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Deep-seated intracranial haematomas

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EANS Training Course , Vascular Neurosurgery

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Why is ICH important?

- one of the top neurological / intracerebral emergencies
  - **ICH** , ischemic stroke, TBI, SAH ….
- despite knowledge on etiology, often timely diagnosis, it has defied attempts to find a scientifically proven effective therapy
- possible treatments
  - slowing or stopping bleeding
  - evacuation of haematoma - decrease mass effect, prevent secondary brain injury, toxic effect of haemoglobin / iron (perihematomal edema, PHE)

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SPONTANEOUS INTRACEREBRAL HAEMATOMA

- most common type of spontaneous intracranial haemorrhage (vs SAH and IVH)
- accounts for 15% of stroke, BUT most serious and least treatable !!!
  - mortality 30-40% in 1st month
- at bedside difficult to differentiate from acute ischaemic stroke..
  - rapidly progressive neurological signs and symptoms,
  - headache, vomiting, seizures,
  - reduced consciousness often disproportionate to focal deficits !!

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Acute assessment

- ABCs (Airway, Breathing, Circulation..)
- **Neuroimaging**
  - **Non-contrast CT** : detection of haematoma !!

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Acute assessment

- ABCs (Airway, Breathing, Circulation..)
- **Neuroimaging**
  - **Non-contrast CT** : detection of haematoma !!
  - CT angiography :
    - detect / rule out aneurysm, AVM nidus…
    - spot sign in primary ICH : prediction of haematoma growth
  - MRI - shows nuances, signs suggestive of underlying pathology (CAA, tumor, AVM, dAVF…)
  - other imaging modalities (which, when?)

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Acute assessment

- About 2/3 of ICH remain stable after initial bleed , but 1/3 progress in size in first 24h !!
- decision to treat (how and when) dependant on haematoma stability

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CT signs (prediction of haematoma growth)

A - spot sign

- detectable on CT-A
- contrast extravasation - indicator of active hemorrhage
- most reliable predictor of the risk of hematoma expansion
- clinical utility not defined

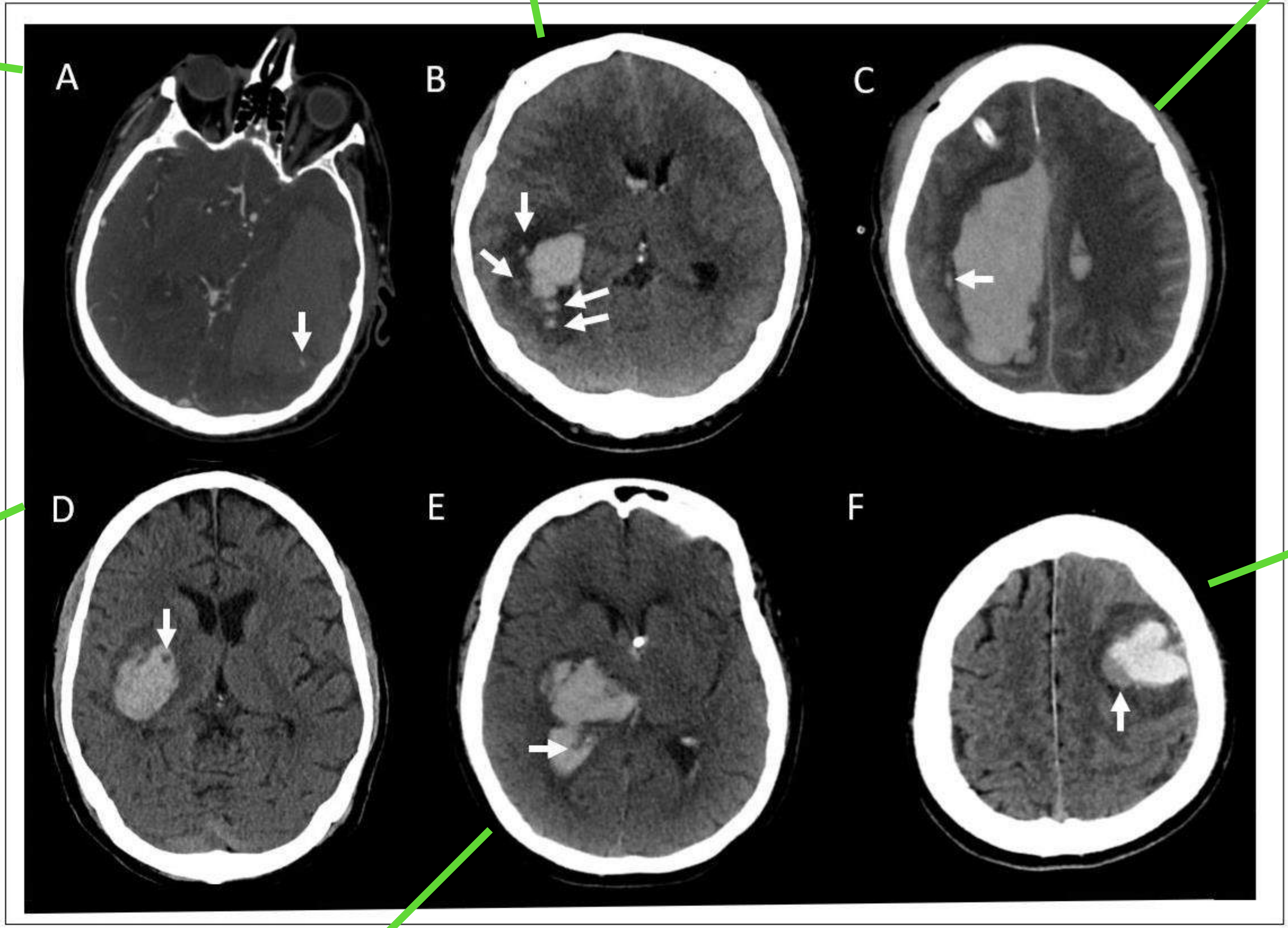
B - island sign

C - satellite sign

D - black hole sign

E - swirl sign

F - blend sign



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Hannah, Diagnostics 2021

SPONTANEOUS INTRACEREBRAL HAEMATOMA

- Etiology
  - Primary vs Secondary
  - Primary : heterogeneous diseases, affecting microvasculature, prone to bleed
  - rule out secondary, detection of causes for primary has prognostic values

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SPONTANEOUS INTRACEREBRAL HAEMORRHAGE

- Primary ICH
  - primary accounts for 78%-88% of all ICH
  - risk factors: **age, hypertension, smoking, alcohol abuse,** dietary, genetic…
  - rupture of small arteries (arterioles)
    - Hypertensive (perforators, basal ganglia, thalamic, brainstem, cerebellar?..)
    - Cerebral amyloid angiopathy (CAA) - presence of amyloid-β in cortical/leptomeningial arteries (lobar haematomas)

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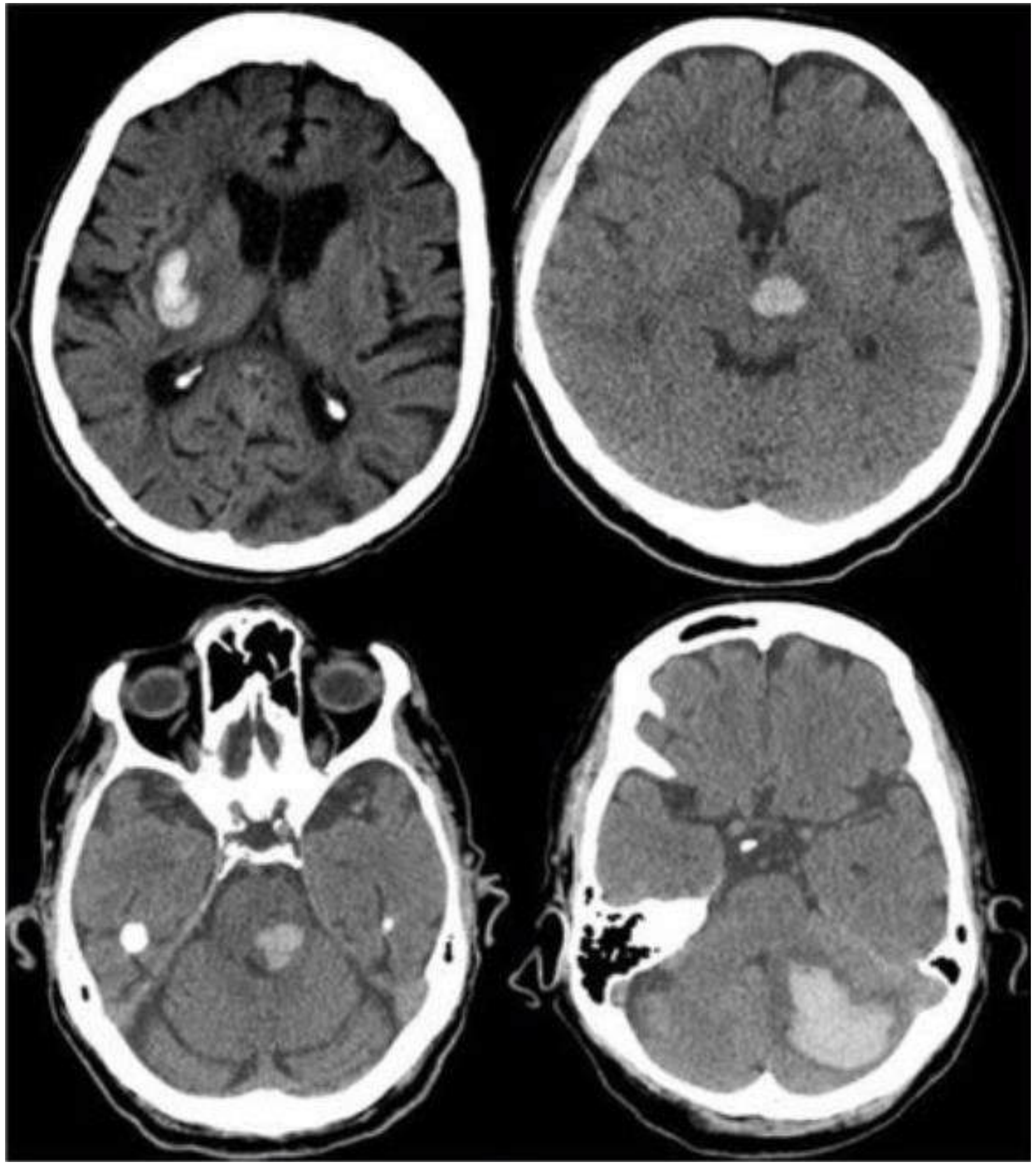
- Most common locations for typical hypertensive ICH
  - basal ganglia
  - thalamus
  - deep cerebellar nuclei
  - midbrain
  - pons
  - lobes
- Hemorrhagic transformation of ischemic stroke (10-15%)



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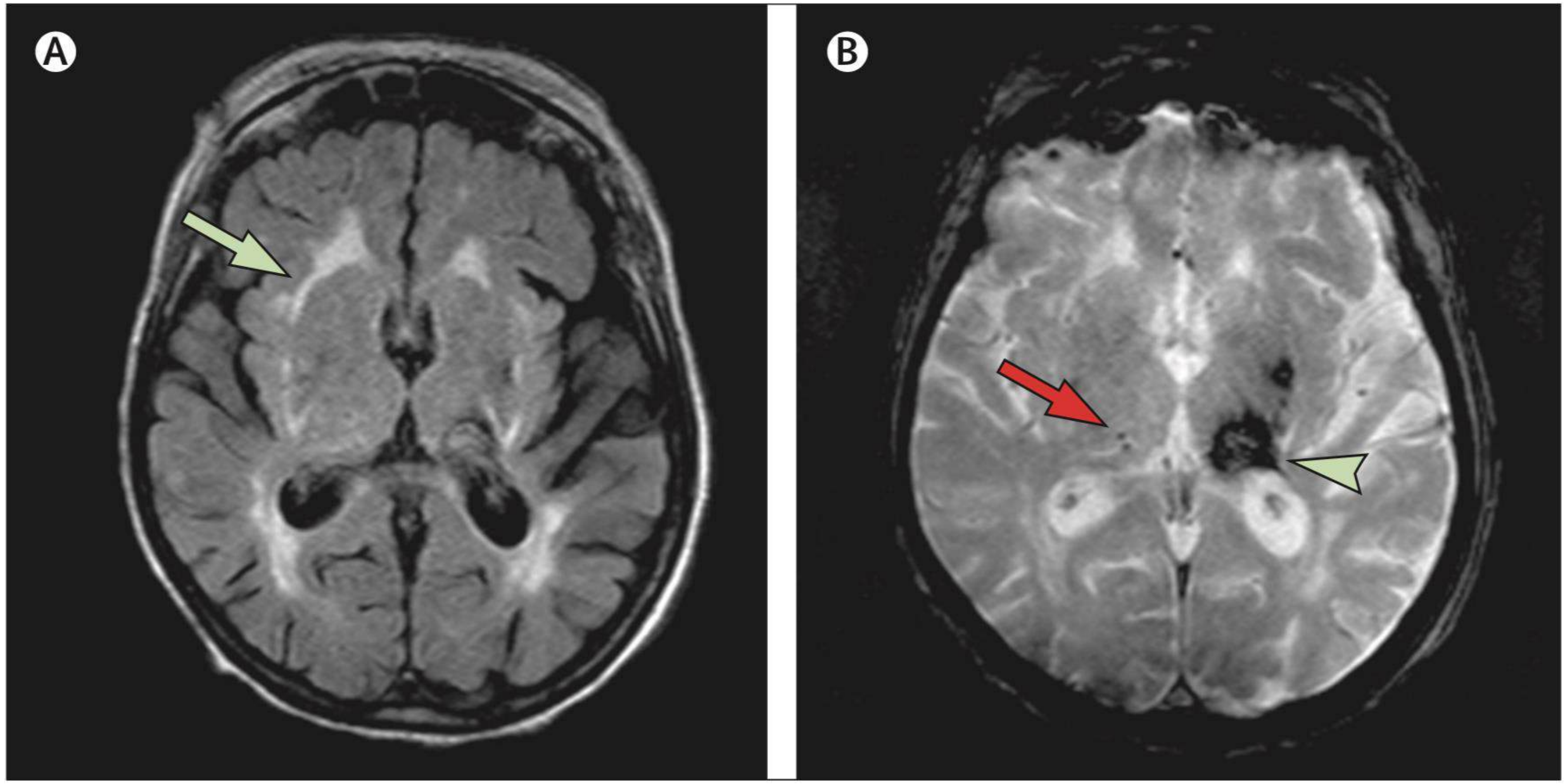
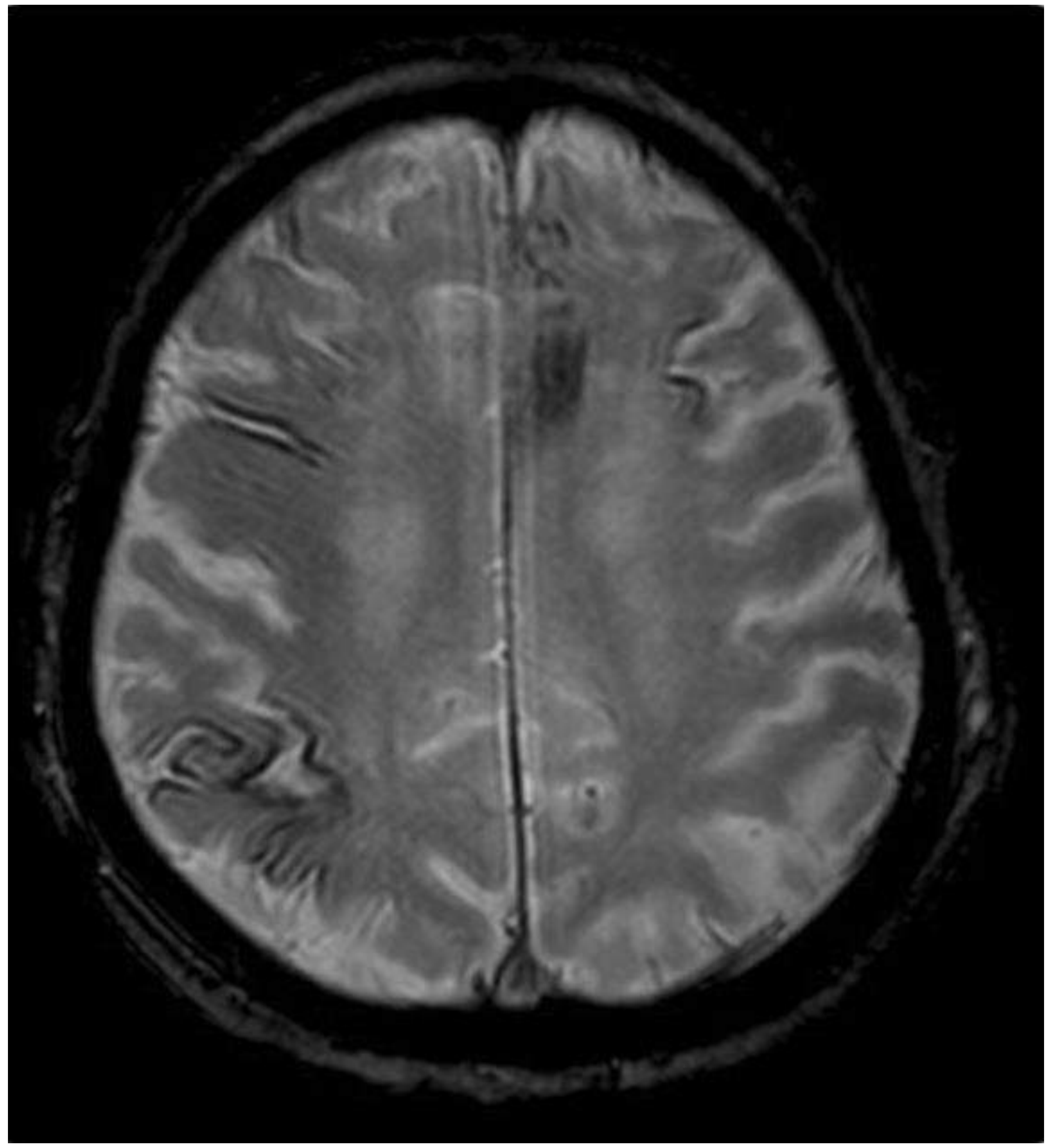
Value of MRI in diagnostics for ICH





vasculopathy, lacunae **microhaemorrhages** **deep haematoma** **superficial siderosis**

Deep perforating vasculopathy or arteriolosclerosis
“hypertensive ICH “

CAA

Cordonnier, Lancet 2018

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Cerebral amyloid angiopathy

- annual rebreeding rate 9% to 26%!
- risk of cognitive decline, dementia
- Diagnosis certain only postmortem, but probable / possible with imaging + clinical +/- histological data
  - MRI - based Boston criteria 2.0 (updated in 2022)
    - age, No of ICH, cortical siderosis
  - CT - based Edinburgh CT and genetic criteria
    - finger-like hematoma, APOE4

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78% - 88%
of all ICH

PRIMARY

Panel 2: Clues for underlying causes of intracerebral haemorrhage

Deep perforating vasculopathy
- Haematoma located in the basal ganglia or brainstem; microbleeds or old intracerebral haemorrhage in the basal ganglia or brainstem; white matter lesions; lacunes

Cerebral amyloid angiopathy
- Lobar intracerebral haemorrhage; cortico-subcortical microbleeds; cortical superficial siderosis; apolipoprotein E ε4; cognitive decline; transient focal neurological episodes

Brain arteriovenous malformation
- Extension to other brain compartments; flow voids; calcification

Intracranial arterial aneurysm
- Disproportionate subarachnoid extension

Cavernous malformation
- Small, homogeneous intracerebral haemorrhage with no extension to other brain compartments

Intracranial venous thrombosis
- Headaches preceding intracerebral haemorrhage onset; intracerebral haemorrhage close to sinuses or veins; high relative oedema volume; onset in pregnancy or postpartum

Dural arteriovenous fistula
- Subarachnoid or subdural extension; abnormal dilated cortical vessels

Haemorrhagic transformation of cerebral infarction
- Substantial areas of acute ischaemic lesions adjacent to the intracerebral haemorrhage or diffuse acute ischaemic lesions in other arterial territories

Severe clotting factor deficiency such as haemophilia
- Abnormal coagulation tests

Tumour (primary/metastasis)
- Large perihaematomal oedema

Vasculitis
- Headaches; small acute ischaemic lesions in different arterial territories; focal diffuse arterial stenosis

Infective endocarditis
- Acute ischaemic lesions in different arterial territories; small irregular arterial aneurysms; diffuse brain microbleeds

Posterior reversible encephalopathy syndrome
- Thunderclap headaches; parietal and occipital asymmetrical oedematous lesions

SECONDARY

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Cordonnier, Lancet 2018

Prognostic scales

- ICH score
- simple, prognosticates outcome (mortality)
  - age,
  - GCS,
  - location and size of ICH

Table 3. The Intracerebral Hemorrhage Score[a]

Factors	Points
GCS score	
3-4	2
5-12	1
13-15	0
Age, y	
≥ 80	1
< 80	0
Infratentorial hemorrhage	
Yes	1
No	0
Volume, mL	
≥30	1
< 30	0
Intraventricular hemorrhage	
Yes	1
No	0
Total score	Risk of mortality, %
0	0
1	13
2	26
3	72
4	97
5	100

Abbreviation: GCS, Glasgow Coma Scale.

[a] Adapted from data from Hemphill et al.[35]

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TREATMENT

- Management within a specialist acute stroke unit
- Blood pressure control
  - attenuation of haematoma growth as most plausible mechanistic action
  - TRIALS on reduced RR:
    - INTERACT2 , ATACH-II - randomised trials, discordant results
    - ..evidence is reasonably strong to recommend intensive blood pressure lowering (target systolic blood pressure range 130–140 mm Hg within 6 h of onset) for most patients

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TREATMENT

- For patients on antiplatelet therapy - RCT showed worse outcome with platelet transfusion!
- Patients on anticoagulation should receive reversal agents ASAP
  - warfarin - 4-factor prothrombin complex, vitamin K
  - dabigatran (Pradaxa) - idarucizumab
  - apixaban (Eliquis), rivaroxaban (Xarelto) - andexanet alpha
- No benefit in homeostatic agents (factor VIIa, tranexamic acid - shown to reduce haematoma size but no effect on mortality or functional outcome)

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Panel 1: **Key management steps in intracerebral haemorrhage**

Brain and vascular imaging

- Imaging should be done to detect an underlying cause that requires early intervention—eg, vascular malformation, cerebral venous thrombosis, vasculitis, reversible cerebral vasoconstrictor syndrome where the likelihood of diagnosis is higher on the basis of patient age (>50 years), intracerebral haemorrhage location (peripheral or cortical), history of hypertension (absent), and presence of cerebral small vessel disease (imaging features)
- CT angiography spot sign predicts haematoma growth but whether this improves upon established clinical and haematoma predictive markers is still to be defined
- MRI can detect chronic microhaemorrhaging and cerebral superficial siderosis, which is helpful for the diagnosis of cerebral amyloid angiopathy

Stroke unit care

Lowering of blood pressure (systolic target <140 mm Hg over 1–2 h)

Correction of haemostatic abnormalities

- Consider whether there is a specific disease (eg, haematological disorder)
- Consider whether this disease is due to a specific anticoagulant drug and whether a reversal agent or antidote is required

Prevention of complications

- Careful identification of deteriorating patients requiring neurosurgical intervention
- Use of intermittent pneumatic compression therapy for venous thromboembolism prophylaxis
- Management of seizures

Search for the cause of the intracerebral haemorrhage

Prevention

- Lower blood pressure to prevent recurrent intracerebral haemorrhage and other serious vascular events
- Consider whether there is a high risk of recurrent intracerebral haemorrhage to prevent starting or restarting antithrombotic treatment to prevent ischaemic events
- Screen for cognitive impairment during follow-up

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Neurosurgery

- Types of surgical procedure?

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Neurosurgery

- Types of surgical procedure?
- Craniotomy and hematoma evacuation

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Neurosurgery

- Types of surgical procedure?
- Craniotomy and hematoma evacuation
- Minimally invasive surgery

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Neurosurgery

- Types of surgical procedure?
- Craniotomy and hematoma evacuation
- Minimally invasive surgery
  - Stereotactic evacuation / catheter placement and drainage
  - Endoscopic evacuation
  - Endoport / microsurgery
  - Craniopuncture

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Neurosurgery

- Types of surgical procedure?
- Craniotomy and hematoma evacuation
- Minimally invasive surgery
  - Stereotactic evacuation / catheter placement and drainage
  - Endoscopic evacuation
  - Endoport / microsurgery
  - Craniopuncture
- Decompressive craniotomy +/- hematoma evacuation

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Craniotomy for supratentorial hemorrhage evacuation

- most studied, most commonly used
- 1st RCT in the 1960s (McKissock, 180 pts) - surgery had worse outcome
- 2 large, well-designed, well-powered, multicenter, multinational RCTs
  - Surgical Trial in Intracerebral Hemorrhage (STICH in 2005 ; STICH II in 2013)

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Surgical Trial in Intracerebral Hemorrhage (STICH)

- Mendelow et al. Lancet, 2005
- Randomized 1033 patients with supratentorial hemorrhage to
  - **Early surgery** within 72 hrs from ictus vs **Standard of care** (medical management, with delayed surgery if necessary)
  - 83 centers from 27 countries
- **RESULT : No difference in favourable functional outcome at 6 months was found (p=0.414)**
  - however, a subgroup of patients with superficial ICHs who underwent surgery had better outcomes; this prompted STICH II
- Criticism due to large crossover to surgical group

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STICH II

- Same authors, same strategy (F-up study), 2013
- Randomized pts with superficial (within 1 cm from cortex, 10-100 mL) lobar haematomas to early surgery vs medical management with delayed surgery if necessary
- Patients in coma or with IVH not included
- **RESULT: no difference in mortality or severe disability with early surgery (p=0.37)**
- When the STICH trials results are combined in a meta-analysis with other 13 studies (sample size of 3366) **patients with predicted poorer prognosis, delayed clinical deterioration or superficial lobar ICH without IVH may have a potential survival benefit**

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Minimally invasive surgical approaches for ICH

- creating as little of brain trauma as possible
- principles of neuronavigation and / or stereotaxy
- catheter + thrombolysis, neuroendoscopy, microsurgery through ports

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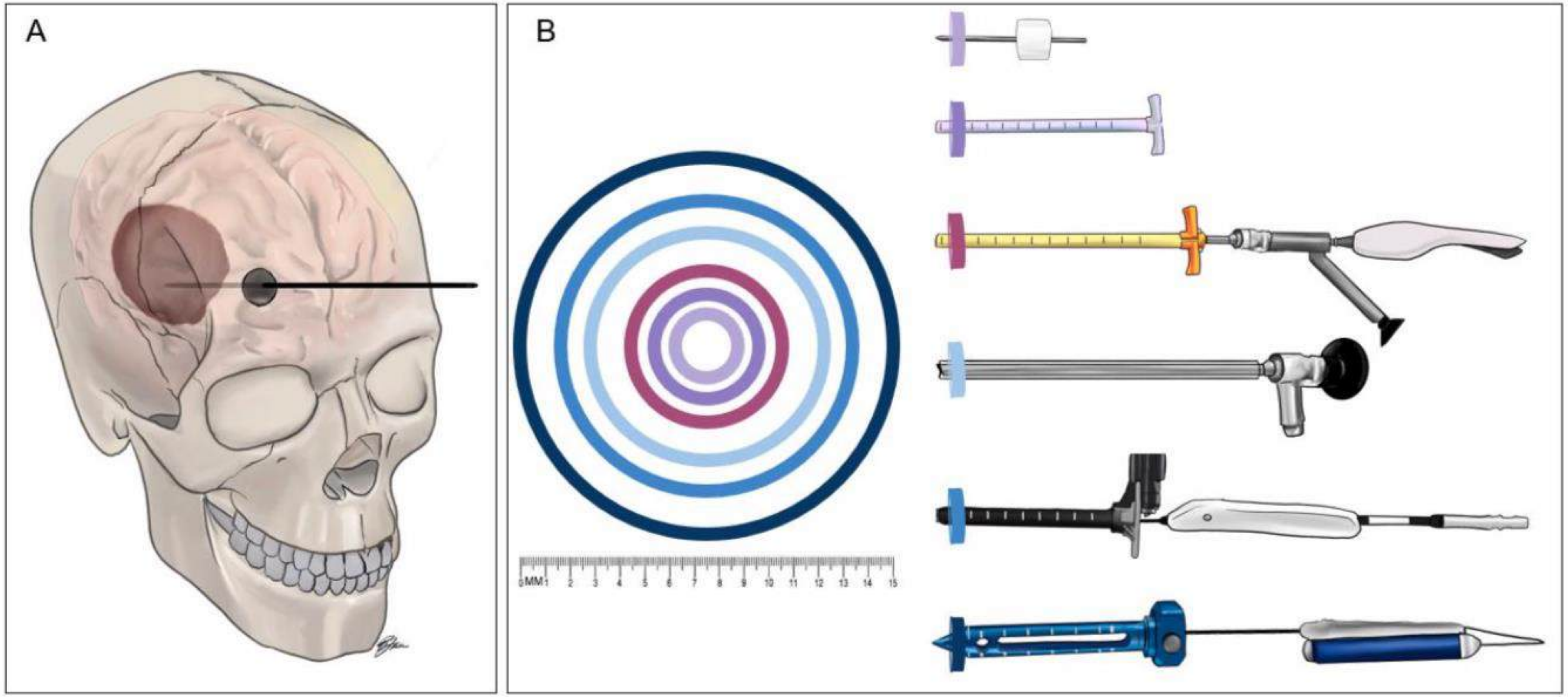

Figure 2. The relative sizes of the instruments of minimally invasive surgery for intracerebral hemorrhage (ICH) evacuation. (**A**) Generic sketch of the minimally invasive approach to intracerebral hemorrhage evacuation. A small craniotomy is made and the chosen device is inserted through the cranial opening and into brain parenchyma until reaching the hematoma. (**B**) Sketches of the ICH evacuation devices with concentric rings demonstrating the widest diameter of the instrument inserted through brain parenchyma for each technique. The color of each concentric ring corresponds to the color at the tip of the device in the illustrations. The devices, from top to bottom, are the craniopuncture YL-1 needle (outer diameter: 3.0 mm), the 14F vascular sheath used in the Minimally Invasive Surgery Plus Rt-PA for ICH Evacuation (MISTIE) procedure (4.8 mm), the Artemis device inserted through a 19F vascular sheath and a 3-port Endoscope such as the Storz Lotta (6.3 mm), the clear sheath used during endoscope-assist procedures (10.0 mm), the Aurora Surgiscope (11.5 mm), and the BrainPath endoport (15.8 mm).

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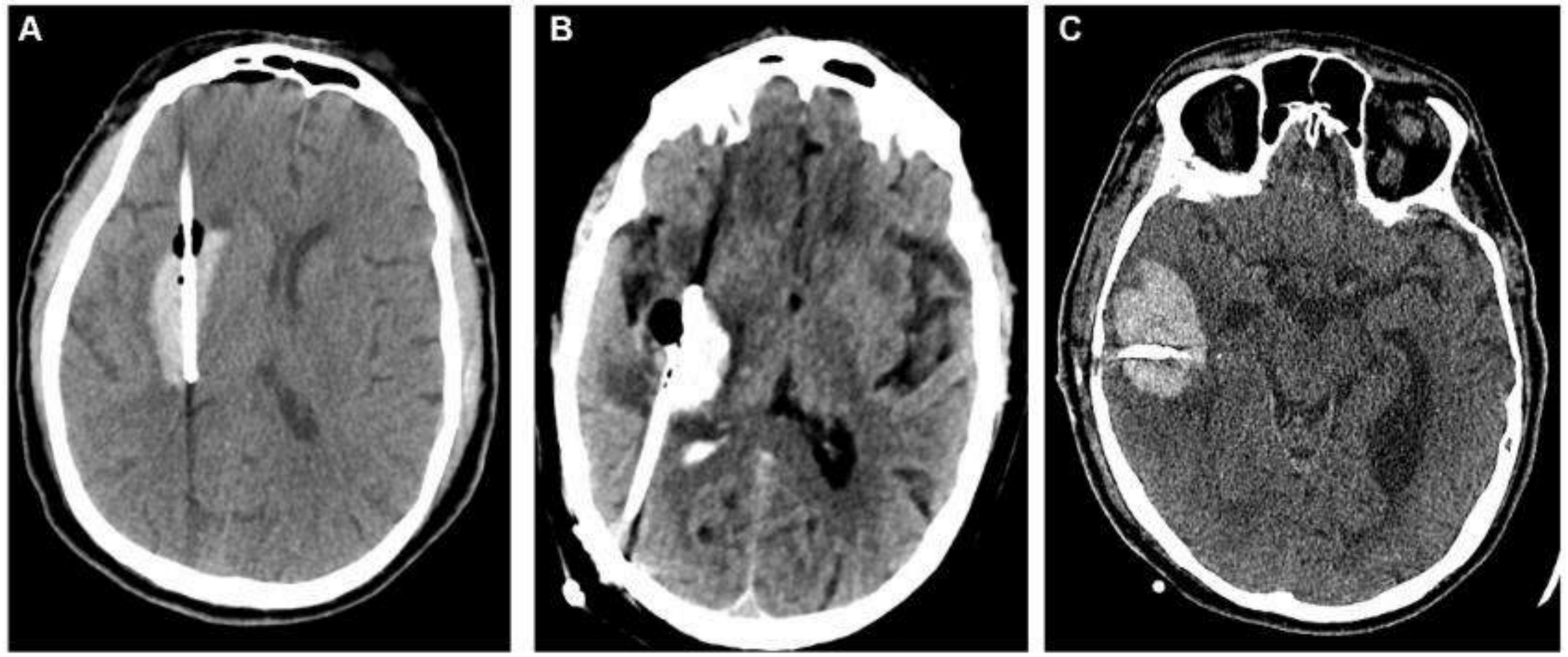
Minimally invasive catheter evacuation followed by thrombolysis (MISTIE)

- stereotactic or image-guided placement of a catheter inside the hematoma, followed by the intrahemorrhage thrombolysis

- initial aspiration through needle, then periodical instillation of 1 mL alteplase every 8hrs to reduce ICH to 15 mL or up to a total of 9 doses of thrombolytic



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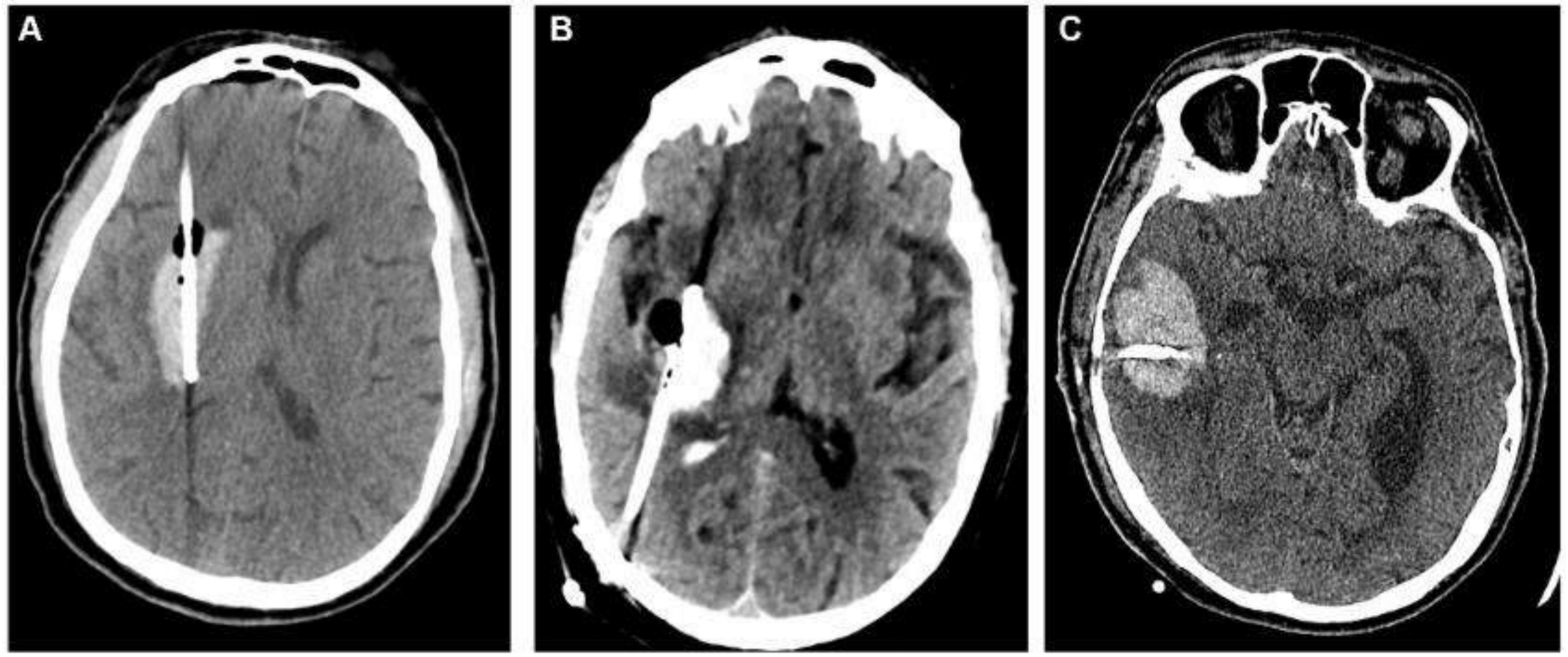
Minimally invasive catheter evacuation followed by thrombolysis (MISTIE)

- CONCLUSION:
- MISTIE is safe, able to reduce ICH size, but does not improve long-term functional outcome



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MIS systems

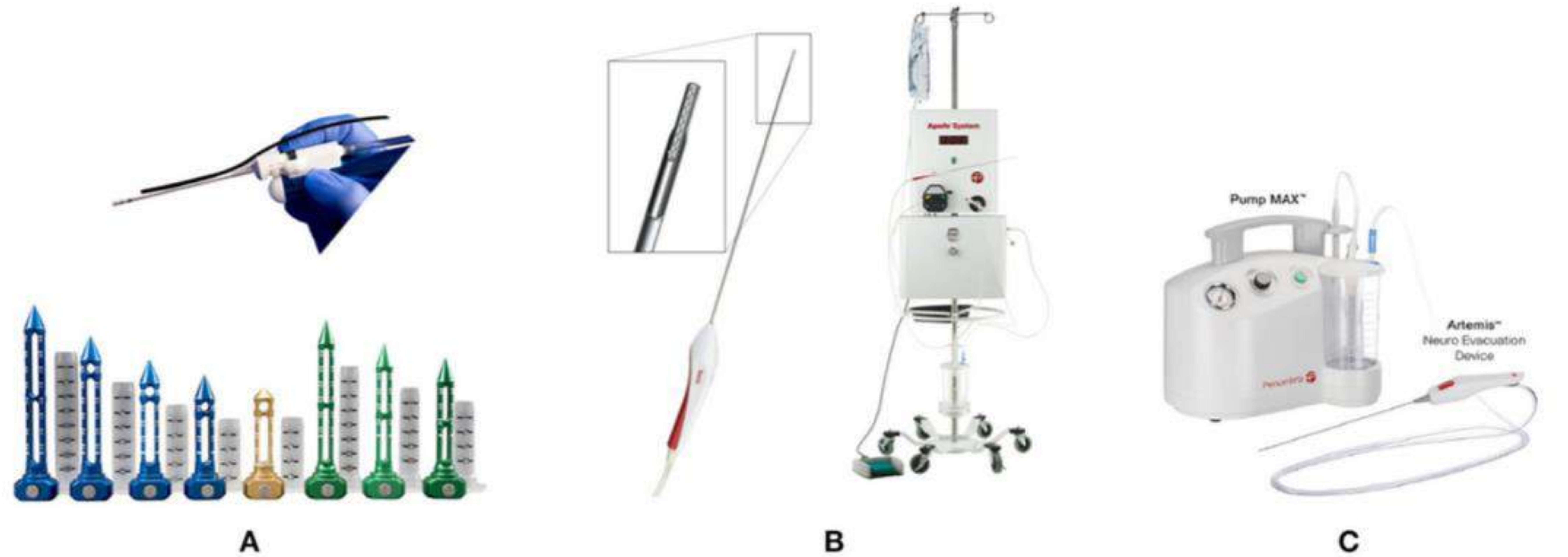

FIGURE 3 | Emerging minimally invasive instruments. **(A)** NICO BrainPath system and myriad handpiece (NICO Corp, Indianapolis, IN, USA). **(B)** The Apollo system. The Wand and aspiration–irrigation system (Penumbra Inc, Alameda, CA, USA). **(C)** The Artemis Neuro Evacuation Device and Pump MAX^{TM} aspiration system (Penumbra, Alameda, CA, USA).

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TABLE 2 | Ongoing studies of minimally invasive surgery for intracerebral hemorrhage.

Study*	Study type	Intervention	Primary endpoint	Patients number	Time window	Study start point	Estimated study completion point
ENRICH	Randomized	NICO BrainPath and Myriad	Functional improvement (mRS)	300	<24 h	December 2016	December 2021
INVEST	Single arm	Apollo System	Rate of recruitment/successful follow up obtainment	50	<72h	June 30, 2017	June 2021
MIND	Randomized	Artemis Neuro Evacuation Devices	Global disability (mRS)/Mortality	500	<72 h	February 7, 2018	July 2025
DIST	Non-randomized	Artemis Neuro Evacuation Devices	Death/Neurological deterioration/Proportion of volume reduction	400	<8 h	December 3, 2018	February 2021
EVACUATE	Randomized	Aurora Surgiscope System	mRS	240	<8 h	September, 2020	December, 2026
MIRROR	Observational	Aurora Surgiscope System	Rate of Surgical Success (reduction to <15 ml)	500	<12 h	October, 2020	October, 2029

**Official title of the study.*
ENRICH, A Multi-center, Randomized, Clinical Trial Comparing Standard Medical Management to Early Surgical Hematoma Evacuation Using Minimally Invasive Parafascicular Surgery (MIPS) in the Treatment of Intracerebral Hemorrhage (ICH).
INVEST, A Single Arm, Feasibility Study of Minimally Invasive Endoscopic Surgical Treatment with Apollo for Supratentorial Intracerebral Hemorrhage (ICH).
MIND, A Prospective, Multicenter Study of Artemis: A Minimally Invasive Neuro Evacuation Device in the Removal of Intracerebral Hemorrhage.
DIST, The Dutch Intracerebral Hemorrhage Surgery Trial Pilot Study: Minimally-invasive Endoscopy-guided Surgery for Spontaneous Intracerebral Hemorrhage.
EVACUATE, Ultra-Early, Minimally inVAsive intraCerebral Hemorrhage evacUATion vs. Standard treatment.
MIRROR, Minimally Invasive IntRaceRebral HemORrhage Evacuation.
mRS, modified Rankin Scale.

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GUIDELINES

- **American Heart Association/American Stroke Association** *Guidelines for the Management of Spontaneous Intracerebral Hemorrhage*
- **European Stroke Organization (ESO)** *Guidelines for the management of spontaneous intracerebral hemorrhage*
- *Emergency Neurological Life Support: Intracerebral Hemorrhage*

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GUIDELINES

Stroke
Volume 53, Issue 7, July 2022; Pages e282-e361
https://doi.org/10.1161/STR.0000000000000407

American Heart Association.

AHA/ASA GUIDELINE

2022 Guideline for the Management of Patients With Spontaneous Intracerebral Hemorrhage: A Guideline From the American Heart Association/American Stroke Association

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6.1.1. MIS Evacuation of ICH

Recommendations for MIS Evacuation of ICH
Referenced studies that support recommendations are summarized in Data Supplements 55 and 56.

COR	LOE	Recommendations
2a	B-R	1. For patients with supratentorial ICH of >20- to 30-mL volume with GCS scores in the moderate range (5–12), minimally invasive hematoma evacuation with endoscopic or stereotactic aspiration with or without thrombolytic use can be useful to reduce mortality compared with medical management alone.[379–388]
2b	B-R	2. For patients with supratentorial ICH of >20- to 30-mL volume with GCS scores in the moderate range (5–12) being considered for hematoma evacuation, it may be reasonable to select minimally invasive hematoma evacuation over conventional craniotomy to improve functional outcomes.[382,383,385–387,389,390]
2b	B-R	3. For patients with supratentorial ICH of >20- to 30-mL volume with GCS scores in the moderate range (5–12), the effectiveness of minimally invasive hematoma evacuation with endoscopic or stereotactic aspiration with or without thrombolytic use to improve functional outcomes is uncertain.[379–385,387,388]

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6.1.3. Craniotomy for Supratentorial Hemorrhage

Recommendations for Craniotomy for Supratentorial Hemorrhage Referenced studies that support recommendations are summarized in Data Supplements 63 and 64.		
COR	**LOE**	**Recommendations**
2b	**A**	1. For most patients with spontaneous supratentorial ICH of moderate or greater severity, the usefulness of craniotomy for hemorrhage evacuation to improve functional outcomes or mortality is uncertain.[380,382,384,393,429–431]
2b	**C-LD**	2. In patients with supratentorial ICH who are deteriorating, craniotomy for hematoma evacuation might be considered as a lifesaving measure.[382,384,429,432]

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6.1.4. Craniotomy for Posterior Fossa Hemorrhage

Recommendations for Craniotomy for Posterior Fossa Hemorrhage Referenced studies that support recommendations are summarized in Data Supplement 65.		
COR	**LOE**	**Recommendation**
1	**B-NR**	1. For patients with cerebellar ICH who are deteriorating neurologically, have brainstem compression and/or hydrocephalus from ventricular obstruction, or have cerebellar ICH volume ≥15 mL, immediate surgical removal of the hemorrhage with or without EVD is recommended in preference to medical management alone to reduce mortality.[442–444]

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6.2. Craniectomy for ICH

Recommendations for Craniectomy for ICH
Referenced studies that support recommendations are summarized in Data Supplements 66 through 68.

COR	LOE	Recommendations
2b	C-LD	1. In patients with supratentorial ICH who are in a coma, have large hematomas with significant midline shift, or have elevated ICP refractory to medical management, decompressive craniectomy with or without hematoma evacuation may be considered to reduce mortality.[453–460]
2b	C-LD	2. In patients with supratentorial ICH who are in a coma, have large hematomas with significant midline shift, or have elevated ICP refractory to medical management, effectiveness of decompressive craniectomy with or without hematoma evacuation to improve functional outcomes is uncertain.[458–462]

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