超音波による頸動脈病変の標準的評価法(案)の公示に際して

頸動脈長軸方向断面像の表示方向については従来の循環器領域の方式と全身臓器の一部と考える方式とで意見が分かれている。

今回公示する「超音波による頸動脈病変の標準的評価法」(案)の目的 は“病変の評価“の標準化に重点を置き、“表示法”の標準化ではないので、意見の分かれている頸動脈長軸方向断面像の表示方向については特に規定をしていない。

この点を含め、公示期間中にご意見をお寄せ下さい。

日本超音波医学会用語診断基準委員会
委員長　田中幸子

超音波による頸動脈病変の標準的評価法（案）

日本超音波医学会用語・診断基準委員会
委員長　　田中　幸子

頸動脈超音波診断ガイドライン小委員会
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矢坂　正弘[9]

1.　目　　的

生活習慣病（糖尿病，脂質異常症，高血圧症，喫煙，肥満など）や動脈閉塞性疾患（脳血管障害，虚血性心疾患，閉塞性動脈硬化症など）の診療に際して参考となる，頸動脈病変の超音波検査による標準的な評価方法を提示する．

2.　適　　応

頸動脈超音波検査の適応は，1）頸動脈の狭窄および閉塞病変が疑われる疾患（脳血管障害，椎骨脳底動脈環流不全，高安病など）や臨床的な所見（片麻痺，動脈雑音，脈拍減弱など）がある場合，または 2）他の領域の動脈硬化性疾患（冠動脈疾患，閉塞性動脈硬化症，大動脈瘤など）を有し，侵襲的治療の適応となる場合とする．

ただし，3）動脈硬化危険因子（糖尿病，脂質異常症，高血圧，喫煙，肥満など）を持っており，動脈硬化の進行の可能性がある場合も検査の適応としてよい．

3.　検　　査

3.1　被検者の体位

被検者の体位は，仰臥位（または座位）を基本とし，観察領域が広く得られるように工夫する（**Fig. 1**）．観察領域を進展させ，頭部を 30 度前後傾ける（**Fig. 1 左**）と観察し易い．体型により肩甲骨背部へ枕やタオルなどをを挿入すると，総頸動脈起始部が観察し易くなる（**Fig. 1 右上**）．また，内頸動脈遠位部の観察には，側臥位にして頸部後方から観察すること（**Fig. 1 右下**）もある．

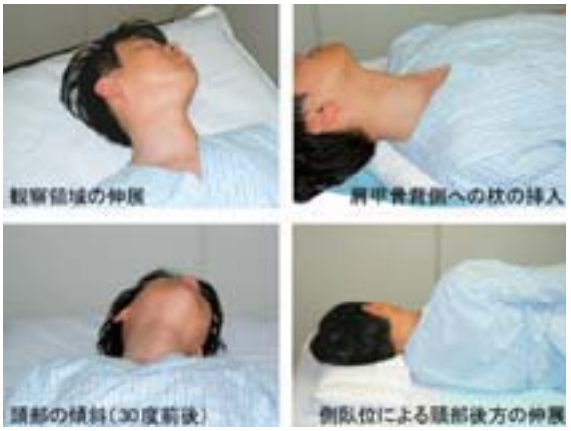


Fig. 1　被検者の体位（左：右頸動脈を検査する際の通常の体位，右：枕を使用して工夫した時の体位）

3.2　探触子の選択

頸動脈超音波検査では，血管形態や走行深度から，一般に高周波のリニア型探触子を用いる．

探触子の中心周波数は，内膜中膜複合体（intima-media complex: IMC）の計測精度を考慮すると 7 MHz 以上を必要とする．

内頸動脈の末梢側など深部を走行する血管の観察には，中心周波数が 5 MHz 前後のコンベックス型やセクタ型探触子も有効な場合がある．

[1]松尾循環器科クリニック，[2]自治医科大学臨床検査医学，[3]幸循会 OBP クリニック臨床検査科，[4]東京都済生会中央病院放射線科，[5]三井記念病院中央検査部，[6]国立循環器病センター脳血管内科，[7]アロカ研究所，[8]奈良県立医科大学中央内視鏡超音波部，[9]九州医療センター脳血管内科

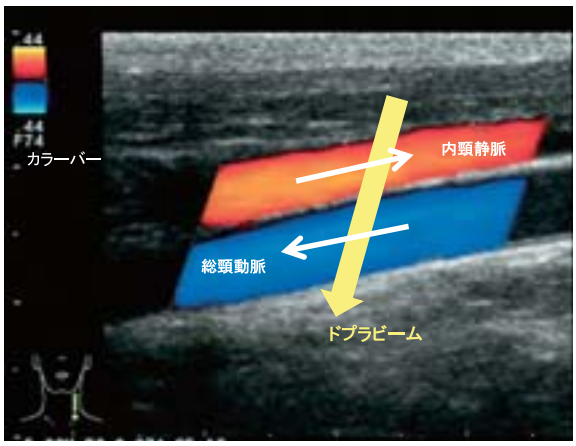


Fig. 2　カラードプラ法による表示方法（左：末梢側）

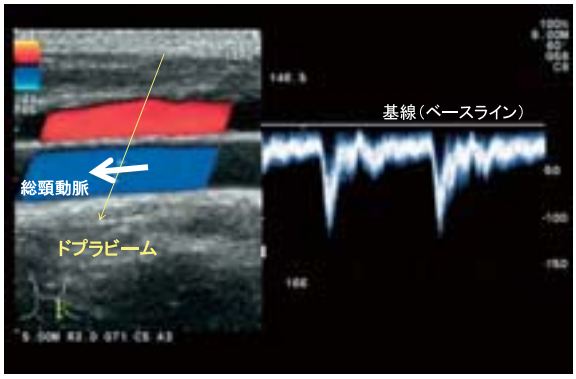


Fig. 3　パルスドプラ法による表示方法（左：末梢側）

3. 3　画像の表示方法

1）超音波断層像

血管短軸断層像は，被検者を尾側（足側）から眺めた像で，画面左に被検者の右側が表示される像とする．血管長軸断層像の表示方向については，ここでは特に規定しない．（注 1）

2）カラードプラ法

カラードプラ法の表示色相は，原則的には探触子に向かう血流を赤色（暖色系），遠ざかる血流を青色（寒色系）とする（**Fig. 2**）．ただし，画面にカラーバーを表示すれば，その限りではない．

3）パルスドプラ法

ドプラ血流波形の基線に対する血流方向の表示は，探触子に向かう血流を基線より上方（正の方向），遠ざかる血流（**Fig. 3**）を基線より下方（負の方向）に表示する．ただし，血流方向を記載すればその限りではない．

また，動脈と静脈との鑑別や，血流波形の評価を必要とする場合は，心電図の同時記録が有用である．

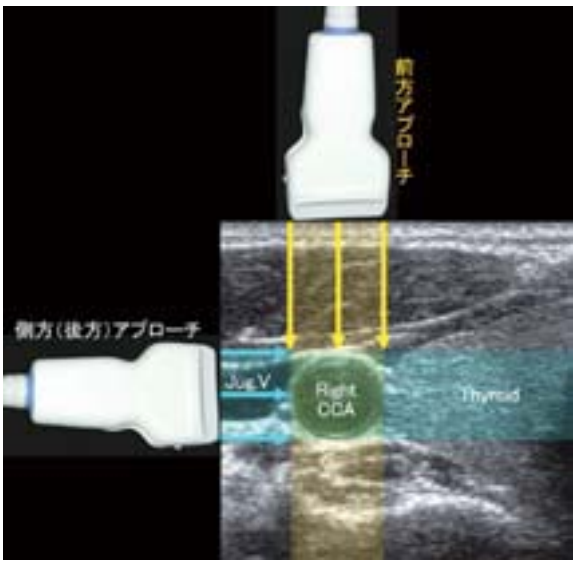


Fig. 4　血管短軸アプローチ：前方と側方アプローチ

3. 4　アプローチ方法

1）観察断面の設定

断層像による頸動脈超音波検査の観察は，血管短軸断面と血管長軸断面の 2 方向で行う．特に，血管病変の検索には，血管短軸断面によるアプローチが有効である．ただし，短軸走査は前方と側方（後方）の 2 方向以上からアプローチし，互いに描出不良な領域を補うように観察する必要がある（**Fig. 4**）．

2）観察領域

頸動脈超音波検査の観察領域は，左右ともに総頸動脈（common carotid artery: CCA），頸動脈球部（bulbus），内頸動脈（internal carotid artery: ICA），および椎骨動脈（vertebral artery: VA）で観察可能な領域とするが，必要に応じて外頸動脈（external carotid artery: ECA），鎖骨下動脈（subclavian artery: SCA），脳底動脈（basilar artery: BA）および周辺の動脈も観察する．ただし，IMC やプラー

注 1）頸動脈長軸方向断面像の表示方向については従来の循環器領域としての方式と全身臓器の一部と考える方式とで意見が分かれている．今回公示する“超音波による頸動脈病変の標準的評価法（案）”の目的は“病変の評価”の標準化であり“表示法”の標準化ではないので，表示方向については特に規定をしていない．

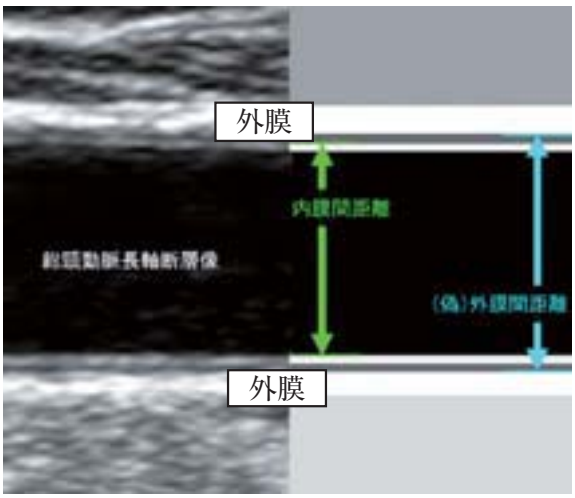


Fig. 5　血管径の計測ポイント

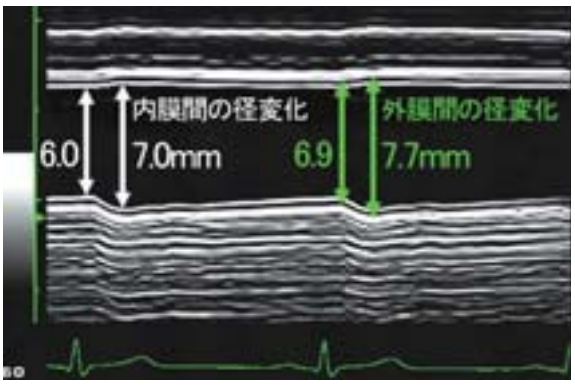


Fig. 6　血管径計測時の時相（心電図 QRS 波相との関連）

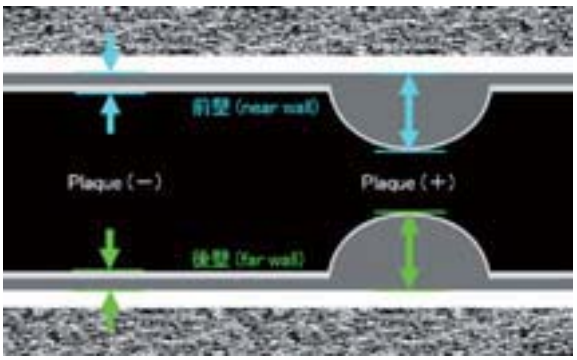


Fig. 7　IMT の計測ポイント

クの評価を行う際は，総頸動脈，頸動脈球部，および内頸動脈を必須観察領域とする．

3. 5　評価項目の計測と記録

1）評価項目

動脈硬化病変の評価として，必須の計測項目は頸動脈での最大内膜中膜複合体厚（maximum intima-media thickness: max IMT）とし，選択項目として，総頸動脈での平均内膜中膜複合体厚（mean IMT）を用いる．

狭窄病変を評価する際には，必須項目として総頸動脈では面積狭窄率を基本とし，必要に応じて径狭窄率を求める．

内頸動脈では North American Symptomatic Carotid Endarterectomy Traial（NASCET）法での狭窄率を基本とし，必要に応じて European Carotid Surgery Trial（ECST）法での径狭窄率や面積狭窄率を求める．さらに狭窄部位での血流計測も同時に行うこととする．

2）動脈径の計測

狭窄や瘤形成の判定に用いる血管径の計測は，病変部を計測する．また，スクリーニング検査における動脈径の計測は，拍動する動脈の最小径時相または最大径時相のどちらかの断層像で行い，計測ポイントは内膜間距離または（偽）外膜間距離とする（**Fig. 5**）．

また，M モードまたは心電図と同時記録ができる場合の血管径計測の時相は，血管収縮後期（心拡張後期：心電図 QRS 波相）とする（**Fig. 6**）．

なお，報告書には，計測部位と計測値を記載する（例）総頸動脈径＝ 6. 0 mm（最小内膜間距離），または，＝ 6. 9 mm（最小外膜間距離）など．

3）IMT の記録と計測

①max IMT の計測：IMC は，血管内腔側の高エコー層と低エコー層の 2 層から成り，その厚み（IMT）の肥厚と生活習慣病と，また IMT の肥厚と脳梗塞や心筋梗塞など他部位の動脈硬化性疾患のリスクとに相関があることが知られている．その最大の厚みを，max IMT として計測する（**Fig. 7**）．

max IMT の計測範囲は，左右共に総頸動脈（CCA），頸動脈球部（bulbus），および内頸動脈（ICA）とし，左右それぞれの観察可能な領域で最大の値を測定する．外頸動脈は，計測範囲から除外する．

また，閉塞部位や石灰化がある場合には，「閉塞」，「石灰化のため評価不能・推定値」とする．

なお，超音波の特性から，前壁での IMC の

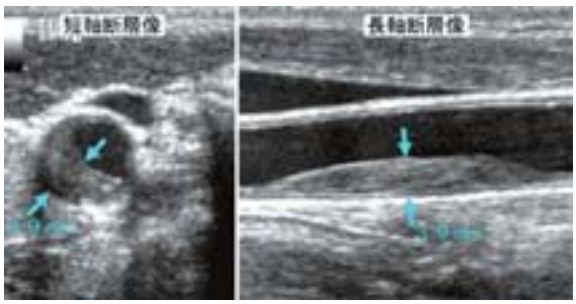


Fig. 8　血管短軸および長軸による病変部の評価

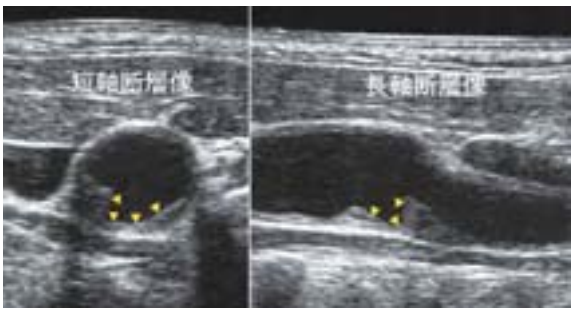


Fig. 9　潰瘍（ulcer）形成を伴うプラーク（長軸像・左：中枢側）

描出が困難な場合もあるため，観察領域を後壁のみに限定した場合は，max IMT が後壁（far wall）での値であることを明記する．IMT 計測の最小単位は 0. 1 mm とし，計測誤差を最小限にするように，画像サイズを大きく表示して計測することが望ましい．

IMT の計測画像は，血管に直交する短軸断面および血管中央の長軸断面のどちらを用いてもよいが，2 方向で描出し両方で確認した計測値とするのが望ましい（**Fig. 8**）．

②mean IMT の計測：mean IMT は，頸動脈球部（bulbus）を含まない左右の総頸動脈で計測する．

mean IMT の計測方法は 2 点以上の多数点の平均値である．その計測方法には，区間を決めて計測する IMT 計測ソフトウェアを用いた方法から，総頸動脈における max IMT 計測部位の両サイド（末梢側および中枢側）1 cm の位置でそれぞれの IMT を計測し，max IMT を含めた 3 点の平均値とする方法などが報告されている．

4）プラークの計測と評価

①プラークの定義：IMC 表面に変曲点を有する限局性の隆起性病変をプラークと称する．ただし，vascular remodeling の症例は，血管内腔への隆起の有無に関係なくプラークとする．

また，プラークを含めた最大計測値が，max IMT である（**Fig. 7**）．

②プラークの画像記録：基本的なプラークの画像記録は，可能な限りその最大厚が描出される血管の短軸および長軸断面の 2 方向で行う．

ただし，表面や内部性状などを記録する場合は，適切な断面を自由に設定してよい．

③プラークの観察項目：プラークは，可能な範囲で，その最大厚と隆起部の範囲を含めた a）プラークのサイズ, b）表面の形態, c）内部の性状，d）可動性などで評価する．これらは，動脈硬化性病変の評価，治療および経過観察において重要である．

a）プラークの計測

プラーク厚は，IMT の計測と同様に，血管内腔との境界と血管外膜面との境界で，最大の厚みを計測ポイントとし，max IMT となる（**Fig. 7**）．プラークのサイズは，一般にプラーク厚で表現されるが，血管長軸方向の範囲や，短軸断面でのプラークの面積や占有率なども用いられる．

b）プラーク表面の形態

プラーク表面（surface）の形態を表す用語として，平滑（smooth），不規則（irregular），および **Fig. 9** に示すように明らかな陥凹を伴う潰瘍（ulcer）形成などが用いられる．

c）プラークの輝度と均一性からみた分類

プラークは，プラーク内部のエコー輝度（echogensity）から三つに大分類し，さらに, その内部エコーの均一性（texture）からそれぞれを二つに小分類することができる．プラークのエコー輝度を評価する際に,「対象となる構造物」が必要となる．この対象構造物は,「プラーク周囲の IMC」に設定し，プラーク内部のエコー輝度と比較して判定する．ただし，観察深度や記録条件によってエコー輝度が変化するため，可能な限りプラーク病

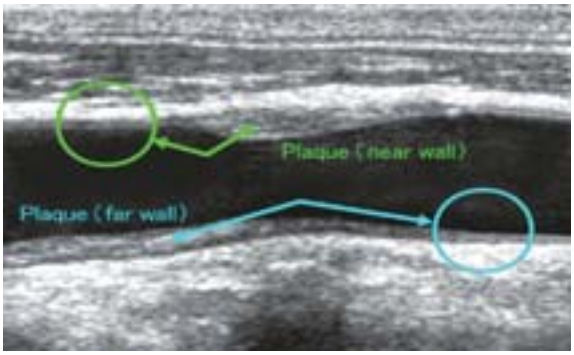


Fig. 10　プラークの輝度評価に用いる対象構造物

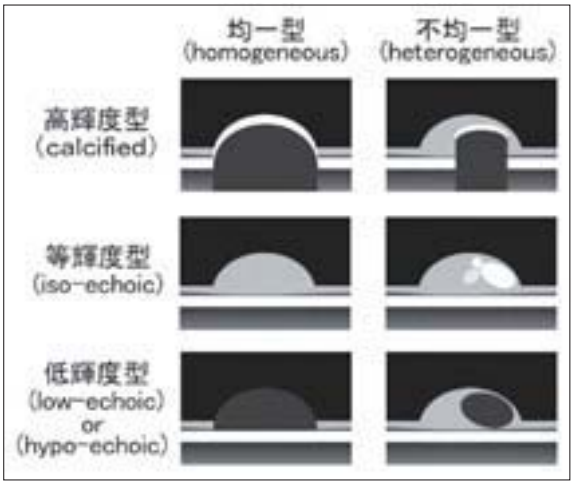


Fig. 11　輝度とその分布によるプラーク分類

変と同側（前壁側または後壁側）の IMC を対象構造物とする（**Fig. 10**）．エコー輝度による分類は，（a）音響陰影を伴う石灰化病変を含む calcified，（b）対象構造物に比べ低輝度エコーの領域を含む low echo，または hypoechoic，（c）石灰化病変や低エコー輝度領域は認めず，対象構造物とほぼ同程度のエコー輝度を示す iso-echoic の三つに大分類する．

ただし，低輝度領域が認められる場合は low echo（hypoechoic）に分類する．

また，それぞれの内部エコー輝度が均一である homogeneous と，エコー輝度が不均一にみられる heterogeneous に小分類する．それぞれの名称は，高輝度均一型，高輝度不均一型，等輝度均一型，等輝度不均一型，低輝度均一型，低輝度不均一型とする（**Fig. 11**）．

ただし，多方向からのアプローチでも描

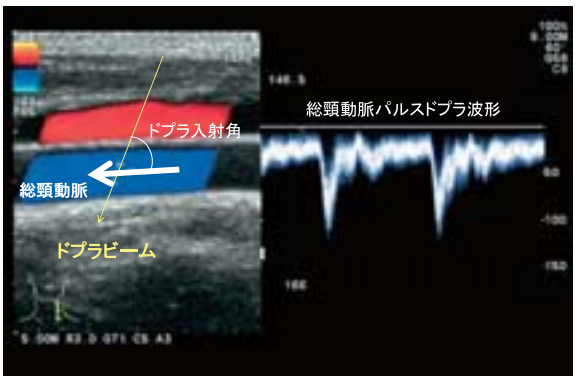


Fig. 12　パルスドプラ法による血流波形記録時の角度補正（左：末梢側）

出が不良で，アーチファクトとの鑑別が困難な場合は，無理には分類をせず，識別困難と表記するに留める．

d）可動性など

特殊な形態として，有茎性の可動性プラーク（mobile plaque）が描出される場合がある．このプラークは血栓性プラークが疑われ，血流に伴う可動性を示し，塞栓症に注意が必要とされている．

④プラークスコア：頸動脈の動脈硬化度を半定量的に評価する方法として，プラークスコアを使用できる．計測法には，最も簡単な方法として内頸動脈，頸動脈球および総頸動脈の 3 区分に分けて，それぞれの左右のプラーク厚の総和をプラークスコアとする方法などが報告されている．

3. 6　パルスドプラ法による血流検査

1）サンプルポイントの設定

血流のサンプルポイントは，狭窄部位では当該部位に設定する．

狭窄のない場合は，良好な画像が得られる部位に自由に設定してよい．しかし，血管径が変化する部位，血管分岐部付近，さらに血管の蛇行部は流速が一定せず，血流の乱れが生じることがあり，計測部位としては適切ではない．

サンプルサイズは，通常は血管径の 1 / 2 以上で血管内腔に収まるサイズとし，血管中央部に設定するが，狭窄部位では狭窄径を考慮したサンプルサイズに設定する．

ドプラ入射角は，計測誤差を考慮して 60° 以内での記録を条件とするが，可能な範囲で入

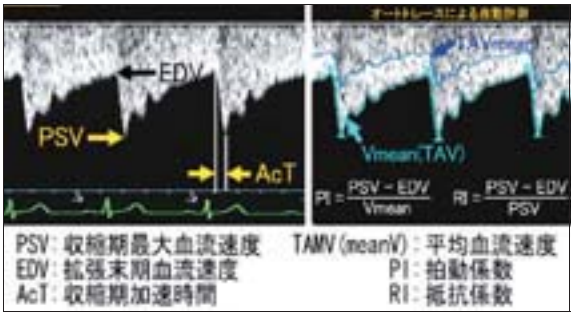


Fig. 13　ドプラ血流波形評価時の計測項目

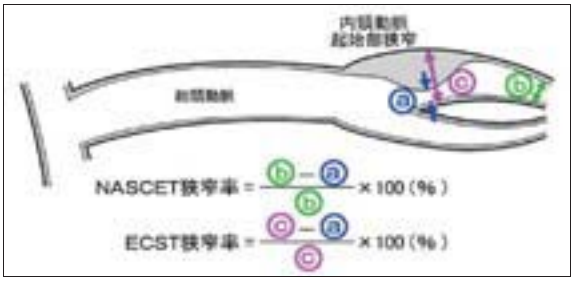


Fig. 14　狭窄率の計測方法（左：中枢側）

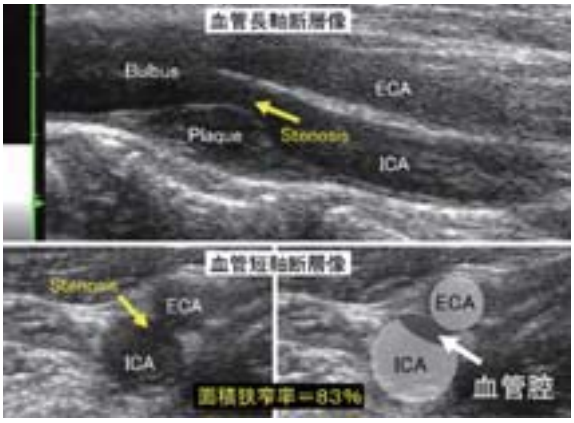


Fig. 15　面積狭窄率の計測方法（長軸像・左：中枢側）

射角を小さくするように設定する（**Fig. 12**）.

2）血流波形の計測

頸動脈の血流評価は，狭窄がない場合には両側の CCA と ICA で，良好な画像と入射角が得られる部位で計測する.

また狭窄がある場合にはその狭窄部と狭窄の前後部位で評価する.

計測項目は収縮期最高血流速度（peak systolic velocity: PSV），拡張末期血流速度（endodiastolic velocity: EDV）などである（**Fig. 13**）.

また必要に応じて，時間平均最大血流速度（time averaged maximum velocity: TAMV），収縮期加速時間（accerelation time: AcT），収縮期最大流速 / 拡張末期流速比（SD ratio），抵抗係数（resistance index: RI 値），および平均血流速度（Vmean）を用いて拍動係数（pulsatility index: PI 値）などを求める（**Fig. 13**）.

また，必要により拡張末期血流速度（EDV）の左右比（速い速度／遅い速度：ED ratiio）も応用でき，CCA での比が 1. 3 から 1. 4 以上では EDV の低い方の遠位側に閉塞や高度狭窄病変の可能性が高い（4 以上は ICA 閉塞）.

【脚注】平均血流速度には 2 通り有り，時間平均血流速度（TAV）の平均（TAVmean）とは，一定時間内で平均した流速値．1 心拍分の平均血流速度波形をトレースして得られる.

Vmean とは最大血流速度の時間平均値で，1 心拍分の最大血流速度波形をトレースして得られる.

3. 7　狭窄病変の評価

1）狭窄率の算定法

狭窄病変の評価は，血管造影と同様に「狭窄率」を求めて定量診断する.

従来，超音波検査は血管造影と異なり血管腔と血管壁の性状が同時に観察できるので，狭窄率の計測方法は径狭窄率：ECST 法（**Fig. 14**）および面積狭窄率が用いられた．しかし，狭窄病変の好発部位である内頸動脈では NASCET 法（**Fig. 14**）が一般的である.

NASCET 法では，狭窄病変末梢側の前壁と後壁が平行となり径が安定した内頸動脈非病変部（**Fig. 14 図中ⓑ**）を基準となる血管径として計算している.

この様に，算定方法で狭窄率の値が異なる為，報告書には必ず狭窄率の算定方法を記載する.

狭窄率を求める際の血管内径の計測には，可能な範囲で B モード断層像を用いる．ただし，B モード断層像が得がたく，カラードプラ法による血流表示をガイドにして計測した場合は，参考値であることを明記する.

2）不整形な狭窄断面での狭窄率の計測方法

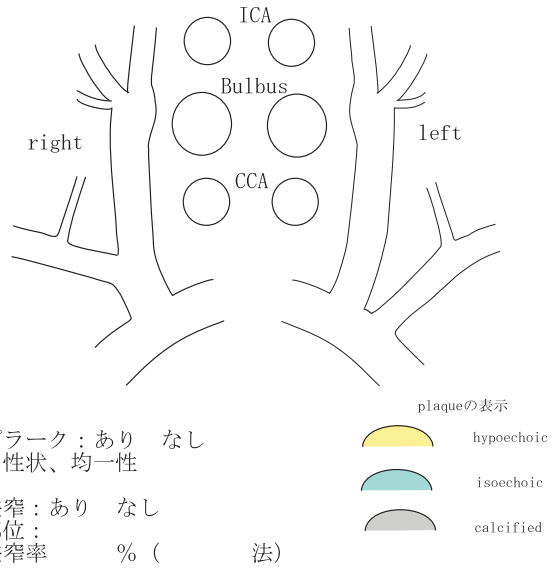
末梢血管の狭窄断面は楕円形や半月状などの不整形を呈することも多く，長軸断面では適切な評価ができないことがある．そこで，狭窄部の超音波断層像は，可能な限り血管短軸断面を用いた面積狭窄率も求める（**Fig. 15**）.

3）ドプラ法による狭窄率の推定

石灰化などにより狭窄部の超音波断層像が得がたい場合は，パルスおよび連続波ドプラ法で総頸動脈や狭窄部および狭窄後の内頸動脈の血流を記録し，収縮期最高流速（PSV）や拡張末期流速（EDV）などを参考に，狭窄率を推定することができる．

狭窄部の PSV が 1. 5 m/sec を超える場合は NASCET 狭窄率 50％以上，さらに PSV が 2 m/sec 以上は NASCET 狭窄率で 70％以上の狭窄が疑われる．

また，重症の狭窄病変では，狭窄部位の末梢側の血流は AcT の延長や乱流が認められる．



図・参考　頸動脈エコー所見の報告書例

参考：頸動脈エコー検査の評価結果の報告

超音波による頸動脈の評価結果を報告する際には，正確に分かりやすく指示医・主治医に伝えるため，病変の有無や性状を図示（図・参考）して提示することを推奨する．

付記

今回の標準的評価法作成に当たり，2006 年現在での報告や施行状況から指標や実施法を作成したが，今後の研究や報告により改訂が必要となる内容もあることを付記する．

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Draft: standard method for ultrasound evaluation of carotid artery lesions

Terminology and Diagnostic Criteria Committee, Japan Society of Ultrasonics in Medicine
Chairman: Sachiko Tanaka

Subcommittee for Preparing Guidelines for Ultrasound Diagnosis of Carotid Artery
Chairman Hiroshi Matsuo[1]
Vice Chairman Nobuyuki Taniguchi[2]
Members Toshiya Ozaki[3] Satoshi Kaneda[4] Eiichi Ennda[5] Kazuyuki Nagatsuka[6]
Rekko Harada[7] Toshiko Hirai[8] Masahiro Yasaka[9]

1. Objectives

This report is aimed at providing standard methods for ultrasound evaluation of carotid artery lesions which will help the diagnosis and treatment of life-style-related diseases（diabetes mellitus, dyslipidemia, hypertension, smoking, obesity, etc.）and atherosclerotic arterial diseases（cerebrovascular disease, ischemic heart disease, arteriosclerosis obliterans, etc.）.

2. Indications

Carotid artery ultrasonography is indicated in the following cases: 1）patients suspected of having stenosis or obstructive lesions of the carotid artery（cerebrovascular disease, disturbed perfusion through the vertebral and basilar arteries, Takayasu disease, etc.）or patients having clinical signs of carotid artery lesions（hemiplegia, arterial bruit, pulse weakness, etc.）or 2）patients having atherosclerotic lesions of other organs（coronary artery disease, arteriosclerosis obliterans, aortic aneurysm, etc.）and are indicated for invasive treatment.

In addition, this examination may be indicated also in patients who have risk factors for atherosclerosis（diabetes mellitus, dyslipidemia, smoking, obesity, etc.）and in whom the possibility of progression in atherosclerosis cannot be ruled out.

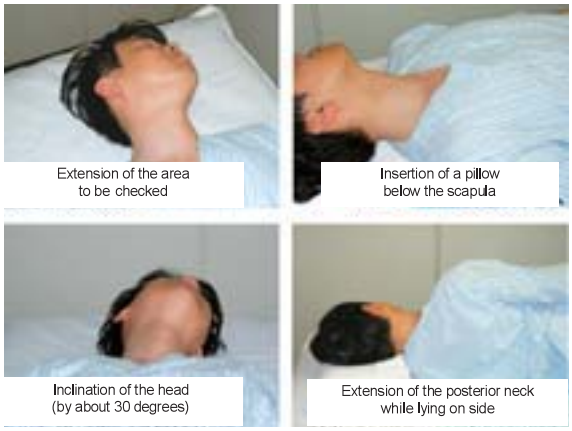


Fig. 1 Position of patient（left: ordinary posture for test of the right carotid artery, right: a posture using a pillow）

3. Examination procedure

3.1 Posture of the patient

Usually, the patient is examined in a supine（or sitting）position. The posture needs to be modified to allow an extensive area of the patient's body to be obserbed（**Fig. 1**）. Observation is expected to be easier if the area to be obserbed is extended and the head is inclined by about 30 degrees（**Fig. 1, left**）. Depending on the patient's physique, insertion of a pillow, towel or the like below the scapula will allow easier observa-

[1]Matsuo Cardiovascular Clinic, [2]Department of Clinical Laboratory Medicine, Jichi Medical School, [3]Clinical Laboratory, Kojunkai OBP Clinic, [4]Department of Radiology, Tokyo Saiseikai Central Hospital, [5]Clinical Central Laboratory, Mitsui Memorial Hospital, [6]Cerebrovascular Division, Department of Medicine, National Cardiovascular Center, [7]Aloka Research Institute, [8]Central Endoscopy and Ultrasonography Division, Nara Medical University, [9]Department of Cerebrovascular Medicine, National Hospital Organization Kyushu Medical Center

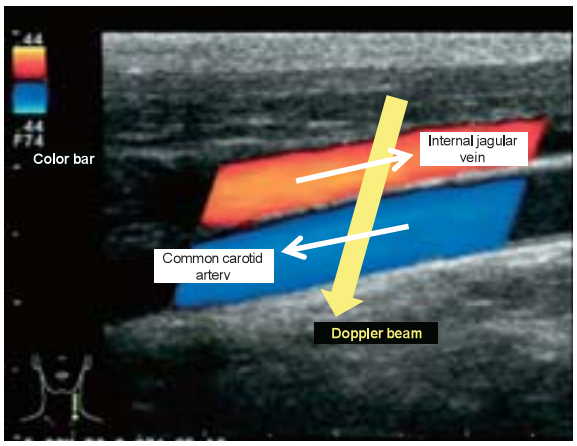


Fig. 2 Representation by color Doppler method (left : the distal side)

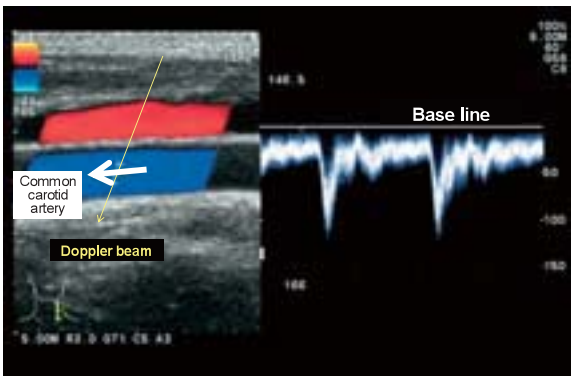


Fig. 3 Representation by pulse Doppler method (left : the distal side)

tion of the origin of the common carotid artery (**Fig. 1, upper right**). The distal part of the internal carotid artery may be obserbed easily if observation is made from behind the neck of the patient with lateral decubitusposition (**Fig. 1, lower right**).

3. 2 Selection of a probe

Usually, a high-frequency linear array probe is used for carotid artery ultrasonography because of the morphological features and location (depth) of the carotid artery.

The center frequency of the probe needs to be 7 MHz or higher if the accuracy of measurement for the intima-media complex (IMC) is taken into account.

For observation of blood vessels located deeply (e.g., the distal segment of the internal carotid artery), a convex probe or a sector probe with the center frequency of about 5 MHz is sometimes useful.

3. 3 Method of imaging

1) Two-dimensional ultrasonography

For short-axis cross-sectional imaging of blood vessels, the patient is observed from the caudal side (the foot side), and the patient's right side is presented on the left side of the image. In the case of long-axis cross-sectional imaging of blood vessels, the direction for presenting images is not specifically defined here (Note 1).

2) Color Doppler method

The color used for color Doppler method is red (warm color) for the blood flow approaching the probe and blue (cold color) for the blood flow leaving the probe (**Fig. 2**). This decision does not apply if a color bar is shown in the image.

3) Pulse Doppler method

When presenting the direction of blood flow relative to the baseline of the Doppler flow, the blood flow approaching the probe is depicted above the baseline (the positive side) while the blood flow leaving the probe (**Fig. 3**) is depicted below the baseline (the negative side). This decision does not apply if the orientation of blood flow is specified on the image.

Simultaneous ECG is advisable if distinction of arteries from veins or evaluation of blood flow patterns is required.

3. 4 Approach

1) Setting the cross-section to be observed

Observation of the carotid artery by two-dimensional ultrasonography involves two directions (short-axis view and long-axis view). Short-axis view is particularly useful to check for vascular lesions. However, short-axis scanning needs to

Note 1: As regards the direction for presenting long-axis cross-sectional images of the carotid artery, opinion is divided between using the conventional method used for cardiovascular imaging and the method used for imaging systemic organs. The objective of publishing Draft: Standard Method for Ultrasound Evaluation of Carotid Artery Lesions is standardization of evaluation of lesions, not standardization of the presentation method. Therefore, the direction for presenting images has not been specifically defined.

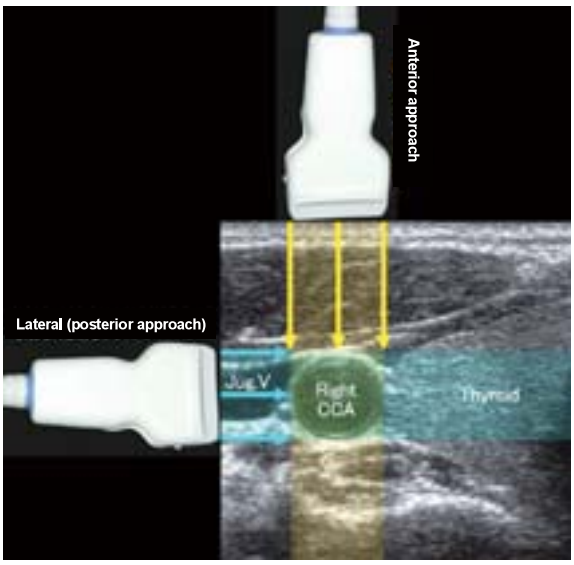


Fig. 4 Short-axis view: anterior and lateral approach

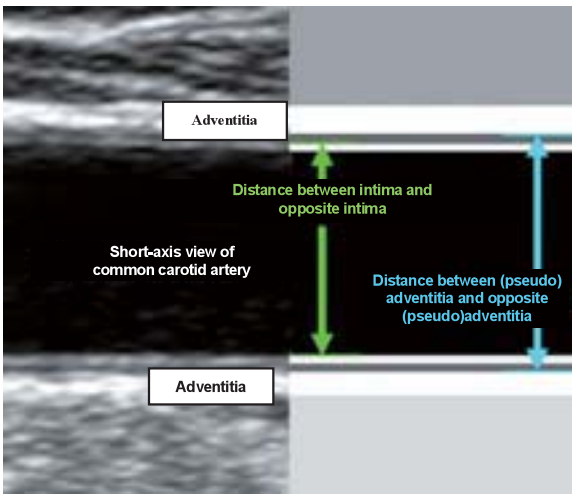


Fig. 5 Sampling points for vascular diameter measurement

be made in at least two directions, i.e., anterior and lateral (posterior) directions, so that inadequate depiction in one direction may be made up for by depiction in another direction (**Fig. 4**).

2) Scope of observation

Carotid artery ultrasonography covers the observation-possible areas of the common carotid artery (CCA), bulbus, internal carotid artery (ICA) and vertebral artery (VA) on both the right and left side. As needed, the external carotid artery (ECA), subclavian artery (SCA), basilar artery (BA) and surrounding arteries may also be covered. Observation of the CCA, bulbus and ICA is indispensable when evaluation of IMC and plaques is needed.

3.5 Measurement and recording of parameters

1) Parameters

When checking for atherosclerotic lesions, maximum intima-media thickness (max IMT) is an indispensable parameter, and mean intima-media thickness (mean IMT) of the common carotid artery may be measured as an optional parameter.

When checking for stenotic lesions, percent stenosis of area of the common carotid artery is measured as an indispensable parameter, and percent stenosis of diameter is additionally measured as needed.

When checking for lesions of the internal carotid artery, percent stenosis according to the criteria of the North American Symptomatic Carotid Endarterectomy Trial (NASCET) is measured as a primary parameter, accompanied as needed by measurement of percent diameter narrowing and percent stenosis of diameter according to the criteria of the European Carotid Surgery Trial (ECST). In addition, blood flow through the stenotic lesion is also measured.

2) Arterial diameter

Vascular diameters used for evaluation of stenosis and aneurysmal dilatation are measured at the affected point of the blood vessels concerned. In screening tests, arterial diameter is measured on two-dimensional ultrasound images taken either during the minimal size phase or during maximal size phase. The diameter measured is the distance between the intimal layer and the opposite intimal layer or between the (pseudo) adventitial layer and the opposite (pseudo) adventitial layer (**Fig. 5**).

In M-mode ultrasonography or ECG-gated ultrasonography, vascular diameter is measured during the late phase of vascular contraction (end diastolic phase: QRS phase on ECG) (**Fig. 6**).

It is necessary for both the point and the value of measurement to be desclibed in the report. For

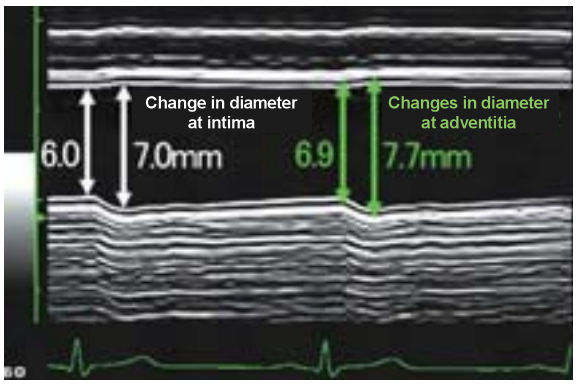


Fig. 6 Phase of vascular diameter measurement (associated with QRS on ECG)

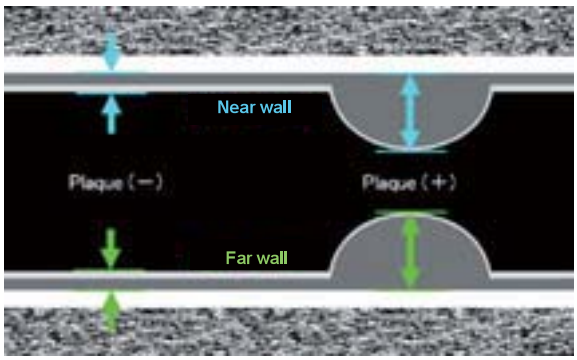


Fig. 7 Sampling points for IMT measurement

example, diameter of common carotid artery = 6. 0 mm (minimal distance between the internal layers) or = 6. 9 mm (minimal distance between the adventitial layers).

3) Measurement and recording of IMT

a) Measurement of max IMT: IMC is composed of two layers, i.e., the hyperechoic layer closer to the vascular lumen and the hypoechoic layer. It is known that an increase in its thickness (IMT) correlated with the risk for lifestyle-related diseases and that thickening of IMT correlates with the risk for atherosclerotic diseases of other sites such as cerebral infarction and myocardial infarction. Maximal thickness of IMC is measured as max IMT (**Fig. 7**).

On both the right and left sides, max IMT is measured in the observation-possible areas of the common carotid artery (CCA), bulbus and internal carotid artery (ICA), excepting the external carotid artery.

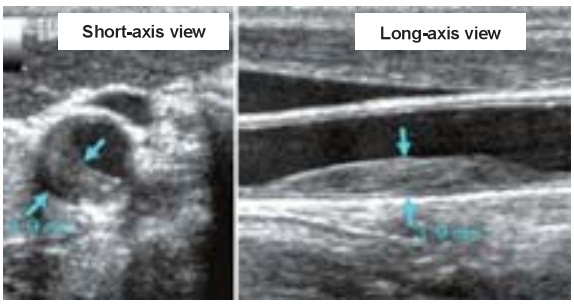


Fig. 8 Evaluation of lesions on short-axis and long-axis view

In cases where the artery has obstruction or calcification, for "obstruction" or "not evaluated or only estimated value due to calcification" it should be described in the report. Because of the characteristics of ultrasound, depiction of IMC along the anterior wall is sometimes difficult. If such difficulty forces observation to be confined to the posterior wall, the report should specify that max IMT has been obtained only for the posterior wall (far wall).

The minimum unit of IMT measurement should be 0. 1 mm. It is desirable to magnify the image for this measurement so that the error in measurement may be minimized.

Either the short-axis view or the long-axis view of the blood vessel may be used for measurement of IMT. However, it is desirable to adopt IMT based on measurement in both directions and comparison between the two observations (**Fig. 8**).

b) Measurement of mean IMT: Measurement of mean IMT is performed on the right and left common carotid artery, excluding the bulbus. Mean IMT is an average of readings at two or more points of measurement. Reported methods for measurement of mean IMT include a method involving measurement of a selected segment on IMT software, 3 points of means (including max IMT) after measurement of IMT at the point of max IMT and two surrounding points on both side (each 1 cm distant from the point of max

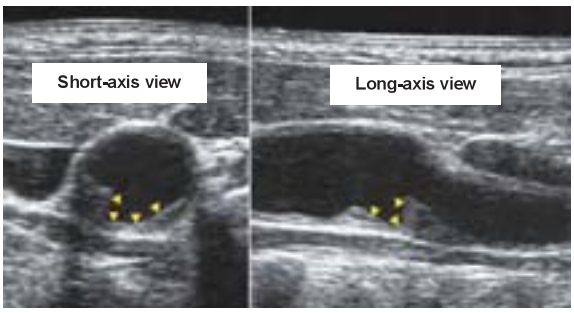


Fig. 9 Plaques accompanied by ulcer (long-axis view / left : the proximal side)

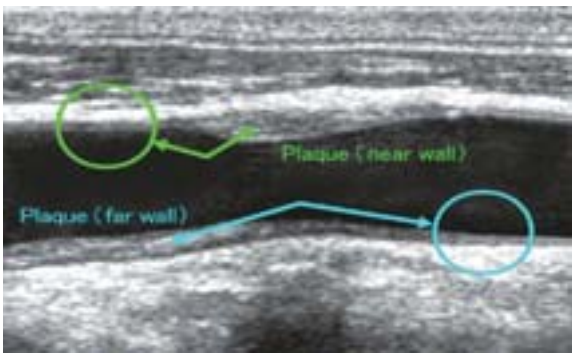


Fig. 10 Structure serving as a control for evaluation of plaque echogenicity

IMT), and so on.

4) Measurement and evaluation of plaques

a) Definition of plaques: Localized elevated lesions, having a point of inflection on the surface of IMC, are defined as "plaques". In cases of vascular remodeling, the term "plaques" may be used, irrespective of the presence/absence of elevation of the lesion into the vascular lumen. Plaques are included when measuring max IMT (**Fig. 7**).

b) Imaging of plaques: Usually, images of the plaque are taken in two directions (short axis and long axis views) of the blood vessel where the maximum thickness may be depicted. However, when imaging is designed to characterize the surface or inside, appropriate cross-sections to be imaged may be selected without a limit.

c) Parameters and properties of plaques: On each plaque, the following parameters and properties are measured or evaluated to a possible extent (including the maximally thick area and the elevated area): a) plaque size, b) surface morphology, c) internal properties, d) mobility, and so on. These parameters and properties are important for evaluation, treatment and follow-up of atherosclerotic lesions.

c-1) Measurement of plaques

Like measurement of IMT, plaque thickness is measured at the maximally thick point at the border with the vascular lumen and the adventitial layer. Plaque thickness serves as max IMT (**Fig. 7**). Usually, plaque size is expressed as plaque thickness. It is sometimes expressed as plaque area, percent occupied area, etc., along the major axis of the blood vessels or on short-axis view.

c-2) Plaque surface morphology

Plaque surface morphology is expressed using terms such as smooth, irregular, and ulcerated (accompanied by marked depression, as shown in **Fig. 9**).

c-3) Classification of plaques by echogenicity and texture

Plaques are divided into three major types by the echogenicity inside the plaques. Each type is subdivided into two types depending on the texture of internal echo. Evaluation of echogenicity of plaques requires a structure for comparison. The IMC around the plaque is adopted as this structure (control), and its echogenicity is compared with that within the plaque. Because echogenicity can vary depending on the depth of observation or conditions of recording, the IMC on the same side as the plaque (i.e., the IMC facing the anterior wall or the posterior wall) is selected as the control (**Fig. 10**). Echogenicity is rated on a three-category scale: (a) calcified (hyperechoic; calcified lesions accompanied by acoustic shadow), (b) low echo or hypoechoic (areas with low echogenci-

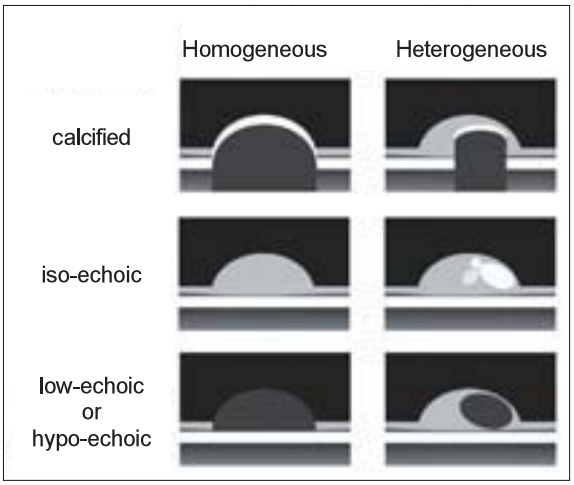


Fig. 11 Plaques classified by echogenicity and texture

ity as compared to the control structure), and (c) iso-echoic (echogenicity comparable to that of the control structure).

Plaques with partially low echogenicity are rated as low echo (hypoechoic) even when they include some hyperechoic or iso-echoic areas.

Each type is subdivided into homogenous type (uniform echogenicity inside the plaque) and heterogenous type (non-uniform echogenicity). In total, there are six types (homogenous hyperechoic type, heterogenous hyperechoic type, homogenous is-echoic type, heterogenous iso-echoic type, homogenous hypoechoic type and heterogenous hypoechoic type), as shown in **Fig. 11**.

If adequate depiction is not possible even with imaging in multiple directions and distinction from artifacts is difficult, the entry should be "difficult to distinguish" instead of attempting distinction based on inadequate findings.

d) Mobility, etc.

Mobile plaques, which possess a pedicle, are sometimes found. This feature of plaque suggests that the plaque is thrombotic in nature. It is mobile with blood flow and requires particular care of the risk for embolism.

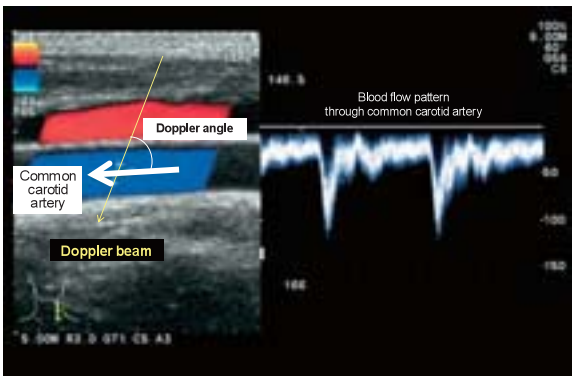


Fig. 12 Correction of angle for pulse Doppler blood flow patterns (left : the distal side)

5) Plaque score

Plaque scoring may be used as a means of semi-quantitative analysis of the degree of atherosclerosis. The simplest way of scoring plaques, reported to date, is to total the plaque thickness for three segments (internal carotid artery, bulbus and common carotid artery) on each of right and left sides.

3. 6 Pulse Doppler test of blood flow

1) Sampling point

In cases of stenosis, sampling points are set at the stenotic points.

In cases free of stenosis, sampling points may be set freely at points which will allow good depiction. However, the points showing a change in diameter, points near bifurcation and tortuous points are not suitable as sampling points because of unstable flow rate and possible blood flow turbulence.

Each sampling point usually should have a size equivalent to 1 / 2 or more of the vascular diameter and within the size of the vascular lumen. It is set at the center of the blood vessel. In cases of stenosis, the extent of stenosis is taken into account when setting the size of the sampling point.

The Doppler incident angle should be within 60 degrees (with error of measurement taken into account). It is advisable to set this angle as small as possible (**Fig. 12**).

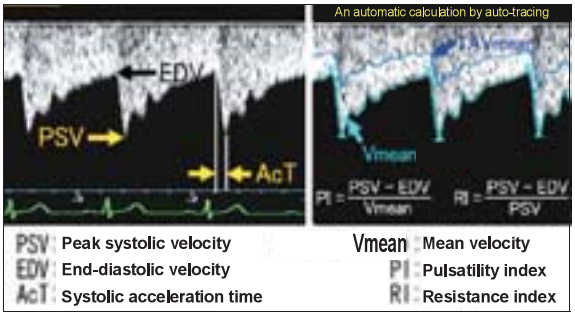


Fig. 13 Parameters for Doppler evaluation of blood flow patterns

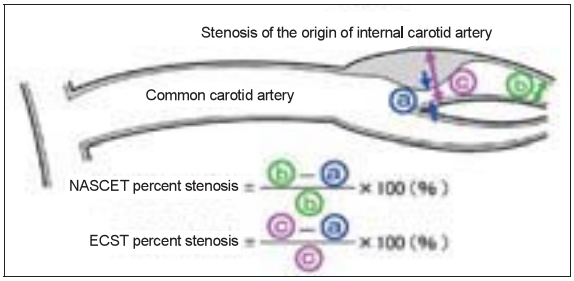


Fig. 14 Methods for calculating percent stenosis (left : the proximal side)

2) Measurement of blood flow patterns

In cases free of stenosis, blood flow through the carotid artery is measured at points of bilateral CCA and ICA where good depiction and incident angle are expected.

In cases of stenosis, this measurement should be done at and around the stenotic point.

Parameters measured are peak systolic velocity (PSV), end-diastolic velocity (EDV) and so on (**Fig. 13**).

As needed, measurement is also made of time averaged maximum velocity (TAMV), acceleration time (AcT), peak systolic velocity/ end-diastole velocity (SD ratio), resistance index (RI), pulsatility index (PI, based on mean blood flow velocity Vmean), etc. (**Fig. 13**).

The laterality of end-diastolic velocity (EDV) (ratio of higher velocity/lower velocity; ED ratio) is also useful in some cases, and individuals with this ratio of CCA over 1. 3 - 1. 4 are likely to have distal obstruction or intense stenosis on the lower EDV side (ICA obstruction suggested in cases where this ratio is over 4).

[Footnote] Mean blood flow velocity can be calculated in two ways. One is TAVmean, which is the average of time-average velocity (TAV) calculated by tracing the mean velocity pattern per pulse. The other is Vmean (time average of maximum velocity) calculated by tracing the maximum velocity pattern per pulse.

3. 7 Evaluation of stenosed lesions

1) Calculation of percent stenosis

Like angiographic evaluation of stenosis, ultrasound evaluation of stenosis involves quantitative evaluation on the basis of calculation of percent stenosis.

Because ultrasonography allows simultaneous observation of vascular lumen and wall, unlike angiography, the past method of measuring percent stenosis was based on the diameter stenosis rate (ECST method, **Fig. 14**) and the area stenosis rate. However, for evaluation of stenosis of the internal carotid artery which is more likely to develop stenosis, NASCET method (**Fig. 14**) is now used frequently. With NASCET method, the criterion vascular diameter is the diameter of the intact area of the internal carotid artery distal to the stenosed area where the anterior wall is parallel to the posterior wall and the diameter is stable (**Fig. 14, b**).

Because different methods are available for calculation of percent stenosis, the method adopted needs to be specified in each report.

For measurement of the vascular internal diameter to calculate percent stenosis, B-mode ultrasound image is used, as far as possible. In cases where B-mode image is difficult to obtain and the blood flow depicted by the color Doppler method is used as a guide for calculation of percent stenosis, the data should be labeled as "reference data."

2) Method for calculation of percent stenosis on irregularly stenotic area

The stenotic lumen of peripheral blood vessels often assumes irregular forms (e.g., oval or half moon forms), making it difficult to make appro-

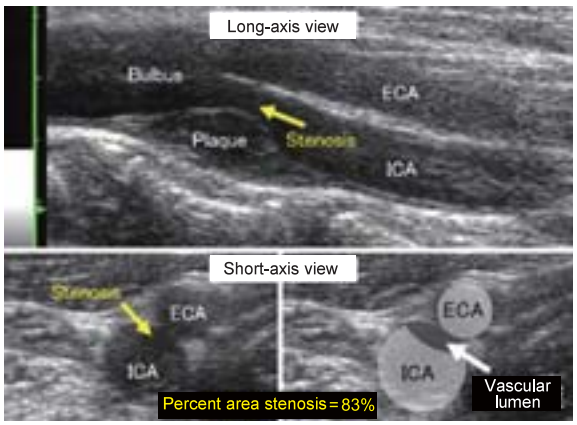


Fig. 15 Methods for calculating percent area stenosis (long-axis view / left : the proximal side)

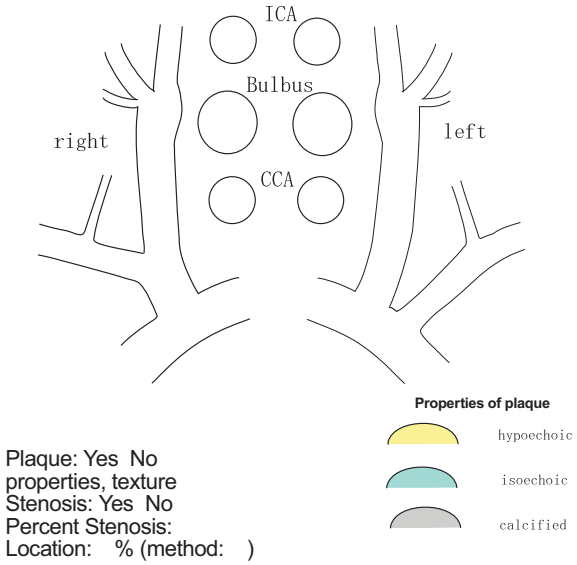
priate evaluation on long axis view. For this reason, when evaluating stenotic area on two-dimensional ultrasound images, area stenosis rate is also measured on short-axis view, whenever possible (**Fig. 15**).

3) Estimation of percent stenosis by Doppler method

In cases where two-dimensional ultrasound images of the stenotic area are difficult to take because of calcification or other reasons, percent stenosis may be estimated on the basis of peak systolic velocity (PSV), end-diastolic velocity (EDV), etc., by taking records of blood flow through the common carotid artery, stenotic area and post-stenotic part of internal carotid artery with pulse Doppler or continuous wave Doppler method.

If PSV of the stenotic area exceeds 1. 5 m/sec, NASCET percent stenosis is estimated to be 50 % or higher. If PSV is over 2 m/sec, NASCET percent stenosis is estimated to be 70 % or hgiehr.

In cases of severe stenosis, the blood flow distal to the stenotic area may show AcT prolongation or turbulent flow.



Figure/Reference: An example of report format for ultrasound findings of carotid artery

Reference: Reporting the results of ultrasound evaluation of carotid artery

When reporting the results of ultrasound evaluation of the carotid artery, it is advisable to attach graphic representation (figure or reference) of presence/absence and properties of lesions to ensure correct and easily understandable reporting to the physician who order imaging or to the attending physician.

Remarks

This standard evaluation method is based on the reports and clinical practice as of 2006. The standard may require modification based on forthcoming research findings and reports in the future.

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