Assessment of Carotid Body Tumor by Superb Micro-Vascular Imaging in a Preoperative Evaluation

Luying Gao
Peking Union Medical College Hospital
Xiaoyan Zhang
Peking Union Medical College Hospital
Yuxin Jiang
Peking Union Medical College Hospital
Hongyan Wang
Peking Union Medical College Hospital
Wanying Li
Peking Union Medical College Hospital
Yuehong Zheng
Peking Union Medical College Hospital
Jianchu Li (jianchu.li@163.com)
Peking Union Medical College Hospital https://orcid.org/0000-0001-9093-5309
Bo Zhang
China-Japan Friendship Hospital

Research

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Abstract

Background: Superb micro-vascular imaging (SMI) provided new advances in vascular imaging, resulting in revealing the overall vascularity detection of small or microflow states without the use of contrast media. This study aimed to explore the blood supply andfeeding artery of carotid body tumor (CBT) on SMI for providing more accurate information for surgery.

Results: Twenty-six CBT lesions underwent color Doppler flow imaging (CDFI) and SMI, and were confirmed later by pathology. The blood flow patterns and feeding artery of CBTson CDFI and SMI were graded and compared.Compared with the application of CDFI, the pattern of more CBT lesionschanged to a higher Adler category by SMI ($P<0.001$). Thefeeding artery of two CBT lesions, which fail to show by CDFI, was internal carotid artery(ICA) by SMI and compared with CDFI the feeding artery of three changed from ICA or external carotid artery(ECA) to MIX (both ICA and ECA) by SMI. We classified the feeding artery of CBTs into originating from ICA or others (including ECA and MIX). For all the lesions, threelesions that stemmed from ICA and 23lesions that stemmed from ECAor MIX. CBT lesions stemming from ECA or MIX with Adler II or Adler III blood flow patterns accounted for 30.4% (7/23) or 69.6% (16/23), respectively, while CBT lesions stemming from ICA with Adler I or Adler II blood flow patterns accounted for 66.7% (2/3) or 33.3% (1/3), respectively.

Conclusions: SMI is superior to CDFI in detecting vascularity of CBTs, and SMI could better investigate the origin of feeding vessels of CBTs in comparison to CDFI.Compared with those originating from ECA, CBTs from ICA has less vascularity.

Background

Carotid body tumors (CBT) are rare, non-chromaffin paragangliomas involving the carotid body chemoreceptor, which represents more than 50% of head and neck paragangliomas [1, 2]. Since CBTs have the malignant tendency to local or distant metastasis [3], surgical excision is advisable [4]. Due to the slow growth of carotid body tumors, it usually takes months to years to find the disease from the time the tumor is discovered. As a result, most patients were already in Shamblin Grade II or III at the time of surgery, which would damage the internal and external carotid arteries, with incidences of 11% and 13–33%, respectively [3–4]. The anatomical relationship between the CBT and carotid arteries are important before the operation to reduce the surgery complications, and to determine whether the carotid artery needs to be blocked during the operation. With the preoperative embolization of the carotid artery, a bloodless operative field could be achieved to reduce the operative morbidity. Thus, reliable and effective imaging modalities for recognizing the relationship between carotid arteries and the CBTs are crucial.

Due to the hypervascularity nature of CBTs and its proximity to vascular and nervous structures, fine-needle aspiration biopsy (FNAB) is not appropriate [5–6]. Therefore, diagnostic imaging modalities are essential for the diagnosis of this condition. Ultrasound (US) has been widely used with the development of color doppler flow imaging (CDFI) enhancing capabilities of characterizing CBTs. Tumors are highly dependent on angiogenesis. However, limited by clutter and overflow, it is difficult for color Doppler flow imaging to obtain the full real vascular information ultrasound. Superb micro-vascular imaging (SMI) provided new advances in vascular imaging, resulting in revealing the overall vascularity detection of small or microflow states without the use of contrast media. SMI has been proven to be effective in identifying microflow in several clinical settings by our team and other researchers, such as breast cancers, thyroid nodules [7–9]. To date, no clinical research with SMI to evaluate CBT vascularity has been reported. The purpose of this study was to better explore the blood supply and feeding artery of CBTs on SMI for providing more accurate information for surgery.

Results

Clinical and US characteristics of CBT lesions

A total of 21 patients with 26 CBT lesions were included in the study. The patients included 7 (26.9%) females and 19 (73.1%) males with a median age of 43.2 years (range, 31–63 years). Eight patients had a single lesion, and five patients had two bilateral lesions. They were all confirmed as benign by pathology. All CBT lesions (100%) were detected by US. The mean size of CBT lesions on US was 3.46 cm (range, 1.5-5.0 cm). Regarding the echogenicity of the nodules, 23 (88.5%) were solid, and 3 (11.5%) had a mixed structure. Furthermore, all lesions (100%) were hypoechoic with well-circumscribed margin, and were located in the carotid bifurcation leading to the separation of the ICA and ECA [Table 1].

Table 1
Clinical and US characteristics of CBT lesions

	CBT
No. of nodules	26
Age (y, mean, range)	43.2 (31–63)
Sex (male: female)	19:7
Size (cm, mean, range)	3.46 (1.5-5.0)
US features	
Composition	
Solid	23(92%)
Partially cystic	3(8%)
Echogenicity	
Hypoechoic	26(100%)
Margin	
Irregular	0
Well circumscribed	26(100%)
CBT, carotid body tumor	

Blood Flow Characteristics And Differences Between Smi And Cdfi

The distribution of blood flow patterns of all lesions was compared between CDFI and SMI. The blood flow categories of 26 nodules differed between the two methods [Table 2]. By CDFI, CBT lesions with Adler I blood flow patterns accounting for 23.1% (6/26), with Adler II blood flow patterns accounting for 57.7% (15/26), with Adler III accounting for 11.5% (3/26), with Adler 0 accounting for 7.7% (2/26). By SMI, CBT lesions with Adler I blood flow patterns accounting for 7.7% (2/26), with Adler II blood flow patterns accounting for 30.8% (8/26), and with Adler III accounting for 61.5% (16/26). By SMI, the pattern of two transformed from Adler 0 to Adler I, the pattern of six transformed from Adler I to Adler II or III, and the pattern of ten masses transformed from Adler II to Adler III [Figure 1–2].

Table 2
Blood flow characteristics and differences between SMI and CDFI

	SMI				
CDFI	I	II	III	Total	P
0	2	0	0	2(7.7%)	0.008
I	0	3	3	6(23.1%)	
II	0	5	10	15(57.7%)	
III	0	0	3	3(11.5%)	
Total	2(7.7%)	8(30.8%)	16(61.5%)	26	

SMI, superb micro-vascular imaging; CDFI, color Doppler flow imaging

Characteristics and differences of feeding artery between SMI and CDFI

With CDFI, the feeding artery of the CBT stemming from ICA accounting for 11.5% (3 of 26), stemming from ECA accounting for 26.9% (7 of 26), and stemming from both ICA and ECA accounting for 53.8% (14 of 26). The feeding artery of two CBT lesions (7.7%) fail to show since the lesion had no color flow by CDFI. With SMI, the feeding artery of the CBT stemming from ICA accounting for 11.5% (3 of 26), stemming from ECA accounting for 23.1% (6 of 26), and stemming from both ICA and ECA accounting for 65.4% (17 of 26). By SMI, the feeding artery of two transformed from ICA to both ICA and ECA, one transformed from ECA to both ICA and ECA. The feeding artery of two CBT lesions, which fail to show by CDFI, was ICA by SMI. Consistency check of the SMI and CDFI was assessed using kappa value. which reached a moderate level with a value of 0.66 [Table 3].

Table 3
Characteristics and differences of feeding artery between SMI and CDFI

	SMI				
CDFI	ICA	ECA	MIX	Total	P
Unable to judge	2	0	0	2(7.7%)	< 0.001
ICA	1	0	2	3(11.5%)	
ECA	0	6	1	7(26.9%)	
MIX	0	0	14	14(53.8%)	
Total	3(11.5%)	6(23.1%)	17(65.4%)	26	

SMI, superb micro-vascular imaging; CDFI, color Doppler flow imaging; ECA, external carotid artery; ICA, internal carotid artery

We classified the feeding artery of CBTs into originating from ICA and others (including ECA and MIX). For all the lesions, three lesions that stemmed from ICA and 23 lesions that stemmed from ECA or MIX. Based on SMI, we calculated the classification of blood flow in lesions stemming from ICA and others, respectively. CBT lesions stemming from ECA or MIX with Adler II or Adler III blood flow patterns accounted for 30.4% (7/23) or 69.6% (16/23), respectively, while CBT lesions stemming from ICA with Adler I or Adler II blood flow patterns accounted for 66.7% (2/3) or 33.3% (1/3) [Table 4].

Table 4
Blood flow characteristics CBTs into originating from ICA and others (including ECA and MIX).

	Adler			
Feeding artery	I	II	III	P
ICA	2 (66.7%)	1(33.3%)	0	< 0.001
ECA and MIX	0	7 (30.4%)	16(69.6$)	

CBT, carotid body tumor; ECA, external carotid artery; ICA, internal carotid artery

Discussions

The previous study showed that contrast-enhanced ultrasound (CEUS) allowed easy identification of collateral vessels of cervical body tumor mass [11]. Similar to CEUS, SMI allows radiologists to visualize the microvascular patterns of lesions in detail without the additional use of a contrast agent [12]. Previous studies also described that SMI provided a better depiction of vessel branching details than did color Doppler flow imaging in thyroid nodules [13]. In our study, we found that SMI is superior to CDFI in assessing the blood flow of CBT. By SMI, the pattern of two transformed from Adler 0 to Adler I, the pattern of six transformed from Adler I to Adler II or III, and the pattern of ten masses transformed from Adler II to Adler III. It may be due to some feeding vessels was too small to be observed by CDFI. CDFI is unable to detect low-velocity blood flow, since the presence of extraneous Doppler signals due to nearby structures. SMI is able to show lower-velocity blood flow, since SMI can analyze clutter motion, and uses a new adaptive algorithm to identify and remove tissue motion and reveal true blood flow. Since there are almost no angle dependence, clutter, and overflow at lower scales, SMI shows much more complete and genuine vascular branches.

We showed that SMI was reported to be superior to CDFI in detecting the feeding artery of CBTs. Two lesions (7.7%) that stemmed from ICA was not detected with CDFI, and three lesions (11.5%) that stemmed from both ICA and ECA was not detected accurately with CDFI. CDFI imaging relied on long and transverse section imaging and showed the feeding artery in a single plane, so CDFI couldn't fully obtain the vascular spatially heterogeneity. To identify the feeding artery has important significance for both pre-operative diagnosis and successful resection. With the preoperative embolization of the carotid artery, a bloodless operative field could be achieved to reduce the operative morbidity [14, 15]. For the tumor close to the carotid artery, forcibly separating the tumor may cause the rupture of the blood vessel and cause massive bleeding. For the CBTs which invaded the internal and external carotid arteries, it is often difficult to separate from the external carotid artery, and the distal end of the external carotid artery can be clamped before the tumor is peeled off.

We classified the feeding artery of CBTs into originating from ICA and others (including ECA and MIX) and found that vascularity was different in the feeding artery of CBTs from ICA or others. All CBTs originating from ICA are with the pattern of Adler I/II, however, only 30.4% of CBTs originating from ECA and MIX are with the pattern of Adler II, most of CBTs (69.6%) originating from ECA are with the pattern of Adler III. The results showed that CBTs mainly originating from ICA has less vascularity compared with those from ECA.

There are several limitations to our study. First, vascularity patterns were not analyzed according to malignant or benign lesions because all the lesions were benign CBTs. Lacking malignant CBTs and neurogenic tumors, such as schwannoma, may have been a hindrance. Second, our study included 26 lesions and future studies that involve more subjects may produce more accurate results. Third, it may have been affected by selection bias as only patients who underwent both ultrasound and surgery were enrolled in the study.

In conclusion, we showed that SMI could be used to better investigate vascularity of the CBTs comparing to CDFI, and SMI is superior to detecting the origin of feeding vessels of the lesion in comparison to CDFI. In addition, CBTs mainly originating from ICA has less vascularity compared with those from ECA or MIX. We expect that with the application of SMI, this approach could become an invaluable tool for CBTs diagnostic and pre-operative workup.

Methods

Patients

Between September 2017 and December 2019, 21 patients with 26 CBT lesions referred to our center for the surgical treatment of lateral neck masses were included. Among this cohort of patients, those who met the following criteria were included in the study: (1) All patients were treated with surgical resection following a standard procedure and (2) post-operative for all patients confirmed the diagnosis of CBT. (3) patients underwent conventional US and SMI for the lateral neck masses before surgical excision at our center. An institutional review board approval by the ethics review committee at our center was obtained for this study.

Ultrasound Examination

All US examinations were performed with Aplio 500 (Canon Medical Systems, Tokyo, Japan) devices equipped with 14L5 linear-array transducer. US was performed by two radiologists who were experienced in US (GLY and ZXY, with more than 5 years of experience with US) and were blinded to the patients' clinical data. In cases of a discrepancy between the two radiologists, a consensus was reached after a discussion.

The size, location, number, margin, echogenicity, and structure were evaluated by using conventional B-mode. The vascularity and relationship of lesions and carotid bifurcation, internal and external carotid arteries, was evaluated by color Doppler imaging and SMI. For SMI, the probe was placed above the lesion and the sampling range was adjusted to cover the entire lesion and surrounding tissue with a mechanical index of 1.5, a low-speed scale of 1.0–2.0 cm/s, a frame rate of 50–60 fps, and a dynamic range of 55–60 dB. Parameters SMI for each CBT lesion were regulated to reveal the best vascularity without much noise, and two SMI modes were available: monochrome and color. A double screen function that allowed grayscale imaging and SMI visualized at the same time was used when vessels were located. Materials were stored as images and videos. The feeding artery of CBT lesions was observed when the video was repeatedly played back. Vascularity was classified as 4 patterns [10]: Adler 0 for no credible vascularity (defined as no perivascular or dotted peri-nodular flow on < 25% of the nodule's circumference and without any internal flow), Adler I for peripheral vascularity (defined as surrounding > 25% of the nodule's circumference without any internal flow), Adler II for mixed vascularity (defined as the presence of any intra-nodular flow and peripheral flow on > 25% of the nodule's circumference), and Adler III for intra-nodular vascularity (defined as exclusively internal flow, including vessels penetrating the nodule and isolated center vessels).

Statistical analysis

The chi-square test with Yates' correction and Fisher's exact test were used to compare categorical variables. The consistency check was assessed using kappa value. Kappa of 0–0.25 indicates slight agreement; 0.25–0.49, fair agreement; 0.50–0.69, moderate agreement; 0.70–0.89, excellent agreement;

and 0.90–1.00 almost perfect agreement. A value of $P < 0.05$ was considered statistically significant. Statistical analyses were performed with SPSS software (Version 19.0, SPSS Chicago, IL, USA).

List Of Abbreviations

CBT, carotid body tumor;

CDFI, color Doppler flow imaging;

SMI, superb micro-vascular imaging;

US, ultrasound;

ECA, external carotid artery

ICA, internal carotid artery;

CEUS, contrast-enhanced ultrasound

Declarations

Ethics approval and consent to participate

Institutional review board approval of this study was obtained from the Ethics Committee of Peking Union Medical College Hospital.All procedures performed in the studies were in accordance with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from individual participants included in the study.

Consent for publication:

Written informed consent for publication was obtained from the participants.

Availability of data and materials:

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests:

All authors declare that they have no competing interests.

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Authors’ contributions:

Jianchu Li, Yuehong Zheng and Bo Zhang conceived of and designed the study. Luying Gao, Xiaoyan Zhang and Wanying Li collected the data. Luying Gao performed the analysis. Xiaoyan Zhang and Luying Gao prepared all the figures and tables. Luying Gao and Hongyan Wang was a major contributor in writing the manuscript. Hong-Yan Wang, Yuxin Jiang and Jian-Chu Li edited the manuscript. All authors read and approved the final manuscript.

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Not applicable

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Figures

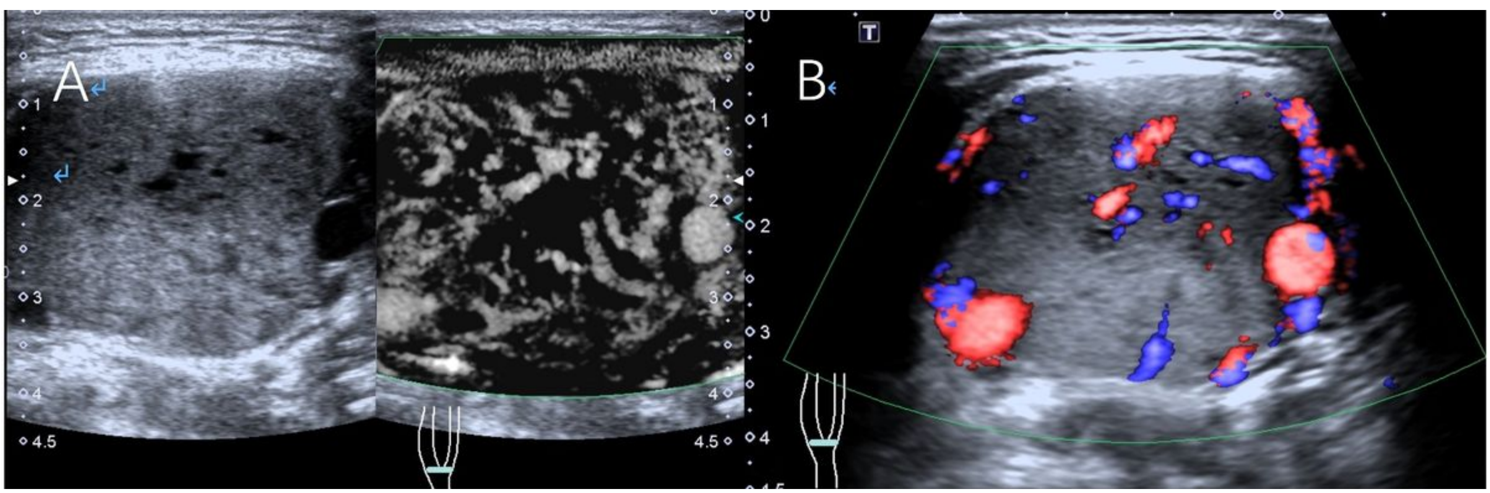

Figure 1

Scans from a 32-year-old man with a right CBTlesion measuring 4.4 cm. A.Grayscale sonography showing the lesion which was classified as Adler III vascularity onSMI.B. The lesion was classified as Adler II vascularity onCDFI.

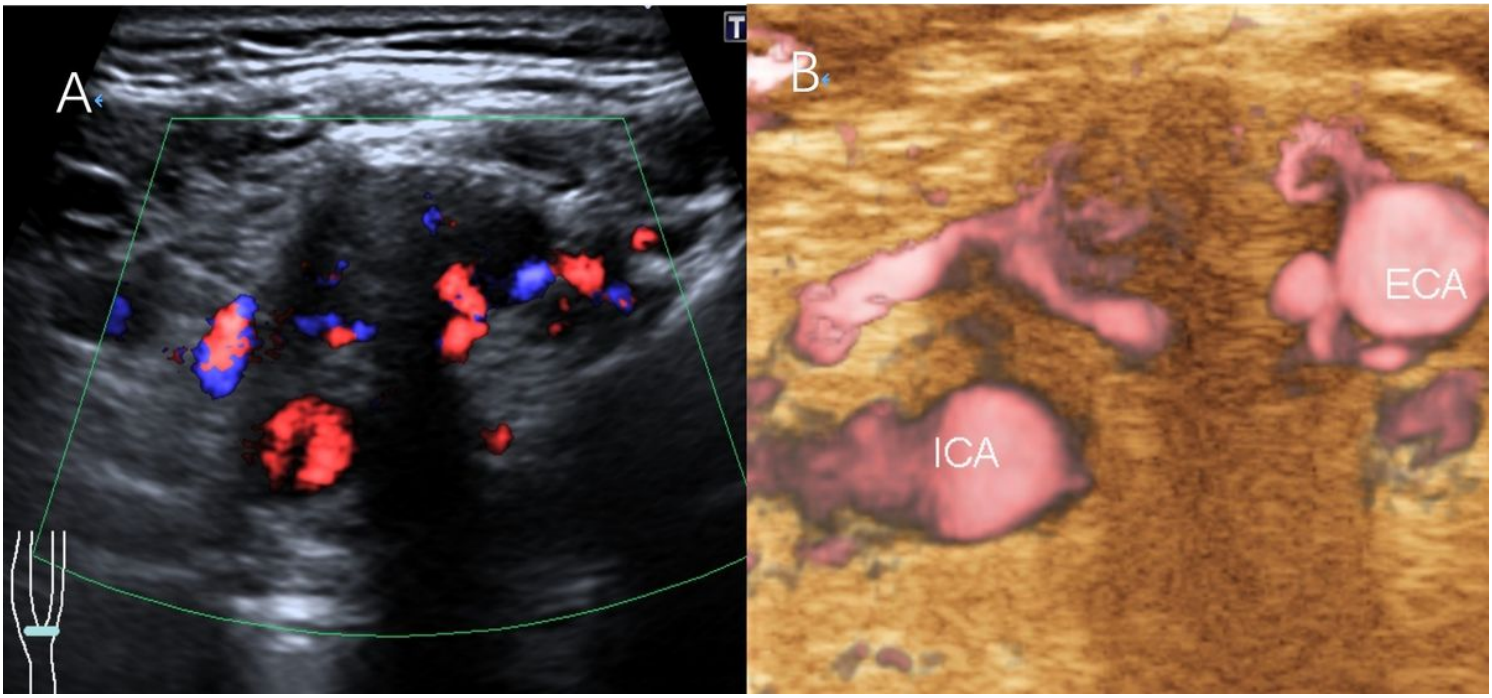

Figure 2

Scans from a 38-year-old man with a right CBTlesion measuring 3.8 cm. A. The CDFI of the lesion B. The feeding artery of the CBT stemming from ECA on SMI.