THE SOCIETY FOR VASCULAR TECHNOLOGY OF GREAT BRITAIN AND IRELAND

Vascular Technology Professional Performance Guidelines

Duplex Ultrasound Examination of Mesenteric Arteries in Adults

This guideline was prepared by the Professional Standards Committee (PSC) of the Society for Vascular Technology (SVT) to aid the clinical vascular scientist / vascular sonographer and other interested parties. This guideline may be used in part or in its entirety with suitable additions made by local policy implementors. Suggestions for improving this guideline are welcome and should be sent to the Chair of the PSC; see www.svtgbi.org.uk for current Chair details.

Purpose

Duplex ultrasound is used to assess the splanchnic arteries (coeliac axis (CA), superior mesenteric artery (SMA) and inferior mesenteric (IMA)) for stenosis or occlusion in suspected mesenteric ischemia.

This guide can be used in conjunction with local protocols agreed between sonography and vascular departments. All flow data for stenoses should be locally validated.

Common Indications

- rapid weight loss
- chronic post prandial pain (mesenteric angina)
- acute, intermittent abdominal pain (suspected CA compression)
- post mesenteric angioplasty, stent or bypass graft.

Contraindications and Limits

- patients with symptoms of severe mesenteric ischaemia should not be given a post prandial test
- obesity / bowel contents
- breathing difficulties
- recent abdominal surgery
- multiple mesenteric artery disease
- patients unable to cooperate due to impaired cognition (*e.g.* dementia) or from involuntary movements.

Equipment

Duplex Doppler ultrasound machine with imaging frequencies of 3.0 to 7MHz and Doppler frequencies of at least 5.0MHz, with colour and power Doppler capability. Linear and curvilinear transducers should be available. Equipment should be able to record images.

Compliance with the Medical Devices Directive is necessary. Electrical safety testing is required annually, with regular maintenance and quality assurance testing to a specified level by qualified personnel. Review of equipment should typically be undertaken four to six years after installation.[1]

The examination couch should be height and tilt adjustable. The Clinical Vascular Scientist's (CVS) chair should provide good lumbar support, be height adjustable and allow the CVS to move close to the examination couch.[2,3]

The examination room should be temperature controlled with adjustable lighting suitable for the examination.[4] Suitable cleaning materials should be available and used in line with manufactures' guidelines.[2]

Explanation of Examination and Patient History

The CVS undertaking the examination should introduce themselves, confirm the patient's identity (*e.g.* full name and date of birth), and explain the procedure, why it is being performed and its duration. Consideration should be made to the patient's age and mental status, and consent for the examination should be obtained. Relevant medical history should be taken and suitability for the examination assessed.

Examination and General Technique

Due to the intimate nature of the examination it may be necessary to offer a chaperone.[5] During the examination, monitor the patient's mental and physical status and modify the examination accordingly.

To minimise bowel gas, fast overnight and perform the scan in the morning.[9] Digestion increases flow in mesenteric vessels, and fasting will remove this influence on PSV and EDV, usually allowing the effects of a stenosis to be more clearly noted. At least six hours' fasting is recommended,[7] taking only clear fluids or minimal food where medically appropriate.

Patients with symptoms of severe mesenteric ischaemia should not be given a post prandial test, as this will cause additional discomfort; only a fasting scan should be performed.

All clothes are removed from the abdomen. The arms rest by the sides to relax abdominal muscles, and the examination couch is tilted head up to tip the viscera away from the CA.[9] The patient can breathe normally. If anterior images are obscured by bowel, lateral decubitus (oblique) imaging may be required. In females, better images may be obtained laterally through the liver window, as the costal margin angle is more obtuse than in males.[8]

Mesenteric artery stenosis is typically diagnosed using PSV, EDV and post-prandial changes to SMA flow. Symptomatic ischemia is generally thought to be caused by at least two severely affected mesenteric arteries.[23] With the exception of testing the CA for compression at the diaphragm,[6] all three arteries should be examined.[23] All vessels must be imaged in transverse and longitudinal sections.

- B-mode, colour, power and spectral Doppler should be used to:

    - ascertain anatomy (may be atypical)
    - determine presence / absence of flow and its direction (possibly including CA branches)
    - identify abnormal flow, quantify stenoses, identify occlusions

Using a Doppler angle ≤60º and a small sample volume in the central jet of flow, slowly pass along length of the vessel from aorta to well into the mesenteric vessel. The CA may be seen rising at a shallow angle, often at 0 to 30º [11]; the SMA is best identified longitudinally; the IMA is usually seen transversely as it arcs to the left. Spectral Doppler should be used to record PSV and EDV. A mid to high wall filter (50 to 100Hz) may be required.

Pushing the abdomen out may move the left lobe of the liver caudally, enabling better visualisation of the CA and SMA as they elevate.

Pathology encountered includes AAA, visceral artery aneurysm, atheroma, thrombus, vasculitis (often difficult to determine), stenoses with focally raised PSV and EDV, dampened and turbulent post stenotic flow (made worse after a meal), and occlusion.

Grading Stenoses

All values below relate to vessel origins, with velocities generally recorded after exhaling during relaxed breathing. Because of the extensive potential for collateralising, there are no absolute criteria for normal and abnormal mesenteric arteries.

1. Normal Values

		PSV cm/s	EDV cm/s	Flow characteristics
CA	Fasting	<200 [18] 90 - 110 [11] 148 [12]	40 [12]	Low resistant waveform PSV <SMA EDV >SMA No significant post prandial change
SMA	Fasting	95 - 150 [11] 125 - 170 [9, 18] 161 [12]	29 [12] 12 - 32 [18]	High resistant (sometimes triphasic) waveform
	Post-prandial	Minimal increase in PSV	At least doubling of EDV [18] (>50cm/s)	Low resistant, hyperaemic type waveform with high diastolic flow
IMA		93 - 189 [19] Up to 190 [20] 93 - 180 [23] 70 - 200 [22]	0 - 32 [22]	High resistant waveform No significant post prandial change

Table 1: selected velocity parameters for normal mesenteric artery origins.

Note: If the right hepatic artery arises off the SMA, the fasting SMA waveform will show low resistance as it is supplying the liver, as well as the gut.[11]

2. Abnormal Vessels

A number of studies quote PSV and EDV values for >50% and >70% stenosis by diameter reduction, considering them diagnostically dependable for these lesions. However, PSV and EDV cannot reliably stratify stenoses that grade below 70% in fasted and post-prandial patients.[18]

For all mesenteric arteries, the PSV is generally considered the single best parameter for grading all degrees of stenosis, and for the SMA the emphasis appears to be on >70% being generally more reliable (greater sensitivity, specificity, negative and positive predictive values.)[11,12]

A >70% mesenteric artery stenosis is said to be always flow limiting (but not always symptomatic) and may represent the stage at which collateral flow develops in response to significant alteration in mesenteric flow.[7] Retrograde flow in the common hepatic artery strongly suggests a high grade CA stenosis or occlusion, as the spleen is 'stealing' flow.[13]

Generally, there is little or no post prandial change to flow in the CA or IMA after eating, but if fasting SMA velocities are equivocal (neither clearly normal nor >70% stenosed), eating a solid, high calorie meal (≥350Kcal; ideally mixed fat, protein and carbohydrate[9]) should raise velocities well into the stenotic range if a severe SMA stenosis is present. The vessel should be rescanned around 30 to 45 minutes after eating. Doing both tests may very effectively rule out a severe SMA lesion.[10]

Even if a stenosis is not present, SMA PSV and EDV should rise, but a severe stenosis will greatly raise PSV and EDV and cause greater downstream dampening of flow compared with fasting flow patterns. Failure of SMA PSV to increase 20 to 30 minutes after eating may indicate very severe stenosis, but this observation requires further study to corroborate.[11]

If a fasting SMA scan has shown a >70% stenosis, post-prandial testing is not necessary as it only marginally improves sensitivity and specificity (but not accuracy) in grading severe SMA stenoses.[19]

SMA÷aorta ratios of >2.5[6] or 3.0[11] are considered abnormal but no better than SMA PSV or EDV for grading stenosis.[9,12] However, a mesentero-aortic ratio of >2.5 to 3.0 in <u>any</u> mesenteric artery may be useful in indicating >50% stenosis where there is abnormally high or low aortic or mesenteric PSV (*e.g.* cardiogenic.) [11,22,23]

PSV/EDV ratios are not considered useful for predicting high-grade stenosis.[9]

3. SVT Recommended Guideline

	Normal		≥70% stenosis		Abnormal flow characteristics	Reference
	PSV	EDV	PSV	EDV		
CA	90 - 200	30 - 40	≥200	>55	High velocity antegrade flow in systole and diastole Dampened, turbulent post stenotic flow High resistant waveform with low PSV or very low or absent EDV Possible reverse flow in common hepatic artery if very severely stenosed	9, 11, 12, 18
SMA Fasting Post-prandial	125 - 170 Increases, but <<275	0 - 29 1.5 to 3 fold increase	> 275 - 300 Greatly increased	>55 Greatly increased	High velocity antegrade flow in systole and diastole Dampened, turbulent post stenotic flow, particularly post-prandial High resistant waveform with low PSV or very low or absent EDV if very severely stenosed Low resistant fasting SMA indicates ischaemia If post-prandial PSV and EDV do not increase, suspect very severe stenosis	9, 12,18, 25
IMA	90 to <200 Possible slight post prandial increase	0 to 33	>200	>25	High velocity antegrade flow in systole and diastole Dampened, turbulent post stenotic flow Very low PSV or high resistant waveform suggests very severe stenosis	11, 19, 20, 22, 23
Absence of flow in any mesenteric artery suggests occlusion						

Table 3: Recommended velocity criteria for normal and severely stenosed (≥70%) mesenteric artery origin. PSV and EDV in cm/s. Values selected from studies that have statistical significance, are currently in wide use, and show velocity ranges that generally concur with other studies.

General points:

- Normal fasting and post-prandial; all three mesenteric arteries should exhibit a PSV of >90cm/s but <200cm/s

- 70% CA stenosis PSV must measure at least 200cm/s, and EDV >55[11, 18]

- 70% SMA stenosis must have PSV of >275 - 300cm/s, and EDV of at least 45 – 55cm/s[11]

- SMA PSV <275cm/s effectively rules out a 70% stenosis[11, 18]

- IMA PSV >200cm/s indicates >70% stenosis[11]

- Mesentero-aortic ratio (MAR) of >2.5 to 3.0 may indicate >50% stenosis in any mesenteric artery.

If a stenosis is noted in a straight segment of the SMA or IMA beyond its origin, the following intra stenosis / pre stenosis velocity ratios can be used:

Velocity Ratio	Grade of Stenosis
<2	<50%
2	50%
>2 but <4	>50%
4	75%
>4	>75%

Table 4: Grading a stenosis in a straight mesenteric artery segment distal to its origin.

Factors affecting diagnostic accuracy:

A <70% stenosis in one mesenteric artery will not significantly alter flow in another.[7] However, if one or more mesenteric artery is severely stenosed (>70%), if there are anatomic anomalies of the arteries, or if significant compensatory collateral flow has occurred, diagnostic accuracy is reduced as PSVs and EDVs in a normal / least affected artery will be nominally higher, either mimicking or overestimating a stenosis.[11,7]

For example, the combination of a >70% CA stenosis and well developed mesenteric collaterals raises the PSV and EDV of an angiographically normal SMA into the stenosed range (≥ 259cm/s), mimicking a stenosis. The effect on SMA flow increases with worsening CA lesion. A severe SMA stenosis similarly affects flow in the CA.[7]

Post prandial velocities in the normal CA has been shown rise into the abnormal range if it is providing significant collateral flow.[11]

Forced exhaling has been shown to significantly raise PSV in the CA and SMA compared with forced inhaling, in both normal patients[17] and those with severe stenoses.[8] This increase may be as high as 25%.[17] Both vessels may require investigation in both phases of respiration.
Flow in a normal IMA may show a high volume, low resistant waveform in SMA occlusion. This effect corresponds with the degree of collateralising.[22]

Other compounding factors include applying an inaccurate Doppler angle, difficulty assessing tortuous vessels, and placing a Doppler sample gate outside the centre of flow.

Bypass grafts and Stents

There are no standard duplex criteria for SMA bypass grafts or stents.[7,13,16] All velocities must be used with caution and locally validated. Velocities in CA and SMA stents and grafts tend to be greater than those in a native vessel.[13]

Even in a normal SMA stent, velocities may correspond with a >70% native vessel stenosis,[16] and the average PSV of an SMA stent does not significantly change over one year post insertion.[26]

In addition, velocities in a stent may be greater still when another mesenteric artery is severely diseased.[7] As a result, post prandial stent testing has been recommended to assess intra and post stent flow.[11]

Criteria in the literature include:

Graft cm/s	Stent cm/s
Normal PSV 150 – 200 [11]	Normal PSV < 250 [11] CA: >50% PSV >274 EDV 58 MAR 3.5[13] >70% PSV 363 EDV 105 MAR 5.7[13] >70% PSV >300 EDV >100 SMA: >50% PSV >325 EDV 30 MAR 3.4[13] >70% PSV 412 EDV 110 MAR 8.4[13] SMA restenosed if PSV >400 if symptoms have returned [26] SMA restenosed if pre stent PSV doubles, or stent PSV approaches 500 regardless of symptoms [26]

Graft or Stent cm/s
CA: suspect severe stenosis if PSV >250, EDV >45
CA / SMA: suspect >70% stenosis if PSV >300 or <40, or if EDV >50 - 70cm/s [21]
Significantly dampened post stenotic flow always indicates >70% stenosis [11]
PSV and EDV are of equal value in predicting >50% and >70% stenoses[13]

Table 5: Stent and graft values. All values under fasting conditions.

Median Arcuate Ligament Syndrome (MALS, or Dunbar's syndrome)

A rare mesenteric ischaemia of unknown cause, thought to be caused by transient, frequent compression (stenosis) and / or deviation of the CA and a nerve plexus by the arcuate ligament of the diaphragm, especially during deep exhalation where intermittent tight stenosis or occlusion can occur.

Flow may normalise when inhaling (normalised flow) as the diaphragm descends away from the CA, or when standing erect as the CA descends into the abdomen away from the MAL.[27]

When exhaling, severe compression of the CA may also severely dampen flow in the hepatic and splenic arteries.

An intralumenal CA stenosis elevates PSV and EDV when inhaling and exhaling when supine. However, MALS has been shown to generally elevate CA PSV when exhaling, not usually when inhaling.[27]

Therefore, if a CA stenosis is suspected when inhaling and exhaling supine, scanning the CA when erect can correctly distinguish between intralumenal stenosis of the CA and MALS; if flow normalises when erect, MALS is diagnosed. Since exhaling can raise velocities in the CA and SMA, it may be necessary to record PSV during relaxed exhalation to minimise negative (inspiratory) results.[17]

Gruber *et al* showed a combination of maximum expiratory PSV of >350cm/s and a CA deflection angle of >50° (from end of deep inhalation to end of deep exhalation) always indicated MALS.[14] They also noted an increase in CA PSV amplitude of 250% between inhaling and exhaling indicated MALS.

The diaphragm can cause a characteristic concavity on the cranial surface of the CA during compression,[15] just beyond its origin, which normalises when standing.[27]

Another parameter indicating MALS is a reduction in aorto-SMA angle, from around 45 to 65° to <25°, during forced respiration. [14,15]

Due to the complexity of the condition, a better overall assessment of MALS may be obtained using 2D and 3D CTA.[14,15] All criteria require local validation.

Reporting

The report is a record of observations and interpretations made during the duplex ultrasound examination. It should be written by the CVS undertaking the examination and viewed as integral to the whole examination[4].

The report should include:

- correct patient details; examination type and date; name and status of CVS
- which vessels were examined
- presence, location and degree of any abnormality; flow characteristics;
- anything limiting the examination
- a note of any follow up or referral as a result of the scan
- an appropriate number of annotated images representing the entire examination, in accordance with local protocols and SVT Image Storage Guidelines.[4]

Referral of critical results should be made to the referring consultant or appropriate medical / surgical team (as per local protocol), so treatment plans can be developed, enforced or expedited accordingly.

REFERENCES:

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APPENDIX

	Grade of stenosis (fasting)	PSV cm/s	EDV cm/s	Flow characteristics	Reference
CA	>50%	>200	55	High velocity antegrade flow in systole and diastole	24
	>50%	≥240	>40		12
	>70%	>200	>55		11, 9, 18
	70%	>250	>45	Dampened, turbulent post stenotic flow	11
	>70%	280 (exhale) 272 (inhale)	57 84		8 8
	70%	>320	≥100	Very low or absent EDV	12
SMA	>50%	≥295	>45	As above	12, 13
	>50%	>300	>45		11, 24
	>70%	268 (exhale) 205 (inhale)	101 52		8 8
	>70%	>275 - 300	>55		9, 18
	>70%	≥400	≥70		12, 13
IMA	>50%	>200	>25	As above	11, 22, 23
	>70%	>270			12
Absence of flow in any mesenteric artery suggests occlusion					

Table 6: selected velocity parameters for abnormal mesenteric artery origins, during fasting conditions.