



## What stroke image do we want? European survey on acute stroke imaging and revascularisation treatment



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### ARTICLE INFO

#### Article history:

Available online 10 August 2019

#### Keywords:

Stroke  
Imaging  
Revascularisation treatment  
Clinical practice variation  
Europe

### ABSTRACT

**Introduction:** The evolution of stroke treatment has been geared toward thrombolysis and thrombectomy, which requires quick imaging assessment. Various imaging and treatment options are available and current evidence suggests European differences in stroke care. We aimed to describe the patterns of stroke imaging and acute revascularisation therapy and examine variations across countries.

**Methods:** A web-based clinician survey was developed and circulated to clinicians through email distribution lists and websites of European professional societies. Statistical analyses were performed.

**Results:** We received responses from Sweden (21), the UK (16), Hungary (15), Germany (12) and Europe (47). Large variations are observed in revascularisation treatment: German respondents report that 81% of their ischaemic stroke patients diagnosed with a large vessel occlusion within 4.5 h receive intravenous thrombolysis and thrombectomy, compared to 12% reported by the UK-respondents. For patients diagnosed with an extensive ischaemic stroke within 2 h from onset, 75% of UK-respondents state thrombectomy as their preferred revascularisation treatment, but only 13% report to use it. Computed Tomography (CT) is reported as the most widely used first imaging test (for 81% to 93% of patients across geographic areas), while Magnetic Resonance Imaging (MRI) is a distant second.

**Conclusion:** The diagnostic workup and, to a greater extent, the revascularisation treatments of typical stroke patients vary considerably across European countries. This study reinforces the need to compare the quality of stroke care in terms of process and outcomes between countries. Research is also needed to investigate the cost-effectiveness of second-line imaging strategies in acute stroke care.

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### Introduction

The rapid evolution of stroke treatment over the past years has been geared toward thrombolysis and more recently thrombectomy, both of which have been proven highly effective [1]. These treatments require a quick differentiation between ischaemic and haemorrhagic brain damage, as well as perfusion impairment. This makes neuroimaging essential in the acute phase. Computed Tomography (CT) combined with CT Angiography (CTA) or Magnetic Resonance (MR) combined with Magnetic Resonance Angiography (MRA) form the imaging standard of diagnostic workup. However, other imaging technologies exist and new technologies emerge: dual energy CT and, more recently, spectral photon-counting CT (SPCCT) are innovative imaging tools expected to improve treat-

**Abbreviations:** ABN, Association of British Neurologists; ASPECTS, Alberta Stroke Program Early CT score; BASP, British Association of Stroke Physicians; CT, computed tomography; CTA, computed tomography angiography; DWI, diffusion-weighted imaging; ESO, European Stroke Organisation; ESNR, European Society of Neuro-radiology; IA, intra-arterial; IV, intravenous; IVT, intravenous thrombolysis; MR, magnetic resonance combined; MRA, magnetic resonance angiography; MRI, magnetic resonance imaging; NRSR, Neurosonology Research Group; NIHSS, National Institutes of Health Stroke Scale; SPCCT, spectral photon-counting computed tomography; TIA, transient ischaemic attack.

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<https://doi.org/10.1016/j.hlpt.2019.08.005>

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ment decision-making in stroke in emergency settings by better quantifying brain perfusion impairment [2]. To assess the relative value of innovation, current clinical practices need to be assessed. Much of what is known about clinical practice regarding stroke care is based upon registry data (for instance Riksstroke in Sweden [3] and SSNAP in the UK [4]). As far as imaging is concerned, the SSNAP registry reports the number of patients scanned within certain time windows without describing the sequence of diagnostic modalities. Furthermore, these registries concern heterogeneous group of (ischaemic) stroke patients and are limited to specific countries. Evidence suggests differences in stroke care and outcomes within European countries [5]. The scarcity of and the need for international comparisons and databases have been pointed out by different authors, suggesting that variations in care need to be understood better.

In this context, we developed and used an online survey aiming to describe current clinical practice in acute stroke care in Europe and to examine variations between countries. The focus was made on diagnostic imaging technologies and the use of revascularisation treatment.

## Method

### Design

In order to assess clinical practice in Europe regarding acute stroke care, an online clinician survey was developed, pilot-tested and distributed. The survey questions were formulated based on expert opinion and feedback collected from a European expert panel, which included five neurologists, two radiologists and one neuro-radiologist. A pilot phase was conducted before the survey was launched in October 2016. The survey was conducted using the online software “Google form” and was made available online. The target population included neurologists, stroke physicians, neurointerventionalists, neuroradiologists, neurosurgeons and emergency physicians (including those completing their specialisation). Because we were interested in examining a range of healthcare systems, Germany, Hungary, Sweden and the United Kingdom were chosen as main target countries. Whereas Sweden is known for its early adoption of medical technologies, Hungary tends to be a late adopter. Besides, the UK is of major interest for its publicly funded system while Germany is characterised by its decentralised healthcare organisation in which private practitioners play a relatively important role.

No financial incentive was offered to participants and survey completion was voluntary.

### Structure

A closed and structured format in English was chosen to enable clinicians to select their responses among multiple predefined choices. An introduction provided the framework of the study and was followed by general questions regarding the respondents' work setting. Subsequently, respondents were asked about the routine imaging workup and treatment used in their centre and the proportion of stroke patients receiving each of these modalities. Section three contained questions about the imaging modalities used to diagnose stroke and make therapy decisions. In sections four and five, respondents were asked about the treatment modalities used in acute stroke care in their centre. In section six, respondents were asked about the typical follow-up imaging strategy used after reperfusion therapy. We investigated the clinicians' opinion towards progress in section seven and requested them to report the guidelines they use in section eight. The questions focused on different patient profiles that are summarised in Table 1. The survey questions can be found in supplement, online only.

**Table 1**  
Patient profiles as defined in the survey.

Case	Patient profile	Procedure	Maximum time from symptom onset to procedure (hours)
A	Suspected of acute stroke	Initial imaging for differential diagnosis	-*
B	With moderate or severe ischaemic stroke	Second imaging test (after differential diagnosis imaging)	4
C	With minor ischaemic stroke or TIA		-*
D	With haemorrhagic stroke		
E	With ischaemic stroke and large vessel occlusion	Choice of revascularisation treatment	4.5
F	Male aged 65, admitted with complete aphasia, NIHSS score of 14. CTA at admission showed an occlusion of the first segment of the left middle cerebral artery (M1). ASPECTS score was 5. No contraindication for thrombolysis or thrombectomy		2
G	Who received reperfusion therapy	Follow-up imaging after reperfusion	48

ASPECTS: Alberta Stroke Program Early CT score.

NIHSS: National Institutes of Health Stroke Scale.

TIA: transient ischemic attack.

\* : timing not specified in the survey.

### Dissemination

The online survey link was circulated through email distribution lists and websites of national and European professional societies. Given our interest in the four different health care systems, the British Association of Stroke Physicians (BASP), the Hungarian Stroke Society and the Swedish Acute Neurology Society invited their members to participate in the survey through personal emails. The European Society of Neuroradiology (ESNR) and the Association of British Neurologists (ABN) advertised the survey to their members via their November newsletter. The Neurosonology Research Group (NSRG) and the Hungarian Stroke Society encouraged their members to participate by circulating the survey through their website.

To boost participation, we adopted a complementary strategy and sent emails to the department leads of 39 Hungarian and 80 German stroke centres with the request to invite their personnel to participate in the survey. In addition, we sent an email containing the survey link to 20 English and 37 Swedish clinicians whose contact information was found on the internet. Up to three reminder emails were sent to potential respondents.

### Statistical analysis

Reported percentages of patients receiving imaging or treatment modalities and percentages of clinicians reporting to use different treatments were extracted from the clinicians' responses. Mean percentages were calculated for five geographic areas: the four countries and the whole group of European countries (including the four countries). The 95% confidence intervals surrounding the mean estimates were computed using the percentile of the bootstrap distributions [6]. This involved randomly resampling the original samples with replacement 500 times, which corresponded to the number of replications needed to ensure stability and accuracy. Each bootstrapped sample yielded a bootstrap statistic (e.g. mean frequency). The bootstrap distribution was computed from the 500 bootstrap statistics, per geographic area. Frequencies of

**Table 2**  
Respondent characteristics.

	Number	%
<b>Respondents' characteristics</b>	111	100
<b>Country</b>		
Sweden	21	19
UK	16	14
Hungary	15	14
Germany	12	11
Other countries	47	42
<b>Specialty</b>		
Neuroradiologist	30	27
Neurologist	24	22
Stroke physician	17	15
Neurologist and stroke physician	16	14
Neurointerventionalist and neuroradiologist	8	7
Neurointerventionalist	7	6
Completing specialty in neurology	5	5
Department chairman, radiologist, rehabilitation specialist	4	4
<b>Year of completion of main specialty</b>		
1976–1985	5	4
1986–1995	23	21
1996–2005	18	16
2006–2015	53	48
2016–2020	12	11
<b>Funding system</b>		
Public	104	94
Private	7	6
<b>Teaching category</b>		
Academic hospital	76	68
Non-academic hospital	35	32
<b>Stroke unit</b>	102	92

CT versus MRI usage were compared using T-tests and between-country comparisons of imaging and treatments were derived using one-way anova tests in SPSS (version 23).

## Results

We received responses from 172 clinicians. Of those respondents, 55 dropped out of the survey before completing 70% of the questions (up to question 14c), corresponding to a drop rate of 32%. Data from these 55 respondents as well as data from 6 non-European clinicians were taken out of the analysis. Among the 111 remaining respondents, 21 were from Sweden, 16 from the UK, 15 from Hungary, 12 from Germany and 47 from 19 other European countries. Details about the respondents' characteristics and work environment can be found in [Table 2](#).

### Diagnosis

#### First line imaging test for differential diagnosis

Non-contrast-enhanced brain CT is reported as the primary routine modality used to diagnose suspected stroke patients (profile A) and differentiate ischaemic from haemorrhagic strokes ([Fig. 1](#)). On the basis of the responses, it is obtained for more than 80% of the patients in each of the four different countries and Europe as a whole and used significantly more than MRI ( $p < 0.001$ ). Hungary shows the most extreme differences between the frequency of CT usage versus MRI usage ( $p < 0.001$ ).

#### Second line imaging tests for prognosis and treatment choice

Following the diagnosis of moderate to severe ischaemic stroke within 4 h of onset (profile B), vascular imaging is reported to be routinely obtained as a second-line modality to evaluate the prognosis and determine the treatment choice ([Fig. 2a](#)). According to the clinicians' responses, CTA is performed in 62% of the patients in Europe, 30% of the patients in the UK, 58% of the patients in

Hungary, 66% of the patients in Germany and 79% of the patients in Sweden. Moreover, non-contrast-enhanced CT and CT perfusion play a relatively important role in this phase while MRI (DWI, Flair, T2\*, T2, T1) and ultrasound appear to be less frequently used. Finally, MR perfusion and MRA are used for an average of 4% and 9% of patients across Europe, respectively (results not shown). [Fig. 2b](#) reports the frequencies of different imaging modalities for patients diagnosed with a TIA or minor stroke (profile C). It illustrates the degree of between-country heterogeneity and the large combinability of imaging tests used in second line. The results show that CTA is obtained for 53% of Swedish patients but for only 4% of English patients. While ultrasound is obtained for 44% of the patients in Hungary, it is used for an average of 22% of the patients in Europe.

Similarly, CTA is routinely performed as the second imaging test, after the diagnosis of a haemorrhagic stroke (profile D) ([Fig. 2c](#)). Substantial proportions of the European patients also receive a brain CT (30%) or an MRI (14%). Remarkably, the German respondents report to perform 48% more imaging tests than their European peers (1.52 versus 1.03) following the initial diagnosis of a haemorrhagic stroke.

### Treatment

[Fig. 3](#) shows the frequencies of revascularisation treatments given to ischaemic patients diagnosed with a large occlusion and within 4.5 h of symptom onset (profile E). For these typical patients, German respondents reported to use mechanical thrombectomy significantly more often than the UK-respondents ( $p = 0.017$ ) and Hungarian respondents ( $p = 0.044$ ). Interestingly, the UK shows the lowest rate of thrombectomy (19% of the patients), in favour of the highest rate of thrombolysis (80% of the patients) amongst the investigated geographic areas. With 73% of English patients from profile E receiving it, intravenous thrombolysis (IVT) is significantly more used in the UK than in Europe ( $p < 0.001$ ), Sweden ( $p < 0.001$ ) and Germany ( $p < 0.001$ ).

The time window of revascularisation treatments varies substantially between and within countries. In Germany, while 33% of the respondents report to use mechanical thrombectomy up to a maximum of 6 h after symptom onset, 50% perform this treatment up to 7–10 h. A similar variation can be observed in Sweden. In addition, 10% of the clinicians in Europe do not use thrombectomy at all and this proportion increases to 20% and 24% in Hungary and in the UK, respectively.

### Detailed clinical case

During the survey, the respondents were asked to indicate their choice of revascularisation treatment for a typical patient belonging to profile F (see [Table 1](#)). The respondents had to indicate both their preferred treatment and the actual treatment they would provide in their health centre. Most respondents in Europe overall (73%) stated that IVT combined with mechanical thrombectomy was the preferred treatment option; this was also true in each of the four countries ([Fig. 4](#)). While the German and Swedish practice tended to be aligned on this preference, wide variations were observed between the preferred and current options in the UK (56 percentage points), in Hungary (33 percentage points) and, to a lesser extent, in Europe (19 percentage points). In these three areas, mechanical thrombectomy was less frequently used than IVT.

### Follow-up imaging

The vast majority of the European clinicians (93%) responded that follow-up imaging was performed for all patients from profile G. After reperfusion therapy, 82% of the European patients receive

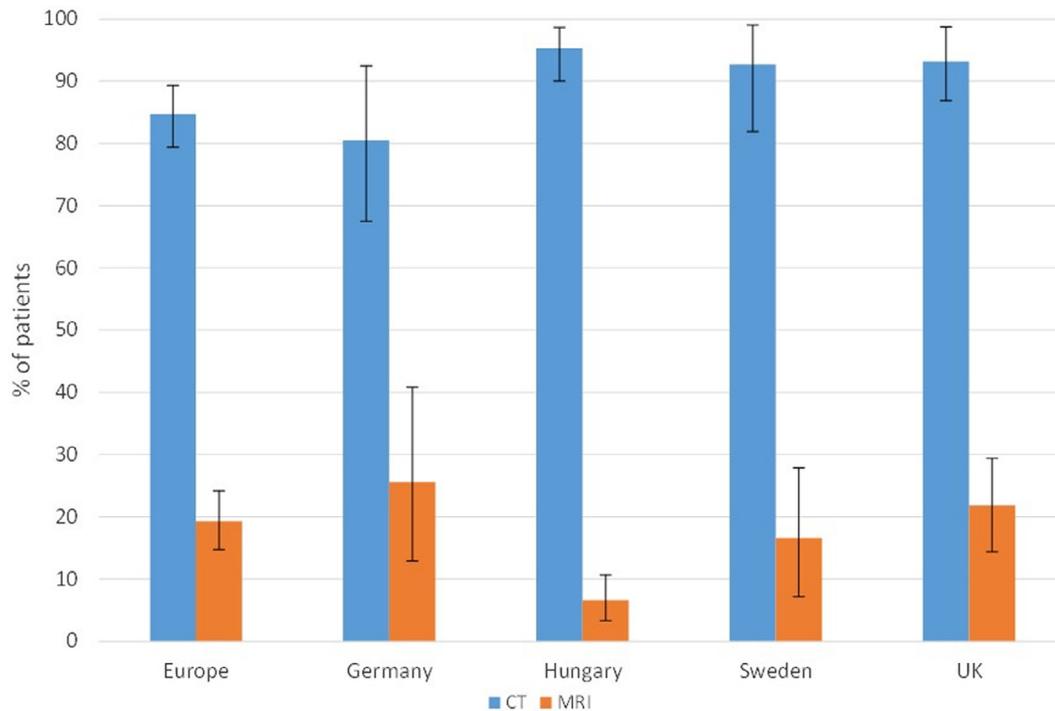


Fig. 1. Differential diagnosis of stroke type (haemorrhagic or ischaemic): CT versus MRI usage with 95% confidence intervals.

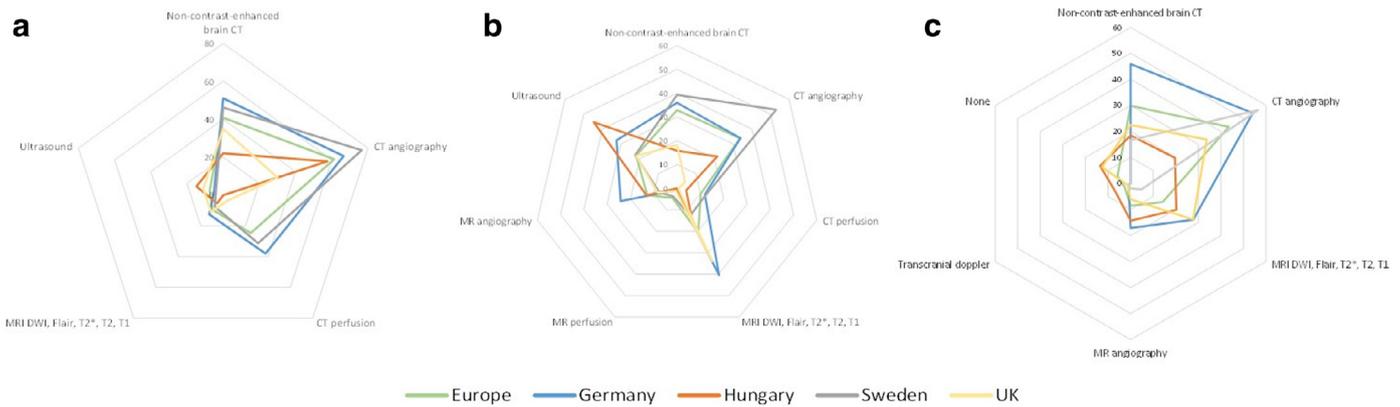


Fig. 2. Proportion of patients receiving a second-line imaging test. 2a: moderate to severe ischaemic stroke (within 4 h of onset) 2b: TIA or minor stroke 2c: haemorrhagic stroke.

a follow-up CT. While MRI also plays a relatively important role in this clinical phase (27% of the European patients receiving it), CTA, MRA and transcranial doppler are less frequently used (for 9%, 19% and 11% of the patients respectively).

Confidence analysis

We calculated the uncertainty around the means presented in Figs. 2, 3 and 4 (Fig. 5). Even when we consider this uncertainty, differences shown in the previous figures appear to be statistically significant except regarding the instances for which confidence intervals overlap.

Summarizing the above, on the basis of the responses received, non-contrast-enhanced brain CT is the first-line routine imaging modality to differentiate ischaemic from haemorrhagic patients. Once a moderate or severe ischaemic stroke is diagnosed, vascular imaging (CTA) is predominantly used for acute therapeutic decisions across the investigated areas. Once a TIA or minor stroke is

diagnosed, a CTA and ultrasound are almost equally likely to be obtained as second-line test. Haemorrhagic stroke patients are likely to receive either a CT (brain CT or CTA) or MR (MRI or MRA) scan. The imaging workup for minor stroke/TIA and haemorrhagic stroke patients tends to be less harmonised than for severe strokes across the areas. A substantial proportion of patients receives a comprehensive imaging work-up which includes a combination of imaging tests. Finally, non-contrast-enhanced brain CT remains the routine follow-up modality after revascularisation treatment of ischaemic stroke.

Discussion

To the best of our knowledge, this study presents the first on-line survey aiming to describe current clinical practice in acute stroke care in Europe and to examine potential variations between countries.

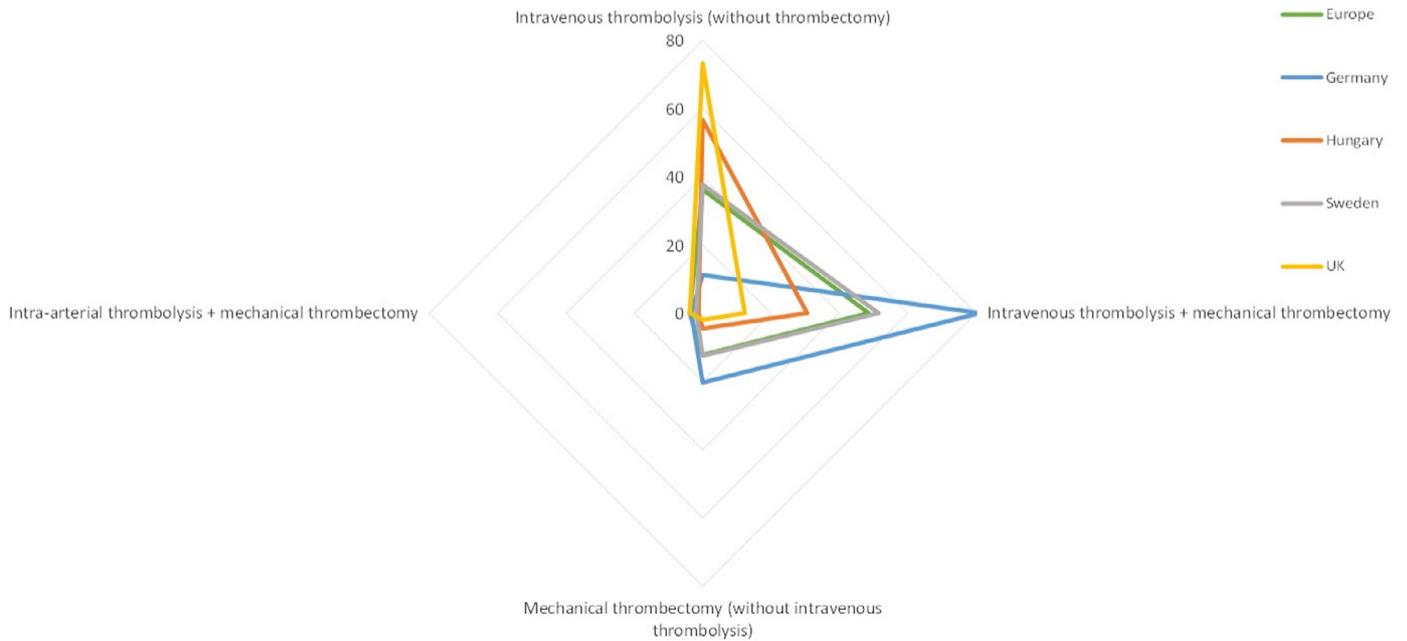


Fig. 3. Proportion of patients (profile E) receiving revascularisation treatment.

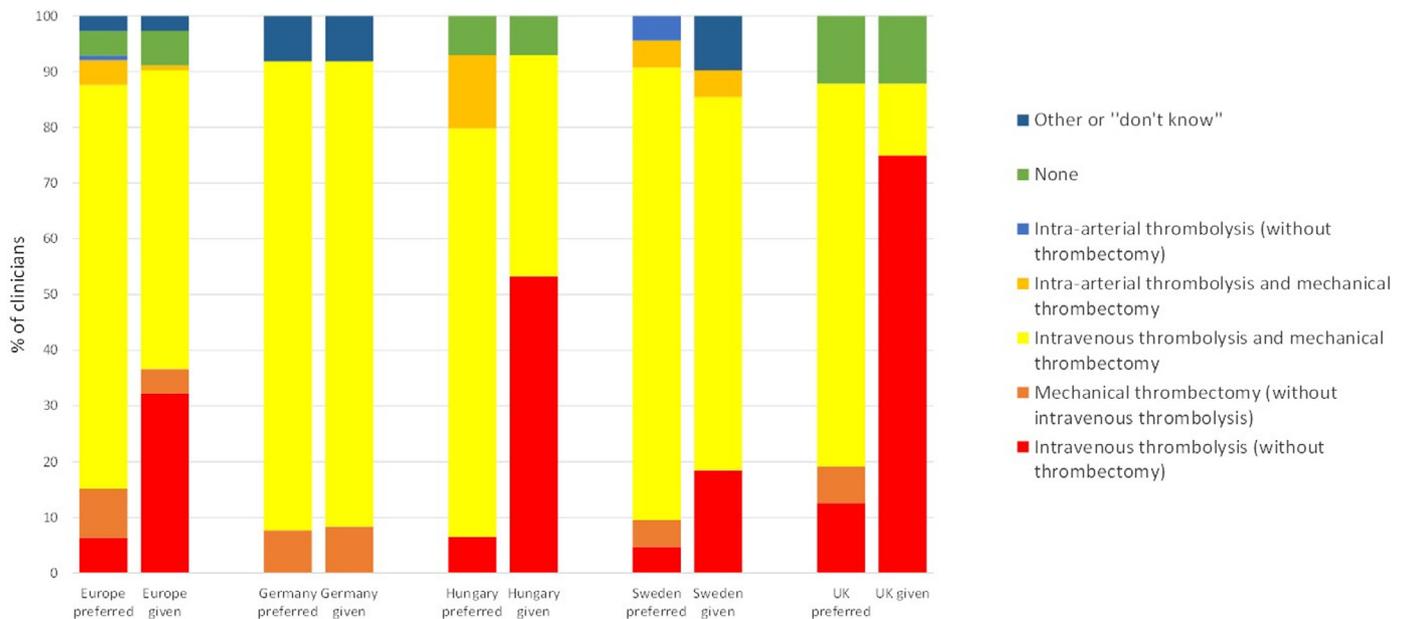


Fig. 4. Clinical case - preferred treatment versus given treatment. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.).

**Main findings**

This survey revealed that variation in acute stroke care is limited regarding the first line imaging test (differential diagnosis) but increases at later stages of the imaging workup and in the choice of treatment. CT is the mainstay of the stroke imaging workup in the initial phase and this observation holds in later phases of acute care. This finding is presumably seen because access to CT is more rapid and requires less organisation, logistics and resources than access to MRI and is consistent with previous studies [7]. Whether the widespread use of CT is the most effective way of dealing with stroke patients is a legitimate question. Interestingly, clinicians reported that not all their patients are imaged with CT despite its wide availability.

Besides, our study shows that a comprehensive imaging workup is used in stroke care which includes a combination of vascular (CTA and MRA), core (brain CT and MRI) and penumbra imaging (CT and MR perfusion). However, our results suggests that stroke imaging is less frequently used in Hungary and the UK compared to Germany, Sweden and the rest of Europe. German clinicians appear to image their patients substantially more often than their European peers do, both during the second-line imaging phase and during the follow-up imaging phase. Ideally, the diagnostic accuracy or prognostic value of an imaging modality should determine its use in clinical practice. However, recent evidence suggests that within 6 h from symptom onset, perfusion imaging does not help in identifying patients who will not benefit from endovascular treatment [8]. This suggests that the imaging workup

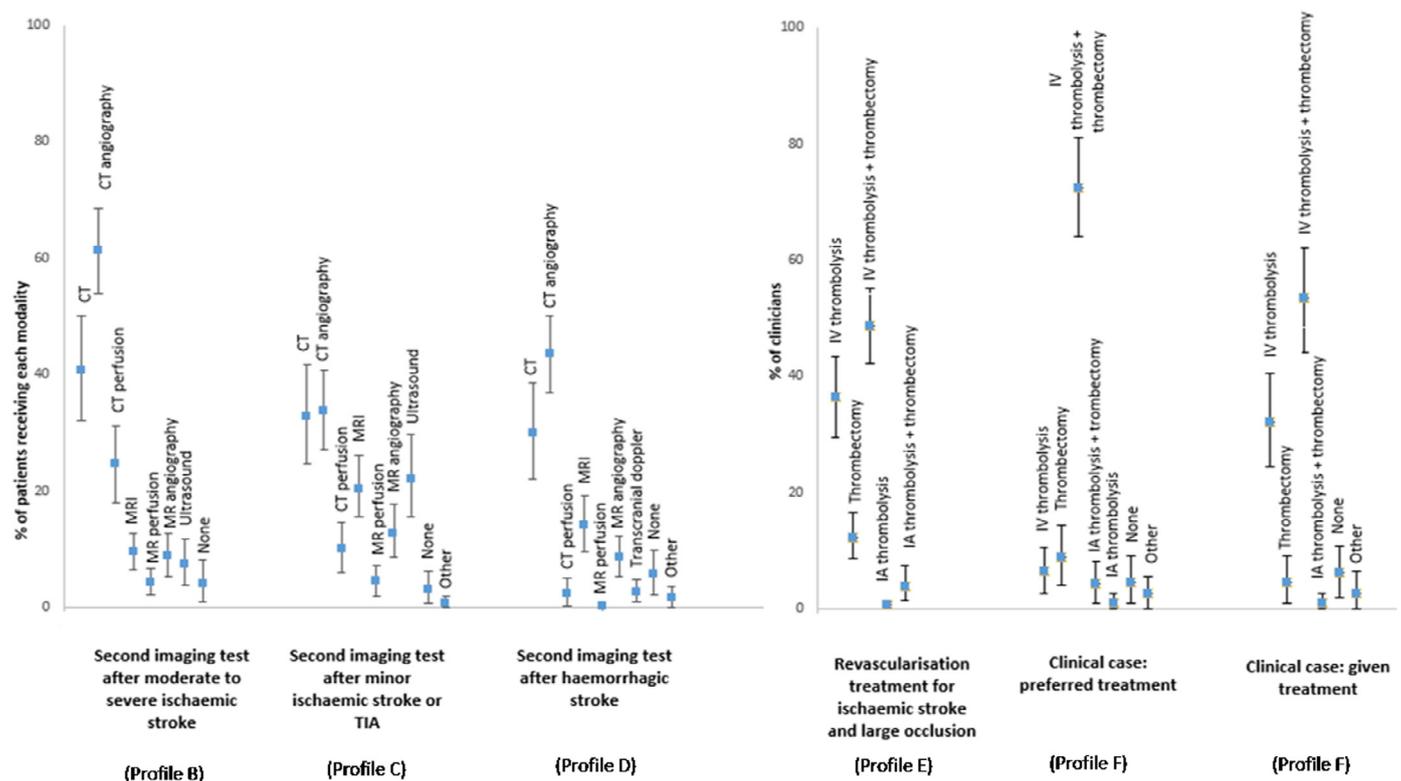


Fig. 5. Estimated relative frequency of use of imaging modalities and treatment in acute stroke care in Europe with 95% confidence intervals by patient profile.

IV: intravenous  
IA: intra-arterial

used by many clinicians in stroke care is not optimal for treatment decisions.

In addition to finding variations in the imaging workup between countries, we also found variations in the choice of revascularisation treatment for ischaemic patients. The main factor of between-country practice variation is related to thrombectomy among the severe stroke patients receiving treatment within 4.5 h of symptom onset: the lowest rates are reported in the UK and the highest in Germany. This observation shows that European stroke guidelines are unequally implemented across countries. Indeed, the European Stroke Organisation (ESO) and three other European associations have recommended mechanical thrombectomy, in addition to IVT, to treat stroke patients with large artery occlusions in the anterior circulation, up to 6 hours after symptom onset [9]. Furthermore, they have recommended mechanical thrombectomy as first-line treatment in large vessel occlusions when IVT is contraindicated. Interestingly, the results of the SSNAP national stroke audit performed in the UK were released in December 2016 [4]. According to these results, only 18% of the patients have access to mechanical thrombectomy on-site, 50% of them can access the treatment by referral to another site and 32% do not have access to it at all. Our survey results are consistent with these findings. Their audit reports that only 83 consultants perform thrombectomies and mentions that the service is only available during the week (not in the weekend). Logistical and workforce issues are pointed out as causes for the limited availability of this procedure [10]. Further research would be needed to identify barriers to thrombectomy.

The mismatch we identified between the clinicians' preferred treatment and the treatment they actually administer might be explained by the fact that thrombectomy is not sufficiently available, especially in the UK and Hungary. Furthermore, the maximum time window applied to perform revascularisation treatment is not harmonised among clinicians. Although treatment has been proven

beneficial within a certain amount of time from the onset (for instance within 4.5 h for IVT [11]), large practice variations are seen, both within and between countries.

This paper adds to the existing literature in two ways. First, it informs about the diagnostic and treatment workup for specific groups of stroke patients and, as such, provides a different level of information compared to registries that focus on the whole group of (ischaemic) stroke patients. Second, it provides insight into the diagnostic and treatment pathway for stroke care in Germany and Hungary. In these two countries, no (or only very limited) information related to stroke care is publicly available.

#### Limitations

As a limitation to our study, we acknowledge that a limited number of responses was received.

Our survey faced the inherent disadvantage of any survey, which is the challenge to reach respondents. Since most of the professional associations advertised the survey on their website or via their newsletter, we assume that only a few clinicians actually found the survey link and were given the opportunity to fill in the web-based questionnaire. Generalizability might be limited by survey-typical selection bias and further research is needed to confirm and generalise our findings. Yet, our results appeared to be statistically significant and consistent with previous findings and the survey method allowed to explore current stroke imaging practices in details. To the best of our knowledge, this is the first study to provide that level of insight in European stroke imaging practices and thus makes an important contribution to the literature.

#### Conclusion

The diagnostic workup and, to an even greater extent, the revascularisation treatments of typical stroke patients vary

considerably across European countries. However, CT and CTA remain the primary routine modalities of the comprehensive imaging workup.

Further research is needed to identify the causes for the variations seen in our study, the barriers to treatment and to compare the quality of stroke care between and within countries in terms of both process and outcomes. Further consideration should also be given to investigate the most cost-effective second-line imaging workup to diagnose stroke patients.

This knowledge may be used as input in evaluations comparing the potential added value of new imaging modalities with the ones currently used in clinical practice.

#### Consent for publication

Not applicable.

#### Availability of data and material

Data will be made available upon request and based on the need and intended goal, at the end of the project. Request should be addressed to the corresponding author.

#### Authors' contributions

ACP was responsible for (1) study design, (2) data collection, (3) data analysis and (4) interpretation, (5) initial draft and (6) revision of the manuscript. DB, DWJD, JLS, KR and SSM and were responsible for (1) study design, (4) data interpretation and (6) revision of the manuscript. DB was responsible for data collection. KR was responsible for data analysis. PCD was responsible for data interpretation and writing. All authors revised the paper critically and approved the final manuscript.

#### Acknowledgements

The project leading to this publication has received funding from the European Union's *Horizon 2020* research and innovation programme under grant agreement no. [668142](#). However, this body had no role in study design, data collection and analysis, decision to publish or preparation of the manuscript.

#### Author statements

#### Funding

None

#### Competing interests

None declared.

#### Ethical approval

No financial incentive was offered to participants and survey completion was voluntary. Completion of the survey by participants was established as a means of consent to participate.

We received an approval by the board of the Medical Ethics Committee from the Erasmus Medical Center of Rotterdam, The Netherlands (Medisch Ethische Toetsings Commissie) to conduct this study, under reference MEC-2017–537.

#### Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:[10.1016/j.hlpt.2019.08.005](https://doi.org/10.1016/j.hlpt.2019.08.005).

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