the high attenuation of haemoglobin.

NCCT enables clinicians to assess:

- Presence and location of haemorrhage
- Haematoma size and volume
- Midline shift
- Mass effect
- Hydrocephalus
- Intraventricular extension

Despite these advantages, NCCT has limitations. It does not reliably identify vascular abnormalities or active bleeding, which are critical for determining the cause of haemorrhage and planning definitive treatment.

Role of Contrast-Enhanced CT

Contrast-enhanced CT has emerged as an important complementary investigation. Intravenous iodinated contrast enhances cerebral vessels, allowing detailed visualization of vascular anatomy and pathology.

The major indications for contrast-enhanced CT include:

- Spontaneous intracerebral haemorrhage in younger patients
- Lobar haemorrhage without hypertension
- Suspected aneurysm
- Suspected arteriovenous malformation
- Tumour-related haemorrhage
- Cerebral venous sinus thrombosis
- Recurrent or unexplained haemorrhage

CTA is particularly valuable because it can identify the source of bleeding quickly and non-invasively, often replacing conventional digital subtraction angiography as the initial vascular imaging technique.

CT Angiography and the Spot Sign

One of the most significant developments in recent years is the recognition of the **CTA spot sign**, which represents active contrast extravasation within the haematoma.

Numerous studies have shown that the spot sign predicts:

- Ongoing bleeding
- Haematoma expansion
- Neurological deterioration
- Increased mortality
- Poor functional outcome

Patients demonstrating a positive spot sign require closer monitoring and may benefit from aggressive medical management or early neurosurgical intervention.

Applications in Different Types of Haemorrhage Intracerebral Haemorrhage

Contrast-enhanced CT detects active bleeding, vascular malformations, tumour-related haemorrhage, cerebral venous thrombosis, and aneurysms. It also assists in predicting haematoma expansion and surgical outcomes.

Subarachnoid Haemorrhage

CTA has become the preferred investigation for identifying ruptured aneurysms. It provides accurate information regarding aneurysm size, morphology, and location, thereby facilitating surgical clipping or endovascular coiling.

Subdural and Epidural Haematoma

Although NCCT usually establishes the diagnosis, contrast-enhanced CT may be indicated when vascular injury or underlying pathology is suspected.

Intraventricular Haemorrhage

CTA helps identify aneurysms, AVMs, and other vascular abnormalities responsible for ventricular bleeding.

Clinical Importance

Contrast-enhanced CT has significantly improved the management of intracranial haemorrhage by providing additional diagnostic and prognostic information.

Clinical benefits include:

- Early identification of treatable vascular lesions
- Improved neurosurgical planning
- Prediction of haematoma expansion
- Better risk stratification
- Guidance for endovascular therapy
- Reduced diagnostic uncertainty

The combination of NCCT and CTA provides comprehensive assessment of both haemorrhage and its underlying cause.

Advantages

Major advantages of contrast-enhanced CT include:

- Rapid examination
- High diagnostic accuracy
- Excellent visualization of intracranial vessels
- Detection of aneurysms and AVMs
- Identification of active bleeding
- Better prognostic evaluation
- Wide availability
- Less invasive than catheter angiography

Limitations

Despite its advantages, contrast-enhanced CT has several limitations:

- Exposure to ionizing radiation
- Risk of allergic reaction to iodinated contrast
- Contrast-induced nephropathy
- Limited soft-tissue characterization compared with MRI
- Contraindications in severe renal impairment

MRI remains superior for chronic haemorrhage, microbleeds, cavernous malformations, and detailed tumour characterization.

Recent Advances

Recent technological developments have enhanced the role of contrast-enhanced CT. These include:

- Multidetector CT (MDCT)
- Dual-energy CT
- CT perfusion imaging
- Artificial intelligence-assisted haemorrhage detection
- Automated haematoma volume measurement
- Radiomics and machine-learning algorithms for outcome prediction

These innovations are expected to improve diagnostic accuracy and facilitate personalized management of patients with intracranial haemorrhage.

Future Perspectives

Future research should focus on large multicentre studies evaluating the prognostic value of imaging biomarkers and artificial intelligence. Integration of clinical, laboratory, and imaging data may further refine risk prediction and optimize individualized treatment strategies.

CONCLUSION

Contrast-enhanced CT has become an indispensable adjunct to non-contrast CT in the evaluation of intracranial haemorrhage. While NCCT remains the first-line investigation for detecting acute bleeding, CTA and other contrast-enhanced techniques provide critical information regarding the source of haemorrhage, vascular abnormalities, active contrast extravasation, and prognosis. The CTA spot sign is a valuable predictor of haematoma expansion and clinical outcome. With continuous advances in CT technology and artificial intelligence, contrast-enhanced CT is expected to play an even greater role in emergency neuroimaging and patient management.

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