

Treatment practice of vasospasm during endovascular thrombectomy: an international survey

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ABSTRACT

Background and aim The clinical importance and management of vasospasm as a complication during endovascular stroke treatment (EVT) has not been well studied. We sought to investigate current expert opinions in neurointervention and therapeutic strategies of iatrogenic vasospasm during EVT.

Methods We conducted an anonymous international online survey (4 April 2023 to 15 May 2023) addressing treatment standards of neurointerventionalists (NIs) practising EVT. Several illustrative cases of patients with vasospasm during EVT were shown. Two study groups were compared according to the NI's opinion regarding the potential influence of vasospasm on patient outcome after EVT using descriptive analysis.

Results In total, 534 NI from 56 countries responded, of whom 51.5% had performed >200 EVT. Vasospasm was considered a complication potentially influencing the patient's outcome by 52.6% (group 1) whereas 47.4% did not (group 2). Physicians in group 1 more often added vasodilators to their catheter flushes during EVT routinely (43.7% vs 33.9%, $p=0.033$) and more often treated severe large-vessel vasospasm with vasodilators (75.3% vs 55.9%; $p<0.001$), as well as extracranial vasospasm (61.4% vs 36.5%, $p<0.001$) and intracranial medium-vessel vasospasm (27.1% vs 11.2%, $p<0.001$), compared with group 2. In case of a large-vessel vasospasm and residual and amenable medium-vessel occlusion during EVT, the study groups showed different treatment strategies. Group 2 continued the EVT immediately more often, without initiating therapy to treat the vasospasm first (9.6% vs 21.1%, $p<0.001$).

Conclusion There is disagreement among NIs about the clinical relevance of vasospasm during EVT and its management. There was a higher likelihood of use of preventive and active vasodilator treatment in the group that perceived vasospasm as a relevant complication as well as differing interventional strategies for continuing an EVT in the presence of a large-vessel vasospasm.

INTRODUCTION

More than 10% of endovascular stroke treatments (EVTs) for acute ischaemic stroke are associated with perioperative complications.¹

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Vasospasm occurs in up to 20% of endovascular stroke treatments (EVTs), in younger patients and might lead to extended infarctions.

WHAT THIS STUDY ADDS

⇒ The neurointerventionalist's opinion on the relevance of vasospasm influences differing treatment strategies.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Future studies should aim to standardise treatment practice of vasospasm during EVT.

They include distal embolisation to a new territory (4%–6%), de novo stenosis of target vessels (3.4%), vessel perforation (0.6%–4.9%), dissection (0.6%–3.9%), groin haematoma (2%–10%) and vasospasm (3.9%–23%).^{2–4} Iatrogenic vasospasm is a common complication that occurs due to the vessel wall irritation during probing or thrombectomy manoeuvres. Extracranial vasospasms of target vessel arteries occur when placing guiding catheters and intracranial vasospasms occur during stent retriever or contact aspiration instrumentation. On angiography, vasospasm can be perceived as a concentric contraction of the arterial vessel wall.⁵

Vasospasm is more likely to occur in younger patients with stroke as well as in EVT with multiple thrombectomy attempts.⁶ While vasospasm during EVT is generally considered as non-serious and a transient complication by many authors,⁷ others discuss vasospasm as a potential cause for extended infarction after EVT, difficulties in further EVT manoeuvres with 'snagging' of stent retrievers or stroke recurrence.⁸ The clinical relevance of vasospasm as a complication during EVT remains

uncertain as well as geographical differences in incidence rates or related clinical sequelae. A higher prevalence of coronary vasospasm is demonstrated in Asian populations compared with the Western world.⁹ While racial differences in vasomotor reactivity after acute myocardial infarction are being discussed for several years¹⁰ and genetic determinants of vasospasm after subarachnoid haemorrhage have been defined,¹¹ regional differences have not been investigated for cerebral vasospasm during EVT yet.

Intra-arterial application of vasodilators, such as calcium channel blockers (CCBs), can resolve vasospasm in most cases.¹² CCBs can be added to catheter flushes to prevent vasospasm during EVT or they can be given intra-arterially via the intermediate or guide catheter after detection of vasospasm. Withdrawal of the catheter from the affected vessel and waiting is another strategy to manage vasospasm. As there are no guidelines available to guide management for vasospasm during EVT, we aimed to define the current treatment practice for vasospasm during EVT among neurointerventionalists (NIs).

Methods

This was an international, anonymous online survey conducted from 4 April 2023 to 15 May 2023. In total, 18 questions were developed to evaluate treatment strategies of vasospasm during EVT by NIs with a survey duration of approximately 5 min. Angiographic images of three patients with vasospasm in different territories (extracranial internal carotid artery, proximal middle cerebral artery M1 segment, distal medium-vessel segment) were shown and respondents asked to answer whether they would treat with intra-arterial vasodilator or not. The complete survey questions are listed in the online supplemental material. Analysis and reporting followed the recommendations of the *Consensus-Based Checklist for Reporting of Survey Studies*.¹³

The survey was distributed at a neurointerventional conference (World Live Neurovascular Conference 2023), via electronic communication of the German Society for Neuroradiology (distributed to 1450 members) and the European Society of Minimally Invasive Neurological Therapy (distributed to 3438 members, email opened by 33%, link opened by 5.4%), and via invitation by coauthors to their global colleagues. Internet protocol addresses were anonymously saved by the survey's online platform to prevent duplicate response bias. Data are available on reasonable request to the corresponding author.

Statistical analysis

Data are shown as number of events and percentage (n, %). After testing for normal distribution with the Shapiro-Wilk test, further analysis was conducted with the Mann-Whitney U test or χ^2 test to compare groups, as appropriate. All tests were performed on the basis of a two-sided level of $p < 0.05$ considered statistically significant. P values were corrected for a false discovery rate of 0.05 (Benjamini-Hochberg adjusted p values). Statistical

analyses were performed by using SPSS Statistics (V.29.0; IBM, Armonk, New York, USA).

RESULTS

In total, 534 NIs from 56 countries participated in the survey with most participants (n, %) from China (109, 20.4%), Germany (66, 13.2%) and the USA (53, 10.3%). The estimated response rate ranges at 20%. The majority of participants was male (77.3%, 22.4% women, 0.6% diverse). Regarding specialty, the respondents comprised interventional neuroradiologists (50.3%), interventional neurologists (28.6%), endovascular surgeons (13.6%), interventional radiologists (3.6%) and other (3.9%). Most participants were experienced with >10 years of experience in EVT in 42.1% (5–10 years in 28.3%, 1–5 years in 25.1% and <1 year in 4.5%) and >200 EVT performed in 51.4% (100–200 EVT in 17.4%, 50–100 EVT in 14.2%, <50 EVT in 17.0%).

Overall, a slight majority of respondents, 52.6% (n=281) considered vasospasm as a complication potentially influencing the patient's outcome (group 1) while 47.4% (n=253) did not (group 2). Group 2 respondents tended to be more experienced with >200 EVTs and male respondents tended to consider vasospasm more often as relevant complication than female respondents (group 1—54.6% of male respondents and 46.6% of female respondents; see [table 1](#)). In the subgroup analysis of more experienced NI (who performed >200 thrombectomies), 55% did not consider vasospasm to be a relevant complication, whereas 45% did (see online supplemental material). Nevertheless, the subgroup analysis of experienced NI shows persistent results regarding treatment strategies depending on the opinion on vasospasm as relevant complication.

Respondents currently practising in North America considered vasospasm less frequently as relevant complication (group 1 n (%): 26 (9.3) vs group 2 42 (16.6), $p=0.033$) while respondents practising in Asia tended to consider vasospasm as relevant complication (group 1 n (%): 107 (38.1) vs 78 (30.8), $p=0.160$). Respondents from Asia added vasodilators more often routinely to their flushes regardless of their opinion on vasospasm being a relevant complication (participants practising in Asia: 84/186 45.2% vs others: 126/348 36.2%, $p=0.027$). Study groups differed regarding treatment strategies for vasospasm during EVT. Group 2 was more likely not to add vasodilators to their catheter flushes to prevent vasospasm compared with group 1 (66.1% vs 56.2%, $p=0.03$). Group 2 was more likely than group 1 to immediately continue EVT to treat an amenable medium-vessel occlusion if a proximal vessel vasospasm was visualised without treating the vasospasm (21.1% vs 9.6%, $p=0.008$). More NI in group 2 would wait for spontaneous regression of vasospasm and then reassess (21.9% vs 12.8%, $p<0.001$). Regarding contraindications for medical treatment of vasospasm during EVT, group 1 considered suspected extended infarction more often as possible

Table 1 Group comparison according to the neurointerventionalist's opinion on potential influence of vasospasm regarding the clinical outcome in patients with stroke after EVT (group 1: yes, vasospasm potentially influences the patient's outcome, group 2: no, vasospasm does not influence the patient's outcome)

	Group 1 N=281	Group 2 N=253	P value
Years of experience in EVT, n (%) answered: 534, missing: 0			
< 1	15 (5.34)	9 (3.56)	0.404
1-5	76 (27.05)	58 (22.92)	0.318
5-10	79 (28.11)	72 (28.46)	1.00
> 10	111 (39.5)	114 (45.06)	0.219
Region where participants are currently practising per continent, n (%)			
North America	26 (9.25)	42 (16.60)	0.033
South America	21 (7.47)	13 (5.14)	0.418
Europe	116 (41.28)	112 (44.27)	0.554
Australia	5 (1.78)	3 (1.19)	0.74
Asia	111 (39.50)	81 (32.02)	0.16
Africa	2 (0.71)	2 (0.79)	1.00
Specialty, n (%) answered: 532, missing: 2			
Interventional neuroradiologist	136 (48.75)	130 (51.38)	0.602
Interventional neurologist	78 (27.76)	75 (29.64)	0.631
Endovascular surgeon	41 (14.59)	32 (12.65)	0.53
Interventional radiologist	9 (3.20)	10 (3.95)	0.816
Other	15 (5.34)	6 (2.37)	0.117
Current position, n (%) answered: 531, missing: 3			
Fellow	21 (7.53)	20 (7.94)	0.872
Resident	17 (6.09)	8 (3.17)	0.151
Attending	89 (31.90)	102 (40.48)	0.038
Consultant	126 (45.16)	109 (43.25)	0.727
Head of Department/Service	26 (9.32)	13 (5.61)	0.095
Number of thrombectomies performed, n (%) answered: 532, missing: 2			
< 50	63 (22.42)	27 (10.67)	< 0.001
50–100	38 (13.52)	38 (15.02)	0.71
100–200	56 (19.93)	37 (14.62)	0.111
> 200	123 (43.77)	150 (59.29)	< 0.001
Gender, n (%) answered: 530, missing: 3			
Male	224 (80.29)	186 (74.10)	
Female	54 (19.35)	64 (25.50)	0.101
Diverse/Other	1 (0.36)	2 (0.80)	
Demographic questions. significant p-values are in bold EVT, endovascular stroke treatment.			

contraindication (60.0% vs 19.9%, $p=0.007$), while group 2 more often than group 1 did not consider any potential contraindication as relevant (19.9% vs 13.6%, $p=0.034$). Group 1 had more often a standard operating procedure on treating vasospasm during EVT in place at their facility (32.1% vs 17.9%, $p<0.001$, [table 2](#)).

When participants were shown a large-vessel vasospasm in the left middle cerebral artery M1-segment and M2-segment ([figure 1A](#)), group 1 was more likely to treat it compared with group 2 (75.3% vs 56.0%, $p<0.001$ [figure 1B](#)). In the setting of a successful EVT and ensuing detection of large-vessel vasospasm, the majority of group 1 would treat the vasospasm and control its regression with diagnostic angiographic imaging (group 1: 74.3% vs 46.2%, $p<0.001$), while there was a high percentage in group 2 who would withdraw the remaining EVT material without any further imaging or treatment (group 1: 11.1% vs group 2: 36.3%, $p<0.001$)—[figure 1C](#). When shown a medium-vessel vasospasm in the left middle cerebral artery M3-segment ([figure 2A](#)), group 1 was more likely to treat it (27.1% vs 11.2%; $p<0.001$ —[figure 2B](#)). This was also the case when shown an extracranial, haemodynamically not relevant vasospasm ([figure 3A](#)) with a higher likelihood of treating the vasospasm in group 1 compared with group 2 (61.4% vs 36.5%, $p<0.001$; [figure 3B](#)).

DISCUSSION

This international online survey showed the differing opinion of NIs on the clinical relevance of vasospasm during EVT as well as heterogeneous treatment practice of vasospasm during EVT. While 52.6% of respondents considered vasospasm as a complication after EVT that potentially influences the patient's outcome (group 1), 47.4% of NIs did not share this view (group 2).

The survey participants were highly experienced with over 200 EVTs performed in more than half of participants and over 10 years of neurointerventional experience in 42%. Experienced NI with >200 thrombectomies performed during their career tended more often to not consider vasospasm as relevant complication. In a conducted subgroup analysis, the conclusion persists, that NI who do not consider vasospasm as relevant complication tend to treat them less often and more often proceed directly with a thrombectomy in case of an ongoing thrombectomy. There was no difference between groups regarding experience in the field or medical specialty (radiology, neuroradiology, surgery or neurology). The surveyed respondents in this analysis were from a diverse geographical background representing 6 continents and 56 countries. Female respondents were under-represented with 22%, which reflects the current status of female under-representation in neurointervention and is therefore not to be seen as a study bias.¹⁴ It has been shown in a Western-European cohort that intracranial vasospasm during EVT for acute stroke was present in the range of 5%–10% and was more likely to occur in younger patients.⁶ The detection rate among respondents did not

Table 2 Group comparison according to the neurointerventionalist's opinion on potential influence of vasospasm regarding the clinical outcome in patients with stroke after EVT (group 1: yes, vasospasm potentially influences the patient's outcome, group 2: no, vasospasm does not influence the patient's outcome)

	Group 1 N=281	Group 2 N=253	P value
Do you routinely give vasodilator (such as calcium channel blockers) during EVT to prevent vasospasm? N (%) answered: 532, missing: 2			
No	158 (56.23)	166 (66.14)	0.033
Yes, add to guide catheter flush	71 (25.27)	55 (21.91)	0.359
Yes, add to intermediate catheter flush	38 (13.52)	20 (7.97)	0.038
Yes, add to microcatheter flush	14 (4.98)	10 (3.98)	0.677
How often do you detect moderate-to-severe intracranial vasospasm during EVT for the treatment of LVO (large vessel occlusion) stroke, approximately? N (%) answered: 526, missing: 8			
<5%	114 (41.45)	120 (47.81)	0.117
5%–10%	93 (33.82)	61 (24.30)	0.028
10%–15%	42 (15.27)	34 (13.55)	0.71
15%–20%	19 (6.91)	25 (9.96)	0.21
>20%	7 (2.55)	11 (4.38)	0.337
What do you consider as a relevant contraindication to medically treat vasospasm (with vasodilator) during EVT? N (%) answered: 531, missing: 3			
Prolonged intervention time	59 (21.07)	38 (15.14)	0.091
Suspected extended infarction	84 (60.0)	50 (19.92)	0.007
Severe systemic hypotension	188 (67.14)	157 (62.55)	0.277
Bradycardia	55 (19.64)	57 (22.71)	0.456
None of the above	38 (13.57)	50 (19.92)	0.034
Other	10 (3.57)	12 (4.78)	0.52
Do you continue with EVT in case of residual and amenable medium vessel occlusion when you observe a proximal vasospasm? N (%) answered: 532, missing: 2			
Yes, I would continue immediately without treatment of the vasospasm	27 (9.61)	53 (21.12)	0.008
Yes, I would continue immediately but after initiating therapy with a vasodilator	86 (30.60)	68 (27.09)	0.389
Yes, I would continue but first wait until the vasospasm regressed substantially after treatment initiation	132 (46.98)	75 (29.88)	<0.001
No, I wait until vasospasm has regressed spontaneously and then reassess	36 (12.81)	55 (21.91)	<0.001
Does a standard operating procedure exist at your facility on treating vasospasm during EVT? N (%) answered: 531, missing: 3			
Yes	90 (32.14)	45 (17.93)	<0.001
Vasospasm-related questions. significant p-values are in bold EVT, endovascular stroke treatment.			

differ regarding study groups or geographical background of the NI. NIs practising in Asia more often added vasodilators routinely to their flushes. Vasospasm was regarded less frequently as relevant complication by respondents practising in North America while respondents practising in Asia tended to regard vasospasm during EVT as relevant complication. It can be hypothesised that Asians could be more prone to the development of cerebral vasospasm, similar to what has been shown for coronary vasospasm,⁹ and are therefore more aware of vasospasms in cerebral vessels as a relevant complication and more willing to take

countermeasures by routinely adding vasodilator to their flushes. To our knowledge, potential population-based differences of the occurrence of cerebral vasospasms during EVT have not been studied yet.

Interestingly, the interventionalist's opinion on the clinical relevance of vasospasm during EVT was associated with different treatment strategies. While we do not know if the presence of vasospasm during EVT can influence technical reperfusion success or the patient's outcome, CCBs are known to reverse vasospasm in the majority of cases and some EVT patients experiencing vasospasm

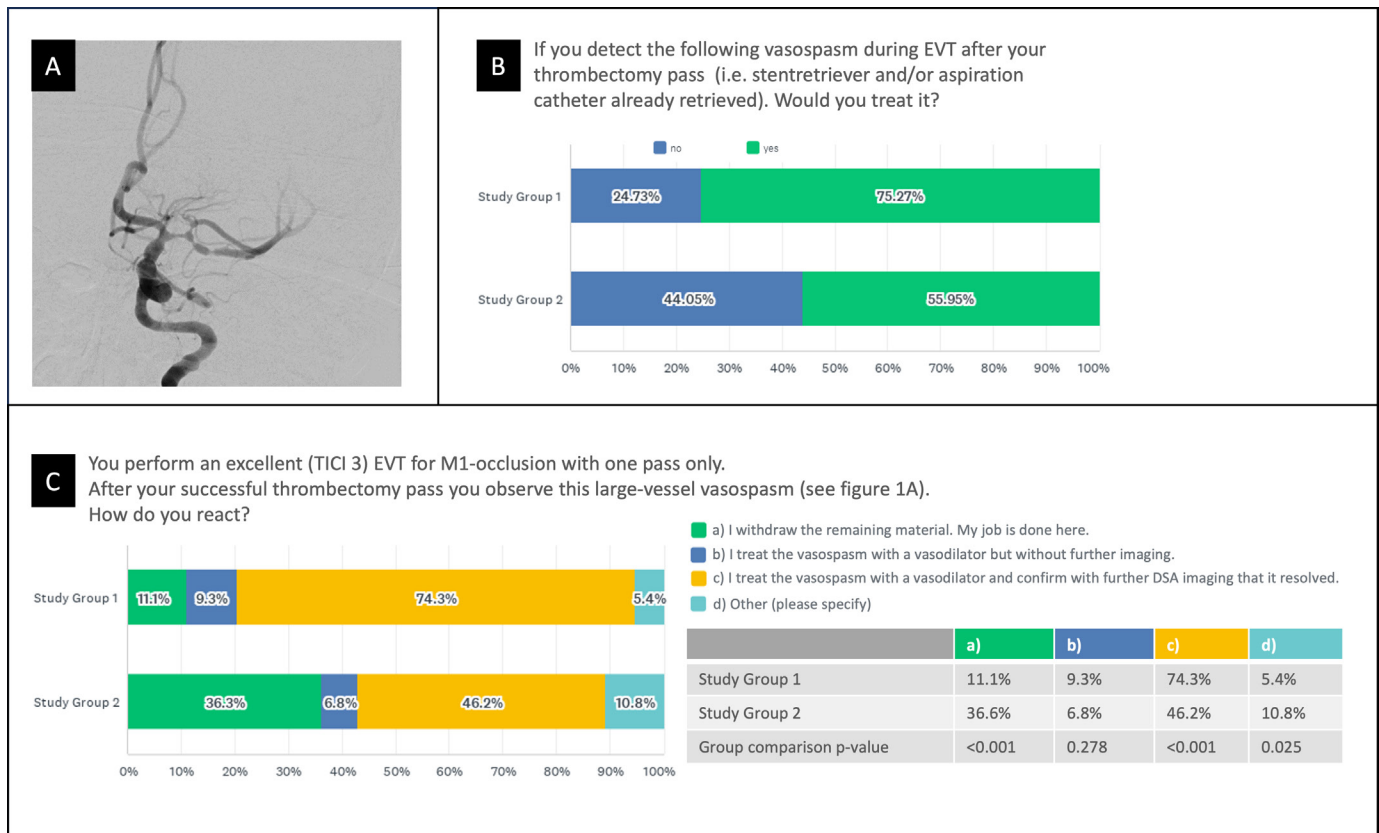


Figure 1 (A) Large-vessel vasospasm in the left middle cerebral artery M1-segment and M2-segment; (B) study group comparison on how to treat the depicted vasospasm and (C) how to continue an endovascular stroke treatment if this vasospasm is detected after successful endovascular stroke treatment (EVT).

might show higher infarct volumes despite vasospasm being a transient phenomenon.¹² Future studies on this subject may be influenced by differing treatment strategies, as we learnt from this study.

Spasmolytic agents, such as CCBs, decrease the systemic blood pressure due to their vasodilation effect.⁴ Pilgram-Pastor *et al* suggest a rate of 0.5–1 mg nimodipine over several minutes to treat vasospasm during EVT and point out the risk of hypotension and steal phenomena.⁴ The potential influence of vasospasm treatment on accurate blood pressure management during EVT and patient outcome is still unknown. Regarding a large-vessel vasospasm, the NIs showed different opinions on treating the vasospasm, and more importantly, when and how to proceed with the EVT in case of a residual medium-vessel occlusion. While 49% of NIs who considered vasospasm as a relevant complication would initiate therapy with intra-arterial vasodilators and continue with the EVT regardless of the vasospasm's resolution, but only 29% of NIs who did not consider vasospasm as relevant complication initiate therapy before continuing. Time to recanalisation is pivotal for patients with acute ischaemic stroke and EVT, so that treatment initiation and related time delay might influence patient outcome,¹⁵ and the risk of continuing EVT and probing in a spastic vessel is not fully clear and might be associated with risks like stent retriever snagging.¹⁶

After a successful EVT with no remaining intracranial vessel occlusion but associated large-vessel vasospasm, 36% of interventionalists, who did not consider vasospasm during EVT a relevant complication, would withdraw their devices immediately without further imaging or therapy.

Further studies are necessary to evaluate the clinical significance of vasospasm during EVT, which will inform clinical practice.

LIMITATIONS

This study is limited by the survey design and question selection. The provided case presentations show classic angiographic imaging of vasospasms. The authors paid special attention that the vascular pathology cannot be misjudged as atherosclerotic stenosis or dissection. However, the translation of dynamic angiographic imaging into figures for this research can influence the respondent's judgement and further case management. The questions in the survey pertained to vasospasm during acute stroke intervention. Given the time-sensitive nature of acute stroke treatment, the results of this study may not apply to vasospasm treatment approaches in other neurovascular interventions such as endovascular aneurysm treatment. With categorical or ordered survey responses, the study allowed for quantitative analysis and

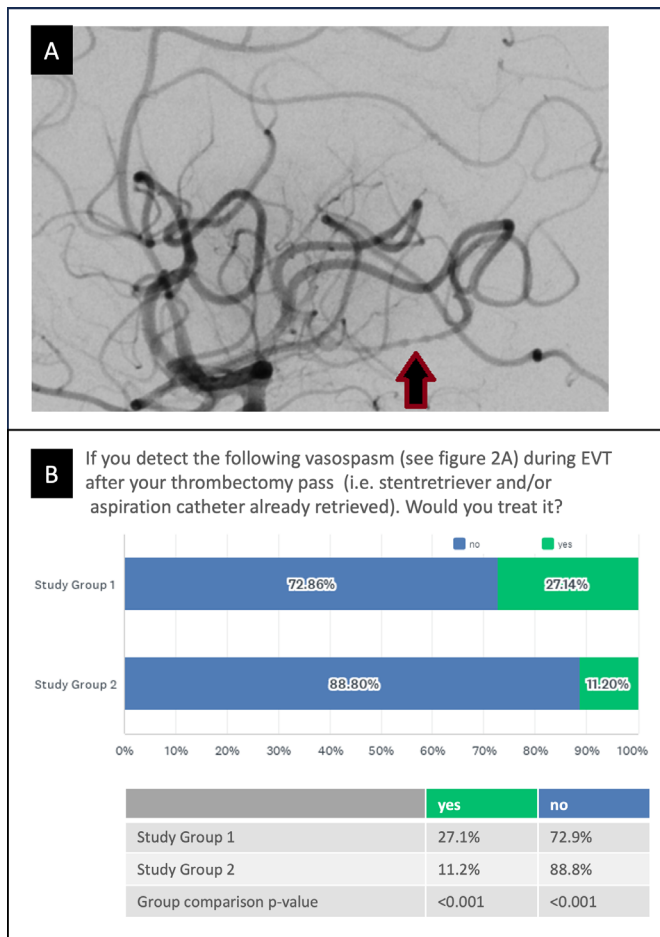


Figure 2 (A) Medium-vessel vasospasm in the left middle cerebral artery proximal M3-segment during endovascular stroke treatment (EVT); (B) study group comparison response on treatment of the vasospasm.

a higher response rate due to a shorter time needed for responding to all survey questions. Free-text responses could have offered a more detailed understanding of the interventionalist's perspective and treatment practice but would have been difficult to quantify. An accurate response rate could not be ascertained because of overlapping members who are part of multiple organisations. The estimated response rate for survey participation was overall low at about 20% most likely due to broad survey distribution via email, which was deliberate to reach a broad and diverse audience. This relatively low response rate could have biased the study results. The survey's completion rate however was very high (99%).

CONCLUSION

The perceived clinical importance and management strategies of vasospasm during EVT varies considerably among NIs. Physicians who believe that peri-interventional vasospasm does not influence clinical outcomes add vasodilators less often to catheter flushes, treat vasospasm less often when they occur and perform check angiograms less frequently. On the other hand, those who believe that

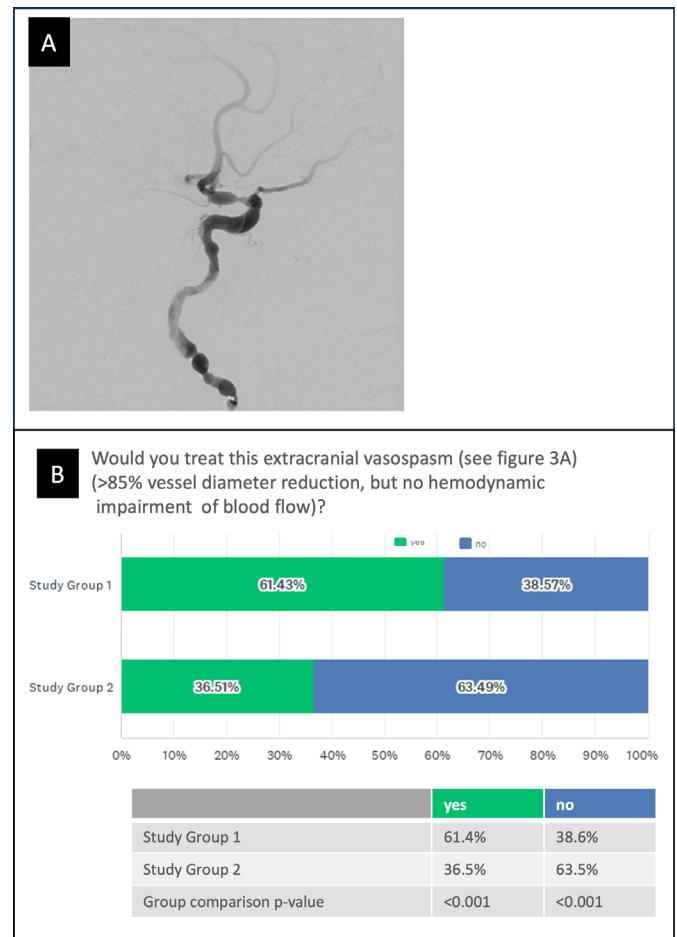


Figure 3 (A) Extracranial vasospasm of the left internal carotid artery C2-C6-segment (>85% vessel diameter reduction, but no haemodynamic impairment of blood flow) during endovascular stroke treatment; (B) study group comparison of response on treatment of this vasospasm.

vasospasm is detrimental to patient outcome often do inject vasodilators and perform angiographic controls to check for vasospasm resolution. The NI's opinion on the relevance of vasospasm also impacts the continuation of the thrombectomy per se. The heterogeneity in management strategies observed in our study reflects the lacking data on optimal vasospasm treatment strategies in the setting of EVT. This evidence gap should be addressed in future research.

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