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Factors impacting on technical success in stroke thrombectomy: experience of a UK neuro-interventional unit

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AIM: To investigate factors that could impact on recanalisation and reperfusion in patients undergoing mechanical thrombectomy and to assess the technical success over time.

MATERIALS AND METHODS: Two hundred consecutive patients who underwent thrombectomy for a proximal anterior circulation occlusion were dichotomised into equal groups (groups 1 and 2) based on the date that immediate access to emergency general anaesthesia (GA) commenced.

RESULTS: Recanalisation success using thrombolysis in cerebral infarction (TICI) 2b/3 or TICI 2c/3 significantly improved in group 2 (67% versus 93%, $p<0.0001$; 52% versus 78%, $p=0.0002$). Symptomatic haemorrhage also reduced from 9% to 4%. Despite similar presentation Alberta Stroke Program Early (computed tomography) CT Scores (ASPECTS), post-procedural ASPECTS was significantly increased in group 2 (7; [interquartile range {IQR} 4–9] versus 8 [IQR 7–9]; $p=0.0034$). The number of patients with a post procedural ASPECTS of 8–10 increased (46% versus 64%, $p=0.0155$) and the difference in ASPECTS between pre- and post-thrombectomy CT was significantly lower (2 [IQR 1–4] versus 1 [IQR 0–2], $p<0.0001$). GA use increased from 8% to 56% ($p=0.0001$) as did use of distal aspiration (59% versus 87%, $p=0.0001$) mostly in combination with a stent-retriever. Failed access fell from 8% to 3%. When GA was used, successful recanalisation (TICI 2b/3) was achieved more frequently (90.5% versus 76.7%; OR 3.04, 1.2–7.69, $p=0.0187$).

CONCLUSION: Technical results for thrombectomy are improving over time. Technique modification, operator experience, and judicious use of GA may be contributing.

Introduction

Multiple randomised controlled trials have demonstrated the efficacy of mechanical thrombectomy for the

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treatment of proximal occlusive stroke[1–8] with more recent studies also demonstrating improved outcome for selected patients last seen well up to 16 or 24 hours prior to presentation.[7,8] The important role of thrombectomy is not disputed, but there are disagreements as to how this treatment should be delivered in terms of operator, institution, neuro-interventional technique, and mode of anaesthesia.[9–16]

Recent registry-acquired data from the Netherlands suggests technical and clinical results are improving over time,[17] implying a progressive learning curve for interventionalists, stroke teams, clinical pathways, and the evolution of technique and devices. Furthermore, it is documented that higher-volume centres obtain superior outcomes for stroke thrombectomy despite longer transfer times[12] suggesting procedural experience is an important factor. Just as device evolution may improve outcomes,[18] device combination may also contribute to improved results.[19] The role of general anaesthesia (GA) currently remains uncertain and controversial. Although randomised data suggest non-inferiority or even superiority for outcomes of patients treated using GA versus conscious sedation,[20–22] most retrospective data[11,13,14] and a large post-hoc analysis of the HERMES (Highly Effective Reperfusion Evaluated in Multiple Endovascular Stroke trials) randomised trial data suggests improved outcomes when the procedure is performed without GA (either with local anaesthetic or sedation)[23]; however, there were variations in the GA and conscious sedation protocols used in included studies and it is difficult to draw firm conclusions from these data. It is also worth noting that there is little mention of provision of GA in a multi-society consensus statement on quality improvement in endovascular stroke treatments.[24]

A number of factors are known to impact on clinical outcome in patients undergoing thrombectomy including recanalisation and reperfusion or infarct growth, extent of final infarct, complicating haemorrhage, and procedural time.[25–28] The present study was undertaken to assess how results had changed over time. Specifically, technical results were compared for two equal cohorts treated before and after the institution of routine immediate attendance of the emergency anaesthesia team at each thrombectomy case; in addition, other procedural factors that could impact on technical success such as thrombectomy technique were also documented.

Materials and methods

This study was approved by the institutional audit and clinical effectiveness committee and is a single-centre analysis of a regional thrombectomy unit's technical results. The outcomes of 200 consecutive patients with an anterior circulation proximal occlusion (terminal internal carotid artery [ICA], M1 or proximal M2 middle cerebral artery [MCA]) treated in the stent-retriever era were compared. The patients were dichotomised into two equal groups based on the date (September 2016) that departmental policy was altered to include routine immediate attendance of the emergency anaesthetic team at all thrombectomy cases. Prior to this, anaesthetic attendance was at the request of the neuro-interventionalist on a case-by-case basis.

All patients were treated by one of four interventional neuroradiologists or an interventional neuroradiology fellow under direct consultant supervision. No formal policy for GA indication was used, but the decision to use GA was made taking into account factors including agitation, the need for airway protection, challenging arterial access, and/or more distal intracranial occlusion. Compliant patients were treated under local anaesthesia only. Conscious sedation was rarely used as an intermediate.

The guideline for anaesthesia in this cohort was developed by local Neuroanaesthetists. Based on the document "Standards for providing safe acute ischaemic stroke thrombectomy services",[29] the emphasis of the local protocol was provision of safe operating conditions, minimising any time delays and haemodynamic control. Rapid sequence induction was commonly required due to the majority of patients not being adequately fasted. Opioids (fentanyl, alfentanil) were co-administered with propofol on induction to allow dose-sparing of propofol. Where necessary, vasopressors (metaraminol, ephedrine) were used to treat hypotension. Maintenance of anaesthesia was achieved with either volatile agents or propofol infusion with supplemental opioids as required. Therapeutic targets included maintenance of oxygen saturations between 94–98%, normocapnia, normoglycaemia, and normothermia. Target systolic blood pressures were 140 mmHg–180 mmHg in patients who had been thrombolysed and 140 mmHg–220 mmHg in those who had not.

Prospectively collated data regarding baseline variables including referring hospital, presenting National Institutes of Health Stroke Scale (NIHSS), prior use of intra-venous recombinant tissue plasminogen activator (rt-PA) and procedural equipment (stent-retriever, distal aspiration catheter, or balloon-guide catheter) was analysed retrospectively. Radiological data including site of occlusion, mode of access, access failure, adjunctive cervical ICA angioplasty or stenting, degree of recanalisation (thrombolysis in cerebral infarction [TICI] and revised TICI score[30]), extent of infarction using Alberta Stroke Program Early CT (computed tomography) Scores (ASPECTS) on pre-procedural and post-procedural CT (performed uniformly at 24 hours post treatment), and cerebral haemorrhagic complications plus timing of initial CT relative to recanalisation and time taken to complete the procedure (first screening to recanalisation) were analysed retrospectively. ASPECTS was assessed by an interventional neuroradiologist of 8 years of neuroimaging experience blinded to the angiographic outcomes with pre- and post-procedural scans analysed separately at different times to minimise bias. A change in ASPECTS from baseline to 24 hours after thrombectomy has been shown to be a marker of reperfusion, correlates well with clinical outcome, and has been suggested as an early marker of treatment success.[26] Recanalisation was assessed by a second interventional

neuroradiologist of 25 years of experience. Symptomatic intracranial haemorrhage (SICH) was defined as neurological deterioration (an increase of four or more points in the score on the NIHSS) and evidence of parenchymal haemorrhage type 2 (according to the SITS-MOST study)[27] or significant subarachnoid haemorrhage.

Data were statistically analysed using Graphpad software. Non-parametric data were assessed using Fisher's exact test and ordinal data with the Kruskal–Wallis test. Parametric data were assessed using the *t*-test. Multivariate analysis was undertaken using binary logistic regression.

Results

Baseline variables

Both cohorts had similar baseline characteristics in terms of age and NIHSS (see Table 1). More patients in the first group were treated with rt-PA prior to thrombectomy (62% versus 43%, p=0.0106). Additionally, more patients in the second group were transferred from primary stroke referral centres into the thrombectomy centre rather than presenting directly (34% versus 57%, p=0.0017). The sites of occlusion were similar in distribution (MCA or terminal ICA) between the two groups (see Table 1). There was a clear difference in case referral between the two groups with group 1 treated >80 months and group 2 >16 months.

Procedural factors

Procedural characteristics are displayed in Table 2. There was significantly more use of GA in group 2 (8% versus 56%, p=0.0001). The threshold for commencing the procedure with GA lowered over time and with routine involvement of anaesthesia prior to the procedure (see Fig 1). A small number of patients in each group were treated using conscious sedation and the remainder under local anaesthetic only. More patients in group 2 had distal aspiration (59% versus 87%, p=0.0001) used as part of the procedure (either alone or in combination with a stent-retriever) whereas more patients in group 1 were treated with stent-retrievers alone (29% versus 4%, p=0.0001) and more patients in group 2 were treated with distal aspiration alone (5% versus 20%, p=0.0022). A significantly larger proportion of patients in group 2 were treated with a combination of stent-retriever and distal aspiration catheter (52% versus 68%, p=0.0301) although this was the dominant technique in both groups. Additionally, balloon guide catheters were used significantly more frequently in group 2 although this was in a minority. Importantly, the procedural time was significantly shorter in group 2, implying better first-pass recanalisation in this group.

Table 1
Baseline variables.

	Group 1 (n=100)	Group 2 (n=100)	p-Value
Age	70.7 (12.3)	70.3 (13.7)	0.8224
Males (%)	53	43	0.2026
NIHSS	19 (IQR 7.5)	19 (IQR 7.5)	0.4308
IV rt-PA (%)	62	43	0.0106
Transfer to thrombectomy centre (%)	34	57	0.0017
Sites of occlusion (%)			
M2 MCA	11	9	0.8143
M1 MCA	63	60	0.7714
TICA	26	30	0.6368
Tandem ICA lesion (%)	14	11	0.6696

NIHSS, National Institutes of Health Stroke Scale; rt-PA, recombinant tissue plasminogen activator; ICA, internal carotid artery; MCA, middle cerebral artery. TICA, terminal internal carotid artery.

Table 2
Procedural characteristics for group 1 and 2.

Variable	Group 1 (n=100)	Group 2 (n=100)	p-Value
General anaesthesia (%)	8	56	0.0001
Conscious sedation (%)	5	7	0.7673
Failed intracranial access (%)	8	3	0.2134
Direct CCA access (%)	0	5	0.0594
ICA stenting (%)	0	10	0.0015
ICA angioplasty (%)	10	1	0.0097
Stent-retriever alone (%)	29	4	0.0001
Stent-retriever use (%)	82	72	0.1299
Distal aspiration alone (%)	5	20	0.0022
Distal aspiration use (%)	59	87	0.0001
Stent-retriever/distal aspiration combined (%)	52	68	0.0301
Balloon guide catheter (%)	4	17	0.0046
Balloon guide aspiration alone (%)	0	1	1.0000
Spontaneous recanalisation (%)	5	4	1.0000
Intracranial stent deployment (%)	1	2	1.0000
Procedural time, minutes (SD)	63.5 (41.1)	41.0 (38.4)	0.0001

ICA, internal carotid artery; CCA, common carotid artery.

Rates of recanalisation, change in ASPECTS, and haemorrhagic complications

Results are displayed in Table 3 and Fig 2. Recanalisation success, as defined by TICI 2b/3 or TICI 2c/3 significantly improved in group 2 (67% versus 93%; 52% versus 78%). Of patients treated with a combined stent-retriever/distal aspiration system those, in group 2 achieved better recanalisation than those in group 1 (see Table 4). Symptomatic haemorrhage also reduced from 9% to 4%. This did not reach statistical significance.

Presentation ASPECTS scores were similar between the groups, but the post-procedural ASPECTS scores were

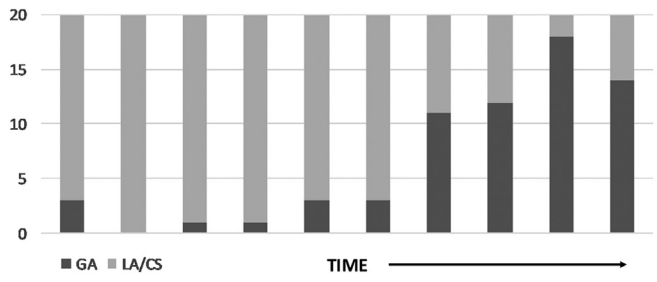

Figure 1 Relative use of GA versus local anaesthetic (LA) or conscious sedation (CS) over time displayed as consecutive blocks of 20 cases.

Table 3
Procedural results for recanalisation, reperfusion, and symptomatic intracranial haemorrhage.

Variable	Group 1	Group 2	*p*-Value
SICH	9	4	0.2507
CT to recanalisation time, mins Median (IQR)	130 (96)	167 (108)	0.0314
Pre-ASPECTS median (IQR)	10 (9–10)	9 (8–10)	0.5845
Post-ASPECTS median (IQR)	7 (4–9)	8 (7–9)	0.0034
Post-ASPECTS 6–10	70	87	0.0055
Post-ASPECTS 7–10	62	81	0.0046
Post-ASPECTS 8–10	46	64	0.0155
Difference in ASPECTS median (IQR)	2 (1–4)	1 (0–2)	<0.0001
Difference in ASPECTS 0–1	40	67	0.0002
Difference in ASPECTS 0–2	58	81	0.0007
Difference in ASPECTS ≥6	20	7	0.0119
TICI 0/1/2a	33	7	0.0001
TICI 2b	15	15	1.0000
TICI 2b/3	67	93	<0.0001
TICI 2c/3	52	78	0.0002
TICI 3	36	54	0.0155

TICI, thrombolysis in cerebral infarction; IQR, interquartile range; ASPECTS, Alberta Stroke Program Early CT Score. SICH, symptomatic intracranial haemorrhage.

higher in group 2, implying improved timely reperfusion in the latter (Fig 3) despite a longer time from initial CT to recanalisation in the second group. There were significantly more patients with minimal change in ASPECTS (Fig 3, Table 3) dichotomised as 0–1 or 0–2, and significantly fewer patients in group 2 with a dramatic change in infarct progression (defined as ASPECTS change of ≥6[24] (Table 3).

For all 200 patients, logistic regression was used to assess for factors impacting on successful reperfusion with minimal infarct growth (ASPECTS change of 0–1; Table 5). Factors assessed included successful recanalisation (TICI 2b/3), age >75, use of general anaesthesia, time from CT to recanalisation, tandem disease, terminal ICA occlusion, use of rt-PA, and direct presentation versus transfer to the thrombectomy centre. Recanalisation was the dominant and only significant factor determining a reduced infarct growth (odds ratio [OR] 6.9, 95% confidence interval [CI] 2.6–18.8, $p<0.0001$). The distribution of post-procedural ASPECTS by level of recanalisation is shown in Table 6 and Fig 4.

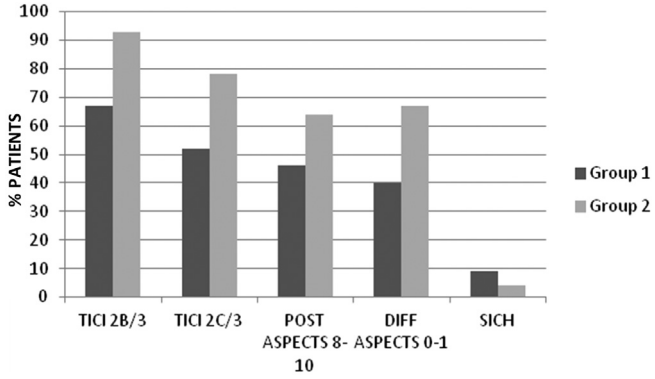

Figure 2 Technical outcome measures for groups 1 and 2 (SICH: symptomatic intracranial haemorrhage).

Table 4
Recanalisation in the combined stent-retriever and distal aspiration cases.

Recanalisation	Group 1 *n* (%)	Group 2 *n* (%)	*p*-Value
TICI 0/1/2a	14 (26.9)	4 (5.8)	0.0018
TICI 2b/3	38 (73.1)	64 (94.1)	
TICI 2c/3	30 (57.7)	52 (76.5)	0.0316

TICI, thrombolysis in cerebral infarction.

Using logistic regression of the data as a whole to assess reasons for recanalisation failure (Table 7), factors including patient age (>75), use of rt-PA, the presence of tandem ICA lesions, terminal ICA occlusion, use of GA, use of distal aspiration, and successful intracranial access showed that the latter was the dominant factor (OR 34.8, 95% CI: 3.5–346.3, $p=0.002$) in determining successful recanalisation. Of the 15 complete procedural failures in group 1, eight were due to failed access. Failed access was more common in group 1 (8% versus 3%). Although this was not statistically significant, it was likely clinically significant.

When GA was used, successful recanalisation was achieved more frequently (57/63 (90.5%) versus 103/136 (76.7%) OR 3.04, 1.2–7.69, $p=0.0187$) for the cohort as a whole. When assessing the impact of anaesthesia in those with successful access and a combined stent-retriever and distal aspiration approach, GA tended to show benefit (39/42 [92.8%] versus 51/65 [78.5%], OR 3.56 95% CI: 0.96–13.29, $p=0.0579$) in terms of successful recanalisation (Table 8). Significantly more patients with GA had a change in ASPECTS limited to 0–1 points (45/63 [71.4%] versus 64/136, [47.1%] $p=0.0014$) or limited to 0–2 points (52/63 [82.5%] versus 89/136 [65.4%], $p=0.0183$). This implies that the successful recanalisation facilitated by GA also equated to improved timely reperfusion.

Discussion

The results of this study suggest that with growing departmental experience, technique modification (to

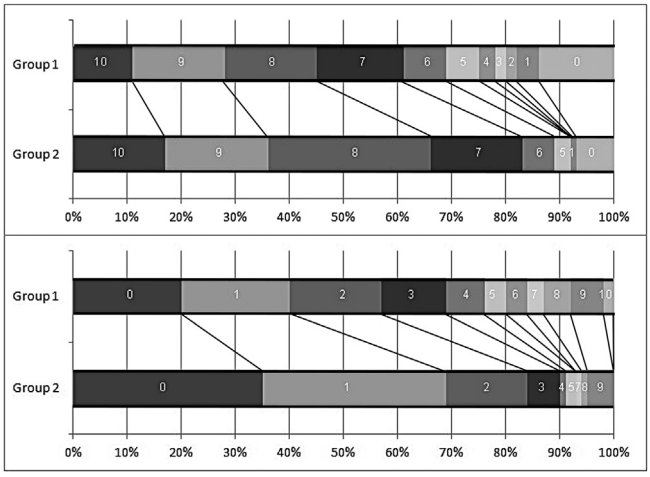

Figure 3 Post-procedural ASPECTS (upper) and change in ASPECTS (lower) for groups 1 and 2.

Table 5
Logistic regression for factors impacting on reperfusion defined as minimal change in ASPECTS of 0–1 points.

Variable	B	SE	Wald	Degrees of freedom	*p*-Value	OR	95% CI	
							Low	High
CT to recanalisation time	0.002	0.002	0.570	1	0.450	1.002	0.998	1.006
Age >75	0.416	0.338	1.507	1	0.220	1.515	0.781	2.941
General anaesthetic	0.672	0.391	2.947	1	0.086	1.957	0.909	4.214
Tandem ICA lesion	0.210	0.537	0.152	1	0.535	0.817	0.431	1.549
Terminal ICA occlusion	−0.171	0.377	0.206	1	0.650	0.843	0.403	1.763
Intravenous rt-PA	−0.203	0.327	0.385	1	0.535	0.817	0.431	1.549
Successful intracranial access	0.398	0.922	0.186	1	0.666	1.489	0.244	9.073
Successful recanalisation (TICI 2b/3)	1.943	0.505	14.801	1	0.000	6.977	2.593	18.771
Transfer into mothership	−0.121	0.342	0.125	1	0.724	0.886	0.454	1.731

CT, computed tomography; ICA, internal carotid artery; rt-PA, recombinant tissue plasminogen activator; TICI, thrombolysis in cerebral infarction; ASPECTS, Alberta Stroke Program Early CT Score.

include distal aspiration and/or balloon guide catheter), and routine anaesthetic attendance, recanalisation and timely reperfusion rates have improved for patients undergoing thrombectomy for anterior circulation stroke. The successful recanalisation rate (TICI 2b/3) rose from 67 to 93%. The proportion with post-procedural ASPECTS of 8–10 rose from 46% to 64% and the proportion with minimal ASPECTS change 0–1 rose from 40% to 67%. It is important to note that this was despite a greater proportion of transfers and longer CT to recanalisation times (likely reflecting the transfer time and possibly time for GA). There was a non-significant reduction in symptomatic haemorrhage between the groups. It is conceivable that a lower rate of rt-PA use and shorter procedural time could have contributed this.[28,31]

Following routine attendance of the anaesthetic team, the rate of GA increased from 8% to 56%. In part, the enhanced rate of recanalisation was possibly facilitated by the routine attendance of anaesthetists at all cases. Patients undergoing GA were more likely to have successful recanalisation and this translated to improved reperfusion in terms of post-procedural ASPECTS. This is in agreement with the results of the GOLIATH (General Or Local Anaesthesia In Intra Arterial THerapy) study that showed improved recanalisation rates and a non-significant reduction in infarct growth with GA over conscious sedation.[21]

In the authors' experience, GA is especially useful in agitated, confused patients and facilitates navigation of more technically challenging arterial access, direct common carotid access, and safe deployment of ICA stents. The frequency of failed access fell in group 2 and the difference in failed access between groups 1 and 2 was matched by the number of direct common carotid punctures performed in group 2, suggesting that this manoeuvre (Fig 5) contributed to the improved rate of access in the latter.[32] Direct punctures were performed under ultrasound guidance and employed an 18 G needle, 0.35″ J wire and 6 F sheath (Cordis, Hialeah, FL, USA). The deployment of carotid stents to facilitate and preserve access in cases of tandem dissection or atherothrombotic occlusion/severe stenosis rather than angioplasty alone was more common in group 2 reflecting a shift in practice (0% versus 10%). In support of this, recent registry-based data suggest that ICA stenting may be associated with improved intracranial recanalisation rates in cases of tandem disease relative to angioplasty only.[33]

There is controversy regarding the routine use of GA in mechanical thrombectomy. Theoretically, GA may delay recanalisation and periods of hypotension can negatively impact on cerebral autoregulation and collateral flow to the ischaemic penumbra, and therefore, limit salvage of ischaemic tissue. The bulk of retrospective data and post-hoc analysis of randomised trial data suggest poorer

Table 6
Post procedural ASPECTS (Alberta Stroke Program Early CT Score) by degree of recanalisation for each of the 200 patients.

Post procedural ASPECTS	TICI 2b/3 (n)	TICI 0–2a (n)
0	8	13
1	1	4
2	0	2
3	1	1
4	1	2
5	7	2
6	9	5
7	28	5
8	43	4
9	35	1
10	27	1

TICI, thrombolysis in cerebral infarction.

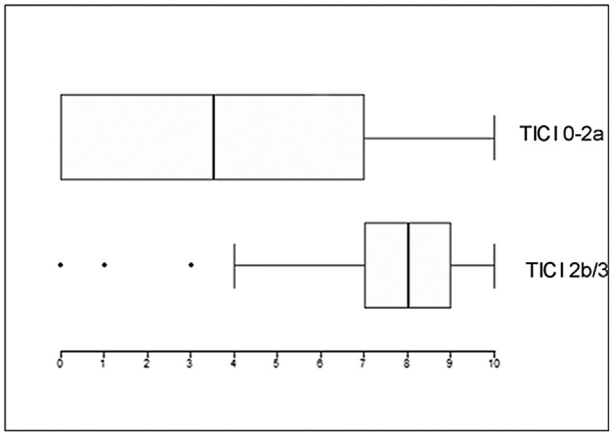

Figure 4 Box plot demonstrating distribution in post-procedural ASPECTS by degree of recanalisation.

Table 7
Logistic regression for factors impacting on recanalisation defined as TICI 2b/3.

Variable	B	Std Error	Wald	Degrees of freedom	*p*-Value	OR	95% conf int	
							low	high
Use of distal aspiration	0.636	0.463	1.893	1	0.169	1.890	0.763	4.679
Age >75	−0.173	0.422	0.168	1	0.682	0.841	0.368	1.923
General anaesthesia	1.084	0.569	3.623	1	0.057	2.956	0.968	9.025
Tandem lesion	−0.041	0.652	0.004	1	0.950	0.960	0.268	3.442
Terminal ICA occlusion	−0.312	0.477	0.428	1	0.513	0.732	0.288	1.863
IV rt-PA	−0.431	0.427	1.019	1	0.313	0.650	0.281	1.501
Successful access	3.552	1.171	9.194	1	0.002	34.871	3.511	346.339

TICI, thrombolysis in cerebral infarction; ICA, internal carotid artery; rt-PA, recombinant tissue plasminogen activator.

outcomes with GA compared to procedures under local anaesthetic or conscious sedation[11,13,14,23]; although it should be mentioned that it is very difficult to separate the fact that often the most ill patients undergo GA[14] and recent randomised trial data suggest that outcomes for patients treated using GA are equivalent to those treated using conscious sedation.[20–22] Conscious sedation may facilitate an earlier thrombectomy procedure, but there is often patient movement to contend with, as well as increased airway protection concerns and aspiration risk. Pragmatically, there is a balance because some patients may tolerate the procedure under local anaesthetic with or without sedation whereas others, who are confused and unable to cooperate, may require GA to facilitate safe, timely recanalisation, which is a dominant factor in achieving improved outcome. Another factor is that the patient's condition can change during the procedure and compliance may dramatically alter after it has commenced. What remains a challenge is deciding which patients should primarily undergo GA. Importantly this may depend on the preference and experience of the attending anaesthetist who may be reluctant to sedate the patient without airway control in the acute setting. Additionally, in the authors' experience, if difficult access is anticipated based on assessment of the CT angiogram, it may well save time to proceed with GA early. A number of anatomical factors have been described, which predict difficult access in neuro-interventional procedures including arch type, arch vessel angulation, and reverse carotid curves.[34–36]

The improvement between the groups in terms of procedural time and recanalisation could, in addition to the impact of GA, also support growing operator experience and a neuro-interventionalist learning curve. With time, thrombectomy techniques have advanced from stent-retriever with proximal aspiration only with or without or use of a balloon guide catheter to widespread utilisation of wide-bore intracranial distal aspiration catheters, often in combination with a stent-retriever and/or balloon guide catheter.[37] The combination of stent-retrieval and distal aspiration has been shown in observational studies to result in high rates of successful recanalisation.[19] Balloon guide catheter use with stent-retrievers is also associated with more efficient recanalisation with a reduction in distal embolisation.[38] Specific techniques involving a combination of distal aspiration and stent-retrievers include CAPTIVE (continuous aspiration before intracranial vascular embolectomy),[39] SAVE (stent-retriever assisted vacuum-locked extraction),[40] or ASAP (A Stent-Retrieving into an Aspiration Catheter with Proximal Balloon).[41] The first two techniques involve removal of the distal aspiration catheter and stent-retriever as a unit. The ASAP technique adds a balloon guide to the combination of stent retriever and distal aspiration catheter, but with stent-retrieval fully into the distal aspiration catheter, which is then left *in situ* for further aspiration rather than removing stent and catheter as a unit. The authors' practice now approximates to a combination of these techniques with (where possible) the use of a balloon guide catheter and removal of the aspiration catheter and stent-retriever as a unit. The latter may reduce clot shearing and distal micro-fragmentation.[41]

In addition to device combination for the intracranial component of the procedure, the choice of access catheters has evolved to allow navigation of more challenging anatomy. Simmonds 5 F Glide catheters (Terumo, Tokyo, Japan) are noted to navigate tortuous aortic anatomy prior to catheter exchange for a co-axial system of ACE (Penumbra, Alameda, CA, USA) or Sofia (Microvention, Aliso Viejo, CA, USA) distal aspiration catheters inside a long guide sheath (Neuron MAX, Penumbra) or use of a 125 cm 5 F VTK select catheter (Cook, Bloomington, IN, USA) with Advantage Glidewire (Terumo) inside a long sheath or balloon guide catheter (Flowgate, Stryker, Fremont, CA, USA) has contributed to improved speed and reliability of access.

Recently, data from the MR Clean registry encompassing approximately 1,500 patients treated in the Netherlands showed an improvement in the rates of recanalisation and the rates of symptomatic intracranial haemorrhage relative to the results seen in the MR Clean trial.[17] It is difficult to discern the reasons for the improvement, which is likely multifactorial, encompassing some of the reasons discussed above. In this study, the referral rate for thrombectomy was

Table 8
Impact of general anaesthesia (GA) on recanalisation rate in all patients and those undergoing a combined stent and distal aspiration thrombectomy.

	TICI	GA *n* (%)	LA/CS *n* (%)	*p*-Value
All patients	0-2a	6 (9.5)	34 (24.8)	0.0187
	2b/3	57 (90.5)	103 (75.1)	
Stent-retriever plus distal aspiration	0-2a	3 (7.1)	14 (21.5)	0.0579
	2b/3	39 (92.9)	51 (78.5)	

TICI, thrombolysis in cerebral infarction; LA, local anaesthetic; CS, conscious sedation.

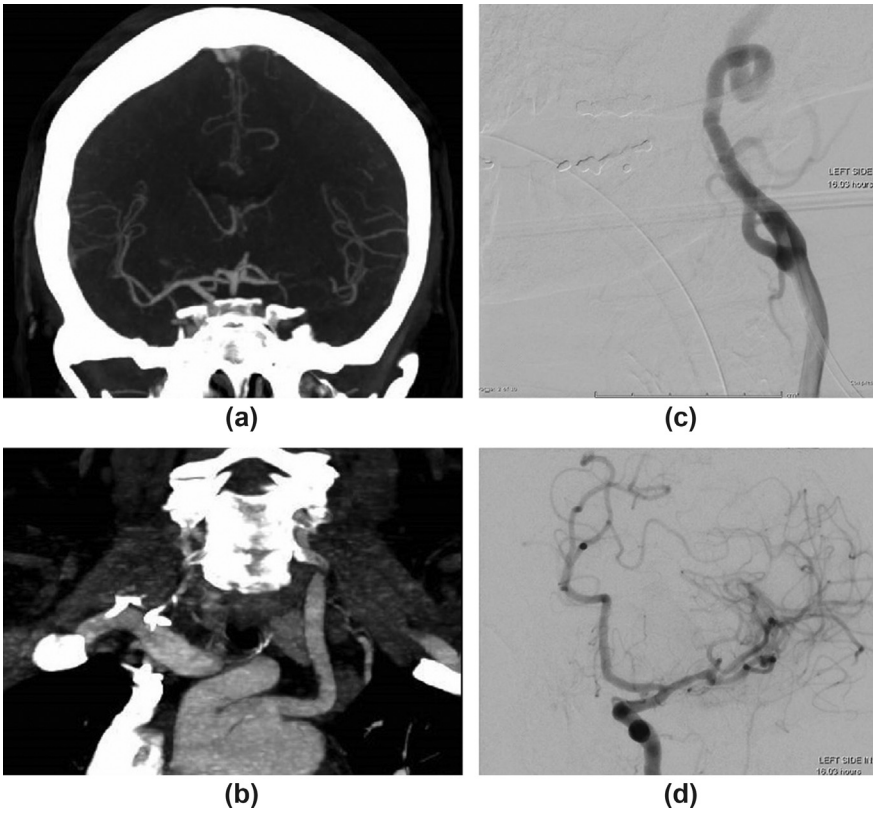

Figure 5 (a) Example case showing occluded left terminal ICA on coronal CTA. (b) Challenging aortic arch anatomy is also demonstrated. Direct common carotid sheath 6 F placement (c) and successful recanalisation (d).

markedly different between the two groups and reflects the increasing procedural experience of the neuro-interventional team. When controlling for combined use of distal aspiration and stent-retrievers, a rise in TICI 2b/3 recanalisation from 73% to 94% was noted. These findings suggest that as volume increases so results improve. It has been demonstrated that patients undergoing thrombectomy in higher-volume centres have lower mortality rates compared to those treated at low-volume centres despite patient transfer resulting in inevitable delay to recanalisation.[12]

Limitations of this study are that this is a single-centre analysis so constraining generalisation of results to other centres. Some data were collected in a retrospective manner so standard measures, such as event-to-treatment time or door-to-needle time were not available. Surrogate measures with accurate times such as CT to recanalisation were used, but it was not possible to assess the added time that GA incurred as travel times were also variable. Technical results are self-reported, which may introduce bias, and there are recognised variations in inter-observer reporting of both TICI and ASPECTS scores. A major criticism of this work is the lack of clinical outcome data to support the improved technical results; however, evidence now suggests that improved recanalisation impacts on clinical outcome (perhaps more especially in the elderly)[42] as does the extent of post-procedural infarction at 24 hours.[25] Liebeskind *et al.*[26] demonstrated that serial ASPECTS change from baseline to 24 hours after endovascular therapy predicts clinical outcome at 3 months and may therefore serve as a useful, early surrogate endpoint for thrombectomy outcome and this was the basis for assessment of reperfusion in this study. In their analysis of the SWIFT data, they found that 24-hour ASPECTS provided better prognostic information than baseline ASPECTS. They noted dramatic infarct progression (categorised as a change in ASPECTS of $\geq$6) in a third of patients. In the present study, infarct progression of ASPECTS $\geq$6 points in 20% of group 1 and 10% in group 2 was noted, which likely reflects the improved recanalisation rate in the latter group.

In conclusion, the present study suggests that technical success is improving over time. Improvement in operator and neuro-interventional team experience and enhanced arterial access has translated into better rates of recanalisation and timely reperfusion. The latter could reflect the device combination and rapid availability of general anaesthesia. Although the present study cannot demonstrate use of GA improves clinical outcomes, it does suggest that routine immediate availability and increased utilisation can aid technical success.

Declaration of interest

The authors declare no conflicts of interest.

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