ORIGINAL PAPERS

Adv Clin Exp Med 2015, **24**, 6, 1037–1043
DOI: 10.17219/acem/39866
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ISSN 1899–5276

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The Quality of Imaging of the Carotid Body by the Standard Protocol for Computed Tomography Angiography of the Carotid Arteries

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A – research concept and design; **B** – collection and/or assembly of data; **C** – data analysis and interpretation; **D** – writing the article; **E** – critical revision of the article; **F** – final approval of article

Abstract

Background. The clinical significance of the carotid body (CB) has been increasing. Currently, research connected with the CB is focused on establishing the significance of chronically increased activity of the CB in the progression of heart failure and in the genesis of hypertension. Moreover, it has been suggested that cardiac hypertrophy may be associated with an increase in CB volume.

Objectives. The aim of study was to assess the quality of imaging the CB by following the standard protocol for computed tomography angiography (CTA) of the carotid arteries.

Material and Methods. The analysis includes 50 consecutive CTA examinations of the carotid arteries. A retrospective assessment of the quality of imaging both the right and left CB (rCB and lCB) was carried out for all the CTA examinations of the carotid arteries.

Results. The rCB was exposed in 62% and the lCB in 56% of the CTA examinations. None of the CTA examinations analyzed resulted in good or very good quality visualization of the CB. Only 22% of the CTA examinations provided a medium quality rCB image. An even lower ratio of medium-quality visualizations of the lCB was noted: only 14% of the analyzed examinations. In the male sample group, the CB was exposed significantly more often than in the female group.

Conclusions. The standard protocol for CTA examinations of the carotid arteries appears to be insufficient for use in assessing the CB (**Adv Clin Exp Med 2015, 24, 6, 1037–1043**).

Key words: computed tomography angiography, carotid arteries, carotid body, quality of imaging.

The carotid body (CB) is an anatomically minor structure located on both sides of the bifurcation of the external and internal carotid artery, slightly towards the back. It does not normally exceed the dimensions of 7 × 4 × 2 mm [1].

Recently, the clinical significance of the carotid body has been increasing. A group of tumors known as paragangliomas originates from the carotid body, and it has recently been suggested that a CB diameter exceeding 6 mm may be related to a heightened risk of developing paragangliomas, especially in persons with a known family occurrence [2].

In the late 20th century, it was found that the basic function of the CB is chemical control of the regulation of respiratory action by means of a reflex from chemoreceptors, but it was not until the last 15 years that research has revealed another important function: the chemoreceptors present in the CB play an essential role in regulating the functions of the circulatory system [3–5]. Research connected with the carotid body is currently focused on establishing the significance of chronically increased CB activity in the progression of heart failure and in the genesis of hypertension [6–9]. Patients with heart failure display (for example) erratic stimulation of the CB chemoreceptor reflex by increased concentrations of angiotensin II, and disorders of the mechanisms that control the activity of the carotid body, especially decreases in the activity of nitric oxide synthase and in the concentration of nitric oxide [10]. In 2013 it was found that denervation of the carotid body may offer a clinical strategy to restore autonomic balance and improve morbidity in heart failure [11]. Preclinical animal studies have confirmed the importance of the CB in mediating sympathetic hyperactivity, heightened renal sympathetic nerve activity and baroreflex inhibition, while demonstrating that selective CB suppression ameliorates blood pressure and left ventricular hypertrophy in animal models of hypertension [12].

Moreover, it has recently been suggested that cardiovascular diseases may be associated with carotid body hyperplasia. In a study by Sivridis et al., 15 autopsy cases with combined left and right ventricular hypertrophy were examined and compared with a control group. A significant increase in carotid body volume was observed in all individuals with cardiac hypertrophy [13].

Due to the growing clinical significance of the carotid body, it seems necessary to address the question of whether current CB imaging protocols are satisfactory. The aim of the present study was to assess the adequacy of imaging the CB by means of the standard protocol for computed tomography angiography (CTA) of the carotid arteries.

Material and Methods

The analysis included 50 consecutive computed tomography angiography (CTA) examinations of carotid arteries carried out in the first half of 2012. The basic clinical characteristics of the patients are shown in Table 1.

Table 1. Basic clinical characteristics of the patients

	X	SD
Age (years)	59.58	15.10
	%	n
Gender		
Men	72.0	36
Women	28.0	14
Indication for CTA of the carotid arteries		
Suspected extracranial artery stenosis		
internal carotid arteries	50.0	25
right internal carotid artery	14.0	7
left internal carotid artery	18.0	9
right external carotid artery	10.0	5
vertebral arteries	2.0	1
undefined	2.0	1
	4.0	2
Suspected extracranial artery occlusion	38.0	19
right internal carotid artery	8.0	4
left internal carotid artery	18.0	9
right vertebral artery	10.0	5
left vertebral artery	4.0	2
Suspected carotid artery dissection	6.0	3
right internal carotid artery	2.0	1
left internal carotid artery	2.0	1
undefined	2.0	1
Cerebrovascular diseases	24.0	12
after brain stroke	16.0	8
after cerebellar stroke	4.0	2
transient ischemic attack	4.0	2
Other	22.0	11
after carotid endarterectomy	8.0	4
neck injury	4.0	2
congenital anomaly of extracranial arteries	4.0	2
visual disturbances	2.0	1
Horner's syndrome	2.0	1
spinal canal tumor	2.0	1

The examinations were performed with a double-source scanner (SOMATOM Definition Dual-Source CT, Siemens Healthcare, Germany) in accordance with the standard CTA protocol for assessment of the carotid arteries, which was similar to the protocol applied by Nguyen et al. in their paper about CB imaging [2]. The differences in the applied CTA protocol concerned the velocity of administering the intravenous contrast medium, the type of contrast medium applied and the thickness of the layers used in the reconstructions of the images: Iomeprol contrast medium (Iomeron 400, Bracco U.K. Ltd, UK) was injected at a rate of 4.5 mL/s; the following image reconstructions were used: axial images in 0.6 mm thick layer and multiplanar reconstructions in 1.0 mm thick layers in the coronal and sagittal sections.

A retrospective assessment of the quality of imaging both the right and left CB was carried out for all the CTA examinations of carotid arteries included in the analysis. All the measurements were performed using a standardized protocol on a picture archiving and communication system (PACS) at 200% magnification. All studies were viewed at the same window/level settings and the same hanging protocol. The CB imaging quality assessment was carried out on two projections (axial and coronal or sagittal), separately for the right carotid body (rCB) and the left carotid body (lCB), using the authors' own CB imaging quality scale based on the

Table 2. The quality scale used in the study based on demonstrating the anatomical boundary of the carotid body and difference in density between the carotid body and anatomically adjacent structures

Image quality	Qualifying criteria
Not exposed (−)	carotid body not distinguished from anatomically adjacent structures
Exposed (+/++/+++/++++)	carotid body distinguished from anatomically adjacent structures
Low-quality visualization (+)	unclear exposure of the anatomical boundary of the carotid body, small difference in density between the carotid body and anatomically adjacent structures
Medium-quality visualization (++)	unclear exposure of the anatomical boundary of the carotid body but quite clear difference in density between the carotid body and anatomically adjacent structures
Good-quality visualization (+++)	at least partially clear exposure of the anatomical boundary of the carotid body, clear difference in density between the carotid body and anatomically adjacent structures
Very good-quality visualization (++++)	entirely clear exposure of the anatomical boundary of the carotid body, evident difference in density between the carotid body and anatomically adjacent structures

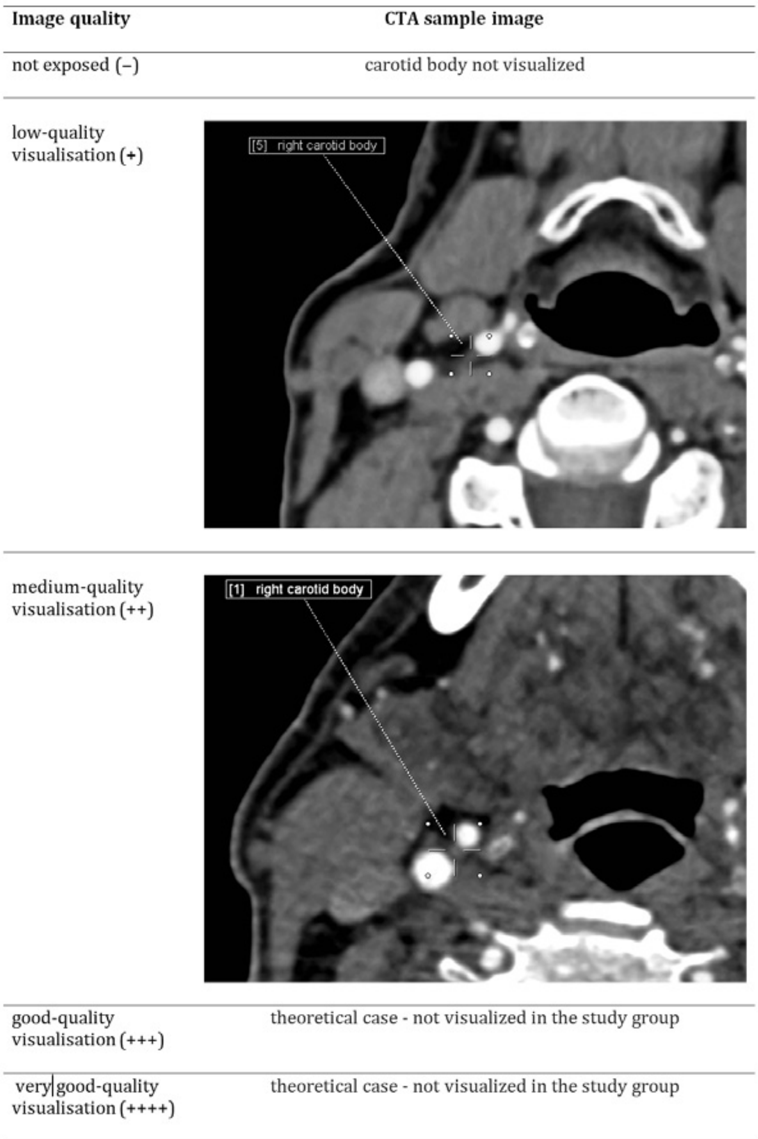

Fig. 1. The authors' own cartoid bodies imaging quality scale

exposition of the anatomical boundary of the CB and differences in density between the CB and the anatomically adjacent structures. The CB imaging quality scale, along with the qualifying criteria, is presented in Table 2 and Fig. 1. Assessment of the quality of CB imaging was done independently by two radiologists. The best of the two projections and the two radiologists' assessments was taken as the final quality of the CB image.

The study also undertook an assessment of possible dependencies between the patients' gender, age and the quality of CB imaging by means of the standard CTA protocol for the carotid arteries. To this end, the possibility of imaging the CB by following the standard CTA protocol of the carotid artery was assessed within each of the sample groups, distinguished by the criteria of gender and median age, followed by a correlation analysis. On the basis of the gender criterion, male (n = 36) and female (n = 14) groups were differentiated, while on the basis of the median age of the patients (62 years), the below-median group (< 62 years of age, n = 24) was distinguished from median-and--older group (≥ 62 years, n = 26).

The results were statistically analyzed using the STATISTICA 9 program (StatSoft, Inc., Oklahoma, USA). Arithmetic means and standard deviations were calculated for quantitative variables. The results for nominal variables were expressed as percentage tables. For nominal variables independent of further statistical analysis, the maximum-likelihood chi-squared test was used. A correlation analysis was then carried out to establish the dependence between variables. For the purposes of

Table 3. Overall results of the quality of imaging the carotid body by means of the standard computed tomography angiography protocol for carotid arteries – authors' own material, January 1st – June 30th, 2012. A) in the whole sample group, B) in the two gender groups (male and female)

A)

Image quality	**Right carotid body**		**Left carotid body**		**p**
	%	n	%	n	
Not exposed (–)	38.0	19	44.0	22	ns.
Exposed (+/++/+++/++++)	62.0	31	56.0	28	ns.
Low-quality visualization (+)	40.0	20	42.0	21	ns.
Medium-quality visualization (++)	22.0	11	14.0	7	ns.
Good-quality visualization (+++)	0.0	0	0.0	0	ns.
Very good-quality visualization (++++)	0.0	0	0.0	0	ns.

B)

Image quality	**Male**		**Female**		**p**
	%	n	%	n	
Right carotid body					
Not exposed (–)	30.5	11	57.1	8	p < 0.05
Exposed (+/++/+++/++++)	69.5	25	42.9	6	p < 0.05
Low-quality visualization (+)	41.7	15	35.7	5	p < 0.05
Medium-quality visualization (++)	27.8	10	7.2	1	p < 0.05
Good-quality visualization (+++)	0.0	0	0.0	0	ns.
Very good-quality visualization (++++)	0.0	0	0.0	0	ns.
Left carotid body					
Not exposed (–)	38.9	14	57.1	8	p < 0.05
Exposed (+/++/+++/++++)	61.1	22	42.9	6	p < 0.05
Low-quality visualization (+)	47.2	17	28.6	4	p < 0.05
Medium-quality visualization (++)	13.9	5	14.3	2	ns.
Good-quality visualization (+++)	0.0	0	0.0	0	ns.
Very good-quality visualization (++++)	0.0	0	0.0	0	ns.

Table 3, cont. Overall results of the quality of imaging the carotid body by means of the standard computed tomography angiography protocol for carotid arteries – authors' own material, January 1st – June 30th, 2012. C) in the two age groups (< 62 years and ≥ 62 years of age)

C)

Image quality	Persons < 62 years		Persons ≥ 62 years		p
	%	n	%	n	
Right carotid body					
Not exposed (–)	29.2	7	46.1	12	p < 0.05
Exposed (+/++/+++/++++)	70.8	17	53.9	14	p < 0.05
Low-quality visualization (+)	50.0	12	30.8	8	p < 0.05
Medium-quality visualization (++)	20.8	5	23.1	6	ns.
Good-quality visualization (+++)	0.0	0	0.0	0	ns.
Very good-quality visualization (++++)	0.0	0	0.0	0	ns.
Left carotid body					
Not exposed (–)	41.7	10	46.2	12	ns.
Exposed (+/++/+++/++++)	58.3	14	53.8	14	ns.
Low-quality visualization (+)	41.7	10	42.3	11	ns.
Medium-quality visualization (++)	16.6	4	11.5	3	ns.
Good-quality visualization (+++)	0.0	0	0.0	0	ns.
Very good-quality visualization (++++)	0.0	0	0.0	0	ns.

the correlation analysis, the qualitative variables were renamed quantitative variables. Due to a lack of normal distribution of variables, Spearman's rank correlation coefficients were used. Results of $p < 0.05$ were regarded as statistically significant.

Results

The average age of the 50 patients examined in the study was 60.28 ± 13.87 years. Men constituted 72% of the group and women 28%.

The rCB was exposed in 62% of the carotid artery CTA examinations, and the lCB in 56%. None of the analyzed CTA examinations resulted in a good or very good quality CB visualization. Only 22% of the examinations provided a medium-quality visualization of the rCB; an even lower ratio of medium-quality visualizations – i.e., only 14% – was noted for the lCB. Low-quality rCB visualizations were recorded in 40% of the examinations, and low-quality lCB visualizations in 42%. The material analyzed did not show any statistically significant differences in imaging quality between the right and left CBs. The overall results of CB imaging quality by means of the standard CTA protocol for carotid arteries in the period between January 1st, 2012, and June 30th, 2012, for the whole research group are presented in Table 3A.

A comparative analysis of the quality of CB imaging in the two gender groups revealed that both the rCB and lCB were exposed significantly more often in the male group than in the female group. The overall results of CB imaging quality for the male and female groups in the study are presented in Table 3B.

A comparative analysis of the quality of CB imaging in the two groups distinguished on the basis of the median age revealed that the rCB is exposed significantly more often in the group below 62 years of age than in the 62-and-older group. The overall results of CB imaging quality for the patients < 62 and ≥ 62 years of age are presented in Table 3C.

No statistically significant dependence was found between the patients' age and the quality of rCB and lCB imaging by means of the standard CTA protocol for carotid arteries. Spearman's rank correlation coefficients for the linear correlations age – rCB imaging quality age – lCB imaging quality were, respectively, $r = -0.01$ and $r = -0.17$ ($p > 0.05$).

Discussion

Based on the analysis of the research results, the authors find the existing CTA protocol for carotid arteries insufficient for the examination of the carotid body. In the retrospective CB quality-focused analysis of 50 CTA examinations of the carotid arteries carried out in the first half of 2012, it was found out that exposing the right carotid body was possible only in 62% of the cases, while the ratio for the left CB was even lower, constituting only 56% of the examinations. In terms of CB exposure, the quality of visualization must be deemed unsatisfactory, as none of the CTA examinations analyzed provided a good or very good quality CB image.

On the basis of the analysis of comparisons between the CTA examinations in the male and female groups, as well as the CTA examinations in the groups of patients below and above the age of 62 years, it may be concluded that it is easier to obtain CB visualizations by means of the standard CTA protocol for carotid arteries in the case of male patients and individuals below 62 years of age. Compared with the female group, the male group was characterized by a statistically more significant frequency of successful exposure of both the right and left CB. In turn, the below-62 group, compared to the patients aged 62 or older, was characterized by a significantly higher frequency of exposure of the right CB. The results seem to indicate a necessity to modify the existing CTA imaging protocol to allow better visualization of the carotid body, especially in women and older patients.

The analysis of the research data indicates that further research is needed, especially to further investigate the correlation between the patients' age and the quality of CB imaging in the standard CTA protocol for carotid arteries. It was found that the below-62 group, compared to the group of patients aged 62 or over, displayed a notably higher ratio of exposure of the right CB. However, no significant differences between the two age groups were found in terms of the quality of lCB imaging. No statistically significant linear correlations between the patients' age and quality of CB imaging were revealed either.

Only one publication in the available literature is related to CB imaging. Nyugen et al. evaluated 180 CTAs and they reported that the normal carotid body could be seen on most scans [2]. The right carotid body was seen on 82.6% of CTAs (148 of 179 studies). The left carotid body was seen on 86.0% of scans (154 of 179 studies). However, in that study no assessment of the quality of CB imaging was carried out [2].

The authors are not aware of any attempts anywhere in the world of using other available imaging methods to visualize the CB, such as plain sonography, Doppler sonography, plain MR, diffusion MR, perfusion MR or conventional angiography. It is possible that such attempts have been made, but that the results were not satisfactory enough to publish. In the authors' view, neither the small anatomical size of a non-enlarged CB, nor the time and spatial resolution of these diagnostic methods, would allow them to be used for reliable CB assessment.

In the authors' view, the increasing clinical importance of the carotid body briefly outlined earlier in the present article, as well as the unsatisfactory quality of CB visualization by means of the standard CTA protocol for carotid arteries demonstrated by this study, requires an improved method for imaging the carotid body. As noted in a previous publication, improved CB imaging can be obtained by using a delay in the commencement of the scanning after the intravenous bolus of the contrast agent (100 mL of IOMERON 400, speed of 4.5 mL/s) [14]. In the authors' opinion, the delay should not be shorter than 60 s and no longer than 120 s from the moment of completing the administration of the intravenous contrast medium. A preliminary assessment of the suggested modification of the protocol seems to confirm that it results in better saturation of the soft tissue structures of the neck, thus significantly improving the visualization of the carotid body. Further research is necessary to investigate the proposed modification of the protocol and to assess its value in improving CB imaging.

In the authors' opinion, the standard CTA protocol for carotid artery examination appears to be inadequate to assess the carotid body. Due to the recent increase in the clinical significance of the CB, it seems necessary to improve the methods for imaging it. A modification of the existing CTA imaging protocol for the carotid arteries to allow better visualization of the CB seems especially necessary in examinations performed on women and older individuals.

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Conflict of interest: None declared

Received: 17.02.2014
Revised: 1.05.2015
Accepted: 4.05.2015