THE SOCIETY FOR VASCULAR TECHNOLOGY OF GREAT BRITAIN AND IRELAND

Vascular Technology Professional Performance Guideline

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) as a template to aid the clinical vascular scientist / vascular sonographer and other interested parties. It can be used in part or in its entirety with suitable additions made by local policy implementors, and should be read in combination with the following SVT guidelines when setting up a mesenteric artery scanning service:

- Vascular Ultrasound Service Specifications[2]

Suggestions for improving this guideline are welcomed 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 artery (IMA)) for stenosis or occlusion in suspected chronic mesenteric ischemia. 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, since this exacerbates existing discomfort
- obesity / bowel contents
- breathing difficulties
- recent abdominal surgery
- multiple diseased mesenteric arteries
- patients unable to cooperate due to impaired cognition (*e.g.* dementia) or from involuntary movements.

Patient pathway
These investigations apply to patients with suspected chronic mesenteric ischemia and those with suspected compression or deviation of the CA.

Patient referral
The referral should include specific details on symptoms and duration. These are complex scans and having as much information as possible will aid the investigation.[1]

Patient preparation
Investigations should be scheduled to minimise the number of hospital visits. Due to the intimate nature of the examination it may be necessary to offer a chaperone.[4]

To minimise bowel gas, fast overnight and perform the scan in the morning.[8] 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,[6] taking only clear fluids or minimal food where medically appropriate.

Examination
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.

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.[22] With the exception of testing the CA for compression at the diaphragm,[5] all three arteries should be examined.[22] All vessels must be imaged in transverse and longitudinal sections.

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

    - ascertain anatomy (may be atypical)
    - determine presence / absence of flow and its direction (possibly including CA branches)
    - identify abnormal flow and quantify stenoses
    - identify partial filling defects and full occlusion.

<u>General Technique</u>

All clothes are removed from the abdomen. 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.[8] 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.[7]

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 chosen mesenteric artery. The CA may be seen rising at a shallow angle, often at 0 to 30º; [10] the SMA is best identified longitudinally; the IMA is usually seen transversely as it arcs to the left of the body. 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 [17] 90 - 110 [10] 148 [11]	40 [11]	Low resistant waveform PSV <SMA EDV >SMA No significant post prandial change
SMA	Fasting	95 - 150 [10] 125 - 170 [8, 17] 161 [11]	29 [11] 12 - 32 [17]	High resistant (sometimes triphasic) waveform
	Post-prandial	Minimal increase in PSV	At least doubling of EDV [17] (>50cm/s)	Low resistant, hyperaemic type waveform with high diastolic flow
IMA		93 - 189 [18] Up to 190 [19] 93 - 180 [22] 70 - 200 [21]	0 - 32 [21]	High resistant waveform No significant post prandial change

Table 1: selected velocity parameters for normal mesenteric arteries.

Note: If the right hepatic artery arises off the SMA, the fasting SMA waveform will show low resistance as it is also supplying the liver.[10]

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.[11] However, PSV and EDV cannot reliably stratify stenoses that grade below 70% in fasted or post-prandial patients.[17]

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.)[10,11]

A >70% mesenteric artery stenosis is said to be always flow limiting (but not always symptomatic[11]) and may represent the stage at which collateral flow develops in response to significant alteration in mesenteric flow.[6] Retrograde flow in the common hepatic artery strongly suggests a high grade CA stenosis, or occlusion, since the spleen is 'stealing' flow.[14]

Generally, there is little or no post prandial change to flow in the CA or IMA, 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[8]) should raise velocities well into the stenotic range if a severe SMA stenosis is present. The 'fasted' SMA should be rescanned around 30 to 45 minutes after eating. Performing both tests should very effectively rule out a severe SMA lesion.[9]

Even if an SMA stenosis is not present, post prandial SMA PSV and EDV should rise, but a severe stenosis will greatly raise both, 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.[10]

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.[18]

SMA ÷ aorta PSV ratios of >2.5[6] or 3.0[10] are considered abnormal, but no better than SMA PSV or EDV for grading stenosis.[8,11] However, a mesenteric ÷ aorta PSV ratios of >2.5 to 3.0 in <u>any</u> mesenteric artery may be useful in indicating >50% stenosis where there is an abnormally high or low aortic or mesenteric PSV (*e.g.* cardiogenic.)[10,21,22]

PSV ÷ EDV ratios are not considered useful for predicting high-grade stenosis.[8]

3. SVT Recommended Criteria

	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	8, 10, 11, 17
SMA						8,11,17, 24
Fasting	125 - 170	0 - 29	> 275 - 300	>55	High velocity antegrade flow in systole and diastole Dampened, turbulent post stenotic flow, particularly post-prandial	
Post-prandial	Increases, but <<275	1.5 to 3 fold increase	Greatly increased	Greatly increased	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	
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	10,18, 19, 21, 22
Absence of flow in any mesenteric artery suggests occlusion						

Table 3: Recommended velocity criteria for normal and severely stenosed (≥70%) mesenteric artery. 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 be at least 200cm/s, and EDV >55[10, 17]

- 70% SMA stenosis must have PSV of >275 to 300cm/s, and EDV of at least 45 to 55cm/s[10]

- SMA PSV <275cm/s effectively rules out a 70% stenosis[10, 17]

- IMA PSV >200cm/s indicates >70% stenosis[10]

- 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.[6] 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 or the least affected artery will be nominally higher, either mimicking or overestimating a stenosis.[10,6]

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.[6]

Post prandial velocities in the normal CA have been shown rise into the abnormal range if it is providing significant collateral flow.[10]

In both normal patients[16] and those with severe stenoses,[7] forced exhaling has been shown to significantly raise PSV in the CA and SMA compared with forced inhaling. This increase may be as high as 25%.[16] It has been suggested vessels are assessed in both phases of respiration.

Flow in a widely patent IMA may show a high volume, low resistant waveform in the presence of SMA occlusion. This effect on IMA flow corresponds with the extent of collateralising present.[21]

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.[6,12,15] 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.[12]

Even in a normal SMA stent, velocities may correspond with a >70% native vessel stenosis,[15] and the average PSV of an SMA stent does not significantly change over one year post procedure.[25]

In addition, velocities in a stent may be greater still when another mesenteric artery is severely diseased.[6] As a result, post prandial stent testing has been recommended to assess intra and post stent flow.[10]

Criteria in the literature include:

Graft cm/s	Stent cm/s
Normal PSV 150 - 200 [10]	Normal PSV < 250 [10] CA: >50% PSV >274 EDV 58 MAR 3.5 [12] >70% PSV 363 EDV 105 MAR 5.7 [12] >70% PSV >300 EDV >100 SMA: >50% PSV >325 EDV 30 MAR 3.4 [12] >70% PSV 412 EDV 110 MAR 8.4 [12] SMA restenosed if PSV >400 if symptoms have returned [25] SMA restenosed if pre stent PSV doubles, or stent PSV approaches 500 regardless of symptoms [25]

Graft or Stent cm/s	
CA or SMA:	suspect >70% stenosis if PSV >300 or <40, or if EDV >50 - 70cm/s [20]
CA:	suspect severe stenosis if PSV >250, EDV >45
Significantly dampened post stenotic flow always indicates >70% stenosis [10]	
PSV and EDV are of equal value in predicting >50% and >70% stenoses [12]	

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

Median arcuate ligament syndrome (MALS or Dunbar's syndrome)

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

Flow may normalise when inhaling, since the diaphragm descends away from the CA, or when standing erect as the CA descends into the abdomen away from the MAL.[26]

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.[26]

Therefore, if a CA stenosis is suspected when inhaling and exhaling supine, scanning the CA when erect can correctly distinguish a CA stenosis from 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.[16]

Gruber *et al* showed a combination of maximum expiratory PSV of >350cm/s and a CA deflection angle of >50° (from end deep inhalation to end deep exhalation) always indicated MALS.[13] 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. [13,14]

Due to the complexity of the condition, a better overall assessment of MALS may be obtained using 2D and 3D CTA.[13,14] All criteria require local validation.

Reporting

The report should include:

- correct patient details; examination type and date; name and status of CVS
- which vessels were examined
- anything limiting the examination
- presence, location and extent of any abnormality; flow characteristics;
- 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.[3]

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:

[1] Guidelines for Professional Working Standards Ultrasound Practice; United Kingdom Association of Sonographers (UKAS) October 2008 www.sor.org/learning/document-library

[2] Vascular Ultrasound Service Specifications. www.svtgbi.org.uk

[3] Society for Vascular Technology Professional Standards Committee Image Storage Guideline April 2012 www.svtgbi.org.uk

[4] Society for Vascular Technology Professional Standards Committee Chaperone Guidelines April 2012 www.svtgbi.org.uk

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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	Dampened, turbulent post stenotic flow	11, 9, 18
	70%	>250	>45		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 arteries, during fasting conditions.