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A quantitative analysis of CT angiography, large vessel occlusion, and thrombectomy rates in acute ischaemic stroke

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AIMS: To determine the workload of acute computed tomography angiography (CTA) in patients presenting with suspected acute ischaemic stroke (AIS) and rate of large vessel occlusion (LVO) and thrombectomy relative to suspected and confirmed stroke diagnoses across three stroke centres within the Republic of Ireland.

MATERIALS AND METHODS: A retrospective review of data from three stroke centres, one of which provides a 24-hour thrombectomy service was undertaken. The number of CTA studies performed from January 2015 to December 2017 for suspected AIS was quantified using the national PACS in addition to occlusion location, collateral status, and rates of LVO and thrombectomy. The hospital inpatient enquiry (HIPE) system was searched for all patients with a primary discharge diagnosis of stroke and then correlated with patients who underwent CTA on admission.

RESULTS: A total of 2,358 CTA studies were performed for suspected AIS during the study period across three stroke centres. LVO was demonstrated in 18.4% of suspected AIS, 18.4% of primary discharge stroke diagnoses, and 40.2% of confirmed AIS who underwent CTA. A total of 283 thrombectomies were performed of which 64.6% were LVO. Thrombectomy was performed in 12% of suspected AIS, 12% of overall primary discharge diagnoses of stroke cases, and 26% of confirmed stroke who underwent CTA.

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CONCLUSION: Establishing the volume of acute CTAs and rates of LVO and thrombectomy when compared to suspected AIS on admission, confirmed stroke diagnoses who underwent CTA and primary discharge diagnosis of stroke is essential for the planning and provision of stroke services worldwide.

Introduction

Acute ischaemic stroke (AIS) causes considerable morbidity and mortality; however, early detection and treatment may reduce mortality rates and improve functional outcomes.[1] Multiple diagnostic paradigms have been demonstrated as effective in selecting suitable patients for endovascular thrombectomy, including evaluation with urgent unenhanced computed tomography (CT) of the brain to out rule haemorrhage and quantify ischaemic change (Alberta Stroke Program Early CT score [ASPECTS]) and CT angiography (CTA) to identify occlusion location and collateral circulation. An advantage of this approach is the availability and accessibility of CTA.[1,2]

Thrombectomy has firmly established itself as the standard of care in the treatment of proximal anterior circulation stroke, with benefit in selected patients demonstrated up to 24 hours from onset.[3,4] Despite an expanding therapeutic time limit, fast workflow remains an essential factor in managing AIS, with time shown to have direct impact on functional outcome.[5–7] Early access to imaging presents a challenge to healthcare systems worldwide, which are obliged to adapt to the evolving treatment paradigms for AIS patients.

Currently, there are few data defining the number of stroke patients who are eligible for thrombectomy, relative to the overall number of AIS patients, or the numbers of those who present with symptoms suggestive of AIS. Furthermore, a paucity of data exists on the impact on radiology workload in the emergent evaluation of all suspected large vessel occlusion (LVO) AIS, regardless of whether the findings are positive or not. The aim of this study was to determine the volume of workload related to initial CTA diagnostic imaging and the rate of vessel occlusion and thrombectomy in patients who present to hospital with symptoms suggestive of AIS and are investigated using CTA, patients with confirmed acute stroke diagnoses who underwent CTA during admission, and patients with overall primary discharge diagnoses of stroke (despite their initial presentation and investigation pathway).

Materials and methods

A retrospective review of data from stroke services operating in three separate hospitals was performed. A prospective database is maintained of all aspects of this process under the remit of ongoing service audit and is therefore excluded from the requirement for ethics approval. Two of the hospitals are tertiary referral centres, while the other is a secondary referral centre serving a total population of approximately 740,000. One of these hospitals provides emergency thrombectomy services, with referrals from multiple institutions across the Republic of Ireland. These three hospitals have a protocol for evaluating all patients presenting with suspected AIS, which includes clinical assessment and neuroimaging with CT and multiphase CTA, so as to determine potential eligibility for intravenous thrombolysis and thrombectomy. All sites used multiphase CTA for evaluation. No strict inclusion criteria to select patients for initial imaging were applied, reflective of real-world practice. FAST positive includes all patients with symptoms suggestive of acute ischaemic stroke that present to the Emergency Department (ED) or when symptoms occur while an inpatient. Not all of these patients will have a final diagnosis of ischaemic stroke but all will proceed to emergent non-contrast CT and CTA. Eligibility for thrombectomy was based on hospital guidelines derived from current best evidence,[3,4] which included inclusion LVO, ASPECTS of $\geq$5, National Institutes of Health Stroke Scale (NIHSS) of $>$5, presence of good collateral circulation (defined as $>$50% of pial circulation) and possibility of revascularisation within 24 hours of stroke onset.

If eligible, thrombectomy was performed in Hospital A, with patients transferred using the “drip and ship” model. Following thrombectomy, patients from the referring hospitals were repatriated immediately in the “drip, ship, retrieve and leave model”, which has been described previously.

The number of emergent CTA studies performed between January 2015 and December 2017 for suspected AIS was quantified (Group B). The hospital PACS systems were searched for all patients having CTA imaging for suspected AIS. The acute stroke CTA study reports were evaluated and occlusion location, if any, was recorded. Occlusion location was categorised as large vessel, including internal carotid artery (ICA), M1 or proximal M2 occlusions in the anterior circulation and vertebrobasilar occlusions in the posterior circulation; or small vessel, including anterior cerebral artery (ACA), distal M2 and M3 branches in the anterior circulation and posterior cerebral arteries in the posterior circulation. For patients with LVO, a record was made of whether the patient proceeded to thrombectomy. If no thrombectomy was performed, the reason for this was determined. Assessment of carotid stenosis was noted, however, for the purposes of this paper, these results were not included.

The number of patients given a primary discharge diagnosis of ischaemic stroke (Group A) was analysed for the same period. These data were collected from Hospital Inpatient Enquiry System (HIPE). HIPE is a health information system that collects clinical and administrative data on discharges and deaths in acute hospitals in Ireland. It is the principal source of national data on discharges from acute hospitals.[8] There data were cross-referenced in Group A with those who had undergone emergency CTA on admission for suspected acute stroke (Group B) to determine patients discharge diagnosis of stroke who had undergone emergency CTA (Group C).

Results

During the 3-year period, 2,358 patients presented to Emergency Departments within the three hospitals with symptoms suggestive of AIS who merited diagnostic CT evaluation. In Group B, 573 (24.3%) had a vessel occlusion, of which 436 (76%) were large vessel and 137 (24%) were small vessel. A total of 283 patients were suitable and underwent thrombectomy, representing 64.6% of all LVOs (See Table 1 for full breakdown per centre). In terms of vessel occlusion, 43.2% (n=248) were M1, 18% (n=103) ICA, 9.4% (n=54) vertebrobasilar, and 5.4% (n=31) proximal M2 (Fig 1).

There were a total of 2,363 patients in Group A. 45% (n=1082) of these had an acute CTA on admission for assessment for suitability for thrombectomy, while 46.5% (n=1113) had no CTA performed during the admission. There were 1,066 patients (45%) in Group B who had a confirmed diagnosis of stroke.

An LVO rate was found in 18.4% of Group A and coincidentally in 18.4% of Group B, while Group C had an LVO rate of 40.2% amongst the three centres (Table 2).

Regarding rates of thrombectomy, intervention occurred in 12% of patients in Group A, 12 % in Group B and 26% in Group C (Table 2). Low ASPECTS was the most common cause of unsuitability for thrombectomy, representing 10% of all cases of LVO and 48% of those unsuitable for thrombectomy. See Table 3 and Table 4 for full breakdown of LVO/EVT rates per hospital.

Discussion

Thrombectomy is the standard of care for AIS patients with LVO up to 24 hours after the onset of stroke symptoms in appropriately selected patients.[3 4] With this, a key priority in AIS management must be in increasing the availability of thrombectomy worldwide. In order to implement effective services, it is essential to quantify the number of patients with LVO AIS, thereby allowing estimation of potential candidates for thrombectomy.

We have demonstrated an LVO rate of 18.4% of primary discharge diagnoses of AIS (Group A), 18.4% of suspected AIS that proceeded to CTA (Group B), 40.2% of confirmed AIS diagnoses who underwent CTA (Group C) at our centres. We consider the number of LVOs to represent the target number of patients for thrombectomy, provided presentation is prior to infarction. A UK study published in 2017 which estimated the number of stroke patients eligible for thrombectomy, reported an LVO rate of 40% based on an estimated annual stroke incidence using National Stroke Registries.[9] A population-based study in the US gave an LVO rate of 11.8% based on patients with a primary or secondary diagnosis of AIS, including Transient Ischaemic Attack (TIAs).[10] This lower rate of 11.8% (compared to our rate of 18.4% of patients in Group A) can be explained by their use of primary and secondary diagnoses of AIS and TIAs. Similarly the STOP-STROKE trial in 2009 published LVO rates of 46% based on confirmed AIS and CTA, compared to 40% in the present study for the same criteria (Group C).[11]

In our series, thrombectomy was performed in a total of 283 cases amongst the three centres, giving rates of 12% based on overall stroke diagnoses (Group A) and clinically suspected strokes (Group B) and 26% of confirmed AIS diagnoses who underwent CTA (Group C) over the 3-year period. The aforementioned UK study, estimated 10% of all stroke admissions were eligible for thrombectomy (even though there is 40% occlusion rate).[9] This implies that only 25% of LVO are suitable for thrombectomy. The US population-based study in West Virginia reported approximately half of their LVOs were amenable to thrombectomy, based on primary and secondary discharge diagnoses of AIS and TIA. A limitation to this study is a time limit of 6 hours from symptom onset dictating eligibility, which no longer applies to all cases.[10] Furthermore, with more efficient systems for evaluating AIS patients, more patients may remain eligible for thrombectomy. From the present data, 64.6% of all LVOs were treated, while a low ASPECTS and established infarction made up 48% of LVOs not suitable for thrombectomy. Therefore, a further 17% may be eligible for treatment with faster workflow.

Malhotra *et al.* showed that 21.4% of all acutely presenting strokes or TIAs were amenable to thrombectomy up to 8-hours after onset of symptoms.[12] This rate is similar to the

Table 1
Acute computed tomography angiography (CTA) examinations, vessel occlusions, and thrombectomy figures.

	Hospital A	Hospital B	Hospital C	Total
No. of acute CTA (2015–2017)	1061	978	319	2358
Total vessel occlusions (of acute CTA)	264 (24.8%)	227 (23.2%)	82 (25.7%)	573 (24.3%)
Small vessel occlusions	71 (26.9%)	53 (23.3%)	13 (15.6%)	137 (24%)
Large vessel occlusion (LVO)	193 (73%)	174 (76.6%)	69 (84.1%)	436 (76%)
No. of endovascular thrombectomy (% of LVO)	121 (62%)	121 (69.5%)	41 (59%)	283 (64.6%)

EVT, endovascular thrombectomy.

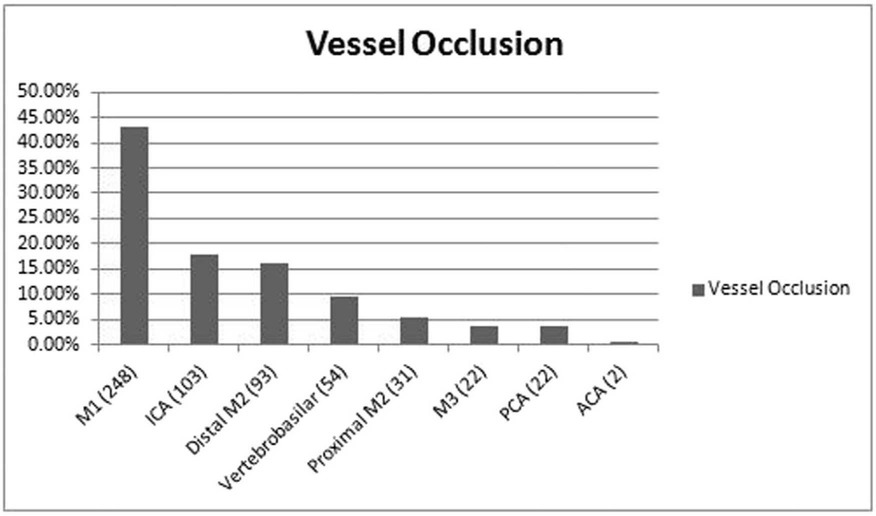

Figure 1 Total vessel occlusions.

Table 2
Total large vessel occlusion/endovascular thrombectomy rates.

	Total no. strokes Group A (*n*=2,363)	Suspected AIS and CTA Group B (*n*=2,358)	Confirmed stroke and CTA Group C (*n*=1,082)
Vessel occlusion (*n*=573)	24%	24.3%	53%
Large vessel occlusion (*n*=436)	18.4%	18.4%	40.2%
Endovascular thrombectomy (*n*=283)	12%	12%	26%

AIS, acute ischaemic stroke; CTA, computed tomography angiography.

Table 3
Large vessel occlusion rates per hospital.

	% Total strokes Group A	% Suspected AIS and CTA Group B	% Confirmed stroke and CTA Group C
Hospital A	20.4%	18%	40%
Hospital B	18.9%	17.7%	39.6%
Hospital C	13.7%	21.6%	42%

AIS, acute ischaemic stroke; CTA, computed tomography angiography.

Table 4
EVT rates per hospital.

	% Total Strokes Group A	%Suspected AIS and CTA Group B	% Confirmed Stroke and CTA Group C
Hospital A	12.8%	11.4%	25.2%
Hospital B	13.1%	12.3%	27.5%
Hospital C	8.1%	12.8%	25%

our rate (26%), but perhaps lower due to the narrower therapeutic window applied. Since our participation in the ESCAPE trial in 2015, we have included some patients up to 24 hours after symptom onset.[13] By contrast Chia *et al.* have estimated thrombectomy rates of 7–13% based on strict and lenient criteria for determining eligibility for thrombectomy.[14]

Previous studies demonstrating LVO rates have been based on one patient group, whereas the present study provides rates based on three patient groups as mentioned above. We find this particularly useful as it will impact both clinicians and radiology services depending on which aspect they choose to use. Only 45% of patients who present with stroke-like symptoms meriting CTA were ultimately diagnosed with AIS. Coincidentally, 45% of patients who turn out to have stroke, will have had an acute CTA. Presumably for the remaining stroke patients the initial diagnosis was not clear or else their presentation was delayed.

Rates based on number of confirmed strokes determine overall expected rate of thrombectomy, whereas rates based on suspected AIS reflect likelihood of positive findings in patients presenting to the Emergency Department prior to final diagnosis. Using a reflection of current clinical practice, one can expect to have to perform a similar number (100%) of acute CTAs for a given number of stroke patients.

Based on evidence from DAWN and DEFUSE-3, the American Heart Association (AHA) supports the use of CTP for those presenting up to 24 hours after symptom onset. We have used CT ASPECTS and multiphase CTA for collateral assessment in the diagnostic paradigm. This is supported by a recent study published in July 2018 showing the use of unenhanced CT and multiphase CTA to select patients for thrombectomy beyond 6 hours of symptom onset.[15] We have not looked specifically at those over 6 hours to see the number requiring perfusion imaging if that approach was to be used.

The strengths of the present study lie in the large numbers of CTA evaluated over a 3-year period, in three different stroke centres, and in particular, the inclusion of those with suspected AIS, as well as considering patients for thrombectomy up to 24 hours after onset. We have shown consistent LVO and thrombectomy rates amongst our three centres and based on our three variable rates of overall primary discharge diagnoses of stroke, suspected AIS and AIS who proceeded to CTA. Given that the decision to perform emergency CTA was made by a large number of doctors in three different sites, the rate of ordering relative to the number of strokes is remarkably consistent.

From our series, Hospital C shows lower rates of LVO and thrombectomy in relation to overall stroke diagnoses compared to Hospital A and B. This is likely due to their imaging of a smaller proportion of stroke patients on arrival; however, when they do undertake imaging, their rates of LVO compared to suspected stroke and confirmed acute stroke are similar to the other two hospitals. Such variation in practice is common between hospitals, and the effect of this is diluted by the present analysis of three hospitals over 3 years.

A limitation to the present study lies in the potential inaccuracy of HIPE figures of stroke diagnoses due to coding inaccuracies; however, the aims were to assess the acute workload of AIS admissions and CTA studies, rather than on the routine work-up of AIS patients. Although HIPE figures have potential for inaccuracy, numbers of CTA were reliably reported given that these data were collected from the National Integrated Medical Imaging System (NIMIS). Furthermore, only primary discharge diagnoses of AIS were included as opposed to secondary diagnoses and TIAs, which would alter LVO and thrombectomy rates if included.

In conclusion, CTA is a useful tool in determining eligibility for thrombectomy in cases of LVO AIS. The present data highlight the volume of CTAs performed over a 3-year period, reflecting trends in the evolving management of AIS. Establishing the volume and rates of LVO and thrombectomy (when compared to overall primary discharge diagnosis of stroke (Group A), clinically suspected stroke on admission (Group B) and confirmed stroke diagnoses who underwent CTA (Group C)) is essential to the planning and provision of stroke services worldwide.

Conflict of interest

The authors declare no conflict of interest.

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