Core Modality 2								
Scan Number	**Date**	**Patient Hospital Number**	**Scan type**	**Pathology (Y/N)**	**Aided (A)/ Unaided (U)**	**Agreement with supervisor? Y/N**	**Comments, learning points, etc.**	**Supervisor**
1	February 08, 2024	RRKS612406	Left Leg Arterial Scan	Y	U	Y	US Doppler lower limb arteries Lt: Diffused intima thickening with minimal calcified plaque formation throughout. The CFA, PFA origin, SFA and popliteal arteries were patent with multiphasic flow signal (biphasic/triphasic). Diseased AT with multiple detected narrowing however remained patent with biphasic flow signal throughout. Diseased PT and peroneal artery but patent with biphasic flow signal from proximal to mid segment. Both the distal PT and peroneal arteries showed thready like flow to completely occluded segments but collateral flow was seen trying to supply flow to main distal PT and peroneal arteries.	Ivan Kalik
2	February 08, 2025	RRKK940691	Right Leg Arterial Scan	N	U	Y	US Doppler lower limb arteries Rt: The CFA, PFA origin and SFA were patent with triphasic waveforms throughout. The interposition graft popliteal artery was patent throughout with multiphasic flow (biphasic/triphasic). Smaller lumen diameter at the proximal anastomosis but currently not causing great impact in the flow within the lumen of the graft and no PSV ratio increase of >2.0 therefore will grade this as <50% stenosis. CONCLUSION Patent interposition graft popliteal artery with multiphasic flow (biphasic/triphasic). Patent arterial tree with multiphasic flow (biphasic/triphasic).	Ivan Kalik

3	February 7, 2024	RRKK546229	Right Leg Arterial Scan	N	U	Y	US Doppler lower limb arteries Rt: Patent with triphasic flow signal in the EIA and CFA. Distal CFA measures 18.3 mm just before proximal anastomosis insert of the graft. The graft was patent throughout with good triphasic flow velocities. Ectatic sausage shaped appearance measuring 11.2 mm in max AP at the distal body of the graft. The graft however remained well patent throughout with good triphasic flow signal. Patent normal dilated appearance of the distal anastomosis hood with no evidence of hemodynamic significant stenosis. Patent AT to the ankle with triphasic flow velocities. CONCLUSION Patent well-functioning femoral-AT graft throughout. Patent AT with triphasic flow signal to the ankle.	Ivan Kalik
4	February 7, 2025	RRKK686195	Right Leg Arterial Scan	Y	U	Y	US Doppler lower limb arteries Rt : *Challenging assessment due to involuntary twitching of legs.* Widespread calcifications throughout. The CFA and PFA were patent with good triphasic flow velocities. The SFA was patent throughout with increased EDV flow secondary to decreased wall resistance. Diseased popliteal artery proximally but patent. The distal half of the popliteal artery showed multiple narrowing and very thready flow that is suggestive of near total occlusion. Very diseased crural vessels that showed thready flow throughout. Collaterals were seen surrounding main crural vessels with some collaterals seen directly communicating to main vessels trying to maintain flow within lumen. Reduced flow velocities with dampened monophasic waveform from distal half of popliteal artery down to the trifurcation. CONCLUSION Severely diseased distal half of popliteal artery down to the arterial tree	Ivan Kalik

5	February 6, 2024	RRKK919616	Right Leg Arterial Scan	Y	U	Y	US Doppler lower limb arteries Rt: The graft is seen to insert from the superficial femoral artery to the TPT/PT origin distal anastomosis. Patent triphasic flow signal in the CFA and SFA before the proximal anastomosis insert of the graft. Occluded graft throughout from end-to-end anastomosis of mixed echogenic densities predominantly hypoechoic. Flow in PT is coming from the collateral before the distal anastomosis insert. Patent PT throughout with dampened monophasic waveform. CONCLUSION Occluded end to end anastomosis graft.	Ivan Kalik
6	February 6, 2024	RRKK448312	Left Leg Arterial Scan	Y	U	Y	US Doppler lower limb arteries Lt: Diffused intima thickening with widespread calcifications throughout. The distal CFA at the bifurcation area showed increased PSV ratio of >2.0 and flow becomes reduced with monophasic waveforms throughout distally. The SFA showed increased PSV ratio of >4.0 (82 cm/sec to 595 cm/sec) in the mid segment. The popliteal artery and trifurcation vessels are all well patent however with reduced flow velocities and monophasic waveforms to the ankle. Patent PFA with triphasic flow signal. CONCLUSION >50-74% narrowing in the CFA at the bifurcation level. Reduced flow velocities with monophasic waveforms throughout distally. >75% narrowing of the mid SFA. SFA appeared severely calcified in the mid-distal segments.	Ivan Kalik

7	February 6, 2024	RRKK197989	Right Leg Arterial Scan	Y	U	Y	US Doppler lower limb arteries Rt : Widespread intima thickening with minimal plaque formations throughout. The CFA,PFA origin, SFA, popliteal and TPT were patent with multiphasic (biphasic/triphasic) flow velocities.PT was occluded with flow reconstitution in the distal segment via collateral. Peroneal artery showed multi narrowing of <50% but patent throughout with multiphasic (tri/bi) waveforms. Proximal half AT was heavily diseased with minimal short occlusions but distal AT was patent with minimal narrowing of <50% and flow was multiphasic (bi/tri).	Ivan Kalik
8	February 6, 2024	RRKS695884	Right Leg Arterial Scan	Y	U	Y	US Doppler lower limb arteries Rt: Widespread intima thickening with minimal plaque formations throughout. The CFA and PFA were patent with triphasic flow velocities. The SFA was well patent throughout with slightly reduced luminal diameter in the mid/distal SFA segment d/t thickened intima but no evidence of significantly raised PSV. The popliteal artery and TPT were patent with triphasic flow velocities. Proximal PT was diseased with minimal flow and mid PT was occluded. The distal PT appeared patent due to collateralization however, the flow was reverse monophasic instead of antegrade which suggest that PT has been previously occluded before. Short occlusion in the proximal peroneal. The mid to distal peroneal was patent with triphasic flow velocities. Patent AT with triphasic flow velocities.	Ivan Kalik

9	February 6, 2024	RRKV736568	Left Leg Arterial Scan	Y	U	Y	US Doppler lower limb arteries Rt: Widespread calcifications throughout. Increased PSV ratio of >4.0 in the distal CFA at the bifurcation level (pre-stenotic-70 cm/sec; Stenotic- 460 cm/sec). Flow distally becomes monophasic with reduced velocities. Patent PFA origin with no significant stenosis. Slightly diseased SFA and popliteal arteries but patent with dampened monophasic waveforms throughout. Diseased AT but patent with dampened monophasic waveform. Heavily diseased PT with minimal short segmental occlusions noted with minimal collaterals. Not assessed peroneal. CONCLUSION >75% stenosis in the distal CFA/SFA origin. Severely diseased crural vessels. Diseased but patent AT. Minimal short segment occlusions in the PT w/minimal flow seen within lumen via collaterals.	Ivan Kalik
10	February 6, 2024	RRKV383462	Left Leg Arterial Scan	Y	U	Y	US Doppler lower limb arteries Lt: Diffused intimal thickening with minimal plaque formations throughout. The CFA, PFA origin, SFA, popliteal arteries and TPT were patent with triphasic flow velocities. Multi narrowing seen in the PT but patent with triphasic waveforms throughout. The peroneal artery was occluded few centimeters distal from the origin and remains occluded to the mid segment level with flow reconstitution distally. The distal peroneal artery appeared to have triphasic/pulsatile hyperemic waveform. Proximal to mid AT was occluded and remains occluded despite of the many collaterals directly communicating with the vessel. The most distal AT above ankle however has showed minimal flow within lumen via collateral with dampened monophasic PSV of 17.2 cm/sec.	Ivan Kalik

11	February 01, 2024	RRKV266770	Left Leg Arterial Scan	N	U	Y	US Doppler lower limb arteries Lt: Diffused intima thickening with widespread calcifications throughout. The CFA and PFA origin were patent with triphasic flow velocities. There was flow 2 cm distal to SFA origin and then it becomes occluded (chronic) to the mid-level segment of SFA. There was flow reconstitution at approximately 10-15 cm above knee level and flow was monophasic throughout distally. The popliteal artery was very diseased but patent. PT and peroneal arteries were occluded. AT proximal segment was very diseased with short segment of occlusion (chronic). AT mid to distal segment was diseased but patent with dampened monophasic flow.	Ivan Kalik
12	January 31, 2024	RRKK688216	Right Leg Arterial Scan	Y	U	Y	US Doppler lower limb arteries Rt: Widespread diffused intima thickening with calcifications throughout. Minimal calcifications in the CFA, PFA origin, SFA, popliteal and TPT but patent throughout with triphasic flow velocities. There was >75% stenosis in the proximal PT and distal flow becomes dampened monophasic but patent throughout. AT was occluded with very minimal flow in some segments via collaterals. Very minimal flow with occluded (chronic) segments in the proximal to mid peroneal artery and there were minimal collaterals seen. Distal peroneal artery above ankle was patent with dampened monophasic flow. Occluded DP.	Ivan Kalik
13	January 31, 2024	RRKK451495	Right Leg Arterial and Bypass	Y	U	Y	US Doppler lower limb arteries Rt: Slightly calcified CFA and PFA origin but patent with triphasic waveforms. The proximal anastomosis insert to CFA , the body of the graft and the distal anastomosis insert to PT was patent throughout with triphasic flow velocities. Native PT vessel distal to the anastomosis was slightly calcified but patent throughout with triphasic flow velocities. CONCLUSION Patent Fem-PT bypass graft	Ivan Kalik

14	January 31, 2024	RRKK688216	Right Leg Arterial Scan	Y	U	Y	US Doppler lower limb arteries Rt: Widespread diffused intima thickening with calcifications throughout. Minimal calcifications in the CFA, PFA origin, SFA, popliteal and TPT but patent throughout with triphasic flow velocities. There was >75% stenosis in the proximal PT and distal flow becomes dampened monophasic but patent throughout. AT was occluded with very minimal flow in some segments via collaterals. Very minimal flow with occluded (chronic) segments in the proximal to mid peroneal artery and there were minimal collaterals seen. Distal peroneal artery above ankle was patent with dampened monophasic flow. Occluded DP.	Ivan Kalik
15	January 30, 2024	RRKV212552	Left Leg Arterial Scan	Y	U	Y	US Doppler lower limb arteries Lt: Widespread calcifications throughout. The CFA and PFA origin are patent with triphasic flow signal. There is >75% stenosis in the proximal SFA. The mid SFA is occluded(chronic) with flow reconstitution in the distal SFA at approximately 10 cm above the knee area. Dampened monophasic flow throughout distally. The popliteal and TPT are patent with dampened monophasic flow velocities. The PT and peroneal are diseased but patent with dampened monophasic flow velocities. AT is occluded.	Ivan Kalik
16	January 29, 2024	RRKV501865	Left Leg Arterial Scan	Y	U	Y	US Doppler lower limb arteries Lt: Widespread heavy calcification and atheroma. The CFA, PFA origin, SFA and popliteal artery were patent with biphasic flow (hardened vessel). The ATA appeared heavily calcified and diseased throughout with numerous collaterals. Flow in the main vessel of mid AT showed reverse flow which signifies that it has been occluded previously but now minimally supplied by collaterals. The distal AT was monophasic. PTA was occluded as before.	Ivan Kalik

17	January 29, 2024	RRK7087054	Left Leg Arterial Scan	Y	U	Y	US Doppler lower limb arteries Lt: Heavy wide calcified vessels throughout. Patent with biphasic flow signals in the CFA, PFA origin and proximal SFA. There was 50-74% stenosis in the mid SFA and then the distal SFA becomes occluded (chronic) with flow reconstitution in the popliteal artery origin. Distal to this, the popliteal artery was patent with very reduced velocity and dampened monophasic flow. Distal PT and peroneal was patent with monophasic flow signal. Proximal AT appeared to have minimal monophasic flow however becomes occluded from mid to distal segment with collaterals noted.	Ivan Kalik
18	January 29, 2024	RRKK388099	Left Leg Arterial Scan	N	U	Y	US Doppler lower limb arteries Lt: Widespread intima thickening throughout. The CFA, PFA origin, SFA and popliteal arteries were all patent with good bi/triphasic flow velocities. The PT and AT were slightly diseased but patent throughout with bi/triphasic waveform velocities.	Ivan Kalik
19	January 26, 2024	RRKV778295	Left Leg Arterial Scan	Y	U	Y	US Doppler lower limb arteries Lt: Widespread calcifications throughout. Left iliac occlusion with mixed echogenicity appearance at approximately 4 cm in length with flow reconstitution at the level of external iliac artery. Diseased but patent CFA, SFA, PFA origin and popliteal arteries with dampened monophasic flow velocities throughout. Diseased but patent crural vessels with very dampened monophasic waveform and low flow velocities.	Ivan Kalik
20	January 26, 2024	RRKS908197	Right Leg Arterial Scan	Y	U	Y	US Doppler lower limb arteries Rt: The CFA, profunda origin, SFA and popliteal arteries were patent with triphasic flow signals. Occluded TPT of mixed echogenicity appearance. Occluded PT with mixed echogenicity predominantly hypoechoic appearance with evidence of minimal formation of collaterals. Peroneal was slightly diseased but patent with biphasic flow signals. Patent AT throughout that occludes 2-3 inches above the ankle level. DPA main vessel was occluded.	Ivan Kalik

21	January 26, 2024	RRKG623577	Left Leg Arterial Scan	Y	U	Y	US Doppler lower limb arteries Lt: The graft origin inserts at distal common femoral artery to mid PT segment of the calf. Good biphasic flow signal in the distal CFA. Patent graft with biphasic flow signal throughout proximal anastomosis to distal anastomosis. The PT segment distal to anastomosis site was patent with triphasic/pulsatile hyperemic flow. Patent AT proximal to distal segment with triphasic/pulsatile pulsatile hyperemic flow.	Ivan Kalik
22	January 26, 2024	RRKS745209	Left Leg Arterial Scan	Y	U	Y	US Doppler lower limb arteries Lt: Patent with biphasic flow velocities in the CFA, PFV origin and proximal to mid SFA. There is narrowing with increased PSV ratio of >2 (58 cm/sec to 188 cm/sec) in the mid/distal SFA therefore indicative of 50-74% stenosis and flow becomes monophasic throughout distally. Slightly diseased but patent popliteal artery with dampened monophasic flow.PT is occluded.AT is occluded and reconstitutes in the distal segment with monophasic waveform. Proximal peroneal artery is occluded and reconstitutes in the mid segment and flow continues distally with monophasic waveform.	Ivan Kalik
23	January 24, 2024	RRKK531536	Right Leg Arterial Scan	Y	U	Y	US Doppler lower limb arteries Rt: Diffused intima thickening with plaque formations throughout arterial segments of the right lower extremity. Heavily calcified distal CFA and PFA origin but patent with triphasic flow signal. Heavily calcified and diseased SFA throughout. The section of the distal SFA to proximal popliteal artery that was previously seen occluded 2 years ago has now showed evidence of collateralization and there was minimal flow throughout the main vessel however, it was poor monophasic flow with reduced peak systolic flow velocities. Very diseased crural vessels with evidence of collaterals but patent with monophasic flow signals throughout.	Ivan Kalik

24	January 18, 2024	RRKS540623	Left Leg Arterial Scan	Y	U	Y	US Doppler lower limb arteries Lt: Widespread calcifications throughout. Most proximal CIA not visualized due to bowel gas. Distal segment of CIA and EIA was patent with triphasic waveform and there was no evidence of significantly raised PSV that may suggest tight narrowing/stenosis despite of calcifications. There was increased PSV ratio of >4.0 noted in the CFA with PSV elevated from 56 cm/sec to 303 cm/sec. Low flow velocity with damp monophasic waveform distal to stenotic area extending to the proximal SFA. The mid SFA was chronically occluded with flow reconstitution in the distal segment via collateral but waveform remains monophasic with flow PSV of 15 cm/sec. Low flow continues throughout popliteal artery and distal calf vessels. Patent popliteal artery with damped monophasic waveform throughout. There were evidence of collaterals seen in the PT and AT segment which may indicate possibility that the main vessels could have almost been near totally occluded considering the very damped waveform and PSV values. However, at its current state, both PT and AT showed minimal color flow with detected minimal Doppler signal in spectral therefore confirming its patency throughout however waveform was very damped monophasic and flow velocities were low between PSV of 8-20 cm/sec (very diseased but patent). There was flow in the proximal PFA with no significantly raised PSV that suggest presence of tight stenosis despite of calcifications. CONCLUSION >75% stenosis in the CFA. Mid SFA occlusion (chronic). Crural vessel disease (PT and AT). Peroneal not visualized d/t shadowing secondary to calcification and considering vessel depth.	Ivan Kalik

25	January 12, 2024	RRKV680420	Right Leg Arterial Scan	Y	U	Y	US Doppler lower limb arteries Rt: Widespread calcifications throughout. The CFA and PFA origin were patent with triphasic waveform pattern. The proximal to mid SFA was patent with triphasic waveform pattern. The distal SFA showed increased PSV ratio of >2.0 (PSV elevated from 123 cm/sec to 388 cm/sec). Dampened monophasic with reduced PSV of 14 cm/sec distal to the stenotic area. The popliteal artery was patent however there was a focal narrowing which demonstrated increased PSV ratio of >4.0 (PSV elevated from 22 cm/sec to 695 cm/sec). Flow distally remains dampened with low velocities throughout. With ultrasound limitation: The PTA showed no colour filling in color mode that demonstrated minimal to no colour filling in power Doppler yet spectral Doppler was sensitive and displayed flow velocity of 15-22 cm/sec PSV from proximal to distal segment. There was flow seen in color mode with PSV of 56 cm/sec few cm from AT origin that went to minimal to no colour filling in power Doppler yet spectral Doppler was sensitive and displayed low flow velocities between 15-20 cm/sec PSV. The distal AT segment was consistent to absent color flow and Doppler signal.The proximal peroneal artery showed absent color flow and Doppler signal with flow detected in the mid segment via collateral but dampened monophasic. The distal peroneal artery unable to detect patency due to vessel depth and smaller calibre in size distally. CONCLUSION SFA- Patent with 50-75% stenosis Popliteal artery- Patent with 50-75% stenosis PT- Spectral Doppler demonstrated reduced dampened flow velocities from proximal to distal. AT- Spectral Doppler demonstrated reduced dampened flow velocities from proximal to mid AT. Distal AT occluded. Peroneal artery- Occluded proximally with low dampened flow in the mid via collateral and unable to visualized small calibre size peroneal distally.	Ivan Kalik

PROTOCOL USED FROM FEBRUARY 2016- JANUARY 2023

Abdominal Aorta and Arterial Lower Duplex Scan

- ✓ **This procedure covers EVAR scanning, aneurysm scanning**

SCOPE OF INSONATION

- ✓ **B-mode (Longitudinal View) with cross sectional and anterior posterior measurement** of the following segments:

- Proximal aorta
- Suprarenal aorta
- Celiac
- Superior Mesenteric Artery
- Inferior Mesenteric Artery (if visible)
- Infrarenal aorta
- Distal Aorta

- ✓ **Color Mode and Pulse Wave Doppler (Longitudinal View)** of the following segments:

- Proximal aorta
- Suprarenal aorta
- Celiac
- Superior Mesenteric Artery
- Inferior Mesenteric Artery (if visible)
- Infrarenal aorta
- Distal Aorta
- Right Common Iliac Artery
- Left Common Iliac Artery
- Right Renal Origin Artery
- Left Renal Origin Artery

NOTE: Color Power Angio is used/applied in the blood vessel segment where there is presence of significant finding or abnormality

For EVAR scanning in the aorta:

- ✓ Perform complete protocol of aorta Duplex scan
- ✓ Scan the stent B-mode (Measure proximal, mid and distal stent both cross sectional and anteroposterior wall
- ✓ Obtain Color Mode and Pulse wave Doppler (Measure proximal, mid and distal stent both cross sectional and anteroposterior wall
- ✓ Color Power Angio is used/applied in the blood vessel segment where there is presence of significant finding or abnormality

For Aneurysm scanning in the aorta:

- ✓ Perform complete protocol of aorta Duplex scan
- ✓ Locate aneurysm
- ✓ Measure cross sectional and anterior posterior wall of the aneurysm in B-mode
- ✓ Measure neck
- ✓ Color Mode and Pulse Wave Doppler (Before connection of Aneurysm, neck, after aneurysm and sac)
- ✓ Color Power Angio is used/applied in the blood vessel segment where there is presence of significant finding or abnormality

Criteria for NORMAL or ABNORMAL

- ✓ Normal Aorta Duplex Svan – No presence of plaque, normal tapering contour and multiphasic waveform

DIAGNOSTIC CRITERIA:

CRITERIA FOR ABDOMINAL AORTA ANEURYSM DIAGNOSIS

>3.0 cm. focal dilatation of the aorta

1.5 times diameter increase than the normal expected diameter.

≥1.2 infrarenal to suprarenal aortic diameter ratio.

PSV DIAGNOSTIC CRITERIA FOR ABDOMINAL AORTA AND BRANCH ARTERY STENOSIS				
ARTERY	NORMAL (cm/sec)	0-69% STENOSIS (cm/sec) *without post stenotic turbulence*	70-99% STENOSIS (cm/sec) *with post stenotic turbulence*	TOTAL OCCLUSION
Celiac artery	98 - 105	< 250	> 250	
SMA	103 - 197	< 275	> 275	Absence of color flow and Doppler signal
IMA	93 - 189	< 275	> 275	
Renal artery	< 180	>180	>200	
	NORMAL (cm/sec)	SIGNIFICANT STENOSIS		TOTAL OCCLUSION
Aorta Iliac artery	-	focal velocity increase of greater than 100% (more than twice) from the normal proximal segment.		Absence of color flow and Doppler signal

DIAGNOSTIC CRITERIA:

CRITERIA FOR ABDOMINAL AORTIC ANEURYSM
>3.0 cm focal dilatation of the aorta
Focal dilatation of > 1.5 times the non-dilated proximal segment
≥ 1.2 infrarenal to suprarenal aortic diameter ratio

CRITERIA FOR VISCERAL ARTERY STENOSIS

Artery	Normal	Stenosis

Celiac Artery	98 – 105 cm/s	>200 cm/s(>70% stenosis)
Superior Mesentric Artery	97 – 142 cm/s	>275 cm/s(>70% stenosis)
Renal Artery	<200 cm/s	>200 cm/s(>60% stenosis)

TYPES OF ENDOLEAK

Type	Description
Ia, Ib	Endoleak whose origin is at the proximal (Ia) or distal (Ib) stent graft attachment site.
II	Endoleak originating from a branch vessel
III	Endoleak that originates at the junction between components of the stent graft modular device or from fabric tears within the graft.
IV	Flow from the graft due to graft fabric porosity
V	Endotension (Increase in aneurysm size in the absence of endoleak)

ABNORMAL DOPPLER FINDINGS IN CELIAC ARTERY COMPRESSION

Respiratory variation in PSV with >200 cm/s PSV during expiration
>3.1 velocity ratio of the PSV of celiac artery during expiration compared to the PSV of the abdominal aorta at the level immediately below the diaphragm

CRITICAL FINDINGS
Initial finding of AAA with >5.0cm AP or transverse diameter Common iliac anuerysm or internal iliac artery aneurysm >3.0 cm AP or transverse diameter Aortic dissection Acute arterial (aorta, iliac, renal, visceral artery) thrombosis/occlusion Ruptured AAA Renal artery occlusion due to migrating aortic endovascular stent sheath Renal hypoperfusion Type I or III endoleak Any other significant venous finding (IVC thrombosis, iliofemoral deep venous thrombosis, May-Thurner lesion, etc.)

DUPLEX SCAN AFTER ENDOVASCULAR THERAPY

2014 Consensus[11]	2019 Consensus[1, 12]
Normal stent angioplasty site • Widely patent color flow lumen • Non-disturbed velocity spectra • PSV < 250 cm/sec • PSV ratio < 2 along the stent length and relative to the distal artery Occlusion • Clearly visualized vessel with no color Doppler flow or velocity spectral signal Abdominal Stent Graft Evaluation[4] Doppler Criteria for stenosis of the aorta: • 50-99%: doubling in PSV across segment of the aorta with visualized plaque or other defect such as thrombus, wall thickening, and post-stenotic turbulence • plaque without evidence of hemodynamically significant stenosis Common iliac (and graft limb) stenosis: • 50-99%: PSV > 300 cms/sec with post-stenotic turbulence and plaque	≥ 50% celiac in-stent restenosis: 274 cm/s (sens 96%, spec 86%, accuracy 93%) ≥ 70% celiac in-stent restenosis: 363 cm/s (sens 88%, spec 92%, accuracy 90%) ≥ 50% SMA in-stent restenosis: 325 cm/s (sens 89%, spec 100%, accuracy 91%) ≥ 70% SMA in-stent restenosis: 412 cm/s (sens 100%, spec 100%, accuracy 97%) **Table IV.** Summary of ideal peak systolic velocity (PSV) threshold values for ≥70% in-stent restenosis (*ISR*) *CA*, Celiac artery; *NPV*, negative predictive value; *PPV*, positive predictive value; *SMA*, superior mesenteric artery. **No available standardized criteria available* Components of Post-EVAR Duplex Ultrasound -Measurement of maximum aortic aneurysm sac diameter -Detection and localization of flow outside the stent graft (endoleaks)

Vessel	≥70% ISR, cm/s	Sensitivity, %	Specificity, %	PPV, %	NPV, %
CA	≥289	100	57	79	100
SMA	≥445	83	83	81	86

	-Assessment of integrity and patency of stent graft components -Detection of thrombus in aortic stent graft main body or iliac graft limbs -Measurement of diameters of common iliac and external iliac arteries -Evaluation for patency and flow disturbances in the celiac artery, superior mesenteric artery and renal arteries -Evaluation of the common femoral arteries for access site complications -Bilateral ankle-brachial indices ** No validated criteria for the degree of stenosis within an endograft* Velocity ratio of ≥2.0 is indicative of at least 50% narrowing/stenosis

- **This procedure also covers (true and false) aneurysm and stent scanning provided its location is in lower extremities**

SCOPE OF INSONATION

- **B-mode, Color Mode and Power Doppler (Longitudinal View) of the following segments:**

- Distal external iliac artery
- Common femoral artery
- Deep femoral artery
- Femoral artery (proximal, mid, distal)
- Popliteal artery ((proximal, mid, distal)
- Tibio-peroneal trunk
- Posterior tibial artery (proximal, mid, distal)
- Peroneal artery (proximal, mid, distal)
- Anterior tibial artery (proximal, mid, distal)

- Dorsalis pedis artery

NOTE: Color Power Angio is used/applied in the blood vessel segment where there is presence of significant finding or abnormality

Criteria for NORMAL or ABNORMAL

- Normal Arterial Duplex Scan- No presence of plaque and multiphasic waveform
- Abnormal Arterial Duplex Scan may present the following:

2014 PSVM Consensus [8]		2020 PSVM Consensus [7]	
Diameter Reduction	PSV/Waveform Criteria	Diameter Reduction	PSV/Waveform Criteria
Normal	Triphasic waveform No spectral broadening	Normal	Multiphasic waveform
1-19%	Triphasic waveform with minimal spectral broadening PSV increased <30% relative to adjacent proximal segment Proximal and distal waveforms remain normal	< 50%	PSV increases slightly but is less than double that in the normal adjacent proximal segment (velocity ratio < 2). Typically, there is a multiphasic waveform with rapid upstroke and no appreciable increase in diastolic velocity. Spectral broadening is pansystolic.
20-49%	Triphasic waveform usually maintained (although reversed flow component may be diminished) PSV increased < 2x of proximal normal segment (increased 30 -100%) Spectral broadening is prominent, with filling-in of the clear systolic area under the systolic peak		

50-99%	PSV increased > 2x (> 100%) relative to the adjacent proximal segment Monophasic waveform with loss of reverse flow component and forward flow through out the cardiac cycle Extensive spectral broadening Distal waveform is monophasic with reduced systolic velocity	**50-74%**	When the lumen of the artery is significantly narrowed, a pressure-flow gradient is present at the stenotic site. PSV increases by more than 100% (velocity ratio > 2) compared to the normal adjacent proximal segment. The early diastolic reverse flow component is commonly lost (may be residual in a high-velocity state with extensive collateralization) with

			continuous, pandiastolic forward flow in response to decreased vascular resistance in the distal tissue bed. Spectral broadening is present.
		>75%	Severe arterial narrowing results in at least a fourfold increase in PSV (velocity ratio > 4) compared to the normal proximal adjacent segment. The waveform is monophasic, diastolic velocity may be increased, and a spectral bruit is commonly noted adjacent to the zeroflow baseline.
Occlusion	No flow in the imaged artery Preocclusive "thump" proximal to occlusion Distal (collateral) waveforms are monophasic with reduced systolic velocities		

2014 PSVM Consensus	2020 PSVM Consensus
Interpretation: • Hemodynamically Signficant Stenosis for lesions with ≥ 50% stenosis • Insignificant Stenosis for lesions with < 50% stenosis **NOTE:** For hemodynamically insignificant stenosis, the degree of stenosis (whether 1-19% or 20- 49%) should only be noted in the comments or descriptive narrative.	**Interpretation:** • **Normal Arterial Duplex Scan** • **Hemodynamically Significant LEAD, (atherosclerotic/embolic/thrombotic) compatible with:** ○ **50-74 % stenosis** ○ **> 75 % stenosis** ○ **Total occlusion** • **Hemodynamically Insignificant LEAD, atherosclerotic, compatible with < 50% stenosis**

- **OTHER INDICATIONS OF ABNORMAL FINDINGS**

- Segmental, concentric, hypoechogenic thickening of the arterial wall
- "Halo sign" on transverse plane
- Color aliasing
- Spectral broadening
- High –velocity jet
- Post stenotic turbulence
- Downstream waveform dampening
- Acute arterial thrombosis /occlusion of the lower limb
- Arterial aneurysm
- Pseudoaneurysm
- Iatrogenic arteriovenous fistula

Arterial Duplex Scan (Upper Extremities)

- **This procedure also covers (true and false) aneurysm and stent scanning provided its location is in upper extremities**

SCOPE OF INSONATION

- **Obtain bilateral blood pressures**
  - Normally, arm pressures are not more than 10 mm Hg different from side to side

- **B-mode, Color Mode and Pulse Wave Doppler (Longitudinal View)** of the following segments:

- Subclavian artery (proximal, mid, distal)
- Axillary artery (proximal, mid, distal)
- Brachial artery (proximal, mid, distal)
- Radial artery (proximal, mid, distal)
- Ulnar artery (proximal, mid, distal)

NOTE: Color Power Angio is used/applied in the blood vessel segment where there is presence of significant finding or abnormality.

Criteria for NORMAL or ABNORMAL

- Normal Arterial Duplex Scan- No presence of plaque and waveform is multiphasic

2014 PSVM Consensus [8]		2020 PSVM Consensus [7]	
Diameter Reduction	PSV/Waveform Criteria	Diameter Reduction	PSV/Waveform Criteria
Normal	Triphasic waveform No spectral broadening	Normal	Multiphasic waveform
1-19%	Triphasic waveform with minimal spectral broadening PSV increased <30% relative to adjacent proximal segment Proximal and distal waveforms remain normal	< 50%	PSV increases slightly but is less than double that in the normal adjacent proximal segment (velocity ratio < 2). Typically, there is a multiphasic waveform with rapid upstroke and no appreciable increase in diastolic velocity. Spectral broadening is pansystolic.
20-49%	Triphasic waveform usually maintained (although reversed flow component may be diminished) PSV increased < 2x of proximal normal segment (increased 30 -100%) Spectral broadening is prominent, with filling-in of the clear systolic area under the systolic peak		
50-99%	PSV increased > 2x (> 100%) relative to the adjacent proximal segment Monophasic waveform with loss of reverse flow component and forward flow through out the cardiac cycle Extensive spectral broadening Distal waveform is monophasic with reduced systolic velocity	50-74%	When the lumen of the artery is significantly narrowed, a pressure-flow gradient is present at the stenotic site. PSV increases by more than 100% (velocity ratio > 2) compared to the normal adjacent proximal segment. The early diastolic reverse flow component is commonly lost (may be residual in a high-velocity state with extensive collateralization) with

			continuous, pandiastolic forward flow in response to decreased vascular resistance in the distal tissue bed. Spectral broadening is present.
		>75%	Severe arterial narrowing results in at least a fourfold increase in PSV (velocity ratio > 4) compared to the normal proximal adjacent segment. The waveform is monophasic, diastolic velocity may be increased, and a spectral bruit is commonly noted adjacent to the zeroflow baseline.
Occlusion	No flow in the imaged artery Preocclusive "thump" proximal to occlusion Distal (collateral) waveforms are monophasic with reduced systolic velocities		

DIAGNOSTIC CRITERIA FOR % STENOSIS OF THE UPPER EXTREMITY ARTERIAL DUPLEX SCAN

% STENOSIS		DESCRIPTION
Normal		PSV within normal limits clear window under peak systole multiphasic (triphasic/biphasic) waveform pattern
<50% stenosis	+	minimal plaque formation PSV within normal limits spectral broadening multiphasic (triphasic/biphasic) waveform pattern
>50 % stenosis (hemodynamically significant stenosis)	+++	Focal velocity increase of greater than 100% from a normal proximal segment PSV ratio = >100%, PSV ratio of 2.0 PSV = >200cm/sec triphasic / biphasic/monophasic waveform pattern
> 75% stenosis (hemodynamically significant stenosis)	++++	PSV of > 400 cm/sec PSV ratio of 4.0 triphasic / biphasic/monophasic waveform pattern
Near total occlusion	NTO	thump signals
Total occlusion	TO	no signal

- For the subclavian artery where the calculation of velocity ratio may be unreliable, the diagnosis of significant stenosis is based on indirect parameters such as:

Color aliasing
Spectral broadening
High –velocity jet
Post stenotic turbulence
Downstream waveform dampening
Low flow velocity with basic or monophasic waveform pattern s in the axillary artery

- SONOGRAPHIC FINDINGS

Segmental, concentric, hypoechogenic thickening of the arterial wall
"Halo sign" on transverse plane

- CRITICAL FINDINGS

Acute arterial thrombosis /occlusion of the upper limb
Arterial aneurysm
Pseudoaneurysm
Iatrogenic arteriovenous fistula

Hemodialysis Access Graft

- **This scanning procedure of the graft is applicable in any location of the body except areas that includes the heart**

SCOPE OF INSONATION

First,

- ✓ **Perform full arterial and venous duplex scan of the ipsilateral arm where the graft is situated.**

For lower extremities:
B-mode, Color Mode and Power Doppler (Longitudinal View) of the following segments:

- Distal external iliac artery
- Common femoral artery
- Deep femoral artery
- Femoral artery (proximal, mid, distal)
- Popliteal artery ((proximal, mid, distal)
- Tibio-peroneal trunk
- Posterior tibial artery (proximal, mid, distal)

- Peroneal artery (proximal, mid, distal)
- Anterior tibial artery (proximal, mid, distal)
- Dorsalis pedis artery

For upper extremities:
B-mode, Color Mode and Power Doppler (Longitudinal View) of the following segments:

- Subclavian artery (proximal, mid, distal)
- Axillary artery (proximal, mid, distal)
- Brachial artery (proximal, mid, distal)
- Radial artery (proximal, mid, distal)
- Ulnar artery (proximal, mid, distal)
-

Then focus on the graft,

- ✓ **B-mode (Longitudinal View) with cross sectional and anterior posterior measurement** of the following segments:

- Pre anastomotic site (artery)
- Post anastomotic site (artery)
- Anastomotic site (connection)
- Graft (proximal, mid, distal)
- Outflow anastomotic site (vein)
- Outflow vein (proximal, mid, distal)

- ✓ **Color Mode and Pulse Wave Doppler (Longitudinal View)** of the following segments:

- Pre anastomotic site (artery)
- Post anastomotic site (artery)
- Anastomotic site (connection)
- Graft (proximal, mid, distal)

- Outflow anastomotic site (vein)
- Outflow vein (proximal, mid, distal)

- ✓ **Measure skin surface(mm)**
- ✓ **Obtain volume flow in the outflow vein (anastomotic site)**

Criteria for ABNORMAL

B- mode :
Describe the following if present:

- Aneurysm, pseudo aneurysm.
  - O If present, measure AP diameter.
- Hematoma
- Peri-access fluid collection
- Edema in the soft tissue

Criteria for >50% GRAFT stenosis at the venous anastomosis

- Peak systolic velocity >400 cm/sec
- Velocity ratio ≥ 2:1 (for anastomosis to graft 2 cm upstream)

Criteria for >50% GRAFT stenosis at the arterial anastomosis

- Peak systolic velocity ≥400 cm/sec
- Velocity ratio ≥ 3:1 (for anastomosis to graft 2 cm upstream (pre-anastomosis)

AIUM Practice Parameter of Ultrasound Vascular Mapping for Preoperative Planning of Dialysis Access
J Ultrasound Med 2020

Volume flow

- MF(cm/sec) x Area (3.14 x [diameter/2]^2) x 60= ml/min

- **Volume Flow for Access Grafts**
  - <350 ml/min = poor dialysis, pending graft failure
  - <500 ml/min = increased risk of graft failure
  - >800 ml/min = normal flow range
  - >1500 ml/min = possible congestive heart failure

"Rule of 6" of AV access

- 6 weeks post-creation
- >6mm diameter
- <6mm depth
- >600ml/min blood flow rate
- >6cm functional length (AVG)

CRITICAL FINDINGS

- Initial findings of a GRAFT thrombosis
- Initial findings of a pre occlusive stenosis
- Pseudoaneurysm in the graft
- Hemodynamically significant external compression of the outflow vein body from surrounding hematoma, mass, perivascular fluid accumulation or pseudoaneurysm
- Significant arterial inflow or outflow pathology
- Evidence of significant steal phenomenon

Arteriovenous Fistula

- **This scanning procedure of the graft is applicable in any location of the body except areas that includes the heart**

SCOPE OF INSONATION

First,

- ✓ **Perform full arterial and venous duplex scan of the ipsilateral arm where the graft is situated.**

For lower extremities:

B-mode, Color Mode and Power Doppler (Longitudinal View) of the following segments:

- Distal external iliac artery
- Common femoral artery
- Deep femoral artery
- Femoral artery (proximal, mid, distal)
- Popliteal artery ((proximal, mid, distal)
- Tibio-peroneal trunk
- Posterior tibial artery (proximal, mid, distal)
- Peroneal artery (proximal, mid, distal)
- Anterior tibial artery (proximal, mid, distal)
- Dorsalis pedis artery

For upper extremities:

B-mode, Color Mode and Power Doppler (Longitudinal View) of the following segments:

- Subclavian artery (proximal, mid, distal)
- Axillary artery (proximal, mid, distal)
- Brachial artery (proximal, mid, distal)
- Radial artery (proximal, mid, distal)
- Ulnar artery (proximal, mid, distal)
-

Then focus on the fistula,

- ✓ **B-mode (Longitudinal View) with cross sectional and anterior posterior measurement** of the following segments:

- Pre anastomotic site (artery)
- Post anastomotic site (artery)
- Outflow anastomotic site (vein)
- Outflow vein (proximal, mid, distal)

- ✓ **Color Mode and Pulse Wave Doppler (Longitudinal View)** of the following segments:

- Pre anastomotic site (artery)
- Post anastomotic site (artery)
- Outflow anastomotic site (vein)
- Outflow vein (proximal, mid, distal)

- ✓ **Measure skin surface(mm)**
- ✓ **Obtain volume flow in the outflow vein (anastomotic site)**

Criteria for ABNORMAL

B- mode :
Describe the following if present:

- Aneurysm, pseudo aneurysm.
  - If present, measure AP diameter.
- Hematoma
- Peri-access fluid collection
- Edema in the soft tissue

Volume flow

- MF(cm/sec) x Area (3.14 x [diameter/2]^2) x 60= ml/min

- **Volume Flow for Access Grafts**
  - <350 ml/min = poor dialysis, pending graft failure
  - <500 ml/min = increased risk of graft failure
  - >800 ml/min = normal flow range
  - >1500 ml/min = possible congestive heart failure

DIAGNOSTIC CRITERIA

NORMAL	PSV – 100 – 400 cm/sec
	EDV - 60 – 200 cm/sec
	No visible atherosclerotic plaque or thrombus formation
> 50% FISTULA STENOSIS	PSV - > 400 cm/sec
	Velocity ratio of > 2:1 or ≥ 3:1 for anastomotic site and outflow vein
	Presence of atherosclerotic plaque or thrombus
OCCLUSION	Absent color flow and Doppler signals in the graft lumen
	High resistance in the inflow artery
	Absent flow in the outflow vein proximal to the outflow anastomose
	Low flow velocity in the central venous outflow

CRITICAL FINDINGS:

- Initial findings of an AVF thrombosis
- Initial findings of an AVF high grade, pre occlusive stenosis
- Pseudoaneurysm of the dialysis access fistula
- Hemodynamically significant external compression of the outflow vein body from surrounding hematoma, mass, perivascular fluid accumulation or pseudoaneurysm
- Significant arterial inflow or outflow pathology
- Evidence of significant steal phenomenon

Renal Duplex Scan

SCOPE OF INSONATION

- ✓ **B-mode (Longitudinal View) with cross sectional measurement** of the kidney.
- ✓ **Color Mode and Pulse Wave Doppler** of the following segments:

- Aorta
- Cortex
- Medulla
- Hilum
- Renal Distal Artery
- Renal Mid Artery
- Renal Distal Artery
- Renal Vein'
- Inferior Vena Cava
- Right Common Iliac Artery
- Left Common Iliac Artery
- Right Proximal External Iliac Artery
- Left Proximal Arterial Artery

NOTE: Color Power Angio is used/applied in the blood vessel segment where there is presence of significant finding or abnormality

Criteria for Normal or ABNORMAL

NORMAL RENAL ARTERY CHARACTERISTICS

Kidney Size: 9-11 cm

High flow velocity	-------- PSV of 80 – 180 cm/sec
Low resistance	-------- RI of less than 0.75
High diastolic flow	-------- EDV of 25 to 35 cm/sec
Renal-aortic ratio	-------- < 3.5

DIRECT CRITERIA FOR RENAL ARTERY STENOSIS

Percent stenosis	PSV (cm/sec)	RAR
Less than 60%	180 - 199	< 3.5
Equivocal for > 60%	≥ 200	< 3.5
60 – 99 %	≥ 200	>3.5
Total occlusion	● absent color flow and Doppler signal in the main renal artery ● kidney size less than 8 cm ● low amplitude, low resistance or no flow in the kidney ● parenchymal PSV of less than 10 cm/sec	

INDIRECT CRITERIA FOR >60% STENOSIS

- Prolonged acceleration time - longer than 0.1 sec
- tardus parvus waveform
- loss of early systolic peak (ESP)
- flattened/blunted systolic upslope
- RI difference of > 5 between kidneys
- reduced color flow in the kidney, unilaterally

CRITICAL FINDINGS

- Renal artery occlusion
- Incidental finding of renal vein thrombosis

- Renal artery aneurysm
- Renal artery pseudoaneurysm
- Renal artery-vein fistula
- Fibromuscular dysplasia
- Other significant arterial abnormalities in the aorta, vena cava or visceral vessels

III. Renal Allograft Artery Stenosis.
Any of the following criteria:
- Hemodynamically significant renal allograft stenosis: Renal artery PSV > 250 cm/sec
- Renal artery to Iliac artery ratio (RIR) > 3

Granata A, Silvia C, et al. "Renal Transplant vascular complications: the role of Doppler ultrasound. J Ultrasound (2015) 18: 101-107"

As in the example above, each criterion stands alone in the diagnosis of renal allograft after stenosis.

IV. Renal Allograft Rejection
D. Sonographic Features
1. Increase Allograft size
2. Increase cortical echogenicity
3. Increase prominence of renal pyramids
4. Focal cortical hypoechoic region

E. Doppler Featur es:
1. High resistant waveform pattern
2. Sharp narrow systolic peak
3. Minimal or absent diastolic flow
4. Flow reversal early in diastole

F. Resistivity index (RI) $\geq$ 0.8

- Renal Artery Stenting
- Hemodynamically significant (>60%) renal artery in-stent stenosis: Renal artery PSV > 250 cm/sec

Fleming S, Davis R, et al. "Accuracy of duplex sonography scans after renal artery stenting." Copyright 2010 by the Society for Vascular Surgery. doi:10.1016/j.jvs2010.04.055

- Renal Parenchymal Disease
  - Resistivity Index (RI) of > 0.8 is indicative of renal parenchymal disease

Gaurav K, Yalavarthy U, et al. "Correlation between renal resistive index and estimated glomerular filtration rate in patients with hypertension." The J for vasc ultrasound 32(2): 82-84, 2008

PROTOCOL FROM JANUARY 31, 2023 -PRESENT

University Hospitals Birmingham NHS
NHS Foundation Trust

CONTROLLED DOCUMENT

Lower Limb Arterial Duplex Ultrasound

CATEGORY:	Clinical Guidelines
CLASSIFICATION:	Clinical
Controlled Document Number:	CG329
Version Number:	1.2
Controlled Document Sponsor:	Clinical Guidelines Group
Controlled Document Lead (Author):	Hayley Silgram, Vascular Scientist - Team Leader
Approved By:	Clinical Guidelines Group
On:	September 2017
Review Date:	June 2024 (Extension x1) September 2020 (Original)

Lower Limb Arterial Duplex Ultrasound

Purpose

Duplex ultrasound examination is used to assess the arteries of the lower limb (aorta to ankle level) to determine the location and severity of vascular disease (occlusive and aneurysmal).

Common Indications

- Common indications for the performance of this examination include:
- Intermittent claudication.
- Ischemic rest pain.
- Gangrene.
- Ulceration.
- Post-surgical intervention follow-up e.g. angioplasty.
- Aneurysm.
- False aneurysm.

Contraindications and Limitations

Contraindications for lower limb arterial duplex ultrasound assessment are unlikely; however, some limitations exist and may include the following:

- Body habitus
- Casts, dressings, open wounds etc.
- Bowel gas when examining the aorto-iliac segment. Calcified arteries resulting from atherosclerosis may obstruct the ultrasound beam and cause acoustic shadowing artefact and may limit Doppler assessment.
- Patients who are unable to cooperate due to reduced cognitive functions e.g.
- Alzheimer's or dementia and through involuntary movements.

Equipment

- Duplex Doppler ultrasound machine with imaging frequencies of 3.5MHz and greater; with both linear and curvilinear transducers available1.
- Doppler frequencies of at least 3.0MHz should be available, with colour Doppler capability.
- Compliance with the Medical Devices Directive is necessary.
- Electrical safety testing is required annually, with regular maintenance and quality assurance testing to specified level by qualified personnel.
- Examination couch should be height adjustable preferably electrical. The scanning chair should provide good lumbar support, be height

adjustable and allow for the operator to move close to the examination couch23.

- The examination room should be temperature controlled with adjustable lighting levels suitable for examination2.
- Suitable cleaning materials should be available in line with local and manufactures guidelines.

Explanation of examination and patient history

The staff member undertaking the examination should:

- Welcome the patient and relatives.
- Introduce themselves and any other members of staff in the room.
- Confirm the patient's identity e.g. full name and date of birth
- Explain why the examination is being performed and give an indication of the test's duration
- Give an explanation of the procedure and it's duration – consideration should be made to the age and mental status of the patient
- Obtain verbal consent for the examination.
- Obtain a pertinent relevant medical history from the patient and/or notes
- Identify presence of any risk factors for example Smoking; diabetes; high cholesterol; obesity; hypertension; cardiovascular disease.
- Verify that the requested procedure correlates with the patient's clinical presentation.
- The test can be terminated at any point if the patient withdraws their consent for the procedure.
- Post procedure the patient must be informed how, when and by whom results/reports will be communicated.

Examination

- During the examination patients must be treated with respect, dignity and discretion.
- Patient comfort should be monitored throughout the test and alterations be made should a patient become uncomfortable.
- The examination may be unilateral or bilateral dependent upon clinical symptoms.
- The patient is asked to remove their clothing to expose the lower limb from groin to ankle.
- The patient is examined supine.
- The patient's dignity and privacy should be maintained at all times. Due to intimate nature of the examination it may be considered necessary to offer a chaperone4.
- During the examination the patient's mental and physical status should be monitored and modifications made to the examination accordingly.

- B-mode should be used to image the artery and assess for, aneurysmal dilation and vessel contents e.g. athermanous plaque.
- Spectral Doppler should be used to determine direction of flow, stenotic flow and absence of flow.
- Colour Doppler should be used to assess for the presence/absence of flow and aid the position of spectral Doppler when quantifying stenosis.
- A 50-75% stenosis is defined as a ratio of 2 but less than 2.5 when the peak sytolic velocity across the stenosis is divided by the nearest normal peak systolic. A >75% stenosis is defined as a ratio of 2.5 when the peak sytolic velocity across the stenosis is divided by the nearest normal peak systolic.

Depending on clinical signs and symptoms the following arteries could be included in the scan:

- Aorta
- Common iliac artery (CIA)
- External iliac artery (EIA)
- Common femoral artery (CFA)
- Proximal profunda femoris artery (PFA)
- Superficial femoral artery (SFA)
- Popliteal artery
- Tibio-peroneal trunk (TPT)
- Posterior tibial artery (PTA)
- Peroneal artery
- Anterior tibial artery (ATA)

Reporting

- The report is a recording and interpretation of observations made during the lower limb arterial duplex ultrasound examination; it should be written by the staff member undertaking the examination and viewed as an integral part of the whole examination.
- The report should include correct patient demographics; date of examination; examination type and the name and status of the staff member.
- Reports are in the form of an annotated diagram.
- The reporting should include; which arteries have been assessed commenting on the presence/absence of flow, the anatomical position of any occlusions or stenosis, the anatomical position and size of any aneurysms, any limitations e.g. difficult examination due to body habitus.
- In the presence of a stenosis the maximum velocity within the stenosis should be noted.
- Ensure appropriate efficient referral of critical ultrasound results to the referring consultant are made prior to the patient being

discharged so treatment plans can be enforced or expedited accordingly.

- Critical results must be verbally communicated to the on-call specialist registrar/consultant on the day of the test. Evidence of this communication should be noted on CRIS using auto report code DVASC2.
- Critical results can be defined as:
  - A diagnosis of an acute arterial occlusion.
  - Patient that describes rest pain
  - An undiagnosed abdominal aortic aneurysm measuring more than 5.5cm in the AP plane.
  - A pseudoaneursym
- Unexpected results must be verbally communicated to the on-call specialist registrar/consultant on the day of the test. Evidence of this communication should be noted on CRIS using auto report code DVASC3
- All reports will be available on IMPAX within 24hrs of the scan being performed.
- Reports can be amended or removed by contacting the PACS team.

Quality Assurance

- Equipment is purchased in line with the Trust Procurement Policy
- Scanners are serviced in accordance with manufactures recommendation.
- Equipment faults are reported on the same day to medical engineering.
- Staff will perform test under supervision until they have been signed off as competent by a senior member of staff.

Monitoring

- Equipment is checked for damage on a weekly basis. Any damage is reported to medical engineers.
- Staff will have competency checked against the SOP on a quarterly basis by a senior member of staff.
- Lower limb arterial duplex will be audited against angiography
- Stakeholder feedback is obtained bi-annually through the Vascular Laboratory feedback questionnaire

Resources:

Society for Vascular Ultrasound Vascular Technology Professional Performance Guidelines Lower Limb Extremity Venous Duplex Evaluation 2011 www.svunet.org

American Institute of Ultrasound in Medicine Practice Guideline for the Performance of Peripheral Venous Ultrasound Examinations 2010 www.aium.org

Australasian Society for Ultrasound in Medicine Policies and Statements D20 Peripheral Venous Ultrasound2007 www.asum.com.au

References:

1. Standards for Ultrasound Equipment Royal College of Radiologists, February 2005 www.rcr.ac.uk

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

3. The Causes of Musculoskeletal Injury Amongst Sonographers in the UK Society of Radiographers, June 2002 www.sor.org/learning/document-library

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

Test Protocol: **Bypass Graft Ultrasound Scan**

Protocol last updated on: April 2018

Graft surveillance is carried out on all vein grafts and selected prosthetic grafts at the clinicians request. Vein grafts are scanned along their entire length to identify atheroma and evaluate any stenotic lesions affecting the graft or anastomoses. The inflow and run-off are also assessed.

Early detection and treatment of lesions (by angioplasty, thrombolysis or surgery) can restore blood flow to the foot and muscle compartments and avert graft failure.

Equipment required:

High quality Duplex ultrasound machine:

Cart based ultrasound system e.g. Philips Epiq5; including low, mid, and high frequency probes (ranging 1MHz-17Mhz)

Portable ultrasound system e.g. Philips CX50; including low, mid, and high frequency probes (ranging 1MHz-17Mhz)

Peripherals:

CRIS, PACS

Consumables:

Paper roll, paper hand towels, ultrasound gel, Clinell wipes

Other:

An adjustable examination couch is required. If the examination is performed with the operator seated, a height adjustable chair with good lumbar support is required. The examination room should be temperature controlled with adjustable lighting levels suitable for the examination.

Quality Analysis & Calibration:

Imaging: Serviced and safety tested every 12 months. Annual quality assurance testing by qualified personnel from radiation protection service (RPS). Review of in-service equipment should typically be undertaken four to six years after installation.
Doppler: none

Patient and staff safety:

Electrical: Equipment must comply with the Medical Devices Directive. Manufacturer completes PPQ (post-purchase questionnaire) form. Safety tested on arrival and then annually.

Infection control:

Appropriate levels of PPE should be worn for the examination (barrier guidelines should be adhered to for infectious patients)**.** Probes should be thoroughly cleaned with a Clinell disinfectant wipe between all patients.

In cases where infectious patients have been assessed (e.g. MRSA and *Clostridium difficile*) the ultrasound machine should be thoroughly cleaned with Clinell wipes post-examination.

For sterile procedures sterile probe covers and gel should be used.

Ultrasound Safety: Output powers are quoted by manufacturer.

Users are required to be aware of the potential risks and methods of minimising ultrasound exposure (guide-lines: The safe use of Ultrasound in Medical Diagnosis. British Medical Ultrasound Society. Ed. G. ter Haar and F A Duck. 2000).

Communication with patients: The vascular scientist undertaking the examination should:

- Introduce themselves
- Confirm the patients identity e.g. full name and date of birth
- Explain why the examination is being performed
- Give an explanation of the procedure and its duration and the reason for the scan – consideration should be made to the age and mental status of the patient
- Obtain verbal consent for the examination
- Obtain a pertinent medical history from the patient and/or notes:
    - Verify that the requested procedure correlates with the patient's clinical situation
    - Type of and position of graft e.g. fem-distal to PTA, fem-pop
    - History of previous treatment e.g. angioplasty
    - Results of other relevant diagnostics & previous vascular studies
    - Any recurrence of symptoms or associated problems with the leg
- Explain how/when the patient will be informed of the results

Test procedure

Patients attend for graft surveillance at week 6 (in consultant clinic); then at months 3, 6, 9, 12 18 and 24 for vein grafts (in surveillance clinics). Patients will be discharged from graft surveillance after 2 years providing there are no issues with the graft.

Femoro-popliteal and fem-distal grafts:

Upper anastomosis:

Using the 12-3 MHz transducer and with the patient supine, the test is commenced at the level of the groin where an assessment can be made of the common femoral artery (CFA) waveform. Demonstration of a sharp upstroke and a biphasic/triphasic signal rules out the necessity to scan the iliac vessels. Any deviation from the normal waveform and flow indicates iliac vessels should also be included in the scan.

Proximal anastomosis must be visualised in B mode and examined using colour and spectral Doppler to confirm normal biphasic/triphasic flow. Any atheroma or stenosis must be noted. The graft must be followed using colour Doppler to check for patency, dilatations, kinking, atheroma, and stenosis, and a normal waveform demonstrated in the mid graft. Distal anastomosis must also be examined as above for proximal anastomosis. Distal run off vessel must be examined using colour and spectral Doppler to confirm biphasic/triphasic waveform and normal flow velocities.

If the graft is to:

a) Above and below knee popliteal/TP trunk it is necessary to scan the popliteal artery and at least one tibial vessel to the ankle (see lower limb arterial protocol). This should be the best/dominant vessel, which can usually be identified from previous scans.

b) One of the tibial arteries (AT, PT or peroneal) - it is necessary to scan the vessel to the ankle.

N.B. Be aware that it is possible to see flow disturbance at the anastomoses sites due to non-physiological geometry of anastomoses e.g. a difference in diameter between native vessel and graft.

Iliofemoral and fem-fem cross-over grafts:

A full aorto-iliac scan should be carried out on the donor side (as outlined above). Both anastomoses should be assessed in detail and the presence of patent SFA or profunda origins confirmed or refuted on the recipient side.

Interpretation and Grading of disease

Graft and vessels are scanned to determine patency and identify stenoses, atheroma, and dilatations.

The extent of atheroma found is assessed by estimating any reduction in the vessel lumen apparent from the image. Filling defects and colour flow disturbances serve to alert the operator to potential sites of stenoses. Colour flow changes will be most apparent if a PRF is selected which places normal flow velocities in the upper part of the colour scale. Higher velocities will then appear as areas of aliasing.

Percentage stenosis is finally determined by comparing peak systolic velocity proximal to a stenotic area with intra-stenotic peak velocity. Thus a peak systolic velocity ratio (PSV ratio) is produced which correlates to a particular degree of narrowing (see table).

The presence of hyperaemia, high resistance signals and particularly low flow should be noted.

N.B. In the single visit clinic setting limited investigations may be carried out as per instruction from the requesting clinician.

Reporting of results:

The report is should be written by the vascular scientist undertaking the examination.

The report should include the correct patient demographics, date of examination and examination type. The report should include:

- Location of the graft, i.e. fem-pop, fem-peroneal etc

- Quality of the inflow to the graft
- State of proximal and distal anastomoses
- Details of any stenosis, atheroma or dilatations, kinks in the graft and any native vessel under investigation
- Comments on patency and quality of flow within the graft and the connected run-off vessel should be made
- Waveforms should be included to support the report
- Velocity increases are indicated in a site-specific fashion.

If no problems have been detected in the graft, patients are advised that all is well and given an appropriate routine follow up appointment.

If moderate disease is noted (i.e. 2-3x velocity increase) the patient is advised that they should return for earlier surveillance. The relevant consultant is informed by email.

If a >3x velocity increase is found, the vascular scientist may tactfully indicate that immediate advice will be sought from a vascular surgeon. In this case a provisional appointment may be given, or may be delayed until advised accordingly. In most cases, lesions above 3x are deemed suitable for intervention.

In the case of very severe disease or impending graft failure, the patient should be asked to wait until a vascular surgeon has been consulted. Graft patients can be discharged after a period of 2 years with no significant graft problems.

N.B. In the single visit clinic setting limited investigations may be carried out as per instruction and this shall be acknowledged in the report.

Anastomosis PSV m/s	Action	
<1.5 m/s	Normal Continue surveillance	
>1.5 and <2.8 m/s	Mid graft flow <0.5 m/s	Intervene
	Mid graft flow >0.5 m/s	Inform consultant Continue surveillance
>2.8 m/s	Intervene	

In graft stenosis (PSR)	Action	
< 1.8	Normal Continue surveillance	
1.8 – 2.8	Mid graft flow <0.5 m/s	Intervene
	Mid graft flow >0.5 m/s	Notify consultant Continue surveillance
>2.8	Intervene	
Occlusion	Inform consultant Discontinue surveillance	

Mid graft velocities	Action
1 – 1.5 m/s	Normal

	Continue surveillance
0.5 – 1 m/s	Inform consultant of reduced velocities within the graft Continue surveillance
>1.5 m/s	Inform consultant of increased velocities within the graft Continue surveillance
< 0.5 m/s	Inform consultant of potential graft failure Continue surveillance

References:

Brennan. J. et al (1991). The role of simple non-invasive testing in infra-inguinal vein graft surveillance. European Journal of Vascular Surgery. 5: 13-17.

Idu. M. et al. (1999). 'Factors influencing the development of vein-graft stenosis and their significance in clinical management.' European Journal of Vascular and Endovascular Surgery. 17: 15-21.

London. N. (1993). interventional radiology in the maintenance of infrainguinal graft patency.' British journal of Surgery. 80: 187-193.

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