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Maximal systolic acceleration in atherosclerotic vascular disease

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Chapter 6

Imaging assessment of carotid artery stenosis varies in clinical practice

Full manuscript, based on *Brouwers JJWM et al. Imaging Assessment of Carotid Artery Stenosis Varies in Clinical Practice (Research letter). Eur J Vasc Endovasc Surg. 2020 Oct;60(4):632-633.*

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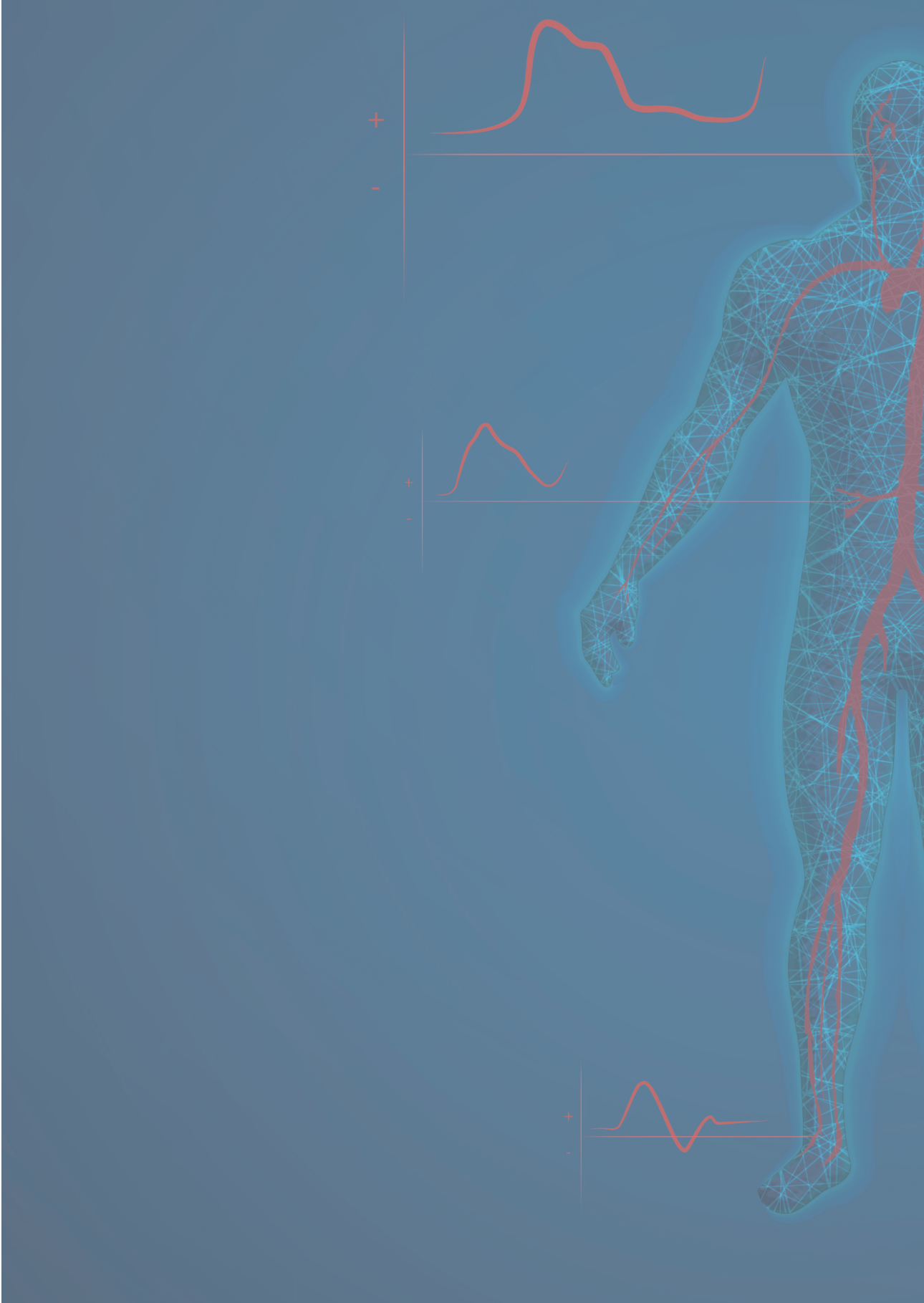

Background

According to current international guidelines, the degree of carotid artery stenosis should be determined by measuring the reduction in lumen diameter. The reduction in the cross-sectional area might provide a more accurate measure of carotid artery stenosis, particularly with irregularly shaped plaques, but it is not yet validated for use in clinical practice. The objective of this study was to determine which method, the diameter reduction method or the area reduction method, is generally used in current clinical practice.

Methods

Participants of the 2018 annual meeting of the European Society of Neuroradiology were approached for participation in this questionnaire-based study. The respondents were asked to indicate which method (reduction in diameter or area) they typically use to assess the degree of carotid artery stenosis according to different type of plaques. Furthermore, the questionnaire included questions regarding the clinical experience and the modalities used in practice.

Results

Ninety-two questionnaires were analyzed. For a regular/non-ulcerated and calcified plaque the diameter reduction was used most often to determine the degree of stenosis, respectively 67% and 62%. However, for an irregular/ulcerated plaque the use of the area reduction method as the sole method was 32%, and 13% used a combination of area and diameter reduction methods.

Conclusions

This study shows a variation in current practice concerning quantification methods of carotid artery stenosis according to the type of plaque. On CTA, the diameter reduction method is used most often to determine the degree of stenosis. Reduction in cross-sectional area for quantification of carotid artery stenosis is also used, in particular for irregular/ulcerated plaques. However, the area reduction method has not been validated for evaluation of patients' eligibility for carotid endarterectomy so far, and needs further evaluation before it can be implemented for use in clinical practice.

Abstract

Introduction

To date, the largest long-term trials with respect to the quantification, treatment, and outcome of carotid artery stenosis are the North American Symptomatic Carotid Endarterectomy Trial (NASCET) and the European Carotid Surgery Trial (ECST).[1,2] Using pooled data from these trials and reassessing the data obtained using the NASCET method, carotid endarterectomy (CEA) was found to be beneficial in neurologically symptomatic patients with a carotid artery diameter reduction of ≥50% on digital subtraction angiography (DSA), excluding patients with a near-occlusion.[3]

The diameter reduction method has therefore been established as the standard quantification method to assess the degree of carotid artery stenosis.[3–9] The diameter reduction method is nowadays being applied to computed tomography angiography (CTA) and magnetic resonance angiography (MRA) images.[7,8] However, diameter reduction method might not be optimal for assessment of carotid stenosis in arteries with irregular plaques.[7,8,10] Furthermore, a recent study showed that diameter-based measurements on CTA underestimate the degree of stenosis.[10] Alternatively, on CTA cross sectional area measurements can be performed; this method also considers the asymmetric shapes of a stenosis. Measuring the reduction in cross-sectional area might provide a more accurate estimate of the degree of stenosis, especially for irregular plaques. [6–8] However, evidence for using the cross-sectional area reduction method to select patients who should undergo CEA is lacking.[6,8–12]

In daily clinical practice, some radiologists already measure cross-sectional area reduction to estimate the degree of stenosis, but it is unclear to what extent this occurs. The objective of this study therefore was to determine which method – the diameter reduction method or the area reduction method – is generally used in current clinical practice to assess the degree of carotid artery stenosis.

Methods

Questionnaire and Respondents

The institutional review board approval was obtained to perform this study. For this study, radiologists and radiology residents from a wide range of countries (see Table 1) were approached at the 41st annual meeting of the European Society of Neuroradiology (ESNR) held in Rotterdam, the Netherlands in September 2018. To investigate which method radiologists generally use to quantify the degree of carotid artery stenosis, we generated a questionnaire (see Appendix 1). These questionnaires were made available for visitors to the congress. The respondents were asked whether they generally use the diameter reduction

	Respondents
Europe	**67 (73)**
Netherlands	16 (17)
Germany	7 (8)
Turkey	6 (7)
UK	6 (7)
Belgium	5 (5)
Switzerland	5 (5)
Asia	**8 (9)**
North America	**8 (9)**
Oceania	**5 (5)**
South America	**3 (3)**
Africa	**1 (1)**

Table 1: Countries in which the 92 respondents were located. Note that only the European countries with ≥5 respondents are listed separately. Data are presented as n (%).

method, which is the current standard for clinically evaluating carotid artery stenosis based on international guidelines.[1,2,12] Or whether they use the area reduction method, which is theoretically a more accurate method, particularly in cases with an irregular plaque. [6–8,10]

The questionnaire consisted of sixteen questions. Seven questions were directed to the respondents' background and clinical experience. The respondents were also asked to specify which diagnostic modalities they generally use in practice: echo duplex ultrasonography, computed tomography angiography (CTA), magnetic resonance angiography (MRA), digital subtraction angiography (DSA), or other. Furthermore, the respondents were asked to indicate which method (reduction in diameter or area) they typically use to assess the following type of plaque: 1. regular/non-ulcerated plaque; 2. irregular/ulcerated plaque; and 3. calcified plaque. The respondents who failed to answer all of the three questions regarding the type of plaque were excluded from our analysis. Data were collected and analyzed using SPSS Statistics version 25.0 (IBM Corp., Armonk, NY).

Results

A total of 93 respondents filled in the questionnaire. One respondent was excluded due to not answering questions in order to determine the used method regarding the type of plaque; thus, the results of 92 respondents (83 neuroradiologists, 8 neuroradiology residents, and 1 neurosurgeon) were included in the analysis. The average number of years of experience was 16 (range: 1- 35 years), and the majority (73%) of respondents is living in Europe (Table 1).

Most respondents (66%) are working in an academic tertiary referral hospital, followed by working in a non-academic teaching hospital (25%) and in a non-academic non-teaching hospital (8%). Four respondents (4%) reported that they work in two different hospital types, and one respondent did not answer.

Half of the respondents (49%) only use one modality to determine the degree of stenosis; the other half (51%) reported that they use two or more modalities (Table 2). The most commonly used modality was CTA, followed by echo duplex ultrasonography, MRA, and DSA.

The quantification methods used by the respondents to determine the degree of stenosis based on CTA are summarized in table 3. Diameter reduction method was used most often, in particular for regular/non-ulcerated plaques, followed by calcified plaques and irregular/ulcerated plaques, respectively 67%, 62% and 53%. However, for an irregular/ulcerated plaque the use of the area reduction method increased to 45% (use either the area reduction method exclusively or both the diameter reduction and area reduction methods). Furthermore, for an irregular/ulcerated plaque 32% used exclusively the area

	1 modality No. of respondents	**≥2 modalities** No. of respondents
Computed tomography angiography (CTA)	33 (36)	78 (85)
Echo duplex ultrasonography	8 (9)	39 (42)
Magnetic resonance angiography (MRA)	3 (3)	31 (34)
Digital subtraction angiography (DSA)	1 (1)	14 (15)
Other	0 (0)	0 (0)
Total	**45 (49)**	**162 (176)**

Table 2: Summary of the modality generally used by the 92 respondents to determine the degree of carotid artery stenosis. Data are presented as n (% of all respondents). The first column includes only the respondents who exclusively use one modality, whereas the second column includes also the 47 respondents who used more than one modality, resulting in a total of 176%. So, for example, in total 85% of the respondents used CTA, whether or not in combination with another modality.

Quantification method	Regular/non-ulcerated plaques	Irregular/ulcerated plaques	Calcified plaques
Diameter reduction	62 (67)	49 (53)	57 (62)
Area reduction	18 (20)	29 (32)	22 (24)
Both (diameter and area reduction)	11 (12)	12 (13)	9 (10)
No answer given	1 (1)	2 (2)	4 (4)
Total	**92 (100)**	**92 (100)**	**92 (100)**

Table 3: Overview of the quantification method used by the 92 respondents to determine the degree of carotid artery stenosis, according to each type of plaque. Data are presented as n (%).

reduction method, and this was 24% for calcified and 20% for regular/non-ulcerated plaques. Interestingly, overall, a total of 42 respondents (46%) reported that they use area reduction method—either exclusively or in addition to the diameter reduction method—for quantifying the degree of carotid artery stenosis.

Discussion

Our survey showed that the method used to assess degree of carotid artery stenosis (diameter or area reduction method) varies according to the type of plaque. The diameter reduction method is used most often for all plaque types, especially in regular/non-ulcerated and calcified plaques, respectively 67% and 62%. However, the cross-sectional area reduction method is also used to determine the degree of stenosis, in particular for irregular/ulcerated plaques. In these type of plaques the area reduction method was used in 45% (either using the area reduction method exclusively or using both the diameter reduction and area reduction methods). Moreover, for an irregular/ulcerated plaque the use of the area reduction method as the sole method was 32%. This result is remarkable, because current guidelines do not consider measuring area reduction to be the standard approach—or even an option—for determining the degree of stenosis.[1,2,9,12] Even though area reduction is suggested to be a more accurate method and theoretically might express the true hemodynamic significance of the lesion better than the diameter stenosis method, it is not validated for use in clinical practice.[7–10]

In a completely concentric stenosis, the reduction in lumen diameter can be directly translated to the reduction in cross-sectional area; for example, a 50% reduction in the lumen diameter translates to a 75% reduction in cross-sectional area.[6] However, atherosclerosis is usually an asymmetrical process.[6–8,10] In addition, a small change in the diameter of the carotid lumen can cause a much larger change in the lumen's cross-sectional area.[6,7] There is currently no consensus to what extent measuring diameter reduction differs from

measuring cross-sectional area reduction in a clinical setting.[6–11] Carnicelli et al. reported no significant overall difference between diameter reduction and area reduction due to carotid artery stenosis on CTA.[9] In contrast, Samarzija et al. argued that measuring area reduction is more accurate for assessing the degree of stenosis compared to measuring diameter reduction; the area reduction method had a higher predictive power for a correct stenosis classification with a better balanced sensitivity and specificity and significantly higher area under the ROC curve (AUC) value.[10] Moreover, they reported that the degree of stenosis can be significantly underestimated when using the diameter reduction method.[10] Zhang et al. found that in case of a non-circular stenosis, the reduction in area often provides a less-severe estimate of the resulting hemodynamic consequences compared to measuring the reduction in diameter. The authors concluded that measuring the reduction in diameter may not be ideal for determining the degree of stenosis, particularly in the case of a non-circular stenosis. Furthermore, they suggest that measuring the reduction in area may be more clinically relevant in terms of assessing the risk of stroke.[8] In addition, both Zhang et al. and Bartlett et al. found excellent intraobserver and interobserver reproducibility with respect to using the area reduction method for assessing the degree of stenosis[7,8], and Bucek et al. reported that interobserver reproducibility is higher with the area reduction method compared to diameter reduction.[11]

In an individual patient, it is clear that the degree of stenosis can vary widely depending on which method is used.[6–11] For example, Carnicelli et al. showed that degree of carotid artery stenosis can be either <40% and > 80% or > 50% and < 20% when determined by diameter reduction and area reduction, respectively.[9] In symptomatic patients with ≥50% stenosis measured based on the diameter reduction method, CEA is generally more effective than medical therapy in reducing the risk of stroke.[1,2,8] It is possible that some patients may undergo CEA unnecessarily due to the variability in measurements between the diameter and area reduction. Also, conversely, some patients might be deprived of CEA unnecessarily. Therefore, determining the appropriate treatment requires an accurate and consistent determination of the degree of stenosis.

This questionnaire based survey shows that the preference for one method over the other varies according to plaque type in current clinical practice, and includes measurement of area reduction, a method that has not been validated to identify patients who might benefit from CEA after an ischemic event. Following the results of two large long-term trials (NASCET and ECST), the current guidelines call for measuring the reduction in lumen diameter to select patients for CEA.[1,2,12] In our opinion, area reduction measurement should be the preferred method to determine the degree of stenosis as there is evidence that this method is more accurate than the diameter reduction method, in particular for irregular plaques. However, firstly, consensus should be reached if measurement of cross sectional area reduction differs from measurement of diameter reduction in a clinical setting. If

consensus is reached that the degree of stenosis is generally different between the diameter and area reduction method, future studies must show whether new cutoff values should be determined when using the area reduction method to identify patients that will benefit from CEA.

Limitations

The questionnaires were completed by participant of an international congress, in which the response rate was unknown which introduces the possibility of response bias and selection bias. So, the percentages generated in this survey must be considered with caution. Secondly, the majority of respondents (73%) were practicing in Europe and 17% came from the Netherlands, which might result in selection bias. Lastly, with respect to table 2, it is not clear to what extent the respondents (especially radiologist) knew about the used modalities for the work-up of a carotid artery stenosis that was done by a vascular surgery or neurologist. So, care must be taken in the interpretation of this table.

Conclusion

The quantification method of carotid artery stenosis on CTA seems to vary according to the type of plaque. The diameter reduction method is used most often, especially for a regular/non-ulcerated and calcified plaque. However, the area reduction method is also used, in particular for irregular/ulcerated plaques. To select patients for CEA the area reduction method should be used with caution, because the relation between the results of cross-sectional area reduction and diameter reduction measurement is still unclear. Although the area reduction method seems promising, there is currently no evidence for using this method to select patients for CEA and this method needs validation before it can be implemented for use in clinical practice.

Acknowledgements

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Appendix 1: Carotid Artery Stenosis Questionnaire

We are currently investigating the radiologists' interpretation of carotid artery stenosis. We would highly appreciate your help in this important study by completion of the following questionnaire. All information is kept confidentially and anonymized. Thank you so much for your time in advance!

1. What is your nationality?_____

2. What is your gender?_____

3. Profession: o Radiologist o Radiology Resident

4. Years of experience (including period of resident)? _____

5. Country of residency training? _____

6. In which country are you currently working?_____

7. Do you work: o Academic (tertiary) o Non-academic training-hospital

o Non-academic non-training hospital

8. Which modality do you normally use to determine the degree of a carotid artery stenosis?

o Echo duplex ultrasonography o Computed Tomography Angiography (CTA)

o Magnetic Resonance Angiography (MRA) o Digital Subtraction Angiography (DSA)

o Other: _____

9. Is there a 3D CT reconstruction possible in your hospital for carotid artery stenosis?

o No

o Yes

10. Which plane/reconstruction do you use to determine the degree of carotid artery stenosis (on CTA)?

o Axial plane reconstruction o Sagittal plane reconstruction

o 3D CTA reconstruction

o Other: _____

11. What is your used method to determine the degree of carotid artery stenosis (on CTA) in case of a regular/non-ulcerated plaque?

o Calculation based on diameter reduction o Calculation based on area reduction

o Estimation based on diameter reduction o Estimation based on area reduction

o Other: _____

12. What is your used method to determine the degree of carotid artery stenosis (on CTA) in case of an irregular/ulcerated plaque?

o Calculation based on diameter reduction o Calculation based on area reduction
o Estimation based on diameter reduction o Estimation based on area reduction
o Other: _____

13. What is your used method to determine the degree of carotid artery stenosis (on CTA) in case of a calcified plaque?

o Calculation based on diameter reduction o Calculation based on area reduction
o Estimation based on diameter reduction o Estimation based on area reduction
o Other:_____

14. Do you use (multi-modality) advanced visualization software (e.g. Vital Vitrea) to determine the degree of carotid artery stenosis?

o No o Yes
o Other: _____

15. Fill in the dotted line.

50% diameter reduction corresponds to …… % area reduction in a full concentric carotid artery stenosis.

16 (last question). What made you decide to use diameter or area reduction to determine the degree of carotid artery stenosis (on CTA)? (you can write it down on the back)