Clinical Radiology 76 (2021) 862.e1–862.e17

Contents lists available at ScienceDirect

Clinical Radiology

journal homepage: www.clinicalradiologyonline.net

Commentary

To support safe provision of mechanical thrombectomy services for patients with acute ischaemic stroke: 2021 consensus guidance from BASP, BSNR, ICSWP, NACCS, and UKNG

A. Mortimer[a,*], R. Lenthall[a,b], I. Wiggam[c], M. Dharmasiri[c], J. Dinsmore[d], F. Doubal[c], A. Hill[e], A. Clifton[a,e]

[a] United Kingdom Neurointerventional Group, UK
[b] British Society of Neuroradiologists, UK
[c] British Association of Stroke Physicians, UK
[d] Neuroanaesthesia and Critical Care Society, UK
[e] Intercollegiate Stroke Working Party, UK

ARTICLE INFORMATION

Article history:
Received 30 June 2021
Accepted 5 August 2021

Foreword

This document supersedes the existing professional multisociety consensus guidance published in 2015.[1] It has been produced in order to respond to the considerable volume of relevant new high-quality trial evidence that has become available since September 2015. It should be emphasised that this document remains applicable to all constituent nations of the UK, and thus, deliberately avoids the use of acronyms or reference to structures that do not pertain to all four nations wherever possible. The guidance was developed (and is now updated) to aid thrombectomy delivery by describing the key requirements for an endovascular stroke therapy service, including the service support requirements and basic performance standards that should be met. Indeed, it substantially influenced the commissioning of thrombectomy by NHS England in 2017.

The standards guidance is intended to support all medical staff and allied health professionals who directly contribute to the delivery of thrombectomy. Both editions of the standards guidance were drawn up through consensus by a working party of appointed representatives from the British Association of Stroke Physicians, the British Society of Neuroradiologists, the Intercollegiate Stroke Working Party, the Neuroanaesthesia and Critical Care Society and the United Kingdom Neurointerventional Group. Drafts were modified in response to review by committees in each society or group. This document draws on publications from other organisations, but is intended to be (whole) UK-

* Guarantor and correspondent: A. Mortimer, Department of Radiology, Southmead Hospital, North Bristol NHS Trust, Southmead Rd, Bristol BS10 5NB, UK. Tel.: +44 (0)117 4149007.
E-mail address: alex.mortimer@nbt.nhs.uk (A. Mortimer).

https://doi.org/10.1016/j.crad.2021.08.002

focussed, practical, and pathway-orientated. The guidance is a consensus on the minimum service standards required to support a thrombectomy service in terms of specialist staffing/skill mix and the organisation of services. These standards are required in order to minimise the inherent risks related to the mechanical thrombectomy (MT) care pathway and to account for new data from the key trials.

It is recommended that acute stroke thrombectomy should only be undertaken within specialist stroke centres that fulfil agreed standards of care for infrastructure, information technology, imaging equipment, staff, and process. Every centre where such procedures are undertaken has a duty to ensure that safe arrangements are in place. The evidence for thrombectomy efficacy may not be generalisable outside neuroscience/experienced comprehensive stroke centres[2] and broad MT implementation without reference to evidence-based professional standards may risk lower individual and population treatment benefit and result in more patient harm.

Introduction

Over 113,000 individuals have a stroke each year in the UK, and there are around 1 million stroke survivors currently.[3,4] The current UK annual societal cost of stroke is £25.6 billion.[5] The natural history for patients with stroke secondary to occlusion of a proximal intracranial vessel is most severe. For example, the National Institute of Neurological Disorders and Stroke (NINDS) trial demonstrated that only 10% of patients with an National Institutes for Health stroke scale (NIHSS) score of 20 or more achieved independence at 3 months.[6]

The outcome of immediate treatment of ischaemic stroke due to large vessel occlusion (LVO) is dependent on recanalisation of an occluded vessel. Successful recanalisation is associated with increased odds of independence and reduced mortality.[7] Broadly, this can be achieved using thrombolytic drugs and/or MT, a neurointerventional procedure performed using radiological guidance. Intravenous (IV) alteplase has been the mainstay of acute stroke treatment; however, it shows limited ability to break down LVOs. Transcranial Doppler studies have shown that, 2 h after thrombolysis treatment, only 44%, 29%, and 10% of distal middle cerebral arteries, proximal middle cerebral arteries, and terminal internal carotid arteries, respectively, achieve complete recanalisation.[8]

MT clearly shows superior clinical outcomes over best medical therapy including use of IV alteplase, if patients are selected based on non-invasive imaging that identifies a LVO in the anterior circulation and a limited (irretrievable) core infarct.[9–14]

Evidence base for thrombectomy

Anterior circulation

Five pivotal randomised trials comparing MT using stent-retriever devices to best medical therapy were published in 2015. The initial publication, (1) MR CLEAN (Multicenter Randomized Clinical Trial of Endovascular Treatment for Acute Ischemic Stroke in the Netherlands; n=500)[9] demonstrated that MT in addition to standard therapy (which may have included IV alteplase) delivered within 6 h of ischaemic stroke resulted in a 13.5% absolute increase in functional independence with no difference in symptomatic haemorrhage or mortality. Patients with acute ischaemic stroke (with immediate computed tomography [CT] or magnetic resonance imaging [MRI] brain imaging at presentation) had a proximal arterial occlusion (terminal internal carotid artery [ICA], M1 or M2) shown on CTA. The positive result of MR CLEAN triggered a review of the results in a number of contemporaneous trials. These were then halted at an earlier time point. The subsequent publications in 2015 included: (2) ESCAPE (Endovascular Treatment for Small Core and Proximal Occlusion Ischemic Stroke; n=316)[10] confirmed that using more advanced imaging assessment (Multiphase CTA) to identify patients with LVO and good collaterals, suitable for treatment with MT within 12 h of onset (15% randomised beyond 6 h), was beneficial and resulted in 24% absolute increase in functional outcome. Patients who could not receive IV alteplase also appeared to benefit. (3) EXTEND IA (Extending the Time for Thrombolysis in Emergency Neurological Deficits — Intra-Arterial; n=70)[11] used perfusion imaging to identify potentially salvageable brain tissue with treatment completed within 8 h. Although there were significant differences favouring MT (31% absolute increase in functional independence), it should be noted that the patients were highly selected. (4) SWIFT PRIME (Solitaire™ with the Intention for Thrombectomy as Primary Endovascular Treatment for Acute Ischemic Stroke; n=196)[12] confirmed that using a complex imaging strategy of CT/CT angiography (CTA) and CT/magnetic resonance perfusion imaging to identify patients treated within 6 h of onset, resulted in a 25% absolute increase in favourable outcome. Of note, the median time of arrival in the emergency department to groin puncture was 90 minutes. (5) REVASCAT (A Randomized Trial of Revascularization with Solitaire FR® Device vs. Best Medical Therapy in the Treatment of Acute Stroke Due to Anterior Circulation Large Vessel Occlusion Presenting within Eight-Hours of Symptom Onset; n=206)[13] demonstrated that in patients with evidence of LVO without large ischaemic core (perfusion imaging), who failed to revascularise after 30 minutes of IV alteplase, delivery of MT within 8 h of onset resulted in a 15% absolute increase in functional outcome.

Following publication of these trials, the HERMES (The Highly Effective Reperfusion evaluated in Multiple Endovascular Stroke Trials) collaboration analysed pooled individual patient-level data.[14] This meta-analysis confirmed the benefit of thrombectomy. Overall, the number needed to treat to reduce disability by at least one level on the modified Rankin Scale (mRS) for one patient was 2.6. This included benefit for those patients treated with or without prior alteplase, for octogenarians and for those with or without tandem ICA lesions. There was benefit of treatment across the range of clinical stroke severity and there was confirmation of benefit for patients with a baseline infarct extent of ASPECTS (Alberta Stroke Program Early CT Score) of ≥ 6 with treatment commenced before 6 h of onset.

The French THRACE trial (Trial and Cost Effectiveness Evaluation of Intra-arterial Thrombectomy in Acute Ischemic Stroke; n=400)[15] was subsequently published in August 2016. The trial compared results for IV alteplase delivered within 4 h to IV alteplase within 4 h plus MT starting within 5 h, the shortest time window of all trials, selected based on CTA or magnetic resonance angiography (MRA). Importantly, imaging assessment of core infarct size using ASPECTS or perfusion was not used to exclude patients, representing the widest patient selection profile of all randomised controlled trials (RCTs) to date except MR CLEAN. There was an 11% absolute increase in functional outcome in the interventional arm. Two additional trials were also published in 2016: THERAPY,[16] using the Penumbra aspiration system rather than a stent-retriever and PISTE (Pragmatic Ischaemic Stroke Thrombectomy Evaluation).[17] THERAPY (The Randomized, Concurrent Controlled Trial to Assess the Penumbra System's Safety and Effectiveness in the Treatment of Acute Stroke) did not achieve its primary endpoint but was an underpowered sample. PISTE was a pragmatic trial conducted in the UK only, which reported a trend to improved outcome, with an odds ratio for Rankin shift analysis remarkably similar to that of the HERMES meta-analysis.[14] PISTE did not reach statistical significance on intention to treat analysis likely due to the small number recruited when the trial was stopped early after publication of MR CLEAN. The HERMES collaboration performed subsequent patient-level meta-analyses of seven randomised trials and showed significant benefit for patients with an ASPECTS score of 5–7[18] and for patients with proximal M2 occlusions.[19]

In 2018, two further trials were published. These investigations aimed to assess the utility of MT in patients last seen well beyond the accepted therapeutic time window of 6 h, including those patients presenting with "wake-up" stroke. The DAWN (DWI or CTP Assessment with Clinical Mismatch in the Triage of Wake-Up and Late Presenting Strokes) trial (n=206)[20] compared MT with best medical treatment in patients last seen well between 6 and 24 h prior to presentation. Patients were selected for MT based on a clinico-radiological mismatch with small volume infarct core demonstrated on perfusion imaging (defined according to age with a threshold at 80 years). An improvement in functional independence of 33% was demonstrated in the MT arm. The DEFUSE 3 (Diffusion and perfusion imaging Evaluation For Understanding Stroke Evolution; n=182) trial[21] compared MT to best medical treatment in patients last seen well at 6–16 h. This trial used perfusion imaging to select patients with a limited infarct core (<70 ml) and ratio of the volume of penumbral tissue to infarct core volume of ≥1.8. The trial demonstrated a 28% improvement in functional independence in the MT arm and a 12% reduction in mortality.

Considering the prevailing evidence, the European Stroke Organisation (ESO) and European Society for Minimally Invasive Neurological Therapy (ESMINT) have made the following recommendations[22]:

(1) In adults with anterior circulation LVO-related acute ischaemic stroke presenting within 6 h after symptom onset, we recommend MT plus best medical management—including intravenous thrombolysis whenever indicated—over best medical management alone to improve functional outcome. Quality of evidence: High ⊕⊕⊕⊕; strength of recommendation: Strong ↑↑
(2) In adults with anterior circulation LVO-related acute ischaemic stroke presenting between 6 and 24 h from time last known well and fulfilling the selection criteria of DEFUSE-3[1] or DAWN,[2] we recommend MT plus best medical management over best medical management alone to improve functional outcome. Quality of evidence: Moderate ⊕⊕⊕; strength of recommendation: Strong ↑↑

The National Institute for Health & Clinical Excellence (NICE) guidelines, 2019[23] state:

(1) Offer thrombectomy as soon as possible* and within 6 h of symptom onset, together with intravenous thrombolysis (if not contraindicated and within the licensed time window)
  - to people who have acute ischaemic stroke and
  - confirmed occlusion of the proximal anterior circulation demonstrated by computed tomographic angiography (CTA) or magnetic resonance angiography (MRA).

(2) Offer thrombectomy as soon as possible[3]
  - to people who were last known to be well between 6 and 24 h previously (including wake-up strokes) who have acute ischaemic stroke and confirmed occlusion of the proximal anterior circulation demonstrated by CTA or MRA and
  - if there is the potential to salvage brain tissue, as shown by imaging such as CT perfusion or diffusion-weighted MRI sequences showing limited infarct core volume.

Posterior circulation

Outcomes after basilar artery thrombosis are usually poor, with approximately 80% being dead or dependent at follow-up.[24] It has been shown that recanalisation rates of 80–90% can be achieved with MT[25] and a meta-analysis of multiple case series reported favourable outcomes in 42.8%, which is better than expected without intervention[26]; however, the evidence base for the use of MT in this patient group is much less substantial than for the anterior

[1] 6–16 h since time last known well: ► Age ≤80 years and NIHSS≥6: infarct core volume <70 ml and penumbra volume >15 ml and ratio of ischaemic tissue/core volume >1.8.

[2] 6–24 hours since time last known well: ► Age <80 years: infarct core ≤30 ml if NIHSS ≥10; infarct core ≤51 ml if NIHSS ≥20. ► Age ≥80 years: infarct core ≤20 ml and NIHSS ≥10.

[3] Whilst considering the above, take into account the person's overall clinical status and the extent of established infarction on initial brain imaging to inform decisions about thrombectomy. Select people who have a pre-stroke functional status of <3 on the modified Rankin scale and a score of >5 on the NIHSS.

circulation. Two randomised trials have been undertaken to assess the efficacy of MT in the posterior circulation, BEST (Basilar Artery Occlusion Endovascular. Intervention versus Standard Medical Treatment) and BASICS (BASilar artery International Cooperation Study).

The BEST trial[27] (n=131) was terminated early because of high crossover rate to MT and poor recruitment. Patients had been randomly assigned with 66 patients allocated to the MT group treated using a stent-retriever or thromboaspiration system (plus IV alteplase if within 4.5 h of stroke onset) aiming to recanalise the vessel within 10 h of symptom onset and 65 patients allocated to the control group (treated with IV alteplase if within 4.5 h of stroke onset). The intention to treat analysis showed no significant difference in favourable outcome (mRs 0–3 at 90 days) and mortality outcomes were similar.

The BASICS trial[28] (n=300) randomised 154 patients to MT within 6 h of stroke onset (plus IV alteplase delivered within 4.5 h where indicated). Angioplasty or stenting of the vertebral artery in patients assigned to MT was allowed if a stenosis impaired access to the basilar artery and stenting of the basilar artery was allowed if there was residual stenosis after thrombectomy. One hundred and forty-six patients were allocated to a control group whose treatment included delivery of IV alteplase if indicated based on local protocols. Those treated with MT demonstrated a favourable outcome rate of 44.2% as compared to 37.7% in the control arm, yielding an absolute risk reduction of 6.5%, much lower than predicted (on trial powering), partly due to better than expected outcomes in the medical arm. Although caution should be applied in interpretation, subgroup analysis did suggest a significant benefit of MT for patients with a severe stroke, defined as an NIHSS of ≥10. The occurrence of symptomatic intracranial haemorrhage (SICH) within 3 days was not statistically different in the two arms, indicating that MT is safe in this setting. This information was not available at the time NICE guidelines were drawn up; however, NICE supports consideration of MT in patients with basilar artery occlusion.[23]

Organisation of care

Clinical networks

Formal MT networks should be developed between hub and spoke sites encompassing referring Acute Stroke Centres (ASC) served by regional Comprehensive Stroke Centres (CSC) delivering MT. This structure was identified as the preferred model by a Delphi and ranking exercise with clinical stroke and neurointerventional experts on the delivery of thrombectomy services in the UK.[29] These networks may sit inside, alongside or in close partnership with, other regional organisations (e.g., Integrated Stroke Delivery Networks in England).

The aim of the network is to facilitate swift patient transfer and safely minimise stroke onset to reperfusion time to optimise patient outcomes.[30] This can be achieved through improvements in and sustainability of high-quality communication and referral processes between units to allow fast decision-making, transfer, and repatriation with robust governance structures and quality-improvement processes. The network should encompass: the ambulance services; staff from referring ASCs (stroke physicians, specialist stroke nursing staff, radiologists, anaesthesiologists, intensive care physicians); and staff from the CSC providing MT services (stroke physicians, specialist stroke nursing staff, radiologists, anaesthetists, emergency physicians, intensive care physicians, neurointerventional specialists).

A network should employ rapid image sharing systems; rapid communication systems; rapid patient transfer protocols and procedures; rapid repatriation procedures; formal governance arrangements to review cases referred for MT (irrespective of whether a procedure was performed or not) on at least a quarterly basis; and quality-improvement processes that include methods of data collection to assess regional pathway metrics.

Networks should seek to create patient care pathways that cross organisations seamlessly; agree regional imaging protocols including developing advanced imaging (multiphase CTA, CTP and/or MRI) in referring hospitals; set network-wide standards that apply to the MT pathway; embed a quarterly meeting to review processes and protocols and improve quality; establish educational meetings inclusive of all clinicians in the pathway to facilitate service development, patient identification and rapid referral; establish back-up plans in the event of MT facility failure or major incident precluding operation of pathway.

Pre-hospital care

Emergency Medical Services (EMS) play a vital role in hyper-acute stroke care and local protocols and algorithms should be in place for dispatch, assessment, pre-notification and transport strategies. All suspected stroke patients potentially eligible for intravenous thrombolysis should be transferred immediately to the closest centre with hyper-acute stroke services (ASC or CSC) experienced in delivering this treatment with early notification of the specialist stroke team. Patients with suspected stroke and a contraindication to IV alteplase should be equally prioritised.

In hospitals receiving acute stroke patients, pre-alert protocols may be extended to include patients presenting beyond 4.5 h and include wake-up strokes or strokes without an immediately apparent onset time. Time extension should be agreed locally by networks.

Construction of protocols for EMS triage direct to CSCs remains controversial. Despite the theoretical advantage of reducing time to reperfusion,[31–33] this has two principle potential downsides including (1) reduction in case numbers below national guidelines for the acute stroke centre (so impacting on sustainability of that service) and (2) the potential to overwhelm the CSC with admissions.[34] The RACECAT (Rapid Arterial Occlusion Evaluation Trial) trial showed no significant difference in outcomes for those triaged direct to the CSC versus those who were initially treated at an acute stroke unit and thence transferred to the

CSC but it is worth pointing out that the door in-door out (DIDO) times in this study were exceptionally fast.[35] Construction of local protocols that alter the patient pathway should be made on a regional basis with appropriate stakeholder support and resourcing.

A number of pre-hospital clinical scales for identification of LVO have been constructed. Current evidence suggests that these are of insufficient sensitivity and specificity to be widely deployed.[36] Video triage may represent a future development to facilitate EMS triage but is currently under investigation. A mechanism should exist for providing feedback to the EMS and referring centres to highlight which aspects of care went well and identify areas for improvement. The quarterly (or more frequent) MT meeting could be developed to fulfil this role. Continuing education of EMS staff is vital and efforts should be made to establish regular training including clinical updates within EMS staff education programmes.

ASC and inter-hospital transfer

The role of the ASC in the patient pathway cannot be underestimated. The majority of thrombectomy patients undergo initial assessment in an ASC with secondary transfer. The ASC is responsible for initial diagnosis and treatment and also has a role in improving patient flow through a regional network by facilitation of both swift patient transfer for MT treatment and efficient repatriation for ongoing care.

Door in-Door out times

The emphasis of care in ASCs should be on minimising DIDO time for patients transferred for MT. Longer DIDO times may have a deleterious effect on outcomes and may represent the single biggest modifiable factor in onset to recanalisation time.[30] There can be significant variability in DIDO times between ASCs.[37] Optimisation of DIDO times is summarised in Table 1 (modified from [38,39]).

Table 1
Optimisation of DIDO time.[38,39]

- Organisation of rotas to ensure all necessary staff are available to support the thrombectomy pathway, mirroring MT availability in the thrombectomy centre
- Utilisation of pre-hospital alert systems
- Rapid assessment and triage by appropriately trained staff “at the front door”
- Rapid imaging including simultaneous non-contrast CT and CTA for all patients suspected of having an LVO
- Minimal “door to CTA times”
- Consideration of simultaneous CTP for those last seen well 6–24hrs in the ASC. If CTP is not available at local ASC, it would be reasonable to organise transfer in the event of favourable ASPECTs on NCCT/CTA
- Swift local radiological interpretation and/or utilisation of automated CTA/multiphase CTA/CTP post-processing software
- Automated image sharing with the comprehensive stroke centre
- Rapid administration of IV alteplase if appropriate
- Simultaneous rapid communication with the CSC and activation of patient transfer
- It is the responsibility of the CSC to respond with a decision as fast as possible
- ASC should target a median DIDO time of <45 minutes. Accurate data entry for National audit database (such as SSNAP in England) to record and share DIDO times across a network would be valuable
- Retaining the initial ambulance crew for transfer is associated with significantly shorter DIDO times[39] and efforts to build this into local processes should be made
- Many of these factors will represent areas for quality improvement

MT: mechanical thrombectomy; CT: computed tomography; CTA: CT angiography; CTP: CT perfusion; NCCT: non-contrast CT; LVO: large vessel occlusion; ASPECTS: Alberta Stroke Program Early CT Score; CSC: comprehensive stroke centre; DIDO time: door in-door out time; ASC: acute stroke centre; SSNAP: Stroke Sentinal National Audit Programme

Telemedicine and artificial intelligence tools

Stroke specialist assessment of the patient in the ASC, particularly out of hours, may be facilitated by shared regional rotas and telemedicine. The role of telemedicine in stroke has been extensively reviewed.[40]

Artificial intelligence (AI) platforms may be useful in aiding clinical imaging interpretation, particularly in hospitals that have limited access to neuroimaging specialists. These tools have been shown to also identify regions of core infarction (including ASPECTS estimation and volume estimation), identify LVOs, estimate collateral flow and post-process perfusion imaging to display regions of core infarct and penumbra with volumetric assessment.[41]

- Stroke AI platforms can process large imaging datasets rapidly and have the potential to accelerate decision-making and reduce patient transfer times between primary and comprehensive stroke centres.[42]
- The sensitivity and specificity of AI platforms for diagnosis of ischaemic stroke and detection of LVO vary. It is therefore imperative that clinical decisions based on AI interpretation of acute imaging are made by clinicians that are aware of the limitations of AI and are able to interpret the imaging independently.[43] Further research is urgently required to fully evaluate these tools.
- The majority of current commercially available stroke AI vendors employ cloud services to facilitate rapid transfer of neuroimaging data across multiple platforms and health organisations. To ensure information governance requirements are met, vendors should fulfil published guidelines and national standards.[44,45]
- Primary clinical review of images should be undertaken on diagnostic workstations. If images are reviewed on mobile platforms (laptops, tablets and smartphones), they should meet minimum display resolution requirements (2 megapixels with a luminance range of 1–250 cd/m^2).[46]

Thrombolysis delivery, transfer and repatriation

It is important that provision of IV alteplase is not delayed. Local protocols for delivery of IV alteplase prior to transfer should be established. Although demonstrated as feasible,[47] there is currently no substantial evidence describing use of IV alteplase during secondary transfer using trained paramedics to reduce DIDO times although similar protocols have been used in the cardiology literature without reported transfer-associated complications.[48] Although stroke nurses may accompany the patient and supervise IV alteplase delivery during transfer, this is a significant resource issue for the ASC. This represents an area for further research and quality improvement.

Networks using paramedic transfer for the majority of cases report few secondary transfer-related complications.

- A recent review of 377 patients transferred for MT assessment within a stroke network in whom 65% had been administered IV alteplase recorded no major complications associated with transfer.[49]
- In another study encompassing 253 patients (168 receiving IV alteplase), thrombolysis related complications on transfer were seen in 0.6% only.[50]

It is acceptable to transfer the patient without stroke nurse escort following IV alteplase if no complications are evident in the ASC.

Rapid endo-tracheal intubation and transfer with anaesthetic escort is required in patients with a Glasgow Coma Scale of ≤8. Neuro-critical care society guidelines detailing features of safe transfer have been published.[51] In these instances, there should be an intensive care to intensive care handover.

Key information that should be shared between ASC and CSC on referral and repatriation is summarised in Tables 2 and 3. Local arrangements for image transfer should include transfer of imaging obtained at the thrombectomy centre back to the ASC in order that the ASC has the most up-to-date imaging for comparison. Repatriation to the ASC should occur without delay as a priority, as per locally agreed protocol and no more than 12 h following a request.

Some systems have utilised immediate repatriation in order to maximise the number of treatments that can be delivered by a CSC.[52] The low reported rate of complications suggests that this is a feasible option but this system of care requires many partners across a wide range of specialties and services to work cohesively. Introduction of such a system is dependent on other factors such as patient selection and use of general anaesthesia. This may work for a proportion of patients but will place a heavier burden on ambulance services and ASCs.

Table 2
Core information that should be made available to the CSC.

- Accurate pre-morbid level of dependence (mRS score)
- Comorbidities, particularly those pertinent to use of general anaesthesia and previous functional level of patient including a measure of frailty, atrial fibrillation/cardiac arrhythmia, diabetes mellitus, hypertension
- Community resuscitation status
- Medication history/allergies
- Stroke onset time or time last known well
- Glasgow coma scale
- Time of last meal/drink (to guide anaesthetic management)
- NIHSS score
- Key observations: blood pressure, heart rate, oxygen saturation
- Investigations (blood results and ECG) to accompany the patient
- Contact details for family members/next of kin
- Local CT/CTA
- Use of IV alteplase
- COVID-19 status or other relevant infection if known

CSC: comprehensive stroke centre; mRS: modified Rankin Scale; NIHSS: National Institutes of Health Stroke Scale; ECG: electrocardiogram; CT: computed tomography; CTA: CT angiography; IV: intravenous; COVID-19: coronavirus disease-19

Table 3
Core information that should be provided to the ASC on repatriation.

- Pre-treatment NIHSS and confirmation of vascular occlusion
- Accurate information on MT procedure and any complications/issues eg. If a permanent stent is left in situ this must be highlighted to inform antiplatelet therapy
- Clinical state and level of care requirement
- Swallowing status and ability to transfer/mobilise
- OT and PT assessment if available but assessment should not delay repatriation
- Medications including current plan for blood pressure management, antiplatelet therapy (including duration if there has been stent implantation) and anticoagulation
- Requirement for any specific investigations, though plan for “stroke work-up” to investigate cause of stroke should be directed by the local ASC
- COVID-19 status and other infectious diseases (MRSA, CRE status) if admission prolonged
- Resuscitation status

NIHSS: National Institutes of Health Stroke Scale; MT: mechanical thrombectomy; OT: occupational therapy; PT: physiotherapy; ASC: acute stroke centre; MRSA: methicillin-resistant Staphylococcus aureus; CRE: carbapenem-resistant Enterobacterales

CSC delivering MT

Trial data supporting improved clinical outcomes in patients treated with MT have almost exclusively been derived from higher-volume CSCs with fellowship-trained neurointerventionalists and CSC-level acute stroke care.[9–13,15–21] It is well established that higher-volume centres have improved outcomes relative to lower-volume centres in delivery of intravenous thrombolysis, carotid artery stenting, coil embolisation for intracranial aneurysms and percutaneous coronary intervention.[53–58]

Likewise, for stroke intervention both observational and prospectively acquired registry data[59,60] and data derived from the US national inpatient sample[2,61] support the notion that higher volume centres obtain improved clinical results for functional outcome, with lower complications and mortality. A recent study of over 900 patients undergoing MT demonstrated that for hospitals treating >150 patients per year versus those treating 20–30 patients per year there was a 10% improvement in independent outcome and 4% reduction in mortality.[62] Similarly, a study of US data encompassing 13,335 patients[61] demonstrated that for every 10 case increase in centre volume, mortality fell by 4% and favourable outcome increased by 3%. A similar association was found for operator volume and outcomes and importantly, odds ratios for mortality continued to fall and odds ratios for favourable outcome continued rise beyond 90 cases.

With the current hub and spoke model of care that exists in the UK, there is concern that transfer times to CSCs can impact negatively on patient outcome or limit access.[63] This highlights the need for consideration of network organisation and minimisation of DIDO times in ASCs. US data does suggest that mortality is lower in patients transferred to high-volume centres for MT rather than being treated at a local low-volume centre.[64] State-wide data obtained in the US questions the clinical impact of MT provided in low-volume centres.[2]

These findings suggest improvements in patient selection, technical performance of MT and post-procedure care may justify the current model of concentrating MT procedures at specialised regional thrombectomy centres incorporating a hyperacute stroke unit (HASU) embedded within a high-quality comprehensive stroke service with access to neurosurgical, neurocritical care, and specialist in- and out-patient stroke services in addition to access to advanced brain imaging facilities and appropriate neurointerventional expertise. Key features of a HASU within a CSC are summarised in Table 4.

Endovascular stroke therapy should only be delivered by CSCs with the appropriate experience in delivering such interventions. For comprehensive centres, the international multisociety consensus guidelines document: Standards of Practice in Acute Ischemic Stroke Intervention states that each institution offering thrombectomy should perform 120 MT procedures per year and each operator should perform at least 50 neuroendovascular procedures including coiling/aneurysm treatment procedures per year.[67] This correlates well with published UK guidance of a minimum operator volume of 40 interventional neuroendovascular procedures per year.[68]

Skill mix

The decision to perform MT should be made jointly by a multidisciplinary team comprising a consultant stroke physician, neurointerventionalist and, if applicable, an anaesthetist (preferably experienced in neurological care) in conjunction with the patient and/or their representatives. The stroke physician undertaking the decision to consider MT should satisfy the British Association of Stroke Physicians (BASP) criteria for a stroke specialist[65] (Table 5).

The stroke physician should be trained in delivering thrombolysis and in the monitoring of any complications associated with thrombolysis and endovascular therapy. They should be aware of advances in peri-procedural care (for example, BP management). This must be underpinned by regular quality and audit meetings within a quality-improvement group incorporating stroke physicians, neurointerventionalists, neuroradiologists, intensivists, and/or emergency medicine physicians.[69]

There should be provision of 24/7 consultant stroke physician cover.[70] BASP have made recommendations on the minimum number of direct clinical care programmed activities that would be required to support such a service.[71] As services develop across the country, workforce requirements should be carefully monitored and recommendations may need to be updated with ongoing experience.

The neurointerventionalist evaluating the diagnostic neuroimaging and performing the MT procedure should satisfy British Society of Neuroradiology (BSNR)/United Kingdom Neurointerventional Group (UKNG)/British Society of Interventional Radiology (BSIR) criteria for an interventional neuroradiologist (INR), or for an interventional radiologist (IR) who has trained to add MT to their scope of practice.[68] These criteria are summarised in Table 6. The Royal College of Radiologists (RCR) Sponsored General Medical Council (GMC) Credential INR (Acute Stroke) was submitted to the GMC in October 2019 and remains under consideration. This credential will enable non-radiologists to train to a level where they can participate in MT service delivery and contribute to 24/7 MT services. Should the credential be supported there will be a third pathway for MT training. In addition to interventional procedural competences, all operators should be independently competent at MRI and CT image interpretation plus non-invasive and invasive angiographic image interpretation for patient selection, treatment planning, and complication

Table 4
The key features of what a HASU in the CSC should incorporate.

- 24-hour availability of an experienced consultant stroke physician[65]
- Immediate access to brain imaging including CT Angiography/Perfusion & MRI as required[66]
- Direct admission to HASU from ED as soon as possible
- Continuous physiological monitoring (ECG, oximetry, blood pressure)
- Specialist stroke physician ward rounds 7 days per week
- Acute stroke protocols/guidelines
- Nurses trained in swallowing screening, stroke neurological assessment (including the NIHSS assessment), eligibility assessment for thrombolysis and administering thrombolysis treatment

CT: computed tomography; MRI: magnetic resonance imaging; HASU: hyper-acute stroke unit; ED: emergency department; ECG: electrocardiogram; NIHSS: National Institutes of Health Stroke Scale

Table 5
Stroke physician criteria.[65]

- Completion of specialist training or recognised expertise (existing specialists)
- Ongoing active involvement in stroke management
- Annual attendance of at least one specific training event
- Evidence of continued professional development in the field of stroke medicine
- Participation in national stroke related audit and local governance processes including quality improvement
- Basic research skills (participation or facilitation of stroke research)

Table 6
Neurointerventionalist criteria.

- Completion of specialist training (INR) or acquisition of recognised expertise in clinical practice (IR)[68]
- Minimum case experience of 40 intracranial neurointerventional procedures/year[68]
- A job-planned commitment to cover neurovascular and stroke MDTs
- Evidence of continued professional development in INR/MT
- Participation in national stroke related audit and local governance processes including quality improvement
- Basic research skills (participation or facilitation of stroke research)

INR: interventional neuroradiologist; IR: interventional radiologist; MDT: multi-disciplinary team; MT: mechanical thrombectomy management.[72] This includes appropriate selection of imaging in thrombectomy triage.

There should be provision of a 24/7 consultant-led service provided by sufficient practitioners to cover services for both ischaemic and haemorrhagic stroke (ranging from 4–6 depending on referral population/activity levels in the CSC).

Multisociety MT guidelines and quality benchmarks

Eligibility for mechanical thrombectomy should not delay the initiation of IV alteplase where this is indicated. A direct to thrombectomy approach is the subject of ongoing trials. MT should also not be delayed to assess response to IV alteplase.

Offer endovascular stroke therapy to:

(a) Patients with proximal intracranial LVO in a symptomatic territory leading to a neurological deficit (NIHSS ≥6) within 6 h of known onset. The decision to treat will also be governed by the overall clinical status and extent of any established infarction on initial brain imaging. This includes those with contraindications to intravenous thrombolysis therapy (e.g., recent surgery or use of anticoagulants) and those with tandem cervical ICA lesions;

(b) Patients with a proximal intracranial LVO in a symptomatic territory leading to a potentially disabling neurological deficit in patients last seen well 6–24 h prior to stroke onset with evidence of limited core infarction on multiphase CTA, CT perfusion or MRI diffusion.

Strict trial evidence[20,21] suggests:

- 6–16 h since time last known well: ► Age ≤80 years and NIHSS≥6: infarct core volume <70 ml and penumbra volume >15 ml and penumbra volume/core volume >1.8.
- 6–24 h since time last known well: ► Age <80 years: infarct core ≤30 ml if NIHSS ≥10; infarct core ≤51 ml if NIHSS ≥20. ► Age ≥80 years: infarct core ≤20 ml and NIHSS ≥10.

It is recognised that patients may fall outside these strict criteria in real-world scenarios[73] and that treatment should be tailored to the individual patient.

(c) Patients suitable for entry into RCT where there is clinical uncertainty.

(d) In the context of a posterior circulation occlusion, consider offering MT in patients with basilar artery occlusions or dominant vertebral artery occlusions as demonstrated on non-invasive angiography with evidence of limited core infarction (ideally with MRI diffusion imaging).

Neurointerventional procedural guidance

Operative technique should be tailored to the scenario and optimised to achieve first pass recanalisation (FPR).[74] Technical considerations include mode of access, balloon guide catheter use, intermediate catheter use, an aspiration only approach, treatment of a tandem cervical arterial lesions and salvage procedures in the event of MT failure.

Use of a balloon guide catheter (BGC) rather than a cervical guide catheter may be beneficial.

- A meta-analysis including 2,022 patients showed higher odds of FPR in the BGC group (OR 2.1, 95% CI 1.65 to 2.55).[75]
- SWIFT PRIME: smaller final infarct volumes and improved reperfusion scores in the BGC group.[76]
- NASA registry (North American Solitaire Stent Retriever Acute Stroke registry): improved clinical outcome and reperfusion scores with the BGC group.[77]
- ROSSETTI registry (registry of consecutive patients with anterior circulation large-vessel occlusion from 10 CSCs in Spain): improved FPR and clinical outcome.[78]
- STRATIS (Systematic Evaluation of. Patients Treated With Neurothrombectomy Devices for Acute Ischemic Stroke) registry: the use of a BGC was associated higher FPR and improved clinical outcomes.[79]
- TRACK registry (TREVO Stent-Retriever Acute Stroke Registry): lower mortality in the BGC group.[80]

It should be recognised that the current generation of BGCs can be more challenging to navigate through more tortuous anatomy, and therefore, use of BGCs is largely down to operator preference taking into account patient-related factors.

Current trial evidence is insufficient to show superiority between an aspiration first technique or stent-retriever first technique for the range of anterior circulation occlusions (ICA, M1, and proximal M2).[81,82]

Concurrent use of contact aspiration using an intermediate catheter and a stent-retriever has been shown to be superior in observational studies[83–86] but there is currently no RCT to prove a synergistic effect. This is currently being investigated in the ASTER (Contact Aspiration vs Stent Retriever for Successful Revascularization) 2 trial.[87] It is reasonable to use this approach in clinical practice.

A number of areas of neurointerventional techniques remain under full investigation including:

(1) Optimal management of tandem cervical lesions with carotid stenting and/or angioplasty.
- A meta-analysis of observational studies comprising 1758 patients showed superiority of emergent carotid artery stenting over balloon angioplasty for functional outcome with no significant increase in symptomatic intracerebral haemorrhage (SICH) or mortality.[88]
- A prospective registry (TITAN=Thrombectomy In TANdem Occlusion registry) of 295 patients demonstrated that emergent carotid stenting with antithrombotic agents with thrombectomy yielded higher reperfusion

rate and favourable outcome compared to other strategies (carotid artery stenting and thrombectomy without antithrombotic agents, angioplasty and thrombectomy, or thrombectomy alone).[89]

- However, concerns remain regarding risk of SICH with anti-platelet use if stenting is required.
- A systematic review reported a neutral effect of peri-procedural use of antiplatelet on the functional outcome with an increased risk of SICH.[90]
- The current evidence favours use of stenting but it is reasonable to consider use of angioplasty alone or stenting with tailored antithrombotic regimes for individual patients, taking into account factors such as infarct extent, stroke severity and whether the patient has received thrombolysis. In cases where perceived benefit/risk of stenting and antiplatelet use is considered safe, it would be best practice to discuss optimal management with the stroke consultant.

(2) Salvage stenting of the intracranial vessel in instances of failed recanalisation (for example in cases of intracranial atheromatous disease, flow limiting dissection or persistent thrombotic occlusion despite multiple passes):

- A meta-analysis of observational data suggests benefit.[91] Stenting was associated with higher rates of 90-day favourable clinical outcome, lower mortality and SICH rates did not significantly differ.
- The level of evidence remains low as it is based on observational studies only.
- It is reasonable to consider use of salvage stenting in cases showing an underlying stenosis with evidence of diminishing flow despite MT, flow limiting dissection flap, or adherent LVO resistant to multiple passes, taking into account baseline stroke severity and extent of core infarction and potential risks of antithrombotic therapy.
- In cases where perceived benefit/risk of stenting and dual antiplatelet use is considered safe, it would be best practice to discuss optimal management with the stroke consultant.

(3) Mode of access (upper limb or direct carotid for difficult arch/neck vessel anatomy)

- A recent case–control study showed that a femoral first technique rather than a radial first technique was associated with higher successful reperfusion rate, fewer passes, lower 3-month mortality, and improved 3-month functional outcomes.[92]
- Another observational study showed no significant difference in outcomes between techniques.[93]
- In instances where access via a femoral route is not possible or challenging, it is reasonable to consider use of upper limb or direct carotid access.[94,95]

It should be recognised that use of these techniques is often governed by individual patient factors including clinical stroke severity, access anatomy, clot sub-type and extent of core infarction. There is insufficient evidence to be prescriptive regarding all situations.

Quality benchmarks for MT

Local protocols in a MT centre should specify indications and inclusion criteria that align with national and international guidelines. These should be reviewed on an annual basis (in view of the rapid evolution of clinical evidence in this field).

- The majority of patients treated with MT should meet the institutional selection criteria. If a patient is treated outside selection criteria, the rationale for treatment and discussion with referring stroke physician should be documented.
- 100% of CSCs should record quality indicators such as patient selection criteria, pathway time intervals, MT result, complications and clinical outcomes as part of local audit and quality improvement processes.

Pre-procedural timings

- Door to Imaging*:* All patients with an acute stroke being evaluated for MT should be imaged immediately (ideally the next imaging slot) in the centre at which the patient presents.
- Use of CTA or MRI/MRA should not unduly delay therapy with intravenous thrombolysis or delay door to arterial puncture. In practice, hospitals that undertake CTA routinely in acute stroke achieve this by review of plain CT occurring whilst CTA is performed and then not waiting for CTA review before instituting IV alteplase (where indicated) or while CTA is being set up, with administration of bolus pre-CTA.
- DIDO for ASCs: aim for 45 minutes.

It is not mandatory to re-image patients after secondary transfer to the CSC. Time delays can be incurred by repeat imaging. A minority (approximately 10% of patients in one network-based study[94]) show recanalisation during transfer. Predictive factors included treatment with IV alteplase and clinical improvement.[96] A recent study with mean time between ASC CT and CSC CT of 240+/-128 minutes showed ASPECTS decay sufficient to preclude MT in approximately 10% only.[97] The proportion of patients who show ASPECTs decay is likely impacted by the proportion of fast vs slow progressors included. Three studies have failed to show a relationship between time from ASC CT to CSC CT and ASPECTS decay.[97,99] Consider repeat imaging in cases of clinical change, in patients with lower baseline ASPECTS (CT performed at ASC),[97] in patients with high clinical scores[95,96] and in patients with poor baseline collateral flow.[98] For patients arriving at the CSC >6 h from symptom onset, use of CTP should be considered to guide further management, unless this has already be done at the ASC.

Door of CSC to groin puncture: the metric of “arrival to start of treatment” should be within 60 minutes or as fact as reasonably possible, unless the indication for intervention only developed after arrival (e.g., deterioration in NIHSS).

Door to groin puncture for those referred from ASCs should be 45 minutes or as fast as reasonably possible.

Procedural timings

- Puncture time to start of revascularisation (first deployment of MT device): <30 minutes in at least 65%.
- Puncture time to end of revascularisation (time of last angiographic run after cerebral thrombectomy finished): centre median <60 minutes.

Outcomes (modified from [69])

- Revascularisation achieved: at least 70% should have TICI grade 2b or better (where target artery accessed).
- At least 90% of patients should have a brain CT or MR imaging within 36 h of the end of the procedure.
- No more than 10% of patients should have embolisation to a new territory.
- SICH using Safe Implementation of Treatments in Stroke (SITS) definition (parenchymatous haemorrhage type 2) combined with deterioration of NIHSS score ≥4 points at 22–36 h (SICH should be expected in no more than 10%).
- All cases with SICH should be reviewed.
- All deaths within 72 h of procedure are measured and reviewed.
- All treated patients have a documented NIHSS score at 24 h.
- mRS 0–2 at 6 months achieved in ≥45% of cases.[14]
- Implementation is summarised in Table 7.

Recommendations for individual hospitals

Neuroradiology departments in CSCs

There should be recognition that existing INR services should be supported to develop/expand ability to provide MT within the NHS subject to NICE guidance.

- Service expansion will depend upon local circumstances, workforce and funding. Urgent regional planning and support for future delivery of extended hours services should continue where 24/7 not yet achieved.

Table 7
Implementation of standards and quality benchmarks.

• Local agreement should be reached amongst neurointerventionalists about what service is provided
• Processes for maintenance of skills should be in place (this may include updating practical skills by spending time in other departments)
• A weekly timetable of MT service h should be available to all referrers.
• Formal contracts should exist with referring centres
• Agreed local protocols should be evidence based (within limits of evidence)
• National guidelines should be adhered to
• Appropriate case review and quality-improvement processes should be in place

MT: mechanical thrombectomy

There should be clarity within the centre and among referring clinicians and service managers about what MT services are available, when they are available and what happens when the service is not available.

- Local patient pathways should exist, be clear and widely available.
- Local protocols and standard operating procedures for each step of the pathway should be accessible.
- The hospital's clinical governance committee and relevant referring clinicians need to be aware of the situation.
- Delivery of MT in acute stroke should only be in the context of established, high-quality stroke services, where all patients have timely access to specialist stroke units.

Service provision must be subject to a formal rota

- It is not safe or sustainable to rely on ad hoc arrangements. Such arrangements do not ensure that all eligible patients are treated.[100] Ad-hoc rotas are not in the best interest of patients.
- This form of service provision may conceal lack of safe, reliable service provision.
- There must be a safe environment for performing the procedure and close liaison with the appropriate clinical team(s).
- It is not acceptable to assume another centre will be willing or able to provide the service without official and agreed service level agreements (an agreed robust mechanism should be in place for informing clinical teams about when service is available).

There should be recognition of the resource implication on neurointerventional consultants of supporting even a limited extended hours MT service and also of the knock-on impact on diagnostic neuroimaging services.

- Consideration should be given to outsourcing of diagnostic neuroradiology work to free up time for INRs to concentrate on staffing neurointerventional rotas.
- There should be recognition of the disruptive impact of an MT service on other radiology services in centres where IR and INR specialists share facilities.

Appropriate diagnostic neuroimaging support and protocols should be in place.

A whole support team of staff is required to deliver MT and this needs to be IMMEDIATELY available:

- Anaesthetic staff with appropriate training/experience in neuro-anaesthetic care plus operating department practitioner support
- Angio suite staffing – nursing and radiographic

- After care is a critical requirement – neuro-critical care facility should be immediately available post-procedure for those who need it and a monitored HASU bed for others.

The neurointerventionalist, in collaboration with the stroke team, should have shared responsibility for preoperative and postoperative patient care with stroke medicine and critical care where applicable.

Thrombectomy should be delivered in specialist stroke centres that fulfil the following attributes:

- Availability of two (ideally biplane) digital subtraction angiography units with flat panel CT capabilities and necessary software and hardware in order to perform high-quality cerebral angiography (it is recognised that many CSCs are working towards the availability of two biplane units).
- Adherence to defined standards (as section above).
- Consultant-led and delivered services with adequate volumes of activity (see section above).
- Formal commissioning arrangements in place.
- Demonstrable research capability and activity where clinical activity extends beyond core evidence from the randomised trials underpinning NICE guidance.

Considerations related to COVID-19

- Availability of rapid testing to confirm patient COVID-19 status and guide decisions on personal protective equipment requirement, aerosol-generating procedures, patient care before, during and after procedure.
- Modified clinical care pathways that account for COVID-19 status.
- Modified departmental procedures that account for COVID-19 status.

Clinical governance and quality improvement

Services should have regular clinical–radiological multidisciplinary team (MDT) meetings where MT patients can be reviewed/discussed. Neurointerventional operators and staff involved in patient selection and post procedural care should participate in multidisciplinary case review. Additionally, enrolment of patients into RCTs or registries is encouraged. Processes to allow entry of data into national audit (e.g., Sentinel Stroke National Audit Programme [SSNAP] or Scottish Stroke Care Audit [SSCA]) and appropriate local audit processes should be in place.

All cases including those patients referred but who did not undergo MT should be discussed.

A quality-improvement group could include a combination of neurointerventionalists, neurologists, stroke physicians, anaesthetists, intensivists and diagnostic neuroradiologists, angio-suite nursing staff and radiographers. Additional members might include representative(s) from quality assurance/improvement or risk management teams.

New thrombectomy centres

Formal links should be developed with nearby CSCs who are already delivering thrombectomy to encompass a coordinated strategy for:

- Training and skills maintenance in all aspects of thrombectomy service delivery including patient imaging, selection, neurointerventional procedural care, intra and post-procedural management including neurocritical care.
- Audit/governance/morbidity and mortality. It is mandatory to enter clinical and radiological data into national audit.

Recommendations for individual neurointerventional operators

All doctors are bound to adhere to GMC guidance and comply with principles and values set out in Good Medical Practice. All consultants contributing to an MT service should have completed a recognised training process in the UK, or should have a Certificate of Eligibility for Specialist Registration.

Operators should not carry out procedures with which they are unfamiliar. At the current time in the UK, this largely limits the provision of endovascular intracranial stroke therapy to consultant INRs or consultant IRs working in neurointerventional teams; however, with appropriate training and acquisition of the required skill-set in the appropriate environment, non-radiology clinicians may perform these procedures. A credential focussed on acquiring the neurointerventional skills required for safe practice, sponsored by the RCR, is being developed and is currently under consideration by the GMC.

If a procedure is required on a regular basis then individual operators must maintain the necessary skills or competencies.[67,68] MT should be practised in neurointerventional teams to optimise exchange of experience and knowledge and provide professional support. Amongst trained INRs, procedural experience significantly impacts on outcome metrics.[101] The solitary practice of neurointervention including MT is strongly discouraged.

There will inevitably be a risk–benefit assessment to be made in any individual case and patients and presentations do vary considerably. The risk of any patient transfer, presence or absence of alternative therapies and INR experience will all need to be taken into account. This risk–benefit analysis should be reflected in the consent/assent obtained and documented.

It is the duty of the operator to report any risk management concerns to the hospital's clinical governance committee and to inform the patient or patient's family in the event of adverse incidents.

Patient consent

Capacity assessment in someone having an acute major stroke is sometimes difficult and, as with thrombolysis, careful decisions need to be made with regard to ability to consent and best interests.

Three scenarios may be encountered prior to thrombectomy:

- MT is indicated and the patient has capacity: rapid explanation to the patient and consent 1. If the patient needs time to understand, explain it is not in their best interest to delay the procedure, but the operator should answer all questions to the patient's satisfaction, even if this causes delay. The patient can decline treatment.
- MT is indicated and the patient does not have capacity: document a capacity assessment and proceed under best interests and consent 4, involving the family where possible or under the legal framework of the devolved nation.
- The operator is considering a procedure that does not align with current NICE guidance, or where the potential benefit of MT is less clear: under these circumstances, regardless of capacity, the best interests of the patient are debatable and patient capacity, autonomy and potentially the family's wishes should be taken into account in the consent process.

Locally agreed patient/family information sheets or decision aids displaying agreed national or possibly local data on outcomes and complications can be employed.

Anaesthetic and peri-procedural management of MT

The bulk of observational data and post-hoc analysis of randomised trial data suggested poorer outcomes in patients receiving general anaesthesia compared to procedures under local anaesthetic or conscious sedation[102–105]; however, there is insufficient information about the type of anaesthesia used and intra-procedural variables in these trials to give a definitive answer regarding an effect of general anaesthesia itself. It is also very difficult to separate the fact that it is often the most ill patients who undergo general anaesthesia.[104]

Three single-centre randomised trials showed no difference, or even possible benefit, of general anaesthesia versus conscious sedation using the same anaesthetic agents.[106–108] Exceptionally fast general anaesthesia induction (median 9 minutes delay when intubating the patients) was achieved and strict protocols for maintaining blood pressure and other physiological parameters were implemented.

The latest recommendations from the American Heart Association/American Stroke Association[109] have evaluated the evidence to date and state that it is reasonable to select an anaesthetic technique based on an individualised assessment of patient risk factors, technical performance of the procedure, and other clinical characteristics.

- The choice of anaesthetic should be tailored to the individual patient based on neurological status, airway control and treatment plan in close communication with the neurointerventionalist.
- Local anaesthesia should be aimed for, if feasible, in patients who are cooperative and can protect their airway.
- General anaesthesia is recommended in patients with a reduced level of consciousness, uncooperative or agitated patients, those who cannot protect their airway or those already intubated. Intra-procedural conversion to general anaesthesia occurs in up to 16% of cases and is associated with greater variance in mean arterial pressure but impact on outcome is uncertain.[110]
- Patients receiving local anaesthesia with sedation should be monitored and provision made to enable rapid conversion to a general anaesthetic if necessary.
- Local protocols should be constructed to routinely identify which patients should be managed using general anaesthesia.
- Institutions should audit their practice including type of anaesthetic, monitoring, timing, anaesthetic agents used, and complications.

Recommendations for provision of care

- The anaesthetic care of these patients should be supervised by anaesthetists with neuroanaesthetic experience with skilled assistance. It should be consultant led and consultant delivered where possible.
- Regular training and educational updates should be provided for those not familiar with the environment or procedure.
- If a patient is sedated the responsible clinician must be present in the procedure suite.
- Sedation protocols must be constructed with anaesthetic department oversight and delivery overseen by anaesthetists fulfilling local governance arrangements.

Pre-assessment

These patients present as time critical emergencies, akin to evacuation of an extradural haematoma or category 1 Caesarean section. Delays have detrimental effects on patient outcome. Pre-assessment of the patient must be done as quickly as possible to avoid delay.

Airway management

- Tracheal intubation is recommended for those patients with reduced level of consciousness, signs of brain stem dysfunction, those unable to protect their airway, with active nausea and vomiting before intervention and patients who become hypoxic or develop airway obstruction under sedation.

- Supplemental oxygen administration is recommended during sedation.
- All patients should be monitored with pulse oximetry and capnography.
- FiO_2 should be titrated to maintain SpO_2 >94%. Ventilation should be adjusted to maintain normocapnia under anaesthesia. Hypercapnia should be avoided in patients undergoing sedation.

Haemodynamic management

- Haemodynamic monitoring should include electrocardiogram (ECG) and continuous blood pressure or, if non-invasively measured at least once every 3 minutes.
- Continuous invasive arterial monitoring is recommended for all interventional procedures under general anaesthetic as long as arterial cannulation will not delay intervention. The femoral artery cannulated by the neurointerventionalist can be used to provide continuous arterial monitoring if necessary.
- In patients having general anaesthesia or sedation, mean arterial pressure should be maintained within 10% of target pressure with fluids and/or vasopressors. Both high and low blood pressures are associated with higher rates of death and dependency. A balance exists between excessive hypertension contributing to an increased intracranial haemorrhage risk and cerebral oedema versus compromised cerebral perfusion to the ischaemic penumbra with an inappropriately low mean arterial pressure.

A recent analysis of all three randomised trials[106–108] identified an optimal range for blood pressure maintenance during thrombectomy (using either general anaesthesia or conscious sedation) of a mean arterial pressure of 70–90 mmHg*.[111]

- *A cumulated period of minimum 10 minutes with <70 mm Hg mean arterial blood pressure (adjusted OR, 1.51; 95% CI, 1.02–2.22) and a continuous episode of minimum 20 minutes with <70 mm Hg mean arterial blood pressure (adjusted OR, 2.30; 95% CI, 1.11–4.75) were associated with a shift toward higher 90-day mRS scores, corresponding to a number needed to harm of 10 and 4, respectively.
- *A cumulated period of minimum 45 minutes with >90 mm Hg mean arterial blood pressure (adjusted OR, 1.49; 95% CI, 1.11–2.02) and a continuous episode of minimum 115 minutes with >90 mmHg mean arterial blood pressure (adjusted OR, 1.89; 95% CI, 1.01–3.54) were associated with a shift toward higher 90-day mRS scores, corresponding to a number needed to harm of 10 and 6, respectively.
- These blood pressure targets may need adjustment in communication with the stroke physician/neurointerventionalist.

Postoperative care

Post-MT procedure, the need for urinary catheterisation should be considered. All areas immediately receiving post-MT patients should have protocols for appropriate monitoring of arterial access sites and limb perfusion and ability to respond to physiological derangement such as hypotension with interventions such as intravenous fluid administration.

If required, critical care should be contacted to establish the availability of level 2/3 facilities for postoperative care; however this should not delay the start of intervention. If necessary, alternative facilities can be sought whilst the procedure is performed.

Patients who have received general anaesthesia should continue to have physiological and neurological monitoring postoperatively. This may be achieved in recovery, neuro intensive care unit, high-dependency unit (HDU) or the HASU depending upon local service provision. Uncomplicated general anaesthesia cases can be discharged to the stroke unit after a period of monitoring in theatre recovery or HDU. Critical care admission is required for patients who have intra-procedural complications or those who arrive intubated or with a reduced level of consciousness. A decision to transfer to the HASU/HDU or intensive care unit (ICU) should be made between INR, stroke physician and anaesthetist. Individual blood pressure targets should be stated and taken into account when deciding where the patient should be managed.

Elevated blood pressure during the peri-procedural period is associated with adverse clinical outcomes including mortality and SICH.[112,113] This could also apply to non-recanalised patients.[114] The American Heart Association/American Stroke Association guidelines recommend BP goal <180/105 mmHg after successful reperfusion.[109] Some trials such as DAWN[20] employed more aggressive blood pressure lowering strategies to a systolic pressure of <140 mmHg. The ENCHANTED (Enhanced Control of Hypertension and Thrombolysis Stroke Study) trial[115] showed no benefit of aggressive blood pressure lowering post IV alteplase but only 1.9% were treated with MT and the recanalisation status of the population was unknown. Currently, it is unclear whether an intervention to aggressively lower the blood pressure will impact positively on outcome post MT. Active blood pressure management is being trialled in the ENCHANTED-MT randomised trial.

Protocols

Irrespective of anaesthetic technique the two most important anaesthetic goals are minimising any time delay and haemodynamic control. Institutional protocols can assist in the safe and timely delivery of care. These protocols should address:

- Choice of anaesthetic agents
- Timeliness of induction

- Blood pressure parameters
- Postoperative care

Conclusion

There is now robust evidence for the use of MT in patients with anterior circulation stroke due to LVO. Treatment may be effective up to 24 h from stroke onset, providing patients are selected based on appropriate clinical and neuroimaging criteria. Evidence demonstrating the efficacy of MT treatment was largely acquired in comprehensive stroke centres staffed by fellowship trained neurointerventionalists and there is accumulating evidence to indicate that delivering this therapy through high-volume centres results in improved clinical outcomes.

This UK-focussed document outlines a revised framework to guide safe MT service delivery referring-to appropriate standards and governance in line with international guidance. The document provides direction with regard to patient selection, staffing standards, outcome measures, and practical options for MT delivery. A networked approach to MT provision is suggested with hub and spoke organisation and integration of ASC and CSC expertise to develop the MT pathway in individual regions. The team-worked arrangements should involve all clinicians and allied staff both between and within networked sites to improve systems through information sharing and construction of governance structures.

In time, the guideline will be updated to account for emerging evidence. Ongoing and future investigations could answer more definitively the role of MT in posterior circulation stroke, anterior circulation stroke with larger core infarction at presentation and stroke as a result of more distal vessel occlusion. The role of general anaesthesia for MT and specific neurointerventional techniques (for example use of a balloon-guide catheter) requires clarification, as does the use of alteplase (or other thrombolytic agents such as tenectaplase) in addition to MT. These issues, along with developments in neurotherapeutics, point of care tools and AI have the capacity to alter systems of care and/or network organisation. It is therefore suggested that a multi-society review of these guidelines is conducted within 3 years.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

We are grateful to the following for providing extensive review of the document on behalf of BASP, BSNR, ICSWP, NACCS and UKNG: Eiman Abdelgadir, Rob Crossley, Martin Dennis, Nick Evans, Peter Flynn, David Hargroves, Tom Hughes, Isuru Induruwa, Wazim Izzath, Martin James, Jatt Khaira, Deborah Lowe, Harriet Joy, Richard Marigold, Norman McConachie, Michael McCormick, Gillian Mead, David Minks, Hamed Nejadhamzeeigilani, Terry Quinn, Tom Robinson, Rustam Al-Shahi Salman, Louise Shaw, Craig Smith, Hannah Stockley, Kamy Thavanesan, Liz Warburton, David Werring, Phil White.

References

1. White PM, Bhalla A, Dinsmore J, *et al.* Standards for providing safe acute ischaemic stroke thrombectomy services (September 2015). *Clin Radiol* 2017;**72**(2):175.e1–9.
2. Saber H, Navi BB, Grotta JC, *et al.* Real-world treatment trends in endovascular stroke therapy. *Stroke* 2019;**50**(3):683–9.
3. Rothwell PM, Coull AJ, Giles MF, *et al.* Change in stroke incidence, mortality, case-fatality, severity, and risk factors in Oxfordshire, UK from 1981 to 2004 (Oxford vascular study). *Lancet* 2004;**363**(9425):1925–33.
4. Geddes JM, Fear J, Tennant A, *et al.* Prevalence of self reported stroke in a population in northern England. *J Epidemiol Commun Health* 1996;**50**(2):140–3.
5. Patel A, Berdunov V, Quayyum Z, *et al.* Estimated societal costs of stroke in the UK based on a discrete event simulation. *Age Ageing* 2020;**49**(2):270–6.
6. Kwiatkowski T, Libman R, Frankel M, *et al.* Effects of tissue plasminogen activator for acute ischaemic stroke at one year. *N Engl J Med* 1999;**340**:1781–7.
7. Rha J-H, Saver JL. The impact of recanalization on ischaemic stroke outcome. A meta-analysis. *Stroke* 2007;**38**:967–73.
8. Saqqur M, Uchino K, Demchuk AM, *et al.* Site of arterial occlusion identified by transcranial Doppler predicts the response to intravenous thrombolysis for stroke. *Stroke* 2007;**38**:948–54.
9. Berkhemer OA, Fransen PS, Beumer D, *et al.* A Randomized trial of Intra- arterial treatment for acute Ischemic stroke. *N Engl J Med* 2015;**372**:11–20.
10. Goyal M, Demchuk AM, Menon BK, *et al.* Randomized assessment of rapid endovascular treatment of ischaemic stroke. *N Engl J Med* 2015;**372**:1019–30.
11. Campbell BC, Mitchell PJ, Kleinig TJ, *et al.* Endovascular therapy for ischaemic stroke with perfusion-imaging selection. *N Engl J Med* 2015;**372**:1009–18.
12. Saver JL, Goyal M, Bonafe A, *et al.* Stent-retriever thrombectomy after intravenous t-pA vs. tpA alone in stroke. *N Engl J Med* 2015;**372**:2229–85.
13. Jovin TG, Chamorro A, Cobo E, *et al.* Thrombectomy within 8 h after symptom onset in Ischemic stroke. *N Engl J Med* 2015;**372**:2296–306.
14. Goyal M, Menon BK, van Zwam WH, *et al.* Endovascular thrombectomy after large-vessel ischaemic stroke: a meta-analysis of individual patient data from five randomised trials. *Lancet* 2016;**387**(10029):1723–31.
15. Bracard S, Ducrocq X, Mas JL, *et al.* Mechanical thrombectomy after intravenous alteplase versus alteplase alone after stroke (THRACE): a randomised controlled trial. *Lancet Neurol* 2016;**15**(11):1138–47.
16. Mocco J, Zaidat OO, von Kummer R, *et al.* Aspiration thrombectomy after intravenous alteplase versus intravenous alteplase alone. *Stroke* 2016;**47**(9):2331–8.
17. Muir KW, Ford GA, Messow CM, *et al.* Endovascular therapy for acute ischaemic stroke: the Pragmatic Ischaemic Stroke Thrombectomy Evaluation (PISTE) randomised, controlled trial. *J Neurol Neurosurg Psychiatr* 2017;**88**:38–44.
18. Román LS, Menon BK, Blasco J, *et al.* Imaging features and safety and efficacy of endovascular stroke treatment: a meta-analysis of individual patient-level data. *Lancet Neurol* 2018;**17**(10):895–904.
19. Menon BK, Hill MD, Davalos A, *et al.* Efficacy of endovascular thrombectomy in patients with M2 segment middle cerebral artery occlusions: meta-analysis of data from the HERMES Collaboration. *J Neurointerv Surg* 2019;**11**(11):1065–9.
20. Nogueira RG, Jadhav AP, Haussen DC, *et al.* Thrombectomy 6 to 24 h after stroke with a mismatch between deficit and infarct. *N Engl J Med* 2018;**378**:11–21.

21. Albers GW, Marks MP, Kemp S, *et al*. Thrombectomy for stroke at 6 to 16 h with selection by perfusion imaging. *N Engl J Med* 2018;**378**:708–18.
22. Turc G, Bhogal P, Fischer U, *et al*. European stroke organisation (ESO) - European society for minimally invasive neurological therapy (ESMINT) guidelines on mechanical thrombectomy in acute ischaemic stroke. Endorsed by stroke alliance for Europe (SAFE). *Eur Stroke J* 2019;**4**(1):6–12.
23. NICE. *Stroke and transient ischaemic attack in over 16s: diagnosis and initial management*. NICE guideline [NG128]. 2019. Available at:, https://www.nice.org.uk/guidance/ng128/chapter/Recommendations#thrombectomy-for-people-with-acute-ischaemic-stroke. Accessed December 2020.
24. Lindsberg PJ, Mattle HP. Therapy of basilar artery occlusion: a systematic analysis comparing intra-arterial and intravenous thrombolysis. *Stroke* 2006;**37**(3):922–8.
25. Meinel TR, Kaesmacher J, Chaloulos-Iakovidis P, *et al*. Mechanical thrombectomy for basilar artery occlusion: efficacy, outcomes, and futile recanalization in comparison with the anterior circulation. *J Neurointerv Surg* 2019;**11**(12):1174–80.
26. Phan K, Phan S, Huo YR, *et al*. Outcomes of endovascular treatment of basilar artery occlusion in the stent retriever era: a systematic review and meta-analysis. *J Neurointerv Surg* 2016;**8**(11):1107–15.
27. Liu X, Dai Q, Ye R, *et al*. Endovascular treatment versus standard medical treatment for vertebrobasilar artery occlusion (BEST): an open-label, randomised controlled trial. *Lancet Neurol* 2020;**19**(2):115–22.
28. Langezaal LCM, van der Hoeven EJRJ, Mont'Alverne FJA, *et al*. Endovascular therapy for stroke due to basilar-artery occlusion. 384(20) *N Engl J Med* 2021;**20**:1910–20.
29. Halvorsrud K, Flynn D, Ford GA, *et al*. A Delphi study and ranking exercise to support commissioning services: future delivery of thrombectomy services in England. *BMC Health Serv Res* 2018;**18**(1):135.
30. Saver JL, Goyal M, van der Lugt A, *et al*. Time to treatment with endovascular thrombectomy and outcomes from ischemic stroke: a meta-analysis. *JAMA* 2016;**316**(12):1279–88.
31. Jayaraman MV, Hemendinger ML, Baird GL, *et al*. Field triage for endovascular stroke therapy: a population-based comparison. *J Neurointerv Surg* 2020;**12**(3):233–9.
32. Mueller-Kronast N, Froehler MT, Jahan R, *et al*. STRATIS Investigators. Impact of EMS bypass to endovascular capable hospitals: geospatial modeling analysis of the US STRATIS registry. *J Neurointerv Surg* 2020;**12**(11):1058–63.
33. Kamal N, Wiggam MI, Holodinsky JK, *et al*. Geographic modeling of best transport options for treatment of acute ischaemic stroke patients applied to policy decision making in the USA and Northern Ireland. *IISE Trans Healthc Syst Eng* 2018;**8**(3):220–6.
34. Allen M, Pearn K, James M, *et al*. Maximising access to thrombectomy services for stroke in england: a modelling study. *Eur Stroke J* 2019;**4**(1):39–49.
35. Society of Vascular and Interventional Neurology. RACECAT trial results. Available at: https://pages.svin.org/2021/01/13/racecat-trials. Accessed June 2021.
36. Turc G, Maïer B, Naggara O, *et al*. Clinical scales do not reliably identify acute ischemic stroke patients with large-artery occlusion. *Stroke* 2016;**47**(6):1466–72.
37. McTaggart RA, Moldovan K, Oliver LA, *et al*. Door-in-door-out time at primary stroke centers may predict outcome for emergent large vessel occlusion patients. *Stroke* 2018;**49**(12):2969–74.
38. Ng FC, Low E, Andrew E, *et al*. Deconstruction of interhospital transfer workflow in large vessel occlusion: real-world data in the thrombectomy era. *Stroke* 2017;**48**(7):1976–9.
39. Choi PMC, Tsoi AH, Pope AL, *et al*. Door-in-door-out time of 60 minutes for stroke with emergent large vessel occlusion at a primary stroke center. *Stroke* 2019;**50**(10):2829–34.
40. Wechsler LR, Demaerschalk BM, Schwamm LH, *et al*. Telemedicine quality and outcomes in stroke: a scientific statement for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke* 2017;**48**(1):e3–25.
41. Soun JE, Chow DS, Nagamine M, *et al*. Artificial intelligence and acute stroke imaging. *AJNR Am J Neuroradiol* 2021;**42**(1):2–11.
42. Hassan AE, Ringheanu VM, Rabah RR, *et al*. Early experience utilizing artificial intelligence shows significant reduction in transfer times and length of stay in a hub and spoke model. *Interv Neuroradiol* 2020;**26**(5):615–22.
43. Murray NM, Unberath M, Hager GD, *et al*. Artificial intelligence to diagnose ischaemic stroke and identify large vessel occlusions: a systematic review. *J NeuroInterv Surg* 2020;**12**(2):156–64.
44. Department of Health and Social Care. Data security and protection requirements. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/675420/17-18_statement_of_requirements_Branded_template_final_22_11_18-1.pdf; 2017/18. Accessed December 2020.
45. The Scottish Government. Information sharing Toolkit Scotland. Available at: https://www.informationgovernance.scot.nhs.uk/wp-content/uploads/2019/05/IS-Toolkit-Introduction-21-05-2019-5.pdf; 2019. Accessed December 2020.
46. The Royal College of Radiologists. *Picture archiving and communication systems (PACS) and guidelines on diagnostic display devices*. 3rd Edition 2019 Available at:. https://www.rcr.ac.uk/system/files/publication/field_publication_files/bfcr192_pacs-diagnostic-display.pdf. Accessed December 2020.
47. Asaithambi G, Chaudhry SA, Hassan AE, *et al*. Adherence to guidelines by emergency medical services during transport of stroke patients receiving intravenous thrombolytic infusion. *J Stroke Cerebrovasc Dis* 2013;**22**(7):e42–5.
48. Widimský P, Groch L, Zelízko M, *et al*. Multicentre randomized trial comparing transport to primary angioplasty vs immediate thrombolysis vs combined strategy for patients with acute myocardial infarction presenting to a community hospital without a catheterization laboratory. The PRAGUE study. *Eur Heart J* 2000;**21**(10):823–31.
49. Pallesen LP, Winzer S, Barlinn K, *et al*. Safety of inter-hospital transfer of patients with acute ischaemic stroke for evaluation of endovascular thrombectomy. *Sci Rep* 2020;**10**(1):5655.
50. Leibinger F, Sablot D, Van Damme L, *et al*. Which patients require physician-led inter-hospital transport in view of endovascular therapy? *Cerebrovasc Dis* 2019;**48**(3–6):171–8.
51. Nathanson MH, Andrzejowski J, Dinsmore J, *et al*. Guidelines for safe transfer of the brain-injured patient: trauma and stroke, 2019: guidelines from the association of anaesthetists and the neuro anaesthesia and critical care society. *Anaesthesia* 2020;**75**(2):234–46.
52. Griffin E, Murphy S, Sheehan M, *et al*. Early repatriation post-thrombectomy: a model of care which maximises the capacity of a stroke network to treat patients with large vessel ischaemic stroke. *J Neurointerv Surg* 2020;**12**(12):1166–71.
53. Prabhakaran S, Fonarow GC, Smith EE, *et al*. Hospital case volume is associated with mortality in patients hospitalized with subarachnoid hemorrhage. *Neurosurgery* 2014;**75**:500–8.
54. Saver JL, Fonarow GC, Smith EE, *et al*. Time to treatment with intravenous tissue plasminogen activator and outcome from acute ischaemic stroke. *JAMA* 2013;**309**:2480–8.
55. Hoh BL, Rabinov JD, Pryor JC, *et al*. In-hospital morbidity and mortality after endovascular treatment of unruptured intracranial aneurysms in the United States, 1996–2000: effect of hospital and physician volume. *AJNR Am J Neuroradiol* 2003;**24**:1409–20.
56. Pandey AS, Gemmete JJ, Wilson TJ, *et al*. High subarachnoid hemorrhage patient volume associated with lower mortality and better outcomes. *Neurosurgery* 2015;**77**:462–70.
57. Jalbert JJ, Gerhard-Herman MD, Nguyel LL, *et al*. Relationship between physician and hospital procedure volume and mortality after carotid artery stenting among Medicare beneficiaries. *Cir Cardiovasc Qual Outcome*. 2015;**8**:81–9.
58. Badheka AO, Patel NJ, Grover P, *et al*. Impact of annual operator and institutional volume on percutaneous coronary intervention outcomes: a 5-year United States experience (2005-2009). *Circulation* 2014;**130**:1392–406.
59. Gupta R, Horev A, Nguyen T, *et al*. Higher volume endovascular stroke centers have faster times to treatment, higher reperfusion rates and higher rates of good clinical outcomes. *J Neurointerv Surg* 2013;**5**:294–7.
60. Nogueira RG, Haussen DC, Castonguay A, *et al*. Site experience and outcomes in the Trevo Acute Ischemic Stroke (TRACK) multicenter

registry higher volumes translate in better outcomes. *Stroke* 2019;**50**(9):2455–60.
61. Stein LK, Mocco J, Fifi J, *et al*. Correlations between physician and hospital stroke thrombectomy volumes and outcomes: a nationwide analysis. *Stroke* 2021;**52**(9):2858–65.
62. Kim BM, Baek JH, Heo JH, *et al*. Effect of cumulative case volume on procedural and clinical outcomes in endovascular thrombectomy. *Stroke* 2019;**50**(5):1178–83.
63. Mueller-Kronast NH, Zaidat OO, Froehler MT, *et al*. Systematic evaluation of patients treated with neurothrombectomy devices for acute ischemic stroke primary results of the STRATIS Registry. *Stroke* 2017;**48**(10):2760–8.
64. Rinaldo L, Brinjikji W, Rabinstein AA. Transfer to high-volume centers associated with reduced mortality after endovascular treatment of acute stroke. *Stroke* 2017;**48**:1316–21.
65. British Association of Stroke Physicians. Definitions of a stroke specialist physician. Available at: https://www.basp.org/wp-content/uploads/2016/11/Definition-of-a-Stroke-Specialist-FINAL-Aug-2011.pdf. Accessed November 2020.
66. Department of Health. Implementing the national stroke strategy- an imaging guide. www.csnlc.nhs.uk/uploads/files/stroke/documents/.../dh_085145.pdf; Accessed November 2020.
67. Pierot L, Jayaraman MV, Szikora I, *et al*. Standards of practice in acute ischemic stroke intervention: international recommendations. *J Neurointerv Surg* 2018;**10**(11):1121–6.
68. Lenthall R, McConachie N, White P, *et al*, UK Neurointerventional Group and British Society of Neuroradiologists. BSNR training guidance for mechanical thrombectomy. *Clin Radiol* 2017;**72**(2). 175.e11-175.e18. Supplementary guidance. Available at: https://www.rcr.ac.uk/sites/default/files/mt_interim_guidance_document_30-10- 2017_final.pdf. Accessed December 2020.
69. Sacks D, Baxter B, Campbell BCV, *et al*. Multisociety consensus quality improvement revised consensus statement for endovascular therapy of acute ischemic stroke. From the American association of neurological surgeons (AANS), American society of neuroradiology (ASNR), cardiovascular and interventional radiology society of Europe (CIRSE), Canadian interventional radiology association (CIRA), congress of neurological surgeons (CNS), European society of minimally invasive neurological therapy (ESMINT), European society of neuroradiology (ESNR), European stroke organization (ESO), society for cardiovascular angiography and interventions (SCAI), society of interventional radiology (SIR), society of NeuroInterventional surgery (SNIS), and world stroke organization (WSO). *J Vasc Interv Radiol* 2018;**29**(4):441–53.
70. Royal College of Physicians London. *National clinical guidelines for stroke 5th edition*. 2016. Available at: www.rcplondon.ac.uk/stroke/guidelines. Accessed December 2020.
71. British Association of Stroke Physicians. Meeting the future challenge of stroke. Stroke medicine consultant workforce requirements 2019–20. Available at: https://www.basp.org/wp-content/uploads/2019/07/BASP-Stroke-Medicine-Workforce-Requirements-Report-FINAL.pdf. Accessed November 2020.
72. Pilgram-Pastor SM, Piechowiak EI, Dobrocky T, *et al*. Stroke thrombectomy complication management. *J Neurointerv Surg* 2021, https://doi.org/10.1136/neurintsurg-2021-017349. Accessed June 2021.
73. Deb-Chatterji M, Pinnschmidt H, Flottmann F, *et al*. Stroke patients treated by thrombectomy in real life differ from cohorts of the clinical trials: a prospective observational study. *BMC Neurol* 2020;**20**(1):81.
74. Zaidat OO, Castonguay AC, Linfante I. First pass effect: a new measure for stroke thrombectomy devices. *Stroke* 2018;**49**:660–6.
75. Brinjikji W, Starke RM, Murad MH, *et al*. Impact of balloon guide catheter on technical and clinical outcomes: a systematic review and meta-analysis. *J Neurointerv Surg* 2018;**10**(4):335–9.
76. Pereira V, Siddiqui A, Jovin T, *et al*. P-016 role of balloon guiding catheter in mechanical thrombectomy using stentretrivers subgroup analysis of swift prime: abstract P-016 Table 1. *J Neurointerv Surg* 2015;**7**:A30.
77. Nguyen TN, Malisch T, Castonguay AC. Balloon guide catheter improves revascularization and clinical outcomes with the Solitaire device: analysis of the North American Solitaire Acute Stroke Registry. *Stroke* 2014;**45**:141–5.
78. Blasco J, Puig J, Daunis-I-Estadella P, *et al*. Balloon guide catheter improvements in thrombectomy outcomes persist despite advances in intracranial aspiration technology. *J Neurointerv Surg* 2021;**13**(9):773–8.
79. Zaidat OO, Mueller-Kronast NH, Hassan AE, *et al*. Impact of balloon guide catheter use on clinical and angiographic outcomes in the STRATIS Stroke Thrombectomy Registry. *Stroke* 2019;**50**(3):697–704.
80. Nguyen TN, Castonguay AC, Nogueira RG, *et al*. Effect of balloon guide catheter on clinical outcomes and reperfusion in Trevo thrombectomy. *J Neurointerv Surg* 2019;**11**(9):861–5.
81. Lapergue B, Blanc R, Gory B, *et al*. Effect of endovascular contact aspiration vs stent retriever on revascularization in patients with acute ischemic stroke and large vessel occlusion: the ASTER Randomized Clinical Trial. *JAMA* 2017;**318**(5):443–52.
82. Turk 3rd AS, Siddiqui A, Fifi JT, *et al*. Aspiration thrombectomy versus stent retriever thrombectomy as first-line approach for large vessel occlusion (COMPASS): a multicentre, randomised, open label, blinded outcome, non-inferiority trial. *Lancet* 2019;**393**(10175):998–1008.
83. Jindal G, Serulle Y, Miller T, *et al*. Stent retrieval thrombectomy in acute stoke is facilitated by the concurrent use of intracranial aspiration catheters. *J Neurointerv Surg* 2017;**9**:944–7.
84. Hesse AC, Behme D, Kemmling A, *et al*. Comparing different thrombectomy techniques in five large-volume centers: a “real world” observational study. *J Neurointerv Surg* 2018;**10**(6):525–9.
85. McTaggart RA, Tung EL, Yaghi S, *et al*. Continuous aspiration prior to intracranial vascular embolectomy (CAPTIVE): a technique which improves outcome. *J Neurointerv Surg* 2017;**9**(12):1154–9.
86. Maus V, Behme D, Kabbasch C, *et al*. Maximizing first-pass complete reperfusion with SAVE. *Clin Neuroradiol* 2018;**28**(3):327–38.
87. Lapergue B, Labreuche J, Blanc R, *et al*. Combined use of contact aspiration and the stent retriever technique versus stent retriever alone for recanalization in acute cerebral infarction: the randomized ASTER 2 study protocol. *J Neurointerv Surg* 2020;**12**(5):471–6.
88. Hellegering J, Uyttenboogaart M, Bokkers RPH, *et al*. Treatment of the extracranial carotid artery in tandem lesions during endovascular treatment of acute ischaemic stroke: a systematic review and meta-analysis. *Ann Transl Med* 2020;**8**(19):1278.
89. Zhu F, Bracard S, Anxionnat R, *et al*. Impact of emergent cervical carotid stenting in tandem occlusion strokes treated by thrombectomy: a review of the TITAN Collaboration. *Front Neurol* 2019;**11**(10):206.
90. van de Graaf RA, Chalos V, Del Zoppo GJ, *et al*. Periprocedural antithrombotic treatment during acute mechanical thrombectomy for ischaemic stroke: a systematic review. *Front Neurol* 2018;**9**:238.
91. Premat K, Dechartres A, Lenck S, *et al*. Rescue stenting versus medical care alone in refractory large vessel occlusions: a systematic review and meta-analysis. *Neuroradiology* 2020;**62**(5):629–37.
92. Siddiqui AH, Waqas M, Neumaier J, *et al*. Radial first or patient first: a case series and meta-analysis of transradial versus transfemoral access for acute ischaemic stroke intervention. *J Neurointerv Surg* 2021;**13**(8):687–92.
93. Phillips TJ, Crockett MT, Selkirk GD, *et al*. Transradial versus transfemoral access for anterior circulation mechanical thrombectomy: analysis of 375 consecutive cases. *Stroke Vasc Neurol* 2020;**6**(2):207–13.
94. Colombo E, Rinaldo L, Lanzino G. Direct carotid puncture in acute ischaemic stroke intervention Stroke. 5(1) *Vasc Neurol* 2020;**29**:71–9.
95. Almallouhi E, Al Kasab S, Sattur MG, *et al*. Incorporation of transradial approach in neuroendovascular procedures: defining benchmarks for rates of complications and conversion to femoral access. *J Neurointerv Surg* 2020;**12**:1122–6.
96. Flores A, Ustrell X, Seró L, *et al*. Vascular occlusion evolution in endovascular reperfusion candidates transferred from primary to comprehensive stroke centers. *Cerebrovasc Dis* 2020;**49**(5):550–5.
97. Requena M, Olivé-Gadea M, Boned S, *et al*. Clinical and neuroimaging criteria to improve the workflow in transfers for endovascular treatment evaluation. *Int J Stroke* 2020;**15**(9):988–94.
98. Boulouis G, Lauer A, Siddiqui AK, *et al*. Clinical imaging factors associated with infarct progression in patients with ischemic stroke during transfer for mechanical thrombectomy. *JAMA Neurol* 2017;**74**(11):1361–7.

99. Fuentes B, Alonso de Leciñana M, Ximénez-Carrillo A, *et al*. Futile interhospital transfer for endovascular treatment in acute ischemic stroke: the Madrid Stroke Network experience. *Stroke* 2015;**46**(8):2156–61.
100. Royal College of Radiologists 2017. Standards for providing a 24-h interventional radiology service. Available at: www.rcr.ac.uk/docs/radiology/pdf/Stand_24hr_IR_provision.pdf. Accessed November 2020.
101. Zhu F, Ben Hassen W, Bricout N, *et al*. Effect of operator's experience on proficiency in mechanical thrombectomy: a multicenter study. *Stroke* 2021;**52**:2736–42.
102. Brinjikji W, Pasternak J, Murad MH, *et al*. Anesthesia-related outcomes for endovascular stroke revascularization: a systematic review and meta-analysis. *Stroke* 2017;**48**(10):2784–91.
103. Goyal N, Malhotra K, Ishfaq MF, *et al*. Current evidence for anesthesia management during endovascular stroke therapy: updated systematic review and meta-analysis. *J Neurointerv Surg* 2019;**11**(2):107–13.
104. Jing R, Dai HJ, Lin F, *et al*. Conscious sedation versus general anesthesia for patients with acute ischaemic stroke undergoing endovascular therapy: a systematic review and meta-analysis. *Biomed Res Int* 2018:2318489.
105. Campbell BCV, van Zwam WH, Goyal M, *et al*. Effect of general anaesthesia on functional outcome in patients with anterior circulation ischaemic stroke having endovascular thrombectomy versus standard care: a meta-analysis of individual patient data. *Lancet Neurol* 2018;**17**(1):47–53.
106. Lowhagen Henden P, Rentzos A, Karlsson JE, *et al*. General anesthesia versus conscious sedation for endovascular treatment of acute ischaemic stroke: the Anstroke trial (Anesthesia during Stroke). *Stroke* 2017;**48**:1601–7.
107. Simonsen CZ, Yoo AJ, Sørensen LH, *et al*. Effect of general anesthesia and conscious sedation during endovascular therapy on infarct growth and clinical outcomes in acute ischaemic stroke: a randomized clinical trial. *JAMA Neurol* 2018;**75**:470.
108. Schonenberger S, Uhlmann L, Hacke W, *et al*. Effect of conscious sedation versus general anesthesia on early neurological improvement among patients with ischaemic stroke undergoing endovascular thrombectomy: a randomized clinical trial. *JAMA* 2016;**316**:1986–96.
109. Powers WJ, Rabinstein AA, Ackerson T, *et al*. American Heart Association Stroke Council. 2018 Guidelines for the early management of patients with acute ischaemic stroke: a guideline for health-care professionals from the American Heart Association/American Stroke Association. *Stroke* 2018;**49**:e46–110.
110. Flottmann F, Leischner H, Broocks G, *et al*. Emergency conversion to general anesthesia is a tolerable risk in patients undergoing mechanical thrombectomey. *AJNR Am J Neuroradiol* 2020;**41**(1):122–7.
111. Rasmussen M, Schönenberger S, Hendèn PL, *et al*. Blood pressure thresholds and neurologic outcomes after endovascular therapy for acute ischemic stroke: an analysis of individual patient data from 3 randomized clinical trials. *JAMA Neurol* 2020;**77**(5):622–31.
112. Malhotra K, Goyal N, Katsanos AH, *et al*. Association of blood pressure with outcomes in acute stroke thrombectomy. *Hypertension* 2020;**75**(3):730–9.
113. Anadani M, Orabi MY, Alawieh A, *et al*. Blood pressure and outcome after mechanical thrombectomy with successful revascularization. *Stroke* 2019;**50**(9):2448–54.
114. Goyal N, Tsivgoulis G, Pandhi A, *et al*. Blood pressure levels post mechanical thrombectomy and outcomes in non-recanalized large vessel occlusion patients. *J Neurointerv Surg* 2018;**10**(10):925–31.
115. Anderson CS, Huang Y, Lindley RI, *et al*. ENCHANTED Investigators and Coordinators. Intensive blood pressure reduction with intravenous thrombolysis therapy for acute ischaemic stroke (ENCHANTED): an international, randomised, open-label, blinded-endpoint, phase 3 trial. *Lancet* 2019;**393**:877–88.