Audit of CT Reporting Standards in Cases of Intracerebral Haemorrhage at a Comprehensive Stroke Centre in Australia

Running title

Audit of CT Reporting Standards in ICH

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Abstract:

Introduction: Multiple CT-derived biomarkers that are predictive of intracerebral hemorrhage (ICH) growth and outcome have been described in the literature, but the extent to which these appear in imaging reports of ICH is unknown. The aim of this retrospective process audit was to determine which of the known predictors of ICH outcome were recorded in reports of the disease, with a view to providing reporting recommendations, as appropriate.

Method: We examined the initial CT report of patients diagnosed with ICH presenting to a metropolitan comprehensive stroke centre and meeting inclusion criteria during the audit period between March 1st, 2013 to February 28th 2014. Each report was assessed for the inclusion of the following ICH characteristics: number of measurement dimensions; volume; location; hydrocephalus; shape; density; 'CTA spot sign' (where CTA was performed).

Results: A total of 100 patients met audit inclusion criteria. At least one ICH dimension was recorded in 90% of reports, however, 39% did not include measurements in three dimensions and volume was reported in just 6%. No ICH dimension was recorded in 10% of reports. With the exception of density and shape, reporting of other CT features exceeded 95%. Where CTA was performed (58%), 14/58 (24%) reported the 'CTA spot sign' status.

Conclusion: In this audit, volume was the most under-reported of the established ICH characteristics predictive of ICH outcome. Readily calculated from multiplanar reformats using the ABC/2 technique, the routine reporting of ICH volume is recommended. More reporting attention to ICH density heterogeneity and shape irregularity is encouraged, given their emerging importance. Where acute CTA is performed, the presence of any dynamic haemorrhage (CTA spot sign) should be reported.

Key Words:

Audit; Computed tomography; CT Angiography; Intracerebral hemorrhage; Report

Introduction:

Timely radiology reports targeting clinically relevant information are crucial for good patient care, for consideration of trial eligibility, medical treatment planning, assessment for potential neurosurgical intervention as well as for the purposes of resource allocation, prognostication and occasionally end-of-life decision making. Prognostically significant clinical and imaging findings of intracranial haemorrhage (ICH) have been comprehensively described in the literature (Table 1).

Whilst previous hemostatic treatment trials in ICH have established the ability to reduce hematoma growth when administered within four hours of symptom onset,¹ the largest Phase III trial did not achieve statistically significant clinical benefit for several reasons, including inclusion of patients without evidence of active bleeding.^{2,3} As a result, three trials of hemostatic agents based upon imaging-based treatment randomisation according to CTA spot sign status are in progress, targeting patients with imaging evidence of dynamic hemorrhage,⁴ two in North America (STOP-IT: NCT00810888; SPOTLIGHT: NCT01359202) and one in Australia, (STOP-AUST: NCT01702636).

A thorough literature search found that the extent to which relevant imaging findings are reported in cases of ICH is unknown. The aim of this targeted retrospective process audit was to assess the reports of patients suffering ICH over one year of admissions at a metropolitan comprehensive stroke centre in Australia, evaluating which of the known predictors of ICH growth and outcome were included in the first imaging report provided, with a view to providing reporting recommendations for our institution and beyond, where necessary.

[INSERT TABLE 1]

Table 1. Predictors of ICH Outcome

(Modified and updated from Butcher et al.)⁵ PCE = post-contrast CT extravasation.

Methods

Patients

At our institution all patients with suspected stroke or transient ischemic attack (TIA) are referred for non-contrast CT brain. Patients with acute stroke are referred to a 'Code Stroke' service that operates 24 hours a day, all year, consisting of an experienced stroke fellow and a stroke research nurse, with continuous on-call neurologist support. Continuous radiologist or radiology registrar reporting is present in the Emergency Department. All 'Code Stroke' patients are pre-notified by the transferring ambulance and undergo expedited transfer to the Emergency CT scanner.²⁸ All patients are screened for trial eligibility by the code stroke team on the basis of their presenting history and examination findings and all admitted stroke unit patients are entered into the stroke database. This database was utilized to identify all cases of CT-demonstrated ICH over a 12 month period from March 1st, 2013 to February 28th 2014. For

the ICH investigation presented, patients were included on the basis of identification of non-traumatic, primary intracerebral hemorrhage identified on baseline diagnostic CT brain, within 24 hours of symptom onset as recorded in the stroke database. In line with recommendations of both European²⁹ and American Stroke authorities,³⁰ patients presenting to our hospital with acute ICH within 6 hours (the period most likely to demonstrate ICH growth), undergo CT angiography of the Circle of Willis as standard care, unless contraindicated or otherwise avoided at the discretion of the responsible physician. No traceable patient information was recorded for the purposes of this project, all results tabulated and anonymised, including imaging, in keeping with standard audit procedure. No templates or mandated guidelines for reporting of ICH were in place over the audit period. Formal institutional ethics approval for this project was obtained.

Audit Criteria

All patients presenting to a metropolitan emergency department and comprehensive stroke centre in Melbourne, Australia with intracerebral hemorrhage over the study period meeting eligibility criteria were included in the audit. Each patient's presenting CT brain scan, at which the diagnosis of ICH was made, and the associated radiology report relating to each patient's ICH, was scrutinised by single rater (CB). Specifically, all stated findings were confirmed or queried by a single radiologist (CB) and where discrepancies arose, a final consensus was achieved with a second radiologist (HA), both experienced in neuroimaging. The designation of the reporting radiologist was recorded (neuroradiologist; general or other subspecialist radiologist; fellow/registrar; external report). After-hours emergency department imaging (Sunday-Friday 6pm-12am; Saturday 6pm-2am) was reported by an external teleradiology reporting service. When co-reported, the most senior designated radiologist was recorded.

Patients were *excluded* from analysis if:

- I. The initial CT scan that was diagnostic of ICH was not performed at the index hospital (ie. cases of transfer from other hospital, with imaging performed and reported elsewhere).
- II. The CT scan revealed no evidence of ICH (ie. in contradistinction to the stroke database) such as primary intraventricular hemorrhage or subarachnoid hemorrhage.
- III. The patient was not recorded in the stroke database

The data *recorded* in this audit were as follows:

- I. Number of dimensions of ICH measurement (none, one, two or three). Note that the omission of the craniocaudal dimension may exclude the greatest ICH dimension from assessment (fig 1)
- II. Whether ICH volume was reported (Y/N)
- III. Whether ICH location was reported (Y/N)
- IV. Whether hydrocephalus was reported as present or absent (Y/N)
- V. Whether intraventricular hemorrhage was reported (Y/N)
- VI. Whether ICH density was reported (Y/N)
- VII. Whether ICH shape was reported (Y/N)
- VIII. If CT angiography of the Circle of Willis was performed, whether the presence/absence of the CTA 'spot sign' was reported (Y/N)

Where no ICH dimension was recorded, a case-by-case analysis of the precise wording of the report was invoked, and an estimate of the ICH volume was performed by a single rater (CB) using the ABC/2 formula.³¹ This procedure was performed to examine for any common features to these cases and to assess the relationship between any subjective size descriptors (for example 'small', 'medium' or 'large') and actual ICH volume.

[INSERT FIGURE 1]

CAPTION:

Fig.1 ICH in which the largest dimension is the coronal plane. ICH dimensions 2.9cm (trans) x 3.7cm (ap) x 4.5cm (cc).

Results

In the 12 month period, 109 patients were recorded in the hospital stroke database as having been admitted with the CT-proven diagnosis of ICH. Nine patients were excluded, leaving 100 patients whose imaging and accompanying radiology report were analysed. A summary flowchart of the audit selection process is presented in Figure 2.

[INSERT FIGURE 2]

CAPTION:

Fig. 2 Enrolment flowchart

The reasons for *exclusion* were:

- I. Presence of primary intraventricular hemorrhage (5 patients). Forms of intracranial hemorrhage other than ICH were not evaluated.
- II. Initial CT scan, diagnostic of ICH, performed external to the index hospital i.e. patient transfer from another hospital (3 patients)
- III. Ruptured aneurysm with predominantly subarachnoid hemorrhage, arguable small intracerebral hemorrhagic component (1 patient)

Reports were provided by a neuroradiologist in 44/100 (44%) of cases, a general or other subspecialty radiologist in 32/100 (32%) cases, an external teleradiologist in 7/100 (7%) and a registrar or fellow in 17/100 (17%) of cases.

Hemorrhage dimensions:

Overall 10 patients (10%) had no ICH dimension reported; zero had one dimension reported (0%); 29 (29%) had two dimensions reported; and 61 (61%) had three dimensions reported. Only 6 patients (6%) had their ICH volume reported (method of calculation not known), and all cases where this occurred were in the context of reporting ICH size in three dimensions.

Of the 10 patients where no ICH dimension was recorded, the report was more likely to have been issued by a registrar or fellow (3/17, 17.6%) than a neuroradiologist (3/44, 6.8%), a general or other subspecialty radiologist (3/32, 9.4%) or an external teleradiologist (1/7, 14.3%). Details of these 10 cases are presented in Table 2.

Table 2: Unreported ICH dimension case-by-case analysis

Location:

98/100 (98%) of patient reports made mention of the location of the haemorrhage. Of the 2 cases where ICH location was not mentioned, both were externally reported by an afterhours

reporting service. One mentioned a 'cerebral haemorrhage' (actually left temporo-parietal) and one report missed a left pontine haemorrhage, subsequently re-reported as an amendment by a local radiologist (within 6 hours).

Intraventricular hemorrhage (IVH):

91/100 (91%) of patient reports made mention of the presence or absence of intraventricular hemorrhage. Of the 9 cases where IVH was not mentioned, none was deemed to be present.

Hydrocephalus:

98/100 (98%) of patient reports made mention of the presence or absence of hydrocephalus. Of the 2 cases where hydrocephalus was not mentioned, none was deemed to be present.

Shape and Density:

Only 1/100 (1%) of patient reports made mention of ICH shape. Only 4/100 (4%) of patient reports made mention of ICH density. Three of the four cases were in the setting of anti-coagulant related ICH. The fourth mentioned 'hyperacute, hypodense intraventricular blood.'

CTA Circle of Willis information:

58/100 (58%) of patients received CTA following their ICH. Of these cases, 14/58 (24%) of reports made mention of the presence/absence of the spot sign. Where present, consensus review of the accuracy of this interpretation was concordant. In one case of spot sign recognition reported by a registrar and subspecialty radiologist that was not a neuroradiologist, the report described presence of a 'dot sign', which is a separate neuroimaging phenomenon, consisting of punctate hyperdensity within the Sylvian fissure indicative of acute middle cerebral artery thrombosis (M2 segment).

The remainder of the 44/58 (76%) cases, the presence or absence of the CTA 'spot sign' was not mentioned. The CTA spot sign was not identified by the authors in any of these cases.

Imaging criteria stratified by reporter designation are presented in Table 3.

[INSERT TABLE 3]

CAPTION:

Table 3: Reported imaging features of ICH, stratified by reporter designation. Data are presented as the number (and percentage) of cases.

Discussion

This audit has demonstrated that whilst the majority of reports (90%) include at least one dimension of hemorrhage size, ICH volume is substantially under-reported, despite the availability of multiplanar reformats and simple volume measurement techniques. Of the reports analysed, 39% did not mention all three measurements and a minority (6%) commented on the estimated volume.

The omission of hematoma volume in reports of ICH is important given the predictive capacity of ICH volume for morbidity and mortality in this disease, and the fundamental importance of this parameter for trial eligibility. The capacity for the radiologist to easily provide accurate volume data is elevated by the ready availability of multiplanar reformats that can accurately depict the craniocaudal ICH volume, where previously this had to be estimated by multiplication of slice thickness by the number of axial CT slices containing hematoma. In this study, 29% of reports included two ICH axial dimensions. The omission of the craniocaudal dimension may exclude the greatest ICH dimension from the hematoma assessment (Fig. 1).

In this study, the reporting radiologist was observed to under-report the importance of ICH volume when the ICH volume was small. Of the 10 cases where no ICH dimension was reported, half of these measured less than 10mL. ICH volume is readily calculated using the ABC/2 formula.³¹ The accuracy of this formula is diminished in irregularly-shaped hemorrhages that depart from the ellipsoid assumptions of this methodology, and in oral-anticoagulant-related ICH.³² A report omitting an ICH dimension was more than twice as likely to have been issued by a trainee radiologist (3/17, 17.6%), rather than a consultant radiologist (7/83, 8.4%).

Descriptors of ICH size appear to be inconsistent and unreliably subjective. Among those reports where no dimension was reported, the word 'large' was applied to ICH volumes that ranged from 13.5mL to 115mL. The largest volume for which no reference to ICH size was made was 17.5mL, greater than the smallest of the subjectively labelled 'large' hemorrhages.

The frequency of reports providing specific reference to important ICH prognostic features of intraventricular extension (91%), hydrocephalus (98%), and location (98%) was high. These imaging characteristics are recognised as relevant descriptors (whether positive or negative) in this dataset.

The density and shape of hemorrhage were not regularly employed descriptors of ICH morphology in this audit. It has been demonstrated that larger hemorrhages are more irregular in shape, more heterogeneous in density and grow more.²³ Though identified in two of the earliest papers describing cardinal morphological characteristics of ICH,^{33, 34} density and shape are possibly regarded as too subjective for reliable assessment and inclusion in reports of the disease. Qualitative methodologies for shape and density categorisation²³ and predominantly operator-independent methodologies of ICH quantitative densitometry measurement have been described,³⁵ and these factors motivated the inclusion of these ICH characteristics in this audit. Irregular ICH shape (but not density) was found to be independently associated with poor outcome in a retrospective study of over 2000 patients.²⁶ Validation studies of qualitative and quantitative densitometry measures as predictors of outcome, presence of CTA spot sign and ICH growth have been performed in different patient cohorts.^{25, 27, 36} More attention to the reporting of ICH density (homogeneous/heterogeneous) and shape (regular/irregular) is recommended.

CT angiography is being increasingly applied in the imaging assessment of acute ICH, most often in comprehensive stroke centres, particularly in patients presenting within 6 hours of ictus. The CTA spot sign has been identified as an independent predictor of ICH growth and outcome,³⁷ and is representative of dynamic hemorrhage due to active contrast extravasation into an expanding hematoma. Three trials of hemostatic agents based on imaging identification of dynamic bleeding manifest as CTA spot sign positivity are in progress.^{4, 38, 39} The incidence of background intracranial vascular abnormality has been calculated at 13.1% in one study of patients with basal ganglia ICH, providing further incentive to perform CTA where deemed clinically appropriate.⁴⁰ Whilst there is generally consistent (>90%) reporting of the majority of relevant ICH growth and outcome predictors, better acknowledgement of presence/absence of the CTA spot sign could be achieved in imaging reports.

The absence of a specific report reference to a particular descriptive characteristic of any particular ICH does not necessarily mean that this characteristic was neglected by the reporter.

The possibility that the imaging characteristic was assessed but not reported is an alternative explanation for its omission. For example, the presence or absence of the CTA spot sign may have been considered to be irrelevant (overlooking the rare case of re-bleeding ICH) where the scan was performed greater than 6-12 hours post ictus, most active bleeding occurring early. Time-to-CTA was not recorded as part of this audit. Time-to-scan (from symptom onset) is a parameter frequently unknown by the reporting radiologist.

In other cases, prognostically important imaging characteristics may have been irrelevant to that case (an 'irrelevant negative'), such as the presence of IVH or hydrocephalus in the setting of a small lobar hemorrhage. These complexities were not explored as part of this audit. In other cases, the tendency to report only positive findings, rather than a comprehensive set of 'relevant negatives', was evidenced by the fact that no cases of 'missed' intraventricular hemorrhage or hydrocephalus were detected upon independent review of every case. Accordingly, it would be unreasonable to expect that all reports include direct reference to every prognostically significant imaging finding.

However, it is contended that ICH dimension (ideally volume) and location should be cardinal features of every report of ICH. The accurate description of ICH location is not only important prognostically (worse prognosis for infratentorial ICH compared to supratentorial ICH; hemorrhage at eloquent foci) but enables inferences regarding aetiology (eg. hypertensive basal ganglia centred ICH versus lobar amyloid angiopathy-associated ICH).

A possible limitation to this study is that a small number of patients presenting to the hospital with ICH may not have been recorded in the stroke database (that is, neurosurgical or emergency admissions without stroke unit consultation).

MRI has an important role in the imaging of ICH, particularly in younger patients where the possibility of an underlying vascular or structural abnormality (such as a tumour) is raised, but assessment of MRI data was outside the scope of this audit. The extent to which the reporting of the CTA spot sign or any other ICH imaging variable influences current clinical management or outcome requires further study.

Evidence-based, prognostically significant ICH characteristics that are recommended for inclusion in CT reports are presented in Table 4.

As a result of this audit, a set of recommendations was assembled, with a view to subsequent closure of the audit loop by way of a repeat audit in 12 months.

Recommendations

1. Educate radiologists and radiology registrars regarding importance of the prognostically-significant CT findings in acute ICH.
2. Explain the key findings relevant to ICH reporting to radiologists and radiology trainees by reviewing the current literature in departmental meetings, including relevance of clinical trials in ICH.
3. Convey the findings of this process audit to stakeholders, to remind everyone of current deficiencies and encouraging methodical reporting.
4. Establish a template for CT reports in cases with intracerebral haemorrhage, that is user friendly and easily accessible on the department's intranet.
5. Provide feedback to external radiologists reporting for the department and sharing the reporting guidelines and appropriate literature with them.
6. When all of the above has been achieved, a repeat audit in a year is recommended to assess the extent of compliance and whether reinforcement of recommendations 1-5 is required.

[INSERT TABLE 4]

Caption:

Table 4: Recommended CT reporting features of ICH

Conclusion

Modern acute stroke management and trials of experimental therapies are founded upon time-critical clinicroadiological assessment, best served by direct interaction of acute stroke neurology and radiology teams. The most under-reported non-contrast CT characteristic of ICH growth and outcome in this audit was ICH volume, and routine reporting of this important imaging feature is recommended. More attention should be given to ICH density and shape in

reporting of the disease. Where performed acutely (especially within 6 hours), the presence of dynamic hemorrhage (the CTA 'spot sign') should be reported.

The timely provision of accurate verbal and, ultimately, written radiology reports containing prognostically significant data is key to the prompt application of existing therapies, prognostication, resource allocation, as well as in assessment for trial eligibility in relevant centres.

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Table 1. Predictors of ICH Outcome

(Modified and updated from Butcher et al.)⁵ PCE = post-contrast CT extravasation.

Indicator	Predictors of favourable outcome	Predictors of unfavourable outcome
Clinical		
Glasgow coma scale ⁶⁻⁸	≥9	≤8
Intubation ^{9,10}	Not required	Required
Age ^{8,9}	Younger	Older (≥80)
Admission to neuro ICU ¹¹	Admitted	Not admitted
Do-not-resuscitate order ¹²	Not issued early	Issued early
Imaging		
Baseline volume ⁶	≤60mL	≥61mL (91% D ₃₀ mortality)
Hematoma growth ¹³	Absent	Present
CTA 'spot sign' or PCE ¹⁴⁻¹⁶	Absent	Present
Intraventricular hemorrhage ^{8,17-19}	Absent	Present
Location of ICH ^{8,20,21}	Supratentorial	Infratentorial
Hydrocephalus ²²	Absent	Present

Density and shape ²³⁻²⁷	Homogeneous density, regular shape	Heterogeneous density, irregular shape
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Table 2: Case-by-case analysis of unreported ICH dimensions

Patient number	Report reference to size	Actual size using ABC/2
1	None	1 mL pontine ICH
2	None	7 mL
3	None	8 mL
4	None	17.5 mL
5	Predominantly IVH, very difficult to measure ICH component	1mL
6	'Very small'	5 mL
7	'Large'	13.5 mL
8	'Large'	55 mL
9	'Large'	60 mL
10	'Large'	115 mL

Table 3. Reported imaging features of ICH, stratified by reporter designation. Data are presented as the number (and percentage) of cases.

	Neuroradiologist (N=44)	General/Other Subspecialty Radiologist (N=32)	Registrar or Fellow (N=17)	Teleradiologist (N=7)	Total (%)
ICH dimension					
None	3 (7)	3 (9)	3 (18)	1 (14)	10
One	0 (0)	0 (0)	0 (0)	0 (0)	0
Two	14 (32)	7 (22)	6 (35)	2 (29)	29
Three	27 (61)	22 (69)	8 (47)	4 (57)	61
Volume	1 (2)	5 (16)	0	0	6
Location	44 (100)	32 (100)	17 (100)	5 (71)	98
IVH	42 (95)	30 (94)	15 (88)	4 (57)	91
Hydrocephalus	43 (98)	32 (100)	17 (100)	6 (86)	98
Density	0 (0)	2 (6)	2 (12)	0 (0)	4
Shape	0 (0)	1 (3)	0 (0)	0 (0)	1

Table 4. Recommended CT reporting features of ICH

Location (side, site)

Three dimensions (ap x trans x cc)

Volume (ABC/2 technique, see text)

Presence of intraventricular hemorrhage

Presence of hydrocephalus/mass effect features

Shape (regular/irregular) and density (homogeneous/heterogeneous)

Presence of the CTA spot sign (where performed in the acute setting)

Presence of intracranial vascular abnormalities (where CTA performed)

Figure 1. ICH in which the largest dimension is the coronal plane.

ICH dimensions 2.9cm (trans) x 3.7cm (ap) x 4.5cm (cc).

Fig 2. Enrolment flowchart

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