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SPECIAL ARTICLE

Interdisciplinary management of acute ischaemic stroke: Current evidence training requirements for endovascular stroke treatment: Position Paper from the ESC Council on Stroke and the European Association for Percutaneous Cardiovascular Interventions with the support of the European Board of Neurointervention

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This ESC Council on Stroke/EAPCI/EBNI position paper summarizes recommendations for training of cardiologists in endovascular treatment of acute ischaemic stroke. Interventional cardiologists adequately trained to perform endovascular stroke interventions could complement stroke teams to provide the 24/7 on call duty and thus to increase timely access of stroke patients to endovascular treatment. The training requirements for interventional cardiologists to perform endovascular therapy are described in details and should be based on two main principles: (i) patient safety cannot be compromised, (ii) proper training of interventional cardiologists should be under supervision of and guaranteed by a qualified neurointerventionist and within the setting of a stroke team. Interdisciplinary cooperation based on common standards and professional consensus is the key to the quality improvement in stroke treatment.

Keywords Acute ischaemic stroke • Interventional cardiology • Neurointervention • Training requirements • Thrombectomy • Carotid stenting • Endovascular

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Why is there a need for the involvement of cardiologists in interventional acute stroke treatment?

Since the efficacy of endovascular therapy (EVT) for acute ischaemic stroke (AIS) was demonstrated by randomized controlled trials (RCT) in 2015, the number of EVTs has doubled to tripled in high income European Union (EU) countries, while in some countries this has even increased by up to 10 times and is close to providing EVT for AIS in all cases where it is indicated. Nevertheless, the growth rate of EVT is strongly dependent on the resources and organization of the health care system in each country, resulting in an unequal distribution within the EU. In order to make the best treatment option available for all potential large vessel occlusion (LVO) AIS patients, involvement of specialties experienced in percutaneous endovascular catheter interventions such as cardiologists, may be of benefit, especially in countries lacking adequate volume in trainees in neurosciences. Interventional cardiologists are well-equipped to contribute to this challenge, because of their high level of catheter skills from primary percutaneous coronary interventions (PCI) and long-term experience with acute endovascular treatments in the STEMI (ST-Elevation Myocardial Infarction) networks, providing that they are sufficiently trained in neurosciences and stroke interventions. Due to the fact that AIS is as frequent as acute myocardial infarction and has even worse outcomes, this document has great potential value for both cardiovascular and neurovascular medicine at large.

Introduction and background

Acute ischaemic stroke is one of the leading causes of death and the single leading cause of permanent disability.[1] Before pharmacologic or invasive reperfusion became available, the treatment of patient with AIS focused on supportive care and rehabilitation.[2] Unlike acute myocardial infarction (with rather uniform aetiology in over 90% of patients), AIS has multiple causes: most (30–50%) AISs are caused by distal embolization of a centrally originated clot (typically middle cerebral artery occlusions are caused by embolized fragments of intra-cardiac thrombi in atrial fibrillation—*Figure 1*), 20–25% are caused by large artery atherosclerosis (typically proximal internal carotid artery—*Figure 2*—or vertebrobasilar occlusions—*Figure 3*) and the rest are either cryptogenic or lacunar strokes.

Intravenous thrombolysis

Revascularization therapy with intravenous thrombolysis (IVT) was proven to be effective in the mid-90s by the NINDS[3] and ECASS[4] RCT, establishing it as the first-line treatment of AIS within 3 h of symptom's onset.[5] Following additional evidence resulting from improved patient selection based on advanced neuroimaging the therapeutic window of IVT was extended first up to 4.5 h,[6] then more recently to up to 9 h.[7] Intravenous thrombolysis is undoubtedly a major step forward in the treatment of AIS. However, its applicability is limited by a broad range of contra-indications, including coagulopathy, recent surgery, and previous intra-cranial bleeding. Intravenous thrombolysis was also found to be less effective than mechanical recanalization in opening LVOs.[8] In moderate-to-severe strokes caused by an LVO, the prognosis after conservative treatment is poor as IVT frequently fails to open LVOs (recanalization rates ranging from 8% to 30% depending on the occluded artery). These LVO are potentially suitable for acute endovascular treatment.

Mechanical thrombectomy

The limitations of IVT have triggered the development of alternative revascularization strategies based on mechanical clot removal. While the early trials of mechanical recanalization failed to show superiority to IVT,[9–11] technical improvements in device technology and better patient selection resulted in new clinical evidence supporting the use of EVT in stroke. In 2015, the *MR CLEAN* RCT proved for the first time the superiority of EVT (plus best medical treatment including IVT) over best medical treatment alone (including IVT) in patients with LVO strokes.[12] Subsequent RCT published in the same year (*ESCAPE*, *EXTEND—IA*, *SWIFT PRIME*, *REVASCAT*)[13–16] confirmed the initial findings. A meta-analysis of the trials' data (summarized in *Figure 4*) further reinforced the evidence in favour of this new treatment modality.[17] Whilst the first RCTs confirmed the safety and efficacy of mechanical revascularization within 6 h of stroke onset, the more recent *DAWN* and *DEFUSE 3* trials showed that the treatment time window for EVT can be extended up to 24 h using strict selection criteria based on advanced imaging technologies.[18,19] Clinical success (functional recovery) is generally defined as the modified Rankin scale (mRs) of ≤2 at 3 months post-stroke. Based on the references above[12,14] with the use of IVT, mRs 0–2 is achieved in 19–40% of patients with LVO stroke, while thrombectomy increases the clinical success[12–17] to 33–71%, giving a remarkably low number needed to treat of 2.6.

Stroke treatment guidelines

As a result of this evidence, recommendations for the management of patients with AIS have been updated. According to the current European[20] (*Table 1*) and North-American guidelines,[21] all patients admitted with anterior circulation LVO within 6 h from symptom onset should be evaluated for the eligibility for EVT. In patients presenting beyond this timeframe, the selection criteria of the DEFUSE 3 and DAWN trials should be applied to determine the optimal treatment strategy.

Stroke teams

According to the above recommendations, AIS is best treated in stroke centres with 24/7 availability of local stroke team. Such stroke team is typically multidisciplinary, involving neurologists, neurointerventionists, neurosurgeons, neuroradiologists, intensivists, cardiologists, vascular surgeons, and other specialists.

Regional availability of stroke thrombectomy

In order to meet these recommendations, EVT services should be available in all regions of Europe. To establish a baseline dataset prior to the widespread application of EVT, the European Stroke Organization (ESO), the European Society of Minimally Invasive Neurological Therapy (ESMINT), and the European Academy of Neurology (EAN) together with the Stroke Alliance for Europe

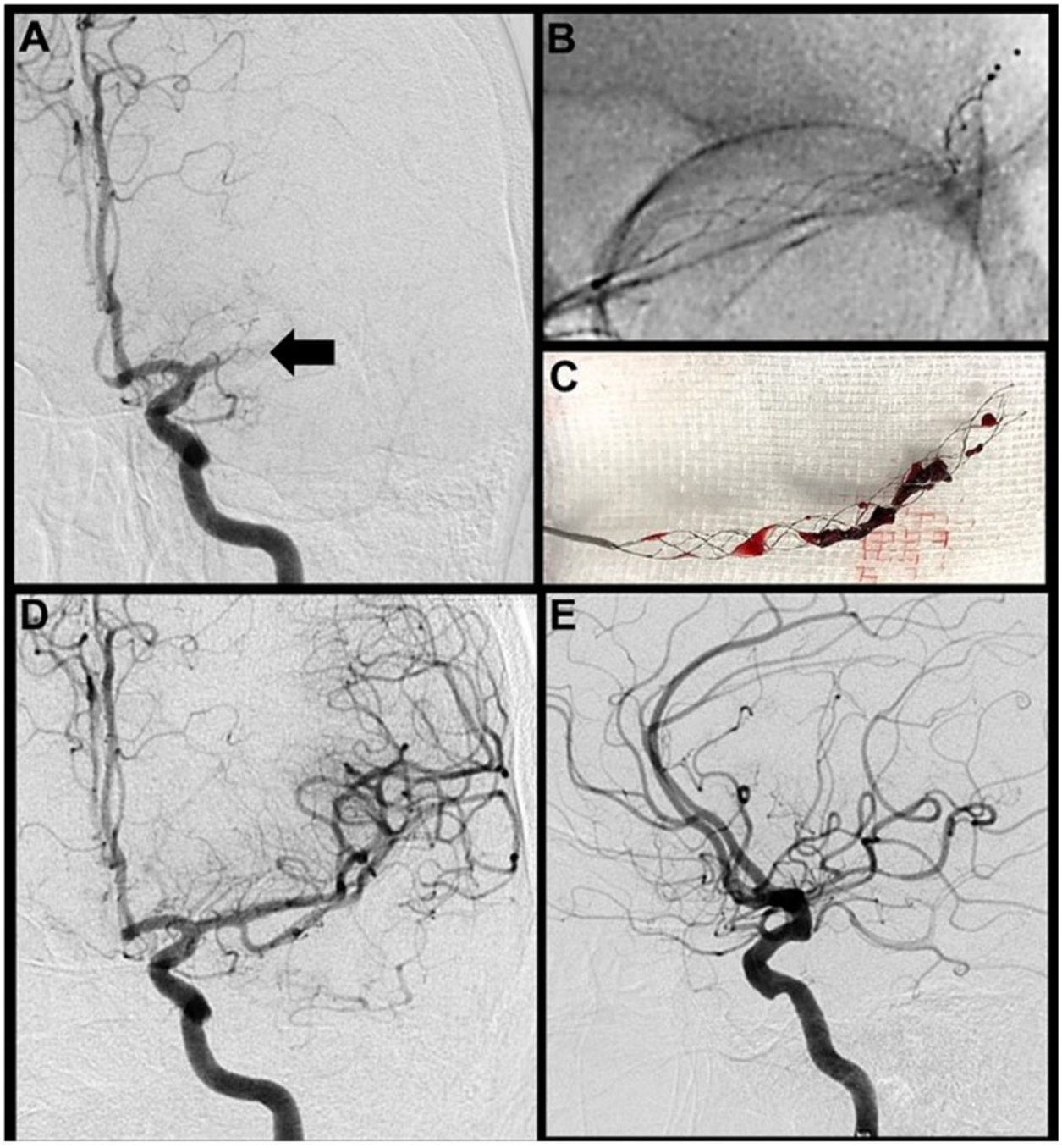

Figure 1 Stent-retriever thrombectomy of the left middle cerebral artery (MCA): The MCA is occluded after its origine (*A*). A self-expandable stent retriever is placed through the occluded segment (*B*). After the removal of the stent from the vessel the thrombus can be observed on its surface (*C*). The complete restoration of the flow is demonstrated within the MCA territory from antero-posterior (*D*) and lateral projections on digital substraction angiography (*E*).

(SAFE) organized a pan-European survey on AIS care in 44 European countries.[22] This survey was conducted between October 2016 and February 2017, thereby reflecting the data in 2015 and 2016 the 1st year following the publication of the major RCT. This showed an average 1.9% of all stroke patients (including non-LVO and posterior circulation strokes) were treated by EVT. In the most developed national stroke networks, a maximum rate of 5.6% of EVT was achieved. In 2016, the reported primary reason for this remarkable regional heterogeneity (*Figure 5*) was reported to be the shortage of trained personnel in 34 countries, followed by the lack of facilities (22 countries) and by the high procedure costs (16 countries).[22] Despite these initial obstacles, there was an extraordinarily fast growth rate

Figure 2 Severe proximal atherosclerotic stenosis of the internal carotid artery (left) and status after carotid stenting (right).

Figure 3 Recanalization of a basilar artery occlusion: The occluded basilar artery (left, arrow) was recanalized using a stent retriever. Complete restoration of flow is achieved (right, arrow). The red circles line the ischaemic/reperfused area.

of EVT in most European countries. According to data provided by the German Society of Interventional Radiology and Neuroradiology, the total number of EVTs in Germany has grown from 5000 in 2015 to over 10 000 in 2017[23] with further growth up to 16 000 in 2019. In the Netherlands, the number of cases increased from 1000 in 2016 to 2140 in 2019 according to the Dutch Acute Stroke Audit. A similar growth rate was observed in other countries, such as the Czech Republic (839 in 2015 to 1460 in 2019, personal communication from Dr Antonin Krajina) and Hungary (133 in 2015 to 1216 in 2019, data from the National Stroke Interventions Audit). Despite this remarkable growth, in some countries, access to this effective treatment still remains limited.

What is the population need for thrombectomy?

Currently, the true proportion of stroke patients suffering from LVO and being eligible for EVT is not known. In a recently published analysis, this population is estimated to be as high as 10% of all stroke cases admitted to hospitals in the UK.[24] In some countries (such as Germany, France, Czech Republic, the Netherlands, Switzerland, and few others) ~4–5% of AIS patients were treated by EVT already in the 1st year following the publication of positive RCTs, while in others (including the UK, Poland, or Sweden), this proportion was ~1% or less at the time of the survey conducted in 2016.[22]

Given the current availability and the fast growth of neurointerventional stroke services observed in the 5 years following the positive RCTs, the goal of meeting the needs for EVT is likely to be achieved in many countries within a reasonable time frame. In some countries, however, with large areas of low population density or less developed health care systems, additional resources may be needed to achieve this goal. Also, and equally important, while the goal of providing EVT to ~10% of all stroke patients may be attainable in most countries, maldistribution of neurointerventionists to metropolitan areas with large comprehensive stroke centres results in unnecessary treatment delays due to transfer times to those centres rather than treatment locally. Timely vessel recanalization cannot be overemphasized. Interventional cardiologists having sufficient experience in the catheter-based treatment of acute myocardial infarction, especially those already experienced in carotid stenting could potentially provide a significant contribution to build a sufficient network for EVT in these countries or regions. It is a well-known fact from RCTs that recanalization within 2 h of stroke onset can yield extremely good clinical results, while there is ~15% worsening outcome per every half hour delay thereafter. The probability of functional independence (mRS 0–2) at 3 months declined from 64.1% with symptom onset-to-reperfusion time of up to 180 min, to 46.1% with symptom onset-to-reperfusion time of up to 480 min.[17] The established widespread networks of interventional cardiology may help to achieve rapid and effective intervention[25] if incorporated into neurointerventional stroke systems as defined in international multi-society consensus documents.[26]

Initial experience in cardiology centres

Based on the results of early feasibility studies, trained interventional cardiologists working as part of a multidisciplinary stroke team demonstrated similar patient outcomes as presented in the above-mentioned RCTs performed by interventional (neuro)radiologists, interventional neurosurgeons, and interventional neurologists.[27–31] However, to deliver optimal stroke care, adequate training and full integration of cardiologists into the local stroke teams lead by neurologists is mandatory.

The aim of the current document

The aim of the current document is to present the official position of the European Society of Cardiology on the potential role of interventional cardiologists to complement, and if needed, to contribute to the development of stroke care networks in the areas of need with the aim to assure broad access to 24/7 EVT services across Europe. Our goal is to describe a practical implementation of the previously published neurointerventional training requirements[32,33] that would

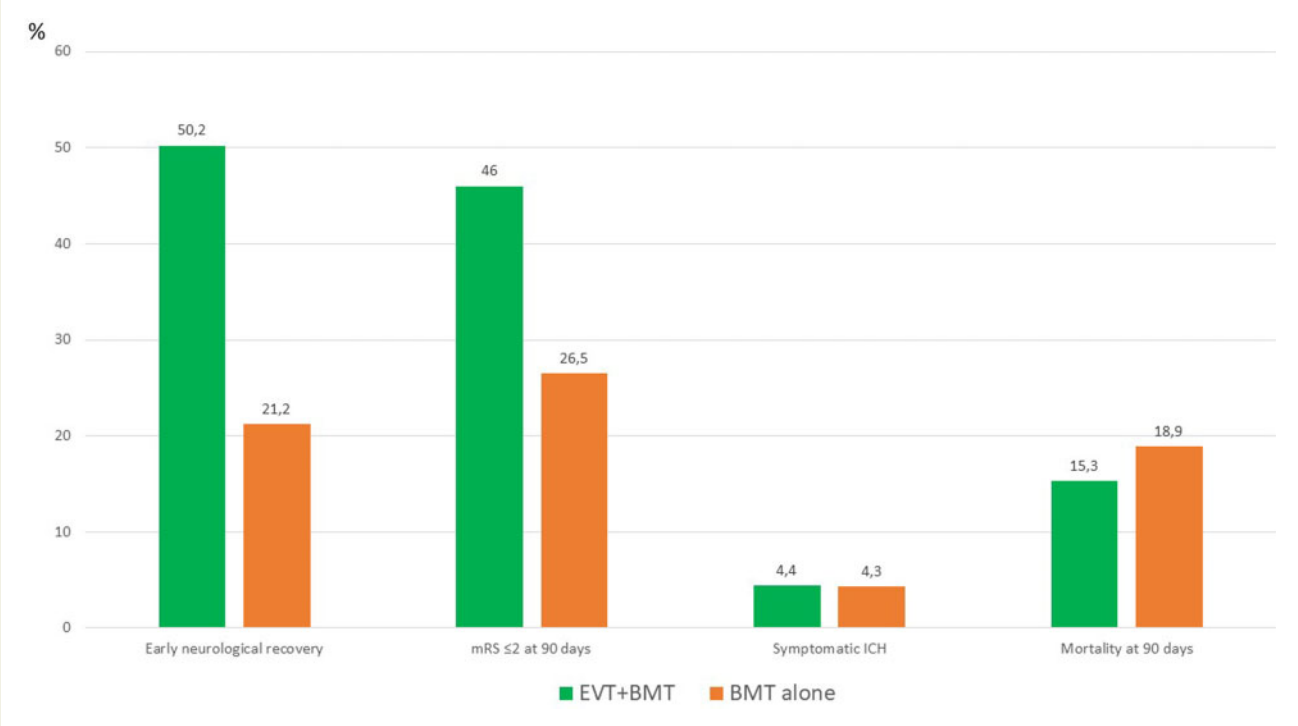

Figure 4 Meta-analysis of the randomized trials on endovascular stroke treatment (data summary from Ref.[17]). BMT, best medical treatment (including thrombolysis whenever indicated); EVT, endovascular treatment; ICH, intra-cranial haemorrhage; mRS, modified Rankin scale.

allow cardiologists to acquire sufficient knowledge in neurosciences and develop all necessary skills required for the safe practice of endovascular stroke therapy. Considering the fast growing number of neurointerventional training options and trained neurointerventionists, this approach may be only transient until enough neurointerventionists have been trained. In some places with lower caseload, it may last longer.

Methods—preparation of the position paper

In 2016, the European Society of Cardiology (ESC) created the ESC Council on Stroke as a multidisciplinary constituent body to promote the interdisciplinary cooperation, education, and research on stroke with the final goal of reducing the burden of cardiovascular disease in Europe. A key objective of the ESC Council on Stroke was to develop position papers and consensus documents in collaboration with sister societies involved in the multidisciplinary management of stroke patients. Between 2016 and 2020 multiple negotiations were carried out with the representatives of the ESO, the ESMINT, and the European Association of Percutaneous Cardiovascular Interventions (EAPCI) to facilitate the future cooperation of the acute myocardial infarction and stroke care networks. As a result, the Council has endorsed and promoted the activities of ESO and ESMINT. Specifically, the European Stroke Course in Minimally Invasive Neurological Therapy (EXMINT) and the standards of stroke care outlined by the guidelines of these societies were endorsed.

The ESC Council on Stroke and the EAPCI jointly nominated the authors of this document. The first author is the ESC official representative in the European Board for Neuro-Interventions (EBNI). The first draft was prepared equally by the first two authors (S.N. and P.L.) and finalized by the senior author (P.W.), all other authors contributed significantly with their comments and additions and approved the final text. Finally, the draft was submitted to EBNI for review and was completed in cooperation with the contributing members of EBNI.

Arguments supporting the role of interventional cardiologists in the stroke team

The European training guidelines for interventional cardiologists have been outlined by EAPCI.[34] Although the newly prepared European curriculum for interventional cardiology training will not list any required numbers of procedures, qualified interventional cardiologists have generally gained extensive experience during their training.

Due to the large number of skills common to all cardiovascular interventions many interventional cardiologists have also become involved in treatments of non-coronary artery disease like peripheral vascular interventions, including extracranial carotid artery stenting.[35,36] Furthermore, several cardiac interventions (left atrial appendage closure, patent foramen ovale closure, embolic protection in structural interventions) mandated close collaboration with clinical

Table 1 The current indications for endovascular treatment of acute ischaemic stroke (summarized from Ref.[20]).

First 6 h from symptom onset or last seen well	In anterior circulation LVO strokes with NIHS score >6 and ASPECT >6 EVT (plus IVT whenever indicated) is recommended to improve the functional outcome.
	With regard to the grim natural course of basilar artery occlusions, the therapeutic approach with IVT plus EVT should strongly be considered in posterior circulation strokes.
Presentation between *6 and 24 h* from symptom onset or last seen well	EVT is recommended for patients with anterior circulation LVO stroke presenting 6–16 h from time last known well and fulfilling the selection criteria of DEFUSE-3 or DAWN trials. EVT is recommended for patients with anterior circulation LVO stroke presenting 6–24 h from time last known well and fulfilling the selection criteria of the DAWN trial.
	According to expert opinions, the 6 h time window can be extended up 7 h without perfusion imaging and the ESCAPE criteria with good collateral score could be applied up to 12 h, but these patients should be treated within clinical trials.
Intravenous *thrombolysis* (IVT) and mechanical thrombectomy (MT)	IVT plus MT is recommended to MT alone whenever IVT is not contraindicated
	MT should not prevent the initiation of IVT, and IVT should not delay MT.
	In patients not eligible for IVT MT as standalone treatment is recommended
	According to expert opinions, before MT tenecteplase (0.25 mg/kg) is preferred over alteplase (0.9 mg/kg) if the decision on IVT is made after vessel occlusion status is known.
Interhospital transfers	There is lack of strong evidence for superiority of one organizational model, the choice of model should depend on local and regional service organization and patient characteristics.
	'Mothership' model (direct transfer to EVT centre) may be preferred in metropolitan areas with transportation time to an EVT centre of <30–45 min.
	'Drip-and-ship' model (IVT in the nearest stroke centre followed by transfer for EVT) when transportation times are longer and patient presents early in the course of stroke.
	Treatment of LVO-related acute ischaemic stroke patients is recommended in comprehensive stroke centres.
Perfusion brain imaging (perfusion CT or MRI)	Advanced brain imaging is not necessary in pts presenting 0–6 h from time last known well.
	During the 6–24 h time window, advanced brain imaging (such as CTA + CTP or MRI-DWI) is recommended to select pts with potential benefit from EVT.
General anaesthesia vs. conscious sedation	There is only low quality of evidence and conflicting results between three small single-centre randomized clinical trials.
	Local anaesthesia or conscious sedation may be favoured over general anaesthesia, if the patient is able to undergo MT without general anaesthesia.
	General anaesthesia should be used only if specifically indicated. Delays to induction of general anaesthesia should be minimized.
	A specialized neuroanaesthesiological or neurocritical care team should perform the general anaesthesia procedure, whenever possible. Excessive blood pressure drops should be avoided.
Acute *carotid stenting*	No recommendation (lack of evidence) can be provided for associated extracranial carotid artery stenosis or occlusion.
	According to expert opinions, patients with high-grade stenosis or occlusion may be treated with intraprocedural stenting if unavoidably needed.

CTP, CT-perfusion; EVT, endovascular therapy; IVT, intravenous thrombolysis; LVO, large vessel occlusion.

neurologists in acute and elective multidisciplinary settings. True to the principle of the acute care delivery close to the patients' residence, and accounting for the established validity of relationships between volumes and outcome in interventional practices,[37] training of interventional cardiologists to treat AIS patients using standard requirements will contribute to achieve broad access to endovascular stroke treatment, especially in regions and countries which are lacking this 24/7 service.

The proposed role of interventional cardiologists in the stroke care networks

Since IVT was approved in AIS, neurologists have created a network of stroke centres (today labelled level 3 centres) able to provide the service. Implementation of EVT was facilitated by these stroke networks, establishing a close collaboration between the level 3 centres and EVT-capable (level 1 and 2) centres. Accordingly, major stakeholders in the stroke community have provided recommendations on required levels and capabilities of stroke care providers. Detailed requirements for the facilities' infrastructure, services, procedural volumes, staff ratio, and quality assurance have been determined in a multi-society document that included ESO and ESMINT (*Table 2*).[26] Since EVT was shown to achieve better outcomes than intravenous (IV) tissue plasminogen activator (tPA) in large vessel occlusion (LVO) stroke patients, all LVO stroke patients need to be referred to comprehensive centres for thrombectomies. Safe and efficient delivery of EVT requires availability of competent stroke centres. Based on the above-mentioned document EVT should preferably be performed in healthcare institutions that routinely provide neurointerventional treatments to patients with a variety of neurovascular

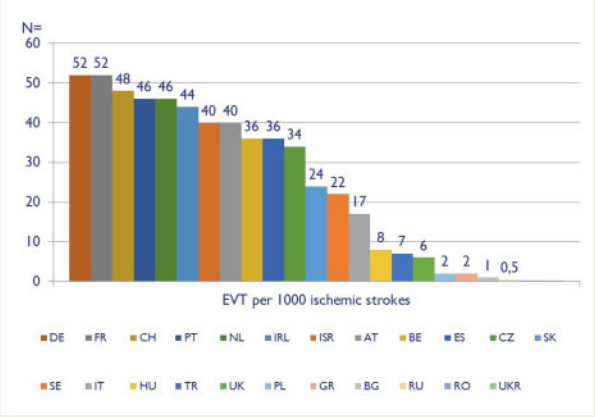

Figure 5 Large regional differences at the beginning of the MT era (as of 2016) in the number of EVT per 1000 ischaemic strokes in European countries as per Ref.[22] The goal should be ~100 (maybe even up to 160) EVT per 1000 ischaemic strokes.[24]

disorders (comprehensive level 1 centres), provided this can be achieved without unnecessary transfer delay. In regions where a level 1 centre is too far away from a level 3 stroke centre, establishment of centres treating only ischaemic stroke with EVT privileges (level 2 centres) has been proposed. Other strategies to facilitate EVT in more remote areas, like driving/flying doctors,[38] remote proctoring[39] or robotic-assisted neuroendovascular interventions[40] may be experimental today, but could potentially play an additional role in the future.

Interventional cardiologists adequately trained to perform endovascular stroke interventions could complement stroke teams to provide the 24/7 on call duty. Another opportunity to improve patient's access to EVT, however, would be to upgrade in some places level 3 stroke centres to level 2 centres by using the cardiac catheterization laboratory as the EVT care facility. Management of stroke patients in dedicated stroke units is an independent predictor of a favourable outcome.[41] Multidisciplinary decision-making involving neurologists and neuroradiologists is the key element of optimal interventional stroke treatment when interventional cardiologists are providing EVT.[29] Therefore, hospitals that do not meet the requirements for level 3 stroke centres should not treat acute stroke patients with EVT, irrespective of capability to provide primary PCI for acute myocardial infarction.

The decision to upgrade a level 3 stroke centre to a level 2 centre using the cardiology catheterization laboratory services must be based on the clinical needs of the local community. It is critically important to minimize the time from symptom onset to revascularization by the shortest possible distance between the place of stroke onset and EVT-capable stroke centres. The decreasing utilization of EVT with increasing distance from the EVT-capable centres,[42] the decreasing efficacy of clinical outcomes due to delayed revascularization therapy[17] and the critical importance of revascularization within the first 2 h,[43] all support the creation of decentralized networks. However, the significantly poorer clinical outcome of EVT achieved in centres performing low procedural numbers (as compared with high-volume centres) argues for more centralized systems.[36]

Table 2 Recommendations for responsibilities of three levels of stroke centres

Level 1 centre	Full spectrum of neuroendovascular therapies
	≥250 stroke patients per year and ≥50 stroke thrombectomy procedures per year
	Dedicated neurointensive unit and dedicated stroke unit incl. IV tPA
	Open neurosurgical services on site
	No geographic restriction and receives cases from levels 2 and 3 centres
Level 2 centre	Neuroendovascular procedures only for stroke treatment
	≥100 stroke patients per year and ≥50 stroke thrombectomy procedures per year
	Optional neurointensive unit and dedicated stroke unit incl. iv. tPA
	Optional neurosurgical services on site
Level 3 centre	No neuroendovascular procedures.
	≥50 stroke patients per year
	Dedicated stroke unit incl. IV tPA
	Standardized transfer protocols with level 1 centre (or with level 2 centre if level 1 centre is more than 2 h transfer time)

Adapted from Pierot *et al.*[26]

Initiating a level 2 stroke centre should follow existing international professional recommendations[26] (*Table 2*). Travel distance (e.g. 1 h travel time) and estimated annual number of stroke thrombectomies per year are equally important parameters. If we assume that competence can be maintained with ~20 acute stroke procedures per year per operator and the minimal number of operators to provide 24/7/365 service is three, then a minimal number of stroke thrombectomy procedures per year should be at least 50 (*Table 2*, Ref.[26]). To achieve this number a minimal served population should be around 0.5 million inhabitants. Based on our current knowledge, it seems reasonable to propose, that only those level 3 stroke centres should be upgraded to offer EVT service (level 2 centre) that achieve the number of procedures required for level 2 stroke centres on a continuous basis (*Table 2*).

Training of interventional cardiologists for endovascular stroke therapy

Traditionally, neuroradiology, neurology, and neurosurgery were assigned for training tracks to perform neurointerventions.[44] However, it is important to note that the current international multisociety recommendations also include and invite other specialists, e.g. interventional radiologists and cardiologists, to train and acquire specialist competence in stroke interventions.[31] Consensus documents define the training required to become proficient in all neurointerventional procedures and distinguish this from the training

Table 3 Fundamental elements of theoretic pre-training for cardiologist willing to learn endovascular stroke therapy

Basic neuroscience	Functional neuroanatomy
	Cerebral arterial anatomy and collateral pathways
	Developmental variants of the cerebral circulation
	Pathophysiology of cerebral ischaemia-reperfusion injury
Vascular neurology	Ischaemic stroke—underlying causes and mechanisms
	Diagnosis of hyperacute stroke and differentiation of mimics
	Examination of the stroke patient: NIHSS score, mRS scale.
	Medical treatment of ischaemic stroke: anti-thrombotic therapy
	IVT for stroke: evidence-based patient selection
	Triage of patients for EVT
	Management/patient selection of acute vertebra-basilar stroke
	Aetiologic workup of stroke patients
Imaging in stroke	Native CT imaging in stroke: focus on the ASPECTS Score
	CT-angiography and CT-perfusion in acute stroke
	MRI imaging in stroke: core imaging vs. perfusion studies
Revascularization	Summary of the evidence-based indications for EVT in stroke
	Optimal technics of stent-retriever thrombectomy and aspiration
	Treatment of carotid artery stenosis in acute stroke patients
	Treatment of intra-cranial stenosis in acute stroke patients
	Management of complications in endovascular stroke therapy
	Role of vascular surgery and neurosurgery in acute stroke
Logistics of stroke care	Logistics of organizing acute EVT services drip and ship vs. mothership
	Quality control of endovascular stroke treatment

EVT, endovascular therapy; IVT, intravenous thrombolysis.

focused alone on EVT of stroke. This training is based on theoretical knowledge of neurosciences with a second focus on learning the skills required to perform EVT in a safe and efficient way. Thus, all specialists including cardiologists must master the same basic knowledge in clinical neurosciences, neurology and neuroimaging as part of the training programme before starting hands-on training (*Table 3*).

Theoretical training

Specialists who did not acquire stroke clinical competence as part of their residencies or fellowships must spend a period of at least 1 year studying clinical neurosciences and neuroimaging, focusing on the diagnosis, imaging, and management of ischaemic stroke. The initial basis of the theoretical knowledge can be obtained at the previously mentioned EXMINT course, which is organized in two short training sessions lasting for 4–5 days within 1 year.

For the clinical practice skills, we propose that interventional cardiologists working in a level 3 stroke centre could start their preparation for EVT training by getting involved in the multidisciplinary management of the acute stroke patients in close cooperation with the local neurology and radiology team. Based on the results of the largest prospective EVT registry, the aetiology of cerebral LVO is cardioembolic in 56% and cryptogenic in 27.6% of the cases.[45] Therefore at least 8 out of 10 EVT patients need cardiologic workup to determine their optimal secondary prevention strategy, thus supporting the need for complementary cardiology expertise within the stroke team. This could involve acute management of the stroke patient undergoing IVT, and stroke imaging evaluation.

Ultimately, the cardiologist trained to deliver EVT for ischaemic stroke might be interested to obtain competence for secondary stroke prevention procedures (e.g. PFO closure, LAA closure), as they acquire the most profound knowledge about cerebrovascular disease within the cardiac team.

Simulator training

Simulator training of acute stroke EVT and carotid stenting is a valuable asset to become familiar with the anatomy, various techniques and equipment, but cannot replace hands-on experience with real stroke patients. However, with the rapidly evolving virtual technology, simulator-based training, employing real-life case scenarios, may become more important in EVT training in the future.

Hands-on training in large volume centres

The skillset of an experienced interventional cardiologist provides important foundation for learning EVT. Although they are able to safely provide vascular access and navigate intravascular catheters, they need to acquire additional technical skills in order to operate safely on stroke patients. Cardiologist with extensive experience in carotid stenting is already more advanced, as they are familiar with access and treatment of the supra-aortic extracranial vessels using dedicated equipment and using digital subtraction angiographic techniques.

Based on the consensus document of the neurointerventional societies in Europe, specialists aiming to practice any neurointervention independently (as first operator and without supervision) should

Table 4 Procedural requirements for interventional cardiologist delivering endovascular therapy in stroke

Reading of cranial CT and CTA images under neuroradiologist's supervision	100 cases
Reading of cranial MRI images under neuroradiologist's supervision	50 cases
Participation in IVT treatment together with the local neurology team	50 cases
First operator in cerebral angiography or carotid stenting	75 cases
Second operator in mechanical EVT	25 cases
First operator role in mechanical EVT	25 cases

EVT, endovascular therapy; IVT, intravenous thrombolysis.

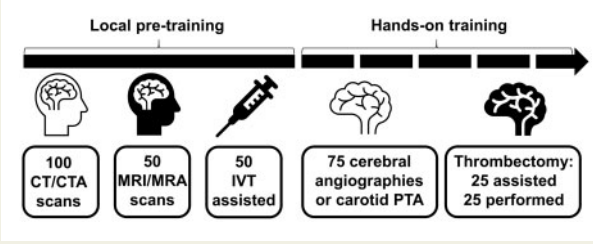

Figure 6 Procedural training requirements for interventional cardiologists to become proficient in endovascular stroke treatment. CT, computed tomography; CTA, CT-angiography; IVT, intravenous thrombolysis; MRA, magnetic resonance angiography; MRI, magnetic resonance imaging ; PTA, percutaneous transluminal angioplasty.

perform at least 75 cerebral angiographies in order to learn adequate cannulation of neck vessels and to understand cerebral vascular anatomy.[33] A minimum of 50 EVTs with at least 50% as first operator is required by the neurointerventional societies before cardiologists can perform EVT independently. The duration of the hands-on training should preferably be 12 months. However, if continuous training is not feasible, intermittent participation in the training programme should be allowed, providing that the candidates are able to spend sufficiently long blocks of time at the training site. While this will evidently increase the total training time, an attempt should be made to complete the required number of procedures within a reasonable timeframe (*Table 4*). Cardiologist who fulfils the requirements will be qualified to perform EVT but not to perform other neurointerventional procedures. The training is summarized in *Figure 6*.

How to start a new level 2 stroke centre when training in level 1 centre is not available?

If training in an interventional neuroradiology centre is not available, it may be acceptable (with full support of local neurologists, neuroradiologists, and health care providers) to initiate an EVT programme with a team composed of a single qualified neurointerventionist and an experienced interventional cardiologist. However, all interventionists treating AIS should have the opportunity to obtain personal experience at a level 1 centre, in order to acquire a broad insight in wide spectrum of neurointerventional techniques and become competent in avoiding, understanding and—if needed—handling complications.

Local training by a qualified neurointerventionist may be supplemented (but not replaced) by the review of recorded live acute stroke EVT cases, dedicated stroke seminars, simulator training, training in animals, flow model training in patient-specific models, and the review of computed tomography (CT), CT-angiography (CTA), CT-perfusion (CTP), and magnetic resonance (MR) images of acute stroke. The required number of cases, however, always has to be performed under the guidance of a qualified neurointerventionist.

Table 5 Summary of the recommendations

Where?	Regions with limited 24/7 access to endovascular treatment and hospitals with a multidisciplinary stroke team in place (minimum level 3 stroke centres providing IVT).
Who?	Interventional cardiologists with sufficient experience in primary PCI for STEMI. Experience in carotid stenting is a significant advantage.
How?	By obtaining the necessary theoretical knowledge about brain and vascular anatomy, materials and devices, stroke pathophysiology, stroke imaging, and periprocedural medication alongside practical training.
Practical training?	Minimum procedures as *first operator* during training: 75 cerebral angiographies or carotid stenting procedures and 25 stroke EVT procedures.
Monitoring?	Participation in a quality assurance programme.

EVT, endovascular therapy; IVT, intravenous thrombolysis; PCI, percutaneous coronary interventions.

Quality control of endovascular therapy in ischaemic stroke

Safety standards need to be universal among the care providers, and all operators should aim for the same high service quality. The standard of practice set for level 2 neurointerventional centre requires at least 50 procedures per centre per year, and at least 15 procedures per operator yearly in order to maintain sufficient experience.[26]

In addition, the centre should participate in an ongoing practice audit, reporting and quality assurance, and improvement programme. The quality assurance programme must review all emergency interventional stroke therapy patients. Standard outcomes (periprocedural and at 90 days) should be tracked and recorded. Based on current evidence, we suggest the following threshold levels:

(1) Successful recanalization (modified TICI 2b or 3) in at least 60% of cases.
(2) Embolization to new territory of <15%.

(3) Symptomatic intra-cranial haemorrhage (i.e. parenchymal haematoma on imaging with clinical deterioration) rate <10%.[32]

Conclusion

Interventional cardiologists may represent an important pool of skilled professionals that can contribute to increase timely access of AIS patients to EVT (*Table 5*). The training requirements for interventional cardiologists to perform EVT should be based on two main principles:

(1) Patient safety cannot be compromised; quality of the interventional services must meet established standards irrespectively of the professional's training background.
(2) Proper training of interventional cardiologists should be under supervision of and guaranteed by a qualified neurointerventionist and within the setting of a stroke team.

We believe that the interdisciplinary cooperation based on common standards and professional consensus is the key to the quality improvement in all fields of cardiovascular medicine.

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