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DIAGNOSIS OF VASCULAR DISEASES
ULTRASOUND INVESTIGATIONS - GUIDELINES

ITALIAN SOCIETY FOR VASCULAR INVESTIGATION

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Guidelines for the assessment of the intracranial circulation

Investigations

— Transcranial Doppler (TCD)
— Transcranial color-coded duplex scanning (TCDS)
— Near infrared spectroscopy (NIRS)
— Somatosensorial evoked potentials (SEPs)
— Radionuclide investigations (PET, SPECT)
— Elettroencephalography (EEG)
— Angiography by computed tomography (AngioCT)
— Angiography by magnetic resonance (AngioMR)
— Digital subtraction angiography (DSA)

Ultrasound investigations

Transcranial Doppler (TCD) and transcranial color-coded duplex scanning (TCDS) are non-invasive investigations of the cerebral circulation [1]. They are used for assessing patients with symptomatic or asymptomatic cerebrovascular diseases to show:

— endoluminal lesions of the detectable intracranial vessels[2];

— the cerebral vasomotor reactivity[3-8]. The cerebral reactivity is a reliable independent index of the risk of stroke;

— the collateral pathways efficacy through the circle of Willis [9-13].

Transcranial Doppler (TCD) monitoring (lasting 30-60 minutes) of the middle cerebral artery (MCA) of both sides allows to detect high-intensity transient signals (HITS) related to circulating emboli (MES) according to the recommendations of the International Consensus Group of Microembolous detection. [14] This technique has high sensitivity and specificity for detecting cerebral emboli both symtoptomatic and asymptomatic. [15]

TCD allows to identify potentially embolic sources[16-22] whether from the cerebral afferent vessels or from the aortic arch and the cardiac cavities.

Detection of asymptomatic MES on TCD can be useful identify patients with asymptomatic carotid plaque at higher risk of stroke [23-24].

MES monitoring by TCD related to intravenous agitated saline injection is also employed for the detection of cardiac right-to-left shunt (RLS). It can be combined with transesophageal or intracardiac echocardiography for the diagnosis of patent foramen ovale (PFO) [25, 26].

Although it cannot be considered a method of screening, TCD can identify intracranial aneurysms[27] and vascular malformations (AVM)[28-30] althought those TCD findings have to be confirmed by more reliable radiological imaging techniques such AngioCT, AngioMR and DSA[31-33].

TCD monitoring of MCA flow of both sides is also employed during the carotid repair (surgical or endovascular treatment) [34-35].

Intraoperative TCD monitoring allows to:

— assess the brain risk of ischemia due to carotid cross-clamping for a selective use of shunting [36-37];

— monitor the patency and function of carotid shunting [38];

— detect cerebral MES throughout the carotid procedure[39-40] and/or during the early post-operative period[41-47].

TCD monitoring can be also performed during carotid stenting in order to:

— record gaseous and/or solid emboli throughout the procedure and in the immediate post-operative period that are closely related to the periprocedural neurologic complications [48] and to the efficacy of the cerebral protection systems[49];

— monitor the cerebral hypoperfusion consequent to the systemic arterial hypotension and bradycardia up to asystolia, which may result from stimulation of the carotid sinus when the stent is released and during ballooning.

After open or endovascular repair TCD is useful as a quality control and to detect early the hyperperfusion syndrome [50-51].

Similar intraoperative monitoring of the MES with TCD can be done during heart surgery and using circuits for extracorporeal circulation[52].

Other applications of TCD are:

— the diagnosis and monitoring of cerebral vasospasm[53-54] whether it is associated with aneurismal subarachnoid haemorrhages [55-59] or headaches[60-63];

— the assessment of the intracranial venous circula-

tion[64] that might also be related to some neurological diseases;

— the diagnosis of brain death, which must be as prompt as possible in order to avoid the risk of futile care and to shorten the time for starting organ donation [65-68]. As far as concern the brain death, EEG is the main test for defining brain death but TCD plays a crucial role to confirm the absence of cerebral flow in the following cases:

1. children under 1 year of age,
2. when concomitant factors (depressants in the Central Nervous System, hypothermia, endocrine-metabolic alterations, systemic hypotension) of such a degree as to interfere with the overall clinical data,
3. in situations that do not permit a reliable diagnosis or that don't allow to assess the encephalic trunk reflexes or to perform a reliable EEG.

The TCD is also employed for:

— studying the cerebral effects of an abnormal high haematocrit as occurred in children and adolescents suffering from sickle-cell disease[69-70];

— assessing the effect of drugs[71], such as the vasoactive ones[72], those for migraine headaches[73], for intracranial hypertension[74], anticoagulant or antiplatelet therapy and fibrinolysis [75-77].

— intraoperative monitoring of patients undergoing cardiac surgery [78-79] with or without extracorporeal circulation[80-82] and patients undergoing major surgery with risk of severe arterial hypotension [83];

— studying orthostatic hypotension [84];

— detecting changes due to gradual therapeutic carotid occlusion[85];

— postoperative control of extra-intracranial bypasses.

It also plays a crucial role in the thrombolytic treatment of occluded intracranial vessel since ultrasound exposure increases the action of thrombolysis[86].

Other methods may be used alternatively or in combination with TCD for the study of cerebral parechyma and circulation.

Near infrared spectroscopy to measure the cerebral saturation of oxygen. It is used during carotid surgery or neurosurgery and for physiopathology studies of the brain circulation and the cerebral vasomotor reactivity.

PET and SPECT for an investigation of the brain perfusion within functional studies or to assess carotid cross-clamping tolerance.

EEG and SEPs monitoring are used by many groups during carotid surgery to select the cases requiring a shunt.

AngioCT or AngioMR are employed to complete the diagnosis of the intracranial vessels where it is deemed advisable for planning treatment

— when TCD or TCDS are insufficient for diagnosis

DSA should be restricted to:

— stage of an endovascular procedure

— rare cases where TCD, AngioCT or AngioMR did not provide sufficient or reliable data or could not be related with the clinical findings.

Transcranial Doppler (TCD) and transcranial color-coded Duplex scanning (TCDS)

Instruments

TCD or TCDS with 2 MHz transducers, for simultaneous bilateral insonation of intracranial vessels, possibly equipped with multi-gates system and devoted software for MES identification and monitoring,

The devices currently used in clinical practice use a pulsed Doppler system with a 2 MHz emission frequency able to change the size of the sample volume the diameter of which is equal to or greater than the diameter of the major intracranial arteries. All TCD devices are equipped with a flow direction detection system and a sample volume depth variator that can be modified with 0.5 mm intervals in a range of 25 to 150 mm.

The TCD is also equipped with a computerized system for analysing the frequency spectrum of Doppler signals. The computed analysis of the ultrasound signals allows to determine the systolic peak velocity, the end diastolic velocity and the average velocities as far as the systolic-diastolic ratio and the pulsatility and resistance indexes.

In order to get a better ratio between quality of the Doppler signal and the background noises, the TCD devices are equipped with a larger and less defined sample volume compared to other pulsed Doppler devices. Other peculiar requirements of the TCD are the emission power between 10 and 100mW/cm^2 sec and a pulse repetition frequency (PFR) up to 20kHz with a focalization of the ultrasound beam at a depth between 40 and 60 mm.

Multi-gates devices with a neural network for the automatic monitoring of MES are also available. They are equipped with a system for recording and off-line processing of MES and their recognition from the artifacts. Two-channel TCD instruments with 2.0 MHz and 2.5 MHz dual-frequency probes (Embo-Dop) can also be used.

Method

The transmission of an ultrasound beam through the skull depends on the structural features of the diploe bone. The almost complete absence of bone spicules makes penetrability of the ultrasound beam close to some regions called "acoustic windows" as they allow the intracranial vessels to be monitored by ultrasound.

There are four acoustic windows that can be employed for TCD and TDCS [87].

The temporal window is located above the zygomatic arch, anterior to the tragus. It can be very large (it can be divided in an anterior, middle and posterior portiont) and allows to monitor the middle cerebral artery (MCA) in M1 and M2 segment; the anterior cerebral artery (ACA) in A1 segment; the posterior cerebral artery (PCA) in P1 and P2 segments; the carotid siphon (CS) in C1 segment. The communicating arteries - anterior and posterior - and the distal end of the basilar artery (BA) can also be detected.

The occipital window, through the foramen magnum, is used to detect the intracranial segment of the vertebral arteries (VA) and the BA[88].

The orbital window, through the foramen of the ocular cavity, allows to record the ophthalmic artery (OA) and the C2, C3 and C4 segments of the carotid syphon, but is less employed for the potential retinal injuries caused by the ultrasound (the minimum emission power of the device should be used).

The submandibular window is used only for detecting the terminal segment (C5-C6) of the internal carotid artery (CI) and of the C1 segment of the carotid siphon. This approach is can be useful in those cases in which the absence of other "windows" precludes a more complete hemodynamic assessment of the Circle of Willis.

The recognition of the arteries of the Circle of Willis by TCD is based on the following parameters[89-90]:

— acoustic window employed for vessel detection;

— depth of the sampling volume;
— direction of the flow signal at each depth;
— pattern of the flow signal.

The TCDS with colorflow and power Doppler provides more important data than TCD since it allows direct imaging of the intracranial vessels, anatomic course, diameter and relationships with the adjacent anatomic structures. The B-mode visualization of the vessels allows the positioning of the sample volume directly within them and the correction of the insonation angle for proper record of the blood velocities, that are 10-30% higher than the corresponding TCD values.

Transcranial examination is performed using the conventional axial plane and coronal scanning planes at a depth that displays the contralateral vessels (14-16 cm depth), with the brain stem structures remaining at about half-way from the scanning plane [91-92].

The *axial plane* is the one most commonly used since it allows two different types of scans:

1. mesencephalic plane is achieved by placing the probe parallel tothe zygomatic arch. At this level highlights the hypoechogenic butterfly-shaped midbrain, anterior to the midbrain (located about half of the plane) activating the color Doppler can be detected.

— M1 segment of the middle cerebral artery (MCA) with red flow signal towards the probe and its branches (M2 segment).

— A1 segment of the anterior cerebral artery (ACA), which flows away from the probe but on the same plane (blue), followed by the contralateral vessel red flow signal towards the probe.

— part of M1 segment of the contralateral MCA.

— the posterior cerebral arteries (PCA), with the P1 segment (pre-communicating) which flows towards the probe and the P2 segment (post-communicating) away from the probe, they surround the mid-brain. The contralateral PCA is the opposite, with the P1 segment flow away from and the P2 segment flow towards the probe, respectively. When the posterior communicating arteries (PcoAs) have relevant diameter, it is possible to show them on the same plane (75% of cases).

2. diencephalic plane: shows the third ventricle (in the middle of the scanning plane) with hyperechogenic pineal gland located behind it, anterior to the third ventricle is the thalamus and internal capsule. The lateral ventricles can be also seen.

By using the colorflow and/or power Doppler the **M2** and **M3** segments of the MCA, the post-communicating segment of ACA (**A2**) and the quadrigeminal segment of the PCA are displayed. The study carried out on this plane is mainly useful for measuring and following the shift of the median line caused by space occupying lesions (ischaemic area, haemorrhage and tumors). This same plane is also used for cerebral perfusion studies.

The *coronal plane* is obtained by rotating the probe 90°. Through this approach the third ventricle, the lateral ventricles, the thalamus and internal capsule are seen. By moving front and back by a few millimetres with the probe we get:

1. anterior coronal plane in which the M1 segment of the MCA, the A1 segment of the ACA and a good part of the carotid syphon can be evaluated with the colorflow.

2. Posterior coronal plane with the PCAs and the apex of the Basilar Artery.

The occipital window is used on an axial scanning plane, with the probe positioned on the median sub-occipital line, with the patient seated or lying down (with head turned to the side and chin lowered toward the shoulder). The intracranial segment of the two vertebral arteries (VA) and the basilar trunk (BT) can explored through this window. All three vessels are displayed in blue, because they flow away from the probe in a Y shape. With small lateral movements it is possible to detect other branches such as the posterior inferior cerebellar artery (PICA) and the anterior inferior cerebellar artery (AICA).

Procedure

1 – Patient in position supine, with head and shoulders on a pillow.

2 – Probe positions: for the temporal window, on a plane perpendicular to the temporal squama, with the patient's head in the antero-posterior position.

For the occipital window in the occiput in the paramedian position, asking the patient to bend his head onto the neck and from the side opposite that of recording.

For the orbital window perpendicular to the eyelid, asking the patient to keep his eye closed, looking from the side opposite where pressure is made with the probe.

For the submandibular window, right underneath the angle of the mandible, in front of the masseter muscle and inclining the probe toward the skull.

The CS, the MCA, the ACA and the PCA are explored through the temporal window; the ophthalmic artery (if necessary) through the orbital window; the VB and BT are detected through the occipital window.

TABLE I.—*Normal parameters of the individual intracranial vessels.*

Artery	Window	Depth mm	Direction of flow*	Velocity cm/sec
MCA	Temporal	50 - 55	+	62 ± 13
ACA	Temporal	60 - 70	-	51 ± 13
PCA	Temporal	60 - 65	+	40 ± 11
BT	Occipital	80 - 110	-	42 ± 10
VA	Occipital	65 - 75	-	37 ± 10
Syphon C1	Temporal	65	+	37 ± 8
C2	Orbital	70	-	41 ± 11
C3	Orbital	60 - 65	+	44 ± 12
C4	Orbital	70	+	47 ± 13
Ophthalmic	Orbital	45-50	+	25 ± 5
CI	Mandibular	25 - 80	-	32 ± 9

*the flow direction is considered + if it approaches the probe and – if it is away from it.

The normal parametrs [93-96] of the individual intracranial vessels are showed in Table I.

The uni or bilateral MCA monitoring is obtained through the temporal windows.

There are several test such as the breath-holding test for TCD study of the cerebral autoregulation.

The examination with TCDS can be enhanced by the intravenous administration of an US amplifier [97-101].

Tables II, III show the accuracy of TCD compared to that of TCDS with and without US amplifier.

The compression manoeuvres of the common carotid artery at the base of the neck are employed to assess [102]:

— the patency and the functional efficacy of the anterior and posterior communicating arteries;

— the risk of stroke owing to critical brain hypoperfusion due to a decrease of mean blood velocity of the ipsilatareal MCA: below 75% of the basal values during the ipsilateral common carotid artery compression [103-104].

Following the basic examination and the compression, the brain vasomotor reactivity is assessed using various vasodilator stimuli such as hypercapnia subsequent to the apnea (breath-holding test), Co_2 inhalation and the activity of intravenous acetazolamide.

A vasomotor reactivity that during stimulation leads to an increase of the mean blood velocity of the cerebral arteries higher than 30% of the basal value is considered preserved.

To assess the possible embolic source (heart, starting from the aortic arch or from a carotid plaque) of cerebrovascular insufficiency, the MCA must be bilaterally monitored for 30 minutes when a cardio-embolic source is suspected and for 60 minutes if a carotid origin of the microembolic events is assumed, using equipment fitted with a microembolism detection and recording system [105-107]. MES as detected by TCD may be gaseous [superimposed signals of broad amplitude (>60dB)] or corpuscular [isolated signals of amplitude less than 60dB]. MES detection in both the MCAs suggest evidence of cardiac genesis, whereas unilateral MES recording indicates their origin from a carotid plaque [108-114].

TCD monitoring during carotid surgery or stenting, and during their immediate post-operative course, allows to assess the efficacy of the intracranial collateral pathways and of the shunt or of any cerebral protection devices that may have been used; it also allows to detect cerebral MES during the various phases of the repair (open or endoluminal);

TABLE II.—*TCD accuracy.*

Indication	Sensitivity %	Specificity %	Exam of ref.	Recommendation levels
Falciform anaemia (screening)	86	91	Conv. angiography	Level A/1
RH/LH cardiac shunt	70-100	>95	TEE	Level A/II
Intracranial stenosis			Conv. angiography	
anterior circulation	70-90	90-95		Level B/11 – III
Posterior circulation	50-80	80-96		Level B/III
Occlusion			Conv. angiography	
MCA 85-95	90-98			Level B/III
CI, VA, BT	55-81	96		Level B/III
Vasomotor reactivity			Clinical	Level B/II – III
For injuries > 70%/occl				
Carotid TEA			MRI/EEG/Clinical	Level B/II
Microembolisms			MRI/Neurol. Test	Level B/II – IV
Thrombolysis			Conv. angiography	Level B/II – III
Total occlusion	50	100		
Partial occlusion	100	76		
Recanalization	91	93		
Spontaneous vasospasm			Conv. angiography	Level A/I – II
MCA	39-94	70-100		
Traumatic vasospasm				Level B/III
Cerebral death	91-100	97-100	Angiography/EEG	Level A/II

TABLE III.—*TCDS accuracy, with and/or without US amplifier.*

Indication	Sensitivity %	Specificity %	Exam of ref.	Recommendation levels
Intracranial stenoses/occlusions	100	100	Conv. angiography	Level B/II – IV
Communicating vessels that can be activated ACoA	100	100	Conv. angiography	Level B/II – IV
ACoP	85	98		
Vasospasm			Conv. angiography	Level B/II – IV
MCA	100	93		

those MES may be related to the onset of new hyperintense areas of the brain detected by cerebral DW-MRI [115-126].

Detection of asymtomatic emboli by TCD is also useful to identify those patients with asymptomatic carotid plaques who are at higher risk of stroke and are likely to benefit from carotid surgery [127-128].

Recommendations

TCD and TCDS are non-invasive ultrasound-based methods for studying the cerebral circulation.

The accuracy on which the recommendations are based is provided in tables 3 (TCD) and 4 (TCDS).

Transcranial ultrasound techniques are indicated:

— to assess the stroke risk of children and adolescent with sickle-cell disease

Recommendation 1 - 1 Level A

— for the diagnosis and prognostic assessment of spontaneous cerebral vasospasm;

Recommendation 1 – 2 Level A

— for the diagnosis and prognostic assessment of post-trauma cerebral vasospasm;

Recommendation 3 Level B

— as a test for diagnostic confirmation of brain death

Recommendation 2 Level A

Transcranial ultrasoun techniques are mainly used to assess patients with symptomatic or asymptomatic cerebrovascular disease to show:

— stenosis of intracranial arteries;

Recommendation 2 – 1 Level B

— cerebral vasoreactivity;

Recommendation 2 – 2 Level B

— effects on the cerebral hemodynamics of plaques and/or stenosis of carotid, vertebral arteries and or subclavian arteries (subclavian steal syndrome);

Recommendation 2 – 3 Level C

— the risk of embolic stroke in patients with potentially embolic sources on the level of supraortic trunks, heart or the peripheral veins (combined with a right-to-left shunt);

Recommendation 2 – 4 Level B

— the presence of aneurysms and/or intracranial artero-venous malformations (AVM)

Recommendation 2 – 5 Level C

In patients undergoing carotid open surgery or carotid stenting TCD is used to:

— assess tolerance to clamping and/or hemodynamic changes due to the PTA-carotid stenting procedure;

Recommendation 2 – 6 Level B

— monitor the efficacy of the shunt (during surgery) or of the cerebral protection devices (during stenting);

Recommendation 2 – 7 Level C

— detecting pre-, intra- and/or post-procedural embolic events;

Recommendation 2 – 8 Level A

— monitoring the cerebral hyperperfusion syndrome that may follow carotid artery repair.

Recommendation 2 – 9 Level C

— the data gathered with those methos in the diagnostic stage are presently still correlated with those of other imaging studies (MR or AngioCT) and or with the DSA

Recommendation 2 – 10 Level B

angioCT or angioMRI should be indicated to:

— completing the diagnosis of the intracranial vessels where it is advisable for planning treatment

— when the TCD or TCDS are insufficient with suspected significant injury of the extracranial vessels

— investigating the brain prior to and after invasive procedures to assess the hemodynamic modifications induced by arterial repair, ischaemic modifications after embolism and bleeding that might possibly follow hyperperfusion.

Recommendation 2 – 11 Level B

DSA should be restricted to:

— cases of endovascular treatment

— cases where non-invasive ultrasound techniques and AngioCT or AngioMRI did not provide sufficient and reliable findings or could not be correlated with the clinical data.

Recommendation 2 – 12 Level B

Near infrared spectroscopy can be used in assessing oxygen saturation during carotid surgery or neurosurgery. Like TCD it detects brain ischemia during operation. It still needs validation.

Recommendation 2 – 13 Level C

The radionuclide techniques (flow measurement, PET and SPECT) assess the efficacy of the cerebral circulation only indirectly, measuring the perfusion of the brain and are restricted to functional and still experimental studies.

Recommendation 2 – 14 Level C

The SEP can be indicated for an intraoperative assessment as a carotid cross-clamping tolerance test to use the shunt selectively.

Recommendation 2 – 15 Level C

REPORTING PROPOSAL FOR TCD AND TCDS EXAMINATION IN DIAGNOSTIC PHASE

Last name, name ..... age date .... / .... / ....
The examination is carried out with
– Device .....
– Probe type .....

SIDE: RH ..... LH .....

Windows: Temporal .....
Occipital .....
Transorbitary .....
Submandibular .....

	Depth	Features	Velocity direction
– MCA	.....	.....	.....
– PCA.	.....	.....	.....
– Vertebral	.....	.....	.....
– Basilar trunk	.....	.....	.....
– Ophthalmic	.....	.....	.....
– Syphon	.....	.....	.....

– Anterior communicating artery
not activated
activated
can be activated
not assessable
– Posterior communicating artery
not activated
activated
can be activated
not assessable
– Asymmetry *: RH < LH RH > LH
– asymmetry is the expression of intracranial hemodynamic changes due to unilateral injury of the arteries district upstream and/or downstream of the insonated vessels
– C.C. compression ipsilateral
contralateral
– Microembolic events
in the basal examination (Yes / No and number)
During compression
During continuous monitoring (specify whether 30/60 min)

– Cerebral autoregulation study: methodology: .....
Reserve preserved ..... reduced ..... exhaused .....
– Interpretative difficulties .....
– power Doppler assessment .....
– assessment with US amplifier .....
– Conclusion: .....

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Guidelines for the assessment of the supra-aortic trunks

Investigations

— Duplex scanning (DS)
— Color-coded duplex scanning (CDS)
— Transcranial Doppler (TCD)
— Transcranial duplex scanning (TCDS)
— Trans-esophageal duplex scanning (TEDS)
— Angiography by computed tomography (AngioCT)
— Angiography by magnetic resonance (AngioMR)
— Digital subtraction angiography (DSA)

Research strategy

Ultrasound investigations are the most currently used and represent the first approach in asymptomatic patients. They are also widely applied as a standard method in laboratories of differing levels and utilised by doctors with varying degrees of specialisation. For all these reasons, it seems appropriate to evaluate its reliability compared with reference methods.

With this purpose in the 2009 review, Pubmed carried out a research using the key words "ultrasound and carotid" and "Meta-Analysis, Randomized Controlled Trial" as limiters. In addition to the 397 articles selected for the 2007 review, a further 114 were added and from these, only those articles relating to studies carried out using ultrasound in comparison with other techniques or DS based studies used in comparison with other techniques or the use of US amplifier were selected.

Pertinent articles resulted such as: factors estimating IMT, prospective studies about modifications in flow rates induced by endarterectomy and stenting, studies about the incidence of post-treatment embolisation and any correlation with neurological events, studies about echo-guided venal catheterisation techniques, variations in reliability regarding US amplifiers etc. Prospective studies, where DS was used exclusively or mainly to evaluate the effects of a medical or invasive treatment, were excluded. In compiling the review, diagnostics literature was utilised and the types of studies carried out were examined including those relating to existing guidelines and the experience of those who drew up the guidelines while studies relating to minor cases were excluded.

The abstract of all the articles was evaluated and all the relevant articles in Italian, English, French and German language were assessed and quoted.

Reliability of imaging diagnostics of supra-aortic trunks

To assess such reliability, it is essential to:
— discard old data obtained using equipment that is now obsolete
— tabulate the results of the main studies carried out relating to ultrasound diagnostics
— give more importance to case histories

The reliability of DS - CDS and AngioMR have been compared with the results provided by DSA in a number of studies from which some meta-analyses and systematic reviews have been worked out.

One of these[1], after analysing 63 publications shows the following results for stenosis between 70-99%: combined sensitivity of 95% (95% CI, from 92 to 97) and combined specificity of 90% (95% CI, from 86 to 93) for AngioRM whereas for DS sensitivity was 86% (95% CI, from 84 to 89) and specificity was 87% (95% CI, from 84 to 90). For the diagnosis of thrombosis, the sensitivity and specificity were 98% and 100% for AngioMR as opposed to 96% and 100% for DS. Based on this meta-analysis, AngioMR would identify better than ultrasound.

Another [2] identified studies that were not of the highest quality both in terms of ultrasound and AngioMR diagnostics. A further to this review is that the work with the highest case history is the the only item of good quality and regards 1011 patients enroled in the NASCET study.

Evidently the data from this study provided lower ultrasound reliability than others because of numerous problems analysed by the author of the review (selection of patients based on angiography, exclusion of ultrasound examination of patients with stenosis < 30%, multicentric studies, use of duplex and not colour). To these criticisms it can be added that the study was published in 1991 and,

that since then, the quality of DS hardware and software has radically improved as has the expertise of operators.

A recent meta-analysis[3] that included 41 articles published between 1980 and 2004 about stenosis in excess of 70% confirmed the greater sensitivity (0.94, 95% IC 0.88-0.97) and specificity 0.93, 95% IC 0.89-0.96) of AngioMR with gadolinium compared with DS, AngioMR (without contrast) and AngioCT that presented respectively sensitivity of 0.89, 0.88, 0.76 and specificity of 0.84,0.84 and 0.94.

The comparison between DS and AngioCT showed a sensitivity of 78.9% and specificity of 96.3%.[4]

Of the various parameters than can be assessed with DS, the peak systolic velocity in the internal carotid resulted the single best parameter to differentiate a stenosis major or minor than 80%.[5]

The limitations of this study are further linked to the facts that:

— angiography as a reference is limited *per se* in that it is usually carried out on a limited number of projections;

— data relative to the extension and morphology of the plaque are more easily obtained by DS and MR;

— as regards the carotid arteries, most of the studies used the NASCET method that has a limit which is linked to the comparison between the diseased segment and the healthy downstream artery thus interpreting well the data about flow but not explaining the morphological data.

The increase in the reliability of the method with the use of US amplifier was reported by several studies with small samples. One of these[6] reports a significant increase in reliability passing from a number of non-diagnostic examinations (inconclusive examinations) of 40.7% to 5.1%. The poor diagnostic reliability of the basic examination is simply astonishing and has not been seen either in the literature or in the personal experience of those who drew up the guidelines.

Another study[7] reported a slight increase in reliability with an US amplifier and suggested measuring as more reliable as related the common carotid.

The choice of velocimetric criteria used to identify carotid stenosis

There is no agreement in the literature about the choice of velocimetric criteria used to identify the degree of stenosis; Table I shows previous, highly relevant studies along with data about relative sensitivity (SENS), specificity (SPEC), accuracy (ACC), positive predictive value (PPV) and negative predictive value (NPV).

Table I shows the velocimetric threshold values suggested over the past 17 years for classifying carotid stenosis and their diagnostic accuracy compared with selective carotid angiography. There are 3 angiographic cut-offs: the cut-offs for symptomatic stenoses are at ≥50% and ≥70% and at ≥60% for asymptomatic cases. These cut-offs have been clinically validated in NASCET (symptomatic stenosis) [29,30] and ACAS (asymptomatic stenosis)[31] studies and can therefore be seen as fixed points despite the fact that angiography is known as an imperfect gold standard.[32] In both studies the stenosis was calculated referring the residual lumen at the level of stenosis compared to the disease-free lumen of the internal distal carotid. A comparison was performed in a few studies with the angiographic method used in ECST (symptomatic stenosis) trials according to which the residual lumen was compared with the presumed diameter of the vessel at the level of the stenosis[33].

This method, compared with the one mentioned previously, provides a stenosis value that is usually greater in that the initial cut-off (even though clinically validated) was successfully raised to about 80%. DS-CDS should provide data accurate enough (and not a range of stenoses) to provide an indication for open surgical or endovascular treatment and a choice of therapeutic strategies. The extreme variability of US criteria proposed in literature to classify stenosis is indicative of just how much the method is both operator and machine-dependent. The adequacy of a criterion depends a great deal on the prevalence of the disease in the population that is screened. Apart from a few exceptions, homogenous groups of patients (symptomatic or a symptomatic) have not been evaluated but there is certainly a significant clinical difference between recognising a stenosis of [3]70% in a patient who has had recent symptoms as opposed to an asymptomatic patient. If on the other hand the patient is asymptomatic, the priority thing is to spare him a radiological examination (AngioCT/MR) or subject him to an unnecessary open surgical or endovascular procedure.

In recent years, angiography is no longer seen as necessary to decide indications for treatment given the risk of stroke after cerebral angiography (1.2% in the ACAS study) with a range in literature from 0.5% to 4%.

The need for local validation of US criteria is by now widely recognised in classifying carotid stenosis, including a quality control programme spread over time.

Local validation comes from collaboration between the vascular ultrasound laboratory and the radiology department. It has been shown that non-selective angiography does to allow accurate measurement[34] and that only angiography carried out with selective catheterisation of the carotids allows the calculation of the degree of stenosis according to the NASCET or ECST method. As angiography is currently carried out almost exclusively during the course of endovascular treatment, since AngioCT is highly reliabble, current validation should be done in comparison with multislice AngioCT.

Radiologists should not know in advance the results of a CDS nor the patient's clinical data and as little time as possible should pass between the two examinations. The CDS should be recorded and the operator should measure all the spectrum analysis parameters to be validated.

It is also important to record the B-mode data that are especially useful in cases where velocimetric data may be modified by a severe stenosis or occlusion of the contralateral carotid, stenosis of the common or of the distal internal carotid, arrhythmia, aortic valvulopathy etc.

The quality of the examination is also to be recorded. The quality might be low due to the presence of shadows or anatomical anomalies (short neck, high bifurcation, kinking, coiling etc.).

Validating the velocimetric criteria means identifying the threshold value of each individual parameter, or the combined threshold values of more parameters that can better discriminate positive from negative examinations based on preselected angiographic/AngioCT cut-off.

At the report stage, using good technical equipment, the morphological congruity then needs to be checked – depending upon the method employed – with the velocity recorded, specifying the apparent incongruity between normal velocity and the extent of the lesion in cases of large plaques largely involving the IC.

With regard to symptomatic stenosis, it is important that the negative predictive value is also high. There are two possibilities: to choose just one criterion that has the

TABLE I.—*Highly relevant studies and data about relative sensitivity (SENS), specificity (SPEC), accuracy (ACC), positive predictive value (PPV) and negative predictive value (NPV).*

AUTHOR	YEAR	N. IC	STEN.	PSV IC	EDV IC	PSV IC/CC	EDV IC/CC	PSV IC/CID	SENS	SPEC	ACC	PPV	NPV
FAUGHT[8]	94	229	50-69	130 +	£100				92	97	97	93	99
WINKELAAR[9]	99	188	≥50			2			96	89	93	92	
			≥50			3.6			77	98	86	98	
ABURAHAMA[10]	99	462	≥50	140					92	95	93	97	89
ZWIEBEL[11]	92		≥60	130 +	40								
CARPENTER[12]	95	210	≥60	170					98	87	92	88	98
			≥60		40				97	52	86	86	86
			≥60			2			97	73	76	78	96
			≥60				2.4		100	80	88	88	100
			≥60	170 +	40 +	2 +	2.4				100		
MONETA[13]	95	352	≥60	260 +	70				84	94	90	92	
			≥60	290 +	80							95	
FILLINGER[14] (4 laboratories)	96	360	≥60	190-240		2.6-3.3					≥90	≥90	
GRANT[15]	99	132	≥60	200		3			≥90	≥90	MAX		
ABURAHAMA[10]	99	462	≥60	150 +	65				82	97	90	96	86
MONETA[16]	93	100	≥70			4			91	87	88	76	96
			≥70	325 +	125								
NEALE[17]	94	120	≥70	270 +	110				96	91	93		
FAUGHT[8]	94	229	≥70	130 +	100				81	98	95	89	96
			≥70	210					89	94	93		
			≥70		100				77	85	80		
PATEL[18]	95		≥70	230					94	83	86		
			≥70			4			79	86	84		
CARPENTER[19]	96	210	≥70	210					94	77	83	68	96
			≥70		70				92	60	77	73	86
			≥70			3			91	78	83	70	94
			≥70				3.3		100	65	79	65	100
HOOD[20]	96	457	≥70	130 +	100				87	97	95	89	96
ALEXANDROV[21]	97	174	≥70	250					93	86		75	96
CHEN[22]	98	185	≥70	175								71	
			≥70	230								81	
			≥70	130 +	100							88	
			≥70	270 +	110							90	
			≥70	125 +	135							91.6	
			≥70			4						86	
ELGERSMA[23]	98	60	≥70	210							0.96 ROC		
	98	61	≥70	270							0.95 ROC		
GRANT[15]	99	201	≥70	175		2.5			≥90	≥90	MAX		
ABURAHAMA[10]	99	462	≥70	150 +	90				85	95	92	91	92
			≥70	150 +	110							[3]95	
RANKE [24]	99	80	≥70					5	97	98			
GOLLEDGE [25]	99	100	≥70	295 +	90				73	85	80		
			≥70			5.5			73	88	82		
STRANDNESS [26]	90		50-79 E	125 +	£140						93		
CURLEY (ACST) [27]	98		≥70E	130					96	67			
			≥70E	250					37	96			
STRANDNESS[26]	90		≥80E		140								
ZWIEBEL [11]	92		≥80	250 +	100								
GOLLEDGE[25]	99	100	≥80E	375					62	95	82		
			≥80E		90				84	86	86		
			≥80E			5.5			74	90	84		
SUWANWELA [28]	96	99	L.R. £1.5	440					58	100			
			£1.5		155				63	100			
			£1.5			10			30	100			
			£1.5	440 +	155+	10			72	100			
			£1.5	200 +	140 or	4.5			96	61			

STEN= % stenosis according to NASCET method unless otherwise specified: E (ECST method); L.R. (stenosis evaluated as residual lumen) – PSV = Peak Systolic Velocity – EDV = End Diastolic Velocity – IC = Internal Carotid – CC = Common Carotid – IDC = Internal distal carotid.
All the US parameter threshold values are to be preceded by [3] unless otherwise specified.
As reference parameters for the degree of stenosis, laboratories may indicate those obtained from experience or data from Table I; it is however recommended to use the data that have higher PPV values or greater sensitivity.

greatest diagnostic accuracy or to establish an intermediate range between two differing values, in which the preoperative assessment is completed with non invasive radiological imaging. The most commonly used statistical tool for comparing the sensitivity and specificity of differing threshold values in the literature is the analysis curve known as ROC (Receiver Operator Characteristic).

Table II shows the Strandness[26] criteria for classifying carotid stenoses taking into consideration their international diffusion.

Following publication of the NASCET and ACAS results, Moneta and Carpenter in the vascular laboratory of Washington University created criteria to identify stenosis of ³70% and ³60% respectively in the context of class D (50-79%). These criteria have already been shown in Tab.... On the other hand, since the classes of stenosis defined by PSV are too broad and apart from variations of inter-observer PSV (technological) on a progressive scale creating problems of the interchangeability of techniques mainly for assessing the progression of stenoses, the use of additional tests has been suggested.[35] A fairly recent meta-analysis, that processed data published between 1966 and 2003 [36] confirms the difference between the properties of measurements taken by various laboratories for the various ultrasound thresholds leading to reconsider the limitations of ultrasound in treatment decision making. The rate of flow in severe stenoses (both PSV and EDV) resulted inversely correlated to the corresponding systolic and diastolic pressure in the carotid stump (stump pressure), an expression of post-stenotic perfusion pressure from collateral circulation[37].

1) This classification is accurate only for predicting a decrease in diameter in the first 3 cm of the internal carotid. It is not reliable for the external, common or distal internal carotid.

2) All the values of frequency and velocity are based upon the use of pulsed Doppler with a frequency of 5 MHz with a cubic sample volume of 1.5 mm and an angle of 60°.

3) The telediastolic frequency and velocity values are only used to classify stenoses of 80-99%. N/A = Not Available;

Table III shows the reference values simplified in view of the current distinction in non-haemodynamically significant (<70%) and haemodynamically significant stenoses (>70%). The NASCET method was used for validation.

This table shows an obvious difference in the PSV (from 130 to > 225 cm/sec) compared with a slight increase in the degree of stenosis (70-75%). This difference is at the same time indicative of the sensitivity of the velocimetric criterion in reaching the critical value of stenosis but also of the difficulty of characterising the same critical value if not taking the spectrum analysis of the flow signal into qualitative consideration.

Considerations on plaque morphology - plaque at risk

Many surgical case reports have identified correlations between the type of plaque and symptoms or risk of stroke but the value of the degree of stenosis was the main factor in the NASCET and ECST studies.

These studies also led us to recognise that, in the "severe" stenosis category, there are features of stenosis such as "ulceration" or "irregularity" which carry a further increase of risk[38].

TABLE II.—*Strandness criteria. Notes*

CLASS	DIAMETER REDUCTION	SYSTOLIC PEAK	TELE-DIASTOLE	FLOW CHARACTERISTICS
A	0%	<4 KHz <125 cm/s	-	minimal or no broadening of the spectrum during the systolic deceleration phase. The bulb sees the usual separation of the blood layer near the wall.
B	1-15%	<4 KHz <125 cm/s	-	minimal broadening of the spectrum during the systolic deceleration phase.
C	16-49%	<4 KHz <125 cm/s	-	Increase in spectrum broadening during systole until the whole systolic "window" is filled.
D	50-79%	>4 KHz >125 cm/s	-	There is usually significant broadening of the spectrum.
D+	80-99%	-	>4.5 KHz >140 cm/s	There is usually broadening of the spectrum.
E	100%	N/A	N/A	No flow signal in a vessel seen in an adequate manner (particularly in the distal segment) with diastolic flow of the common carotid low or inverted. A typical thump may be detected in the tract before the blockage.

TABLE III.—*PSV: peak systolic velocity; EDV: end diastolic velocity; ICA: internal carotid artery; CCA: common carotid artery*

Stenosis	PSV ICA	EDV ICA	PSV ICA/PSC CCA
>50 %	> 125 cm/sec		> 1.5
>60 %			> 3.2
>70 %	> 130 cm/sec	> 100 cm/sec	> 3.3
>75 %	> 225 cm/sec		
>80 %		> 140 cm/sec	
>95 %			
100 %	0 cm/sec	0 cm/sec	

So a correlation between type of plaque and neurological symptoms was established suggesting the concept of "plaque at risk"[39,40,41,42,43,44].

DS led to some classifications regarding the echogenicity of the plaques; the International Consensus Conference of 1996[45] proposed a classification, that considers both echogenicity and structure and divides plaques into 5 types:

1. uniformly anechogenic;
2. mainly anechogenic;
3. mainly echogenic;
4. uniformly echogenic;
5. calcified.

The relevance of plaque morphology in predicting the risk of cerebrovascular events was confirmed by the Tromsö study that showed that patients who had hypoechogenic carotid plaques had a higher risk of cerebrovascular events regardless of the degree of stenosis and of the concomitant presence of other vascular risk factors[46].

Other authors have also successfully confirmed that the progression of the degree of stenosis and the echographic features of the plaque are relevant predictive markers of cerebrovascular events[47].

AngioCT too, particularly the multislice CT (MSCT) can measure the density of the plaque, distinguish between structures made from calcium, lipids and fibrous tissue and detect the irregularities of the surface.

MR also can identify and quantify various components of the plaque such as a lipid/necrotic core, a fibrous cap, intraplacque haemorrhage or trombus[48].

Many other methods aim to identify a plaque at risk by means of metabolic activity or the identification of inflammations, such as fluorodesoxyglucose positron emission tomography (FDG-PET), optical coherence tomography (OCT) and time-resolved laser-induced fluorescence spectroscopy (TR-LIFS). The detection of some molecules such as C-reactive protein, matrix metal proteinases and their inhibitors, cytokines, myeloperoxidase etc, may be used as instability and plaque rupture biomarkers.

Ultrasound investigation of intracranial arteries can show microembolic signals (MES) that suggest ulceration of the carotid plaque and confirm the role of MES as a surrogate marker of the presence of embolising carotid plaque (see specific section).

The importance of instable plaques that is suggested by recent studies is changing the guide lines that a few years ago were mainly based on the degree of stenosis.

The current guide lines from the European Society for Vascular and Endovascular Surgery[49] state:

— Plaque morphology should be assessed in all cases before invasive treatment [B].

— The plaque at risk of peri-procedural embolisation should be identified by validated imaging (GSM, etc.) or other diagnostic techniques such as biological markers [C].

Considerations on vertebral arteries

Ischemic stroke of the vertebrobasilar territory can account for up to 20% of all ischemic cerebrovascular events.

The recurrence of episodes is high in the early phases and comparable with that of the carotid territory[50,51,52] however a repair of vertebral arteries is rarely performed. From the anatomopathological point of view, it appears that at least a third of patients with TIA or stroke in the vertebrobasilar territory present stenosis of the distal vertebral artery greater than 50%.

A randomised controlled study was carried out with regard to the feasibility and results of stenting symptomatic stenosis of the vertebral arteries[53].

Its results suggested the absence of correlation between the presence of stenosis of more than 50% in the vertebral artery and age, gender and vascular risk factors (apart from the presence of coronary atherosclerosis)[54].

With CDS there was a significant increase in sensitivity in the study of the entire length of vertebral artery but with differences that depend upon the extracranial segments.

The vertebral artery is divided into 4 segments:

V1 (from its origin to the transverse process of C6), V2 (from C6 tothe top of the transverse process of C2), V3 (fromthe top of C2 to the atlanto-occipital membrane) and V4 (intracranial segment).

The study of the V1 segment allows the areas that are mainly affected by stenosis to be examined in detail. An assessment of V2 alone does not provide any indication about the presence of ostial stenosis. A change in the rate of flow and spectrum characteristics is present in V2 only in cases of severe stenosis or occlusion at its origin. For this reason, the stenoses less than 80-85% are not detected if the ostial segment is not examined.

The V3 segment is below the Tillaux triangle near the retromastoid space and can easily be compressed with consequent increase and decrease in resistance in segment V1. This to a large extent allows the vessel to be recognised and prevents the very common mistake of recording the flow signal from the thyroid-cervical-scapular trunk.

The vertebral arteries are very often of different diameter, the left vertebral artery being bigger than the right in 66% of cases. A study that measured flow rates (ml/min) in both the vertebral arteries shows a correlation with size of the vessels. For this reason, in case of disease, any compensation may be insufficient[55].

Segment V1 is visible in about 65-85% of cases with the right side more visible; segment V2 is visible in about 95% of cases[56].

Recent improvements to CDS including the type of probe, have certainly increased the possibilities of studying the V1 segment where most lesions occur. Recent assessments regarding flow rates and the degree of stenosis in the ostial vertebral artery have indicated the potential of evaluating PSV cut-off that increases the sensitivity of CDS[57].

There is literature on the range of normal velicities for segment V2 at between 20 and 60 cm/sec while for segment V1 an average velocity of 64 cm/sec is recorded with a range from 30 to 100 cm/sec[57].

In a comparison of AngioCT, AngioRM and CDS on the vertebral arteries, recent publications have shown a high correlation for stenosis 50 to 99% with a high degree of uniformity between the methods. The CDS can therefore be placed at the same level as diagnostic methods that are currently considered as more reliable[55,58,59,60].

The reliability of ultrasound techniques for vertebral artery disease was assessed in a blind prospective study on symtomatic patients in 316 vertebral arteries as compared to selective angiography; stenoses > 70% were correctly diagnosed in 71% of cases with a specificity of 99% and a K value of 0.80, 2 false negatives over 12 occlusions in 2 cases of recanalised occlusion. The other false negatives (38) were associated with intrathoracic origin, with anechogenic stenosis or with tortuosity[61].

Occlusion of the vertebral artery at intracranial entry, can be suspected in the presence of a very high resistance stump-flow type signal at segments V1-V2. Dissection of the vertebral artery, usually starting from V3, determines a

similar velocimetric signal and can be suspected in young patients or in post traumatic lesions.

Assessment with TCD and TCDS complete the investigation[61,62].

The vertebral arteries and the subclavian steal syndrome

Severe stenoses and subclavian occlusions are signalled by upper limb fatigue following exercise but symptoms can also arise from little physical effort ("writer's cramp").

If the stenosis/occlusion is prevertebral it can be associated with neurological symptoms: "subclavian steal syndrome".

In a physical examination hyposphigma may be detected or the absence of axillary, brachial, radial and ulnar pulses. Moreover a pressure gradient can be measured between the two limbs [63].

Stenosis or occlusion of the subclavian artery in the prevertebral segment can entrain changes to the direction of flow signal, as detected by CDS from the homolateral vertebral artery.

Severe and stable neurological complications are rare.[64]

When the direction of vertebral arterial flow is constantly inverted the definition "continuous subclavian artery steal" is used. CDS shows a flow signal that runs away from the probe towards the homolateral subclavian artery.

PW Doppler investigation will therefore indicate the inversion along an axial direction of the flow signal.

The same CWD was able to detect continuous or intermittent steal conditions with high sensitivity and specificity. [65]

In "intermittent steal phenomenon" two phases are seen in the velocitogram that can indicate both a slight degree of flow inversion or an increasing inversion with a decreasing orthograde component of the PW Doppler signal.

Since the steal phenomenon is associated with a haemodynamic equilibrium between demand from the limb and compensation from the homolateral vertebral artery, the postischemic hyperemia test triggers a worsening in continuous steal and in cases of intermittent steal[66].

When prevertebral stenosis of the subclavian artery is moderate a basal study of the vertebral artery shows a proto-meso-systolic notch that tends towards the zero crossing line. In this case the term used is "latent steal or presteal" [67].

Investigation of subclavian steal with TCD in some studies did not show conditions of basilar steal but rather a compensatory increase of the average flow[68]. However completing the study with postischemic hyperemia showed a basilar artery steal and was useful for selecting patients at higher risk of vertebro-basilar stroke[69,70].

More recent studies indicate less frequent intracranial steal by the basilar artery in cases of continuous steal in a vertebral artery (about 20% of patients).

TCD is indicated in patients who have to undergo major surgery[71].

Endovascular treatments aneurysm or dissection of the aortic arch and thoracic aorta, frequently need coverage of the left subclavian artery. Under those conditions, continuous steal may occur by the homolateral vertebral artery. Data from a few studies carried out using CDS confirm the phenomenon of steal and show that symptoms often absent or modest[72].

A jatrogenic arteriovenous fistula (AVF) in dialysis patients can entrain a stea by the vertebral artery in absence of disease of the prevertebral subclavian artery [73,74,75]. Under those conditions the homolateral vertebral artery can show all the types of steal conditions.

Recent investigations of the subclavian steal syndrome with AngioMR have provided images that

of temporal variations of the intensity of signal studied with gadolinium[76].

Procedures

1. The CDS is the procedure of choice for first investigating and screening cerebrovascular diseases.

2. Technology increased its reliability of ultrasound when measuring the degree of stenosis and in assessing the morphology of the vascular wall also with the use of US amplifiers:

— The findings of ultrasound scans with US amplifier have shown excellent correlation with DSA.[77]

— Analysis of the features of plaques (markings, delimitation of the vessel wall and plaque) improved by the use of the "real time compound ultrasound" technique.[78]

— Measuring the gray scale median (GSM) has shown to be quite useful in defining the embolic risk of a plaque[79] and in the ICAROS[80,81,82] study, it has been indicated as one of the elements to be assessed during ultrasound scanning of the carotid arteries.[83] Further studies did not quite confirm this parameter as a risk factor particularly with in[84] regard to false negatives.

— B-flow imaging (BFI) has shown a high correlation with DSA and is better than power-Doppler.[85,86,87,88]

— Volumetric determination of plaques using 3D ultrasound has shown a reliability increasing with the volume of the plaque.[89]

— The high reliability of US investigations led many surgeons to perform open endarterectomy of the carotid only on the basis of CDS. So a statistical analysis based on a technique with higher reliability shows that out of 1000 symptomatic patients with a prevalence of stenosis of >70% respectively of 10%, 30% and 50%, the patients who would be operated upon without surgical indication (based on stenosis gradient) would be respectively 144, 112 and 80. With AngioMR, the number of patients operated on without surgical indication would be respectively 32, 25 and 18[2].

— 3. Indications for Duplex Scanning

— DS-CDS of the supra-aortic trunks has many indications: some are based on neurologic symptoms and some on screening in high risk patients.

— Symptomatic carotid stenosis
  - Recent TIA or stroke are the main indication for CDS. From some guidelines in and from the literature and SPREAD 2005[90] guidelines, some points should be emphasized:
  - 20-40% of patients with ischemic stroke can present spontaneous worsening in the early hours after and up to a week after the onset of symptoms;
  - many patients with several TIAs or minor-stroke develope a stroke in the early hours – days so that the NNT for randomised patients within the first two weeks is 5 while it is 125 for randomised patients after more than 3 months.[91]
  - CDS is simple, low-cost, reproducible and non-invasive and can detect with accuracy in patients with stroke and even acute stroke a stenosis or occlusion of the internal carotid artery and can also

provide prognostic data.
- for this reason all patients with recent TIA or stroke are should be given an early CDS of the supra-aortic trunks (SAT).
- An urgent CDS of the SAT should be carried out within 2 hours of a TIA or within 1 hour of the onset of a stroke as part of a complete investigation in order to begin the emergency treatment of patients with stroke (within 3-6 hours)

— Diagnosis of stroke in the acute phase

— The diagnosis of stroke in the acute phase with the purpose of treatment within 3-6 hours (depending upon the protocols and type of treatment) should be carried out as an emergency, should be reliable and should be coordinated with equipment available in the hospital where the treatment will be carried out or in line with the logistics of its departments.

Vascular diagnosis should quick and early and provide the following data:

1. Exclude haemorrhage as a cause for stroke
2. Confirm the vascular nature of the stroke or TIA
3. Define the patency or degree of occlusion of the common/internal carotid artery
4. Evaluate the patency or occlusion of the middle cerebral artery and the type of occlusion
5. Define the collateral pathways
6. Assess the extent of ischemic damage

In many hospitals points 2-5 are defined by CDS and TCD while in others the investigation is based entirely on AngioMR or AngioCT depending on the equipment available.

Assessment of the brain is based on AngioMR and AngioCT; the better the equipment, the more reliable the findings that may show ischemic areas in an early phase.

At present the most reliable method is diffusion/perfusion MR.

TCD or TCDS are used in many hospitals to monitor thromboembolisms and to enhance the effects of thrombolytic drugs[92] even if it appears that this approach increased the incidence of haemorragic complication using 300 KHz probes.[93]

— Asymptomatic carotid stenosis
- 20-30% of patients with chronic lower limb obstructive disease present carotid stenosis of >50% that is often asymtomatic and on occasion no murmur can be heard.
- The presence of a murmur is not always correlated with carotid disease whereas the absence of a murmur does not exclude the absence of a carotid lesion.
- Marek et al.[94] report an incidence of carotid stenosis of less than 50% in 8% of cases examined, stenosis of more than 50% in 21.8% of patients and occlusion of the internal carotid in 2.7%. The incidence of carotid lesions is even greater in young patients with arterial disease; Valentine et al.[95] encountered normal carotid arteries in only 26% of a group of 75 patients with an arteriopathy and an age of 42±0.5 years while 11% presented occlusion and 18% had greater than 60% stenosis. [96]
- The same risk was encountered in patients with coronary disease who were older than 65 and had multiple risk factors.
- A study in patients needing cardiac surgery showed in 17% of cases an incidence of carotid stenosis in excess of 50%, and, in 6% of cases, carotid stenosis in excess of 80%[97].

— Carotid intimal-media thickness and its predictive value
- An increase in carotid intimal-media thickness (IMT) is associated with coronary atherosclerosis and with the most common risk factors for atherosclerosis. It also appears to take on clinical relevance particularly with other parameters such as:
- Flow-mediated dilatation (FMD) of the brachial artery and pulse wave velocity (PWV).[98]
- A recent meta-analysis confirms that carotid IMT is a good predictor of vascular events with a slightly greater risk for end point stroke than for myocardial infarction[99].
- An increase in IMT has been recorded in patients with numerous diseases that often present an association with atherosclerosis such as hypertension, autosomal dominant polycystic kidney disease[100], renal insufficiency, diabetes or hyperinsulinemia.[101] In all the cases investigated, IMT was associated with: age, hypertension, low HDL values, increase in body mass and duration of diabetes,[102] even if some studies show no correlation between abdominal obesity and increase in IMT.[103] In children with familial hypercholesterolemia[104] and in pediatric patients with hypertension, IMT was encountered correlated with: systolic blood pressure, BMI, homocysteine, low HDL values, apolipoproteine A1.[105]

Based on these epidemiological data, ECD examinations of all symptomatic and asymptomatic patients suffering from arteriopathy or coronaropathy would be indicated, even in the absence of laterocervical murmurs following the first clinical investigation as part of the metabolic, haemocoagulative, clinical and instrumental examination of the patient with arteriopathy. It should also be used in patients undergoing radiological treatment of the neck, in patients with ocular vascular diseases and in patients who present a carotid plaque to be dealt with by pharmacological therapy so as to evaluate progress.

3. Indications for Transesophageal Duplex Scanning (TEDS)

The complementary use of TEDS is indicated for the examination of the aortic arch and thoracic aorta and abdominal aorta and rarely to assess the origins of the supra-aortic trunks particularly for possible source of microembolism in the absence of cardiac lesions (valvular, patent foramen oval and septal aneurysm) and/or of the carotid axis.

4. Indications for AngioMR and AngioCT

AngioMR and angioCT should be reserved for:

— multilevel disease of the supra-aortic trunks

— planning endovascular treatment

— completing the investigation of intracranical vessels when considering therapeutic planning

— CDS with insufficient diagnostic value (e.g. for sizeable calcification) with suspected significant lesion under haemodynamic profile

— CT of the carotid arteries can provide useful data about the structure and composition of carotid plaques through density analysis and application of the Hounsfield scale. The use of US amplifiers can also contribute to assess the degree of stenosis using multislice CT and assess both axial and 3D-MIP reconstruction that can currently be compared with angiography and CDS

— AngioCT and multislice CT are excellent methods for assessing extracranial vessels and can be used for intracranial vessels even if they need a large amount of contrast

medium. They can provide important data about the vessel walls, particularly with regard to subintimal calcification. Such information can be very useful in surgical planning even if the same data is often provided by CDS.AngioCT appears to be reliable in detecting occlusions and subocclusions of the extracranial carotid arteries in comparison with DSA.[106]

— AngioMR is used for panoramic examinations of the aortic arch and of the origin of the supre-aortic trunk and to assess carotid bifurcation and intracranial circulation. As regards extra-cranial vessels acquisition using the intravenous bolus administration of a contrast medium appears preferable with the superfast acquisition technique, that, in a just few tenths of a second allows any carotid bifurcation and the main supra-aortic trunks to be assessed.

— although it is not possible to obtain AngioMR on all patients, it does not carry the risks associated with angiography and an accounting study showed it to be less expensive.[107]

— there have been recent descriptions of cases of adverse effects following the use of AngioMR and gadolinium that would seem to induce systemic nephrogenic fibrosis and nephrogenic fibrosing dermopathy. The incidence of this complication appears to be very small (about 200 cases out of 200 million patients)[108]. The systemic nephrogenic fibrosis seems to be caused by a combination of factors that include impaired renal function, inflammatory process and exposure to gadolinium[109] and is particularly associated with the administration of gadolinium to dialysis patients with acute hepatorenal syndrome and chronic renal insufficieny[110].

Indications for angiography

Angiography should be reserved:

— as preliminary phase of endovascular treatment

— when AngioMR/AngioCT are not possible due to the presence of metallic foreign bodies that produce artifacts or hinder the examination.

— when non-invasive investigations were not sufficient or did not correlate with symptoms

— for suspected vasculitis, dissections, malformations and defects in cerebral circulation as complementary diagnostic evaluation by means of imaging.

— for patients with claustrophobia

5. Indications for clotting, metabolic and inflammatory assessment

— A study of haematological parameters has shown that the clotting system plays a role in the development of carotid plaques, even if it does not appear to be responsible for symptoms;[111] symtomatic plaques have a higher concentration of thrombin-antithrombin compounds [112]

— In patients with carotid disease, the metabolic and haemocoagulative profiles have to be studied so as to minimise the risk factors and prevent the disease from progressing.

— Recent studies are assessing inflammatory aspects in the formation and evolution with rapid progression of atheromatous plaques.

Color-coded Duplex scanning of the supra-aortic trunks

Equipment: Duplex scanner - color-coded Duplex scanner; transducers: Linear probes are used with variable frequency ratings of between 5 and 12 MHz in which the lowest frequencies are used for PW Doppler and Color flow functions. Microconvex probes are used to depict segments that are very difficult to reach or where there are problems associated with the neck.

Procedure

1 – Patient in supine position with head and neck on a pillow.

2 – Probe placed in a flat transverse position on the common carotid (CC) starting from the lower part of the neck.

Examination:

a) Starting caudally to identify the proximal CC, brachiocephalic, subclavian and vertebral arteries. Description and documentation of lesions.

b) Proceeding in cranial direction along the CC until reaching the carotid bifurcation.

Description and documentation of lesions.

c) Proceeding distally until reaching the carotid bifurcation to assess the internal carotid (IC) and external carotid (EC).

Description and documentation of lesions, specifying the intima-media thickness.

If some disease is identified and clearly defined, the percentage of stenosis is estimated (diameter and area)

3 – The probe is placed in a flat saggital position along the CC and the examination includes:

a) The neck starting from the clavicle then moving upwards to the carotid bulb. Description and documentation of any lesion of the wall and of the diameter of the lumen as well as measuring intima-media thickness (IMT)

b) The carotid bifurcation with description and documentation of the CC and bulb.

c) Next are IC and EC. Description and documentation.

d) Duplex and color-coded spectrum analysis of the CC. Description and documentation.

e) Duplex and color-coded spectrum analysis of the IC.

Next is sampling of the proximal, medial and distal IC; recording of the fastest speed for calculation of peak and ratio (peak to peak).

f) Duplex and color-coded spectrum analysis of the EC. Description and documentation.

g) Duplex and color-coded spectrum analysis of the brachiocephalic (when detectable) and right proximal and left proximal subclavian arteries. Description and documentation.

Duplex and color-coded spectrum analysis of the origin of the vertebral artery. Compression manoeuvre at the Tillaux triangle when assessing segment V1 allows to recognise it; measurement of proximal and distal arterial flow with confirmation of the direction of the flow signal.

Detection of vertebral artery between vertebral bodies with antero-posterior sagittal projection; measurement of velocity and direction of flow signals.

4 – The procedure is repeated on the other side.

5 – For the Duplex spectrum analysis, changing to the angle of incidence of the pulsed Doppler is needed keeping it to the smallest possible value or between 40° and 60°.

Exceeding 60° entrains a logarithmic increase of the flow rate value that makes the velocimetric data unreliable. The angle of the CC and IC is kept as close as possible when assessing the ratio. The sample volume will be as small as possible except in a case of suspected occlusion.

6 – In the case of stenosis, samples are taken from proxi-

mal level, at the site of minimal residual lumen and distally from the stenosis using as a reference one of the criteria of classification of stenosis shown in Table I or even better, the results from laboratory assessment that follow the investigation depending upon the criteria shown in the following paragraphs.

7 – When the morphological report allows correct measure of the stenosis both in terms of diameter and area, the velocimetric report is complementary and for the definition of the degree of stenosis, as in conditions of extremely high carotid bifurcation and/or extensive disease of the distal section of the carotid, the investigation might be completed with a trans-oral study.[113]

8 – In a case of endoarteriectomy, samples are taken at the site of arterial repair and proximally and distally.

Methods for measuring IMT

Measuring IMT presents several problems that involve changes to the method over time.

— The main problem regards the difference in intima-media thickness of the two CC. Several studies show bigger IMT on the left if measured on the posterior wall. On measures of the anterior wall, the thickness of the right common carotid appears bigger.[114] The variability of interobserver and intra-observer measurement is less when measuring the posterior wall and is bigger at the right carotid.[115] Measurement of the IMT of the IC is more predictive, however since it is often abnormal, it is generally not considered.

— For "interventional" studies, some authors deem it more appropriate to consider the median variations of maximum IMT.[116]

— For this reason, it is recommended to:

— measure the IMT on the posterior wall of the CC 1 cm from the bifurcation in a segment of carotid of about 1 cm, taking the measurement on the posterior wall in at least 2-3 projections and to note the median and maximum values

— use zoomed images and dedicated software

— take repeated measurements or have the measurements taken by independent operators

— note the IMT measurement separately on both common carotids

— note on the report whether the value shown is the median or the maximum

— do not report a maximum "normal value" as this data varies with gender, age and race. Include incorporate the measure of the lumen as there can be differing levels of distension associated with pressure, particularly in prospective studies on man[117].

Postoperative assessment

An intra-operative check on completion of carotid endarterectomy (CE) or graft was recommended many years ago by Blaisdell.[118] Some years later Courbier[119] demonstrated with a prospective study the decrease in post-operative complications when completion angiography was used.

Other studies confirmed the efficacy of angiography in decreasing the incidence of periprocedural stroke and in follow-up [120,121].

Prospective studies have demonstrated the reliability of ultrasound when compared with DSA;[122] CDS is an easy intra-operative check,[123] detecting technical defects that need an immediate re-intervention[124] and providing a base for follow-up.

In a prospective study, using 2 types of materials for patch, AbuRahma reported velocimetric differences between patients with restenosis on patches and patients with primitive stenosis. This confirms that the PSV of a non-stenotic artery downstream from a polyester or PTFE patch is faster than the PSV of a normal non-operated artery. Both patch and stent entrain changes to flow that cannot be ignored when carrying out the assessment. stenosis[125].

The timing of post-operative checks is controversial as well as its duration. The greater incidence of carotid restenosis is encountered within the first year and this has led to the suggestion of more frequent checks within the first 18 months.[126] Periodical out-patient checks in follow-up are a good way of detecting late restenosis and checking the results of a centre for accreditation and certification purposes. The timing for such checks is outlined in Table V.

The parameters to be evaluated are as follows:

— Patency of the IC

— Patency of the EC

— Presence and degree of restenosis at the CE site

— Presence and degree of stenosis above and below the CE site

— Presence of thrombus and description of the site

— Presence of CC step at the limit of the CE site

— Detection of flaps or wall dissections and their locations

— Presence of patch pathology if appropriate (parietal thrombus, ectasia, separation)

— Stenosis features: rate of flow, echogenicity, spread, minimum diameter of carotid, study and photographic documentation with Power-Doppler to exclude false restenosis.

Postcarotid stenting investigations

Generally uncovered stents are implanted into the carotid arteries for the treatment of stenosis but in some cases covered stents are employed to treat aneurysms or pseudoaneurysms. The first CDS following the implantation of a carotid stent should be at patient discharge then at 1 month. From here on, the same timing is used as for CE: 4-8-12-18 months etc. The check at patient discharge should exclude recoiling as compared with post-procedural angiography and residual stenosis or faults in stent opening.

As the atheroma was not removed, the assessment of the degree of stenosis cannot follow the ECST criteria that involve measuring the relationship between residual lumen and vessel diameter. It is however in line with NASCET criteria; the residual percentage of the stent imprint, if present, should however be described and this information is more reproducible if the assessment is performed using the ECST method. The method used must always be reported.

Some "new" terms are used in the literature

— Minimum lumen diameter (MLD)

— Percent diameter stenosis: it is the measurement obtained with the ECST method i.e.: [(vessel diameter – minimum diameter)/vessel diameter] x 100

— Late loss: the difference between the minimum lumen diameter on completion of the procedure and that measured at follow-up

— Binary restenosis: it is the measure of restenosis in the stented section and the term is usually interchangeable with angiographic restenosis: it is normally considered with a cut-off of 50%. There are two sub-meanings:
- in stent binary restenosis: when only the intrastent part is involved
- in segment binary restenosis: when the segments immediately near the stent are also involved

The parameters to be considered differ from those that are assessed following surgery and are as follows:
— Patency of the IC
— Patency of the EC
— Presence of residual stenosis in the stented segment
— Presence of stenosis (new atheroma, hyperplasia, thrombus) inside the stent (in-stent restenosis)
— Presence of stenosis above or below the stent
— Presence of thrombus
— Adhesion of the stent to the vessel wall
— Presence of kinking of the IC at the end of the stent created by differing compliance between stent and carotid wall
— Stent migration
— Stent integrity or breakage
— Complications relating to a previous CE procedure (patch separation etc.)
— Diameter – residual area along the stent
— PSV – EDV

As the stent reduces artery compliance, the velocimetric criteria normally used for measuring stenosis are not applied. Studies on this subject agree and confirm an increase in speed in the stented segment (Table IV). Lal et al.[127] propose the following values for identifying a normal carotid following stenting (stenosis < 20%):
— PSV < 150 cm/s,
— ICA/CCA ratio < 2.16

Robbin et al.[128] used PSV > 125 cm/sec and a PSV ratio of between ICA and CCA ≥ 3:1 or a doubling of the intrastent PSV as criteria for stenosis or restenosis. With these criteria, they found a correspondance with angiography in severe intrastent stenosis.

New velocimetric criteria need to be furtherly defined for the various classes of stenosis; the stenosis should also be defined under a morphological profile.

In post-operative and post-stenting monitoring if the lesions are of litttle importance, a minimal description is sufficient. If however the lesions are relevant, the morphological evaluation must be accurate.

The report in cases of stenosis should include:
— site - percentage - features,
— features of the direct suture or patch
— any disease in the non-treated lesions with regard to the contralateral carotid and to the first segment of the
— subclavian artery

The timing of postoperative and prospective assessment

— The ACAS trial indicate a beneficial effect in CE in patients with asymtomatic carotid stenosis between 60% and 90% (measured according to NASCET), in patients with asymtomatic carotid stenosis of between 60% and 99% only if severe perioperative complications (invalidating stroke or death) were less than 3%. However the NNT was high and did not offer unquestionable indications for surgery.

— Several studies demonstrated an increased risk in patients with echolucent or ulcered plaques.

— Restenoses are the most frequent complication after CE and stenting and are mainly seen in the first 12-18 months (myointimale hyperplasia). After a few years restenoses appear that are associated with a recurrence of atheriosclerosis, particularly in patients who did not correct their risk factors; the incidence of restenosis between 1 and 2 years varies from 9 to 33%[134].

— Restenosis is linked to many risk factors, to the female sex and to the type of treatment. Some sub-groups at annual risk of severe restenosis greater than 6% (patients with hyperlipidemia, diabetes mellitus, current smokers, patients with coronary artery disease, women, young patients) [135]. With regard to surgery, the use of a patch significantly reduces the incidence of restenosis and thus the need of follow-up investigations[136].

The following timing for check-up is suggested:

TABLE V.—*Timing for check up.*

Degree of stenosis	Asymptomatic stenosis	Symptomatic stenosis
< 50%	Check-up at 1 year	Check-up every 6 months
50-70%	Check-up at 6 months then once a year	Check-up every 3 months
> 70% or echolucent or ulcerated placques	Surgical procedure-Check-up at 3-6 months then once a year	Surgery

Post-operative check-up: Check-up following CE: 4 – 8 - 12 – 18 months then at 2 – 4 – 6 - 8 years. In check-up following stenting, it is better to add one check-up at one

TABLE IV.—*Studies on velocimetric criteria.*

Author	Degree of stenosis	PSV cm/sec	EDV cm/sec	ICA/CCA
Peterson [129]	Normal	< 170	< 120	
Chahwan [130]	Normal	30-118	18-60	
Lal[134]	< 20%	< 150		< 2.16
Chahwan[137]	20-50%	137-195		
Robbin [131]	Stenosis	> 125		> 3
Stanziale [132]	50-70%	≥ 225		≥ 2.5
Chi [133]	50-70%	> 240		> 2.45
Stanziale[139]	> 70%	≥ 350		≥ 4.75
Chi [140]	> 70%	> 450		> 4.3

month and leave the following check-up for the CE unchanged.

If the contralateral carotid is stenotic, carry out the check in accordance with the table for known stenosis.

Recommendations

CDS is first choice for screening and detecting cerebrovascular diseases

Recommendation 1 Grade III-A

CDS of the supra-aortic trunks is indicated in patients with TIA or recent stroke.

It should be performed immediately after the onset of the symptoms in order to allow planning of treatment within 2-3 hours for thrombosis or a few days for stroke without complete thrombosis.

Recommendation 2 Grade III-A

CDS of the supra-aortic trunks is indicated in patients with latero-cervical murmur, with peripheral arterial disease, with aortic aneurysm, with coronary disease, in those over 65 years with multiple risk factors and in patients who are candidates for major vascular surgery or with retinal vascular disease.

Recommendation 3 Grade IV-B

Assessment of IMT is important in many observational or interventional studies on atherosclerosis and on the management of risk factors

Recommendation 4 Grade III-A

CDS is indicated in monitoring the progression of plaques in patients with carotid stenosis not yet candidates forinvasive treatment. It is also indicated in the follow-up of treated patients.

Recommendation 5 Grade III-A

TEDS is indicated for the investigation of the aortic arch and ascending and descending thoracic aorta and to assess the origins of the supra-aortic trunks, particularly for sources of microembolisms.

Recommendation 6 Grade IV-C

AngioCT is useful to detect a lesion of the brain, its true ischemic nature, its site and dimension and its congruity with symptoms.

Recommendation 7 Grade V-B

AngioCT or AngioMR should be reserved for:

— multilevel disease of the supra-aortic trunks when carotid bifurcation disease is suspected

— the aortic arch for atheroembolic disease (ulcers, parietal thrombus)

— all the details of intracranical vessels when planning treatment

— planning endovascular treatment particularly in elderly patients

— non diagnostic CDS with suspected significant clinical lesion of the extracranial vessels

— when TCDS cannot be performed or when it identifies tandem disease of the intracranial vessels that needs to be defined more accurately

— TIA or minor stroke prior than one week or with consistent carotid stenosis less than 70%

When proposing an AngioCT, problems arising from exposure to X-rays need to be considered, particularly with regard to eye lenses.

Recommendation 8 Grade VI-B

Angiography was the "gold standard" reference for validating other methods but considering the inherent risks involved and the current reliability of other techniques, [the *Consensus Conference* in Paris in 1994 decided that angiography it should only be used in cases of discrepancy between the data obtained by CDS and those of AngioMR. Present day equipment, particularly multislice AngioCT can provide data that are better than those provided by DSA. Thus angiography should be limited to:

— as preliminary assessment in the same session when endovascular treatment is adviced

— when AngioCT or AngioMR are not not feasible due to metallic foreign bodies.

— when non-invasive methods did not provide ciear indication or if the findings did not correlate with symptoms or if the patient suffers from claustrophobia.

— in cases of suspected vasculitis, dissections, malformations and defects in cerebral circulation

Recommendation 9 Grade VI-C

Intraprocedural control during CE since that can lead to the detection and immediate repair of the defectsis (quality control is associated with a significant decrease in post-operative complications such as restenosis and delayed onset stroke.

Recommendation 10 Grade III-A

CDS is recommended in post-operative controls both after syrgery and endovascular treatment. As the incidence of restenosis is higher in the first year after treatment and decreases after the second year, follow-up shlould be more close in such period, modifying it to suit intraoperative control conditions, to the type of suture, to the patient's risk factors and to the conditions of the contralateral carotid.

Recommendation 11 Grade III-A

CDS of the vertebral arteries should be performed at both the pretransverse V1 and intertransverse segments. Intertransverse investigation alone greatly decreases the sensitivity of this method as well as its detection of the stenoses since they are more frequently located at the vessel origin. This method is also more reliable for documenting early subclavian steal (latent steal).

Recommendation 12 Grade VI-B

Supra-aortic trunks flow-chart for diagnosis

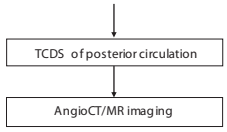
TIA – stroke <3 hours

Emergency diagnosis
— CDS + TCD or AngioMR or AngioCT
— Brain MR/CT
— Neurological assessment for emergency treatment

Diffusion MR and perfusion MR allow earlier information about ischemia and particularly about ischemic shadow areas (Figure 1).

Patients with coherent vertebro-basilar symptoms

— Bilateral measurement of brachial arterial pressure
— CDS supra-aortic trunks
  – V1 investigation
  – Flow direction investigation
    – Continuous – intermittent
  – Activation with reactive hyperaemia
    – Latent



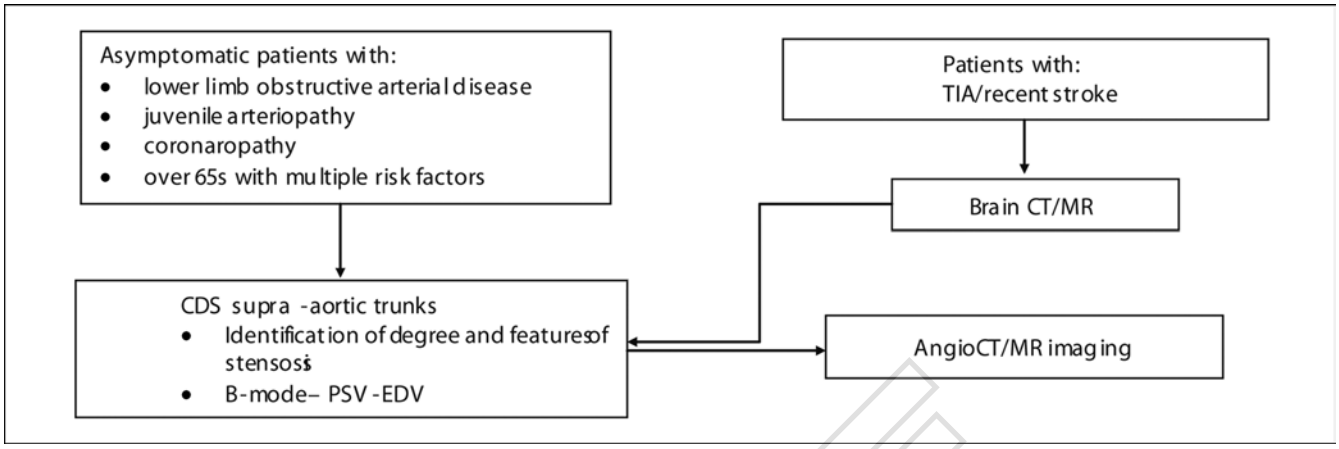


Figure 1.

REPORTING PROPOSAL FOR COLOR-CODED DUPLEX SCANNING OF THE SUPRA-AORTIC TRUNKS

surname, Name..... age
date...../..../...../
Investigation conducted with
– Equipment.....
– Type of probe.....
Right carotid artery:
– morphological description of vessel wall (features - thickness) .....

Features of the plaque
– echogenicity (homogenic, dishomogenic, hyperechogenic, hypoechogenic).....
– surfaces (smooth, uneven, excavated > 2 mm)..... Ø excavation.....
– locations (common carotid, carotid inside the bulb – extent beyond bulb)
– diameter of common carotid artery... Ø bulb.... Ø distal IC.... stenosis...% in longitudinal section
– stenosis...% (in transverse section)
– residual area..... % Ø residual lumen minimum.....mm
– stenosis PSV..... cm/sec - (angle..... °)
– stenosis EDV..... cm/sec -
– internal carotid assessable by.... cm - anatomical internal/ external carotid inversion yes/no
Left carotid artery:
– morphological description of vessel wall (features - thickness) .....
Features of the plaque
– echogenicity (homogenic, dishomogenic, hyperechogenic, hypoechogenic).....
– surfaces (smooth, uneven, excavated > 2 mm)..... excavation.....
– locations (common carotid, carotid inside the bulb – extent beyond bulb)
– diameter of common carotid artery... Ø bulb.... Ø distal IC.... stenosis...% in longitudinal section
– stenosis...% (in transverse section)
– residual area..... % residual lumen minimum.....mm
– stenosis PSV..... cm/sec - (angle..... °)
– stenosis EDV..... cm/sec -
– internal carotid assessable by.... cm - anatomical internal/ external carotid inversion yes/no

Right vertebral artery: present-absent-dominant; ostial stenosis...%. diameter, direction of flow
Left vertebral artery: present-absent-dominant; ostial stenosis...%, diameter, direction of flow
Right subclavian artery: description.....
stenosis...% diameter, pre-vertebral / post-vertebral segment
Right subclavian artery: description.....
stenosis...% diameter, pre-vertebral / post-vertebral segment
Innominate artery: description
(wall - thickness).....
Interpretation difficulties.....
– Power-Doppler investigation or with systems not dependent upon type B-flow angle.....
– US amplifiers investigation.....
– Conclusion:.....

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Guidelines for the assessment of the circulation of the upper limbs and of the thoracic outlet syndrome

Investigations

— Continuous Wave Doppler (CWD)
— Duplex scanning (DS)
— Color-coded duplex scanning (CDS)
— Standard radiography (Xray)
— Angiography by computed tomography (AngioCT)
— Angiography by magnetic resonance (AngioMR)
— Digital subtraction angiography (DSA)
— Light reflection rheography (LRR)
— Digital plethysmography
— Capillary microscopy (CM)

Procedure

Vascular diseases of the upper limbs are less frequent than that of the lower limbs and of different nature.

The most common in young patients is the thoracic outlet syndrome (TOS), due to compression of the subclavian artery and/or of the subclavianvein and/or of the roots of the brachial plexus or a combination of them. "Arterial TOS accounts for approximately 1% of the cases, "venous TOS" for 5% and the great majority is "neurogenic TOS". When the vein becomes occluded by thrombosis such condition is called "Paget-Schroetter Syndrome". The extrinsic compression of artery, vein or nervous roots is frequently secondary to anatomic anomalies as the presence of a cervical ribor an elongated C7 transverse process or anomalous fibrous or muscular bundles. On the arterial side a secondary post-stenotic aneurysm may be observed and be the source of embolism. Primitive aneurysms are rare.

Amongst atherosclerotic lesions, stenoses of the subclavian artery, usually pre-vertebral, or of the innominate artery are the most frequent.

On the venous side axillary-subclavian thromboses caused by central venous catheters or pacemakers are becoming more frequent. Lymph node compressions and neoplastic infiltrations are to be taken into consideration-frequent.

After clinical assessment, the first investigations are by ultrasound. CWD and CDS are complementary in assessing both the extrinsic compression and the lesions of the arterial wall.

An Xray of the cervical spine is indicated to detect a cervical rib and other osteo-articular anomalies.

AngioMR and /or AngioCT complete the ultrasound studies in defining the site and nature of the compression and in assessing the lesions of the wall.

DSA is indicated only for patients wno are candidates for open surgery or endovascular treatment when the non-invasive studies are insufficient.

The assessment of the digital arteries and of the palmar arch can be performed both with CWD and with CDS or with plethysmography under basal conditions and with Allen test. The circulation of the fingers can be completed with physical tests (hot and cold stimulation) or with pharmacological tests using plethysmography (photo plethysmography). Microcirculation studies can also be undertaken with nailfold capillary microscopy.

Assessment of a thoracic outlet syndrome by US investigations

The techniques are those described for arterial and venous studies applied as follows:

— Study of the patient seated and then laying down on his back
— Assessment of the axillary-subclavian artery and vein with limb adducted along the body
— Assessment of the axillary-subclavian artery and vein with the limb abducted (Wright manoeuvre 0-180°)

— Assessment of the subclavian artery with Adson manoeuvre
— Assessment of the axillary-subclavian artery and vein with Eden or McGowan manoeuvre
— Description of the analog flow or tracing (dynamic)
— Features of the arterial and venous wall
— Assessment of the compression angle

The most useful dynamic manoeuvres while assessing the vessels of the upper limb are:

1. Abduction and external rotation of the arm (Wright manoeuvre), which allows to detect any compression on the costo-clavicular space or below the tendon of the muscle pectoralis minor (probe position in subclavicular region).
2. Lowering and retropulsion of the shoulder (McGowan or Eden manoeuvre), which equally reduces the costoclavicular space.

The Adson manoeuvre, although still frequently used presents a rather greate incidence of false positives.

Color-coded Duplex scanning of the arterial circulation of the upper limbs

The duplex and color-coded duplex scanning assessment is recommended for its high accuracy in aneursymal, or compressive, or occlusive disease of the upper limbs as well as in most injuries. Such investigations are particularly useful in:

— diagnosis of stenosis or obstructions of the innominate-subclavian area with possible hemodynamic involvement of the vertebral arteries;
— monitoring and followup after trauma or after arterial repair
— preparation and monitoring of the arteriovenous fistulas for dialysis.

In a recent study comparing CDS with angiography, the CDS of the upper limb showed a sensitivity, specificity, positive and negative predictive value and an accuracy of 98%, 99%, 97%, 99.5% and 99% respectively with regard to the occlusions and 79%, 100%, 100%, 99% and 99% respectively with regard to stenoses 50% or greater.

Procedure

It is advisable to perform the examination first with the patient lying on his back, with adduction of the upper limb [during sound insulation of the axillary-subclavian district at the source; then the limb is placed in abduction during the study of the vessels of the arm and forearm. Moreover the patient should be seated during the manoeuvres for detection of compressive phenomena.

In choosing the probe, we resort to linear or sectorial transducers with a frequency of 7.5 MHz.

The arterial CDS begins assessing the subclavian artery at its origin, at the base of the neck, and continues assessing the axillary artery in the mid subclavicular and in the axillary region. To examin the proximal subclavian artery one may take position on the common carotid artery, transversally, and follow it proximally to its origin. The longitudinal or oblique image of the proximal subclavian artery in the supraclavicular region will appear. On the right side viewing the bifurcation of the innominate trunk and its division into common carotid and subclavian artery is rather easy.

On the other hand, if a complete view of the subclavian artery cannot be achieved, the hemodynamic information reached through the Doppler signal with spectral analysis contributes to define proximal and distal lesions.

The images of the brachial artery in longitudinal and transversal sections are achieved using a front probe approach. Specifically, the probe must be kept at about a 30° angle to the longitudinal axis of the arm. The same artery is found in the upper third of the arm by a medial approach and then moving the probe upwards toward the axillary region.

The same manouevres are used whenstudying the brachial and cephalic vein.

The radial and ulnar arteries can be identified at the wrist, both proximally and distally.

The study becomes more difficult at the hand due to the smaller diameter of the vessels and their winding course. It is not possible to get the superficial and deep arteries and the metacarpals on the same plane, so it is a good idea to survey sequences of subsequent sections. The bone, cartilage and tendon structures usually interfere with the ultrasound signal. It may be useful to use a pouch of water to get better definition of the vessels of the hand and fingers. The use of probes with a higher emission frequency (10 MHz) may be helpful.

The arteries of the hand can be seen better using power Doppler.

The investigation should be completed with the manoeuvres aimed at detecting compression of the vessels at the thoracic outlet.

Color-coded Duplex scanning of the venous circulation of the upper limb

The CDS of the superficial and deep veins of the upper limb can contribute to

— identifying the extrinsic compression sites during the dynamic compression manoeuvres;
— revealing the presence of thrombophlebitic processes with total occlusions or floating thrombi;
— revealing the presence of congenital, post-stenotic, post-trauma or angiodysplasic venous ectasias. They will appear as venous lakes, mainly intramuscular, or multiple angiodysplasic " bunches", often containing thrombi and intra angiomatous calcium.

The main indications for a CDS of the veins of the upper limbs is screening of thrombi and choosing venous segments to use for peripheral arterial bypass or for arteriovenous fistulas for dialysis.

Procedure

The veins of the arm are examined with the patient seated and upper limbs dangling. As an alternative, the patient may be in a supine position in slight Trendelemburg with his arms abducted above his head. The compression manoeuvres are similar to those used foe the veins of the lower limbs. The investigation of the deep venous axis follows that employed for the arteries, bearing in mind the presence of two brachial satellite veins and double ulnar and radial veins.

Various manoeuvres are used to dilate the veins and better identify and assess them, such as the local application

of nitrated derivatives or immersing the limb in lukewarm or hot water.

The arm is usually examined in a dangling position, and a tourniquet is placed in the axillary site to help fill the veins. The exercise increases the flow and venodilatation. All of these manoeuvres objectively improve the assessment the superficial veins, even when the dilatation is not clinically evident.

Applying a tourniquet at the base of the limb generates mechanical venodilatation, and consequently helps to identify the vein and to estimates its diameter. However, the vessel occasionally takes on the ultrasound features of the adjacent tissues after the venous stagnation of blood underneath the tourniquet. When the tourniquet is released the flow resumes and the vein can then be easily identified.

Nailfold capillary microscopy

Capillary microscopy (CM) is a non-invasive, harmless and repeatable examination, which allows to study the microcirculation in vivo. Unlike other techniques as laser Doppler and light reflection rheography, which assess the total flow of the district, CM selectively estimates nutritional circulation. The nailfold is the selected site since at its site the capillary loops are arranged parallel to the surface of the skin and thus assessable in the various anatomic components: arteriolar and venular branches of the loop, subgemmal venous plexus, pericapillary connective.

There are a many applications of CM in so far as it is well known how alterations of the microcirculation are the final track of ischaemic damage both in arterial and venous diseases, the common denominator of metabolic disorders such as diabetes and rheumatism, or the autoimmune-based connective tissue diseases.

The main application of CM is the screening of patients who have acral vasomotor disturbances, such as Raynaud's Syndrom and acrocyanosis6. Since in about 10% of cases Raynaud's Syndrom is a symptom of a connective disease, at times very early, CM is used to detect the presence of alterations of the capillaries such as the "scleroderma pattern". A predictive value for scleroderma and similar connective tissue diseases (mixed connective tissue disease, dermatopolymiositis, undifferentiated connective tissue diseases) is given to this particular capillary pattern greater than the positivity for autoantibodies.

The instrument most commonly used is the videocapillarioscope, an optical microscope fitted with various lenses and a cold light source, completed with a high-resolution telecamera connected to a monitor directly or via a videotape recorder. An optical probe videocapillarioscope (Videocap) has started to be used recently. It provides easy exploration of any skin area.

Procedure

The examination is carried out with the patient seated in front of the operator, his hands resting on the observation table placed at heart level, at a room temperature of between 20° and 25°C. A drop of paraffin is laid on the nail fold to prevent refractive phenomena from the skin. Usually all the fingers of the hand are observed since initial alterations can be seen even in just one finger, with particular attention paid to the 4th and 5th fingers of the non-dominant limb, which are less subject to traumatisms. Hypercheratosis, caused by work or manicure-induced traumatisms, can reduce visibility of the capillary palisade layer to such an extent as to make the study unreliable. The examination must be completed with photographs of the areas involved. The more recent capillary microscopes offer computerized filing and printing on the same sheet as the medical report.

The assessment starts at a low magnification (40-60X) to assess the order and density of the capillary palisade layer, visibility of the subcapillary venous plexus, the conditions of the connective tissue (transparency, colour, presence of edema), and if there are any microhemorrhages. With a greater magnification (100-160X), the pattern of the capillary loops (single and complex distortions), and the presence of enlarged or giant loops (giant capillaries) becomes evident. With further magnification, between 250X and 1000X, it is possible to appreciate the flow of the erythrocyte column, more visible if fragmented by "plasma gaps".

In order to be able to count the capillaries in a millimeter on a monitor, like measuring the diameter of the loops (enlarged >20m; giant >50 m), it is necessary to calibrate the system using a scale of reference.

According to the Maricq classification, the scleroderma pattern can be divided into active (aggressive) and slow (non-aggressive). The first corresponds to the rapidly developing form, with visceral involvement, and the latter corresponds to the limited version of the scleroderma in which the vascular damage predominates and which appears spared from visceral complications if the late onset of pulmonary hypertension is excluded.

Active scleroderma pattern: Anarchic appearance of the capillary palisade layer, avascular areas up to the appearance of "capillary desert", marked anomalies suggestive of neoangiogenesis, marked "flou" effect (edema of the connective).

Slow scleroderma pattern: Regular appearance of the capillary palisade layer, reduction in number of the capillaries, widespread giant capillaries, "balloon" appearance, many microhemorrhages in apical site, no "flou" effect.

Recommendations

After clinical assessment, the first investigation should be done by US. CWD and with cDS are complementary; both should be used to define compression.

Recommendation 1 Level C

The X-ray of the cervical spine is indicated to detect a supernumerary rib and osteo-articular anomalies of the thoracic outlet

Recommendation 2 Level C

AngioCT and angioMR angiography (supplementary or complementary) complete the US study in defining the site and nature of a compression and in precising the lesions of the wall.

Recommendation 3 Level C

Angiography should be reserved for patients with arterial or venous diseases or for candidates to surgery when the non-invasive assessment is considered insufficient.

Recommendation 4 Level C

The study of the digital arteries and of the palmar arches can be performed both with CWD and with CDS or with plethysmography, in normal conditions and with Allen test.

Recommendation 5 Level C

Studying the microcirculation with CM is the best optiom to confirm or exclude a vascular disease secondary to collagen disease.

Recommendation 6 Level C

The investigation for the TOS should to be carried out first on the patient seated and then lying on his back, assessing the artery and the axillary-subclavian vein, first with the upper limb adducted along the body and then with the limb abducted (Wright manoeuvre 0-180°), with the Adson manoeuvre and with the Eden or McGowan manoeuvre.

Recommendation 7 Level C

The CM of the nailfold is indicated as a screening test in all patients with Raynaud's syndrome;

Recommendation 8 Level A

CM is the best examination for assessing the microcirculation in case of scleroderma as it provides pathognomonic features.

Recommendation 9 Level A

REPORTING PROPOSAL FOR CW DOPPLER AND DUPLEX SCANNING OF THE UPPER LIMB

Surname, Name..... age
date...../..../...../ The examination is performed with
– Device.....
– Probe type.....
Description of the analog tracing – basal imaging (patient seated or lying down) of the subclavian, axillary, radial and ulnar artery, and of the subclavian, axillary and brachial vein
– Basal arterial and venous flow
– State of filling of the veins – presence of endoluminal thrombi, presence of post-stenotic dilatation – presence of parietal lesions – evidence of compression – stenosis – aneurysms
– Estimation of the angle of arterial flow arrest with the Wright manoeuvre (abduction)* in the seated patient
– Estimation of the angle of venous flow arrest with the Wright manoeuvre (abduction)* in the seated patient
– Estimation of the arrest of arterial flow with the Adson manoeuvre (inspiration + turning of the head)
– Estimation of the arrest of arterial flow with the McGowan manoeuvre
– Assessment of other conditions of flow – outflow based on the patient's anamnesis

The abduction manoeuvre must be performed slowly with the patient seated, with the shoulders kept horizontal and without antepulsion. The angle is measured starting from the normal adduction position (along the body) = 0°; with arms raised, the angle is 180°. The manoeuvre can be repeated with the patient lying down.
Both ultrasound methods are used as complementary in the study of the thoracic outlet.

REPORTING PROPOSAL FOR CAPILLARY MICROSCOPY OF THE NAIL FOLD

name and surname ..... Date of birth .....
Address .....Phone .....
Reason for the request .....
Arrangement of the palisade: Regular, Irregular, Anarchic.
Number of capillaries: < o ≥9/mm Length of capillaries: < o ≥150 micron Tortuosity: Absent, <20%, <o >50%, widespread
Complex distortions: < o ≥10%
Distortion type: .....
(branched, bushy, ball-shaped, festoon-shaped loops)
Enlargement (>20 µ): < o ≥20% Giant capillaries (>50 µ): Absent, isolated, Microhemorrhages: Yes/No, Thrombosed loops: Yes/No
Oedema: Yes/No Transparency: Normal, Reduced, Increased
Subgemmal venous plexus: Yes/No
Avascular areas: Yes/No
Flow pattern: Normal, Slow, Arrest phases, Non-assessable
Conclusion: Normal Picture, Aspecific, Suspect for non-sclerodermal collagen disease, Scleroderma Pattern.

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Plethysmography

Plethysmography is the graphic recording of the changes of volume of body fluids due to the circulating blood [3-7].

[Arterial plethysmography that assesses the sistodiastolic changes (pulse volume), volume plethysmography assesses the longer period ranges (arterial blood-flow velocity and changes of the venous volume).

The plethymosgraphy methods can be classified based on their physical principle (electrical impedance, light, volume of air, water, strain-gauge) and on the ability to provide a zero line of volume. Bipolar electrical rheography and photo plethysmography, both simple and low-cost, assess the changes of pulse volume basically by looking at the arterial and arterial-venule side. Tetrapolar electrical impedance plethysmography and light reflection rheography can assess the long-lasting changes (post-ischemic arterial hyperaemia, venous occlusion plethysmography, phlebodynamometry) [1, 2, 4, 8].

Venous occlusion plethysmography the becomes an actual district flowmetry.

Plethysmography was gradually replaced in clinical practice by CWD and CDS, but still today retains an unaltered value in the study of the physiopathology of vascular diseases.

Digital photoplethysmography

Digital photo plethysmography is used as an additional method in investigation of arterial diseases, both functional (Raynaud's Syndrome, acrocyanosis) and organic, owing to its possibility to detect a condition of rigidity or spasm during the early stage or of the residual functional capacity in the advanced stage [5, 6, 10].

Methods

Photoplethysmography (PPG) is a rather easy investigation. However many errors and artefacts may result from a hasty or shoddy execution.

The room where the examination is performed should be quiet and warm enough (22-25°C). The peripheral detectors are placed on the first phalanx of the fingers or toes.

To perform the examination on the fingers, the patient is examined lying down or seated with his forearms resting on the bed and the palms of his hands facing up with the fingers slightly bent. To study the toes, the patient is positioned in clinostatism.

The PPG curve consists of:

— an ascending, anacrot slope, with rapid ascent line;

— a slightly softened or pointed apex or crest;

— a descending catacrotic slope, where it is possible to distinguish two separate segments from an incisure or a rebound wave. The first segment shows a very steep slope in direct continuity with the arterial phase. The second segment shows a gentler slope and ends when the next systole begins. The inflection point between the two parts, represented by the incisure and the dicrotic wave, derives from the distensibility of the arterial wall and the next centripetal reflection of the sphygmic wave.

According to Jacques [7], who defined the photoplethysmogram as an "arteriovenous bigram", the first part of the plethysmographic wave (ascending slope, apex, first descending segment) corresponds to the initial wave or cardio leak and is the arteriolar flow and hemodynamic and parietal factors act on it. The second part of the signal (point of inflection and gently sloping segment) depends on the veno-venular stagnation and resistances.

The interpretation of the photo plethysmographic plot is based on the assessment of several quantitative and qualitative parameters.

The quantitative parameters are the amplitude, the swiftness, the crest time, the dicrotic incisure time and the total time.

The qualitative elements are the global pattern of the wave and that of its constituents.

The amplitude measures the distance between the base of the wave and its highest point. It is a reliable indication of the fluency of the blood flow and is therefore in connection with the parietal elasticity and tone, viscosity of the blood, the venous return and mostly with the peripheral resistances. It is expressed in millimetres and a comparative measurement of the two limbs and a constant calibration of reference are needed because of the lack of standardized calibration. A 30% drop of the maximum amplitude of a wave compared to the contralateral one gives evidence of an obstructive disease. Assessment of the amplitude is expressed in terms of "asphygmia - normosphygmia - hypersphygmia".

The examination is completed by carrying out the functional tests that provide additional informations particularly in dubious clinical situations or in cases of advanced obstructive disease to assess the time and possibilities of recovery following reactive hyperaemia.

Among these, the stress test and pharmacological tests play an important practical role.

Stress tests

They assess the changes of the photo plethysmographic plot after muscular work, and can be obtained in various ways.

The plot is first obtained under basal conditions and is then repeated after the end of exertion at 30-second intervals.

Planned exertion according to a scheme envisaging 40 flexo-extensions of the hand in 30 seconds for the upper limbs or of the feet for the lower limbs has been proposed.

In the normal subject increased sphygmic amplitude is noted. It reaches the maximum 10 minutes after the end of the stress test with an average increase of approximately 67% compared to the basal plot. The base values are returned to after roughly 30 seconds.

A marked reduction of amplitude is seen in the arterial diseases, andmay even disappear (mute wave) in the most serious cases.

Following the stress test according to Goetz [3-7], four different types of response can be obtained:

1. Rapid positive reaction with maximum amplitude in the first plot right after the exertion;
2. Delayed positive reaction, where the maximum amplitude appears in the second plot;
3. Prolonged positive reaction with maximum amplitude in the third plot;
4. Reversed or negative reaction where, based on the severity of the disease, decreased amplitude of the plethysmographic wave up to its complete cancellation is found. The hypersphygmia found in the normal subject after physical exercise is the result of the hemodynamic and metabolic adaptation mechanisms: an increase in the systolic range, a peripheral vasodilatation with reduced resistance of the muscular district and consequent increased flow. The latter is induced by the presence of acid catabolites with vasodilatating action (histamine, bradykinin, lactic acid, etc.). The

hyperaemia lasts longer as physical exertion increases due to the additional time necessary for eliminating the catabolites. In the patient with arterial disease, hyposphygmia can be due to vascular hypertonia, deprivation of haematometakinesis between the deep and superficial vascular districts, an inadequate vasodilatating response to increased acid catabolites or more simply to another reduction of the arteriolar vascular resistances so that although there is an increased flow, there is a reduction or cancellation of the pulse's systo-diastolic ranges.

Pharmacological and thermal tests

The pharmacological tests are based on the action of vasoactive substances on the ganglionic synapse, on the peripheral receptors or on the neuromuscular elements of the arterioles. One that is easy to use is the nitroglycerine test (TNG - 0.3-0.6 mg sublingually). The plot is recorded 3-8 minutes before and after administration of the drug. Increased amplitude, greater rapidity of the ascending branch, and an accentuation of the dicrotic incisure that appears deeper while the dicrotic wave positions itself closer to the base are seen in the normal subject.

The TNG test in organic arterial disease provides helpful information regarding the treatment to follow:

— Positive TNG test: increase of the maximum amplitude signals preservation of the elastic module and is an indication for vasoactive treatment.

— Stable TNG test: no modification of the photoplethysmographic wave suggests no indication for vasoactive treatment.

— Negative TNG test: reduction of the photoplethysmographic wave; vasodilating treatment is not recommended, thereis also indication for blood flow studies.

Beyond the indication for vasodilating treatment, the type of response to nitroglycerine is an indication of the residual functional capacity.

A thermal test is indicated in functional arterial diseases but is not as helpful in organic disease.

Light reflection rheography (phlebodynamometry)

Light Reflection Rheography (LRR) provides assessment of the conditions of the veins and particularly of the function of the venous valves [7].

The physical principle is that of photo plethysmography with keeping the base line, so the graph takes into account not so much the immediate sistodiastolic changes but rather the total volume over a lengthy period of measurement.

The physiopathological principle and the type of plot is superimposable with that of the direct venous phlebomanometry according to the principles of Byordal [7].

The LRR uses a non-invasive infrared light system. The transducer is composed of three light-emitting diodes tilted 30° and a receiving diode; it ensures that the investigation is specific for the subcutaneous venous plexus. Although it examines the blood near the surface, it provides information about the entire venous system in so far as the veins of the subdermal layer are closely connected to the deep veins of the leg. The investigation consists of two phases as described below:

1. In the first phase, the muscular pumping exercise (venous reflux test) empties the veins. For this exercise the calf muscles are contracted and relaxed alternatively about 10 times. The muscular contraction pumps the blood in the veins to the heart. The valves of the healthy veins are able to block the return of blood to the calf. The blood volume is recorded as soon as the blood is pumped outside the calf.

2. The blood starts to refill the veins immediately after pumping. The plethysmograph continues recording the blood volume to measure the time the veins need to refill completely.

When the veins are healthy and with normal function the veins refill slowly and all the venous flow is due only to the normal arterial input since the vein valves are closed and prevent the blood from returning back in the opposite direction. A filling time more than 25 seconds is considered normal. On the other hand, when there is valvular incompetence, the filling time drops considerably. If the valves do not close completely the blood falls back into the veins. If the valvular incompetence is more severe, the blood will immediately return into the veins in greater amount. In the mean time the arterial blood will continue to fill the vein from the opposite direction. The venous filling time drops considerably and that time is a function of venous incompetence.

Study of the upper limb

The transducer is placed 10 cm from the plica of the wrist on the medial region of the forearm of the patient seated and with upper limbs along the body [1-7].

Once the basal plot is calibrated, the various manoeuvres aimed at detecting an obstructed venous outflow are carried out passively and the changes of plot pattern corresponding to the emptying or filling of the venous plexus are recorded.

This method does not provide absolute values and the assessment is carried out by analyzing the changes compared to the basal value.

In the normal subject there is a rapid ascending branch corresponding to emptying during the superelevation test. Then a plateau and a steep descending branch is noted, which in its final portion becomes slower, corresponding to the filling of the venous plexus with the upper limb adducted. In the patient with obstructed venous outflow, an arrest of the emptying proportional to the degree of compression is seen when the limb is abducted.

Recommendations

The digital vascularisation study can be completed with physical tests (hot and cold stimulation) or with pharmacological tests using plethysmography.

Recommendation 1 Level C

The LRR is complementary to the other techniques in the assessment of the obstructed venous outflow of the upper limb.

Recommendation 2 Level C

PPG is used as an additional method in studying arterial diseases both functional (Raynaud's Syndrome, acrocyanosis) and organic, owing to its possibility to detect rigidity or arterio-capillary spasm in an early stage.

Recommendation 3 Level C

REPORTING PROPOSAL FOR LIGHT REFLECTION RHEOGRAPHY OF THE UPPER LIMB

The amplitude of the fluctuations recorded on the plot during the functional manoeuvres are compared to the basal line corresponding to the state of venous filling.

Dynamic emptying: good (100%) average (50%) reduced (25%) poor (10%) absent.
Dynamic filling: good (100%) average (50%) reduced (25%) poor (10%) absent.
The plot should be attached to the written report.

Reporting proposal for digital photo plethysmography

The curve and its characteristics and the type of response to the tests should be described. Wave: hypersphygmic, dicrote, half-circle, hyposphygmic, asphygmic or flat.
Response to the tests (amplitude of the sphygmic wave): increased, unaltered, reduced, flattened wave,
blood shift. The dicrote wave appears, the dicrote wave disappears.
The plot obtained, both basal and after the sensitization test, should be attached.

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Guidelines for the assessment of the aorta and iliac arteries

Investigations

— Continuous wave Doppler (CWD)
— Duplex scanning (DS)
— Color-coded duplex scanning (CDS)
— Standard radiography (Xray)
— Angiography by computed tomography (AngioCT)
— Angiography by magnetic resonance (AngioMR)
— Digital subtraction angiography (DSA)

Procedure

After clinical assessment of the patient, the first diagnostic procedure is duplex scanning (DS) and color-coded duplex scanning (CDS). They are extremely reliable in aneurysm and obstructive disease. In a review of 14 comparative studies of DS and angiography reported in literature, Koelemay et al.[1] indicate a sensitivity for the aorto-iliac district that ranges from 80% to 86%, with specificity of 95-97% for the stenosis above 50%, and a sensitivity of 94%, with specificity of 99%, for occlusion. The CDS allows for the highlighting of the profile of the aortic and iliac wall and of the diameter [2-3] as well as providing information on the origin of the main branches. In aneurysms, it allows an assessment of the diameter at the renal level (above and below), of the maximum diameter of the aorta and, whether there is a horizontal collar below the renal area. [4-5] It also highlights any thickening of the walls (aortitis – inflammatory aneurysm) and the presence of a endoluminal thrombus or signs of dryness.

Supplementary radiological imaging completes the US study in determining the area and nature of the lesion and in assessing the wall pathology, in view of a reconstructive surgical or endovascular approach. The planning of surgical treatment based on AngioMR[6] with contrast means as completion of an CDS differs significantly from that based on US investigation alone. A study carried out by 3 surgeons who proceeded to plan treatment to the aorta-iliac-femoral area highlighted a correct choice in 49-63% with DS alone, and in 70-77% with AngioMR alone, which is thus proved to be more efficient than US, but does not suffice for correct therapeutic planning.[7]

The supplementary and complementary angiography is no longer used in diagnostics. In patients with multi-district arterial disease, destined for surgery and for whom non-invasive diagnostics is not considered to be sufficient, angiography may be performed during actual surgery.[8]

The aorta can generally be fully assessed using the DS, which allows for the planning of endovascular treatment (PTA-stenting) of the iliac and, in some cases, also aorta-femoral revascularisation.

Generally speaking, with AngioCT or AngioMR, an open surgery or endovascular treatment can be completely planned.[9]

There are only very few cases due to infection where other types of investigation, by means of radioisotopes, are required. [10-11]

In the study of aorta-iliac arteriopathies, the DS of the aorta should be completed by a study of the femoral axis: for assessment of the arteriopathies of the lower limbs, please refer to the specific section.

Color-coded Duplex scanning of the aorta and its branches

Instruments: duplex scanner or color-coded duplex scanner; 3-4 MHz transducer.

Procedure

Preferably, the examination should be performed after 12 hour fasting. This reduces the presence of air and liquids in the bowel, facilitating penetration by ultrasound. Moreover, a full bladder can create a window of low sonic attenuation that facilitates the study of the pelvic region and, therefore, the iliac axes.

The study of the abdomen must be performed with the patient lying down on his back, in a slight anti-Trendelemburg position: this improves the descent of the intestines towards the pelvis and increases venous filling.

Low frequency (3-4 MHz) probes are generally used for in-depth scans. The probe is initially applied parallel to the sternum, below the xiphoid process, in order to view the aorta longitudinally.

By rotating the probe 90 degrees, we can obtain a transversal section of the aorta.

By using this vessel as a point of reference and altering probe angle, the celiac trunk and its bifurcation (hepatic and splenic) can be identified; the left gastric artery is difficult to identify unless there is good gauge.

The proximal segment of the superior mesenteric artery is more easily viewed in longitudinal sections, given that it runs parallel to the aorta. The rapid metric Doppler findings are generally revealed at the origin of each vessel, but can be taken along the entire visible axis of each artery. The hepatic and splenic arteries are viewed beyond the trifurcation of the celiac trunk.

Again in transversal section, the probe is moved downwards to view the other branches of the aorta. The left renal vein runs between the aorta and the superior mesenteric artery and represents a good ultrasonography point for the right renal artery that originates laterally and runs under the inferior vena cava; the left renal artery is instead located under the left renal vein and is often suddenly revealed. Take care over potential accessory or double renal arteries on each side.

The inferior mesenteric artery is only viewed in some cases.

With the probe at the umbilical level, the distal aorta and aortic bifurcation is viewed in longitudinal and transversal section. The scan then continues downwards for a study of the iliac arteries.

Scans in B-mode, with the help of color-flow-mapping allows for high reliability of the method. The morphological assessment is always supplemented with the flow meter data.

From an ultrasonography viewpoint, the criteria for non-invasive diagnosis of the aorta-iliac district were suggested by Schneider et al.[8] and were based on the comparison with the angiography.

Recommendations

The first procedure, in addition to the clinical assessment is DS and CDS, which are extremely reliable in aneurysm and obstructive disease.

Recommendation 1 Grade A

The CDS allows for the highlighting of the profile of the aortic wall and the diameter as well as providing information on the origin of the main branches. In the case of aneurysm, it allows for the measurement of the diameter at the renal level (above and below), the maximum diameter of the aorta and its branches and whether there is a horizontal collar below the renal area. It highlights thickening of the walls (aortitis – inflammatory aneurysm), the presence of endoluminal thrombus or the presence of [signs of dryness.]? vedi sopra

Recommendation 2 Grade B

Supplementary radiological imaging with AngioCT or AngioMR completes the US investigation in determining the area and nature of the lesion and in assessing the wall pathology, in view of a reconstructive surgical or endovascular approach.

Recommendation 3 Grade C

Angiography, supplementary and complementary, is only recommended in patients with associated arterial disease or patients bound to surgery in whom non-invasive diagnostics has not been deemed sufficient.

Recommendation 4 Grade C

REPORTING PROPOSAL FOR DUPLEX SCANNING OF THE AORTA AND THE ILIAC ARTERIES

Surname, Name..... age
date...../.../...../
The examination is performed with
Equipment.....
Probe type.....
Description of aortic wall and profile:.....
.....
.....
ø suprarenal aorta.... cm; ø iuxta renal aorta..... cm; ø subrenal aorta.... cm
presence of plaques No Yes % stenosis
Aneurism No Yes
ø maximum AP..... cm, ø maximum LL.... cm, length of dilated stretch... cm
Features of the aneurysmal sac (blister, sacciform, fusiform)
Parietal thrombosis No/Yes Residual lumen.... cm
Features of thrombus (concentric, eccentric etc.)
Horizontal collar under renal area No/Yes length cm...
Perianeurysmal formations (sac collections, sclerosis)
Description of iliac wall and profile:
Stenosis NO/YES..... % stenosis
Occlusion NO/YES
Length of stenosis – occlusion..... cm
Aneurysm NO/YES ø maximum aneurysm..... cm
Interpretation difficulties.....
Power-Doppler assessment.....
Other investigatio
ns.....
Conclusion:.....
.....
.....

THIS DESCRIPTION MUST BE STATED FOR COMMON, EXTERNAL, INTERNAL, RIGHT AND LEFT ILIAC.

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Guidelines for the assessment of the visceral arteries and veins and of the renal artery

Investigations

— Continuous wave Doppler (CWD)
— Duplex scanning (DS)
— Color-coded duplex scanning (CDS)
— Standard radiography (Xray)
— Angiography by computed tomography (AngioCT)
— Angiography by magnetic resonance (AngioMR)
— Digital subtraction angiography (DSA)

The celiac trunk (CTr) and superior mesenteric artery (SMA) are not frequently affected by atheromatous type steno-obstructive disease and even when they are, patients remain free from symptoms for a long time due to the presence of a rich collateral circulation between CT, SMA me and inferior mesenteric artery (IMA) and between these vessels and the aortic circulation, through gastric and haemorrhoid arteries.

At present the use of CDS investigation is required in the following conditions:

a) chronic obstructive mesenteric disease and secondary ischemia;

b) occlusive or aneurysmatic disease of the abdominal aorta and iliac arteries;

c) portal hypertension;

d) aneurysms of the visceral arteries;

e) control of surgical repair of the visceral arteries and of a porto-caval shunt or other surgical anastomosis performed to reduce portal blood pressure.

Procedure

1. The first procedure, in addition to clinical assessment, is CDS, reserving radiological imaging to the study of aneurysms and/or lesions that can only be poorly assessed by ultrasounds.

2. Investigation with CDS is the only non-invasive method that allows for the diagnostic definition of visceral arterial lesions and is an objective method by which to monitor the results of reconstructive surgery, by-pass or angioplasty. The advantage of the CDS mainly consists in the highlighting of the presence of flow also in areas where two-dimensional resolution is poor and therefore it is correctly guiding the haemodynamic study with pulsed Doppler.

3. The sensitivity and specificity in the diagnosis of stenosis is increased by the use of US amplifier. The reliability of such investigation is increased by the association with CDS without amplifier. Argalia et al. reported sensitivity and specificity of 75% and 70.1% with CDS, of 100% and 87.5% with the use of an amplifier and, respectively, of 100% and 91.6% with angio-MR[7], reporting accuracy in the diagnosis of haemodynamic stenosis of 50% with the standard CDS and 75% with an amplifier, whilst the viewing of normal or minimally pathological arteries was 94% with the standard examination and 97% with the use of an amplifier. [According to Cianci et al., contrast means does not improve diagnostic reliability in ostial stenosis. The use of an amplifier in patients with uncertain diagnosis results in a certain diagnosis with possible etiological treatment and related reduction of drug costs[9].

4. Even in expert hands, a good view of the CTr and SMA can be obtained in 80-95% of cases, and controlled studies with angiography, both in multilevel disease patients and in symptomatic patients have shown a high level of accuracy of US investigation. Variations of the origin and anatomical anomalies of the visceral vessels are so frequent, and the range of normal and abnormal flow velocity is so broad, that the duplex parameters reported by studies on healthy volunteers do not automatically apply.

5. In terms of visceral vessels too, radiological imaging, and particularly AngioMR is proposed more and more frequently in literature in lieu of angiography.

6. Angiography, therefore, should be used in situations of doubt, in patients with symptoms for whom a better definition of the disease is required or in view of a revascularisation, taking also into account the high incidence of cholesterol emboli after angiography. Fine et al. [17], in a review of 221 cases proven by histological examination report that 17% of patients had been subjected to angiography of the large vessels during the days prior to onset of symptoms.

Color-coded Duplex scanning of the visceral vessels

Instruments: duplex scanner and color-coded duplex scanner; 3-4 MHz transducer.

Procedure

As for the study of the abdominal aorta, the examination is best performed after 12 hour fasting. This reduces the presence of air and liquids in the intestine, facilitating penetration by ultrasound. Moreover, a full bladder can create a window of low sonic attenuation (that facilitates the study of the pelvic region). The study of the abdomen must be performed with the patient lying down on his back in a slight anti-Trendelemburg position. This improves the descent of the intestines towards the pelvis and increases venous filling.

The technique is as described for the abdominal aorta. The probe is initially applied perpendicularly, below the xiphoid process, in order to view the aorta longitudinally. By rotating the probe 90 degrees, we can obtain a transversal section of the aorta. By using this vessel as a point of reference and altering probe angle, the CTr can be identified and its trifurcation into left gastric, hepatic and splenic artery. The proximal segment of the SMA is more easily viewed in longitudinal sections, given that it runs parallel to the aorta. The rapid metric Doppler findings are generally revealed at the origin of each vessel, but can be taken along the entire visible axis of each artery. The hepatic and splenic arteries are viewed beyond the trifurcation of the CTr. Sometimes the SMA and CTr originate from the aorta as a common trunk.

Again in transversal section, the probe is moved downwards to view the other branches of the aorta. The IMA is only viewed in some cases.

To view the vascularisation of the liver, an anterior-lateral scan is used. The patient lies on his left side and the study is performed through the right hepatic lobe, below the costal arch. Portal vein is accompanied on the right by the common bile duct and on the left by the hepatic artery.

The inspiration and expiration phases modify intra-abdominal pressure and the position of the structures on the soundproofing plain, in addition to focussing the sample volume in the use of the pulsed Doppler. The examination must, therefore, be performed by interrupting respiration for brief periods and, in any case, one must become used to the intermittent observation of the various structures. Additionally, the sample volume of the PW Doppler, best guided if associated with a CDS, can be extended to include the changes in vessel movement and to allow for the continuous soundproofing.

Findings

Celiac trunk

The CTr is a few centimetres long and divides up into common hepatic, left gastric and splenic artery.

Normal flow levels of these vessels are characterised by low vascular resistance similar to those of the internal carotid. The flow undergoes a systolic peak but maintains high speed during diastole too. At the CTr level, measurements of the systolic peak range from 120 to 200 cm per second.

Superior mesenteric artery

This is generally identified in longitudinal section as a parallel vessel with little divergence in its first segment from the aorta; its origin is located a few centimetres from the CT. DS findings normally show three-phase velocity pattern that indicate during fasting, the high resistance component of the peripheral circulation, as is the case in muscular arteries such as the common femoral artery.

During digestion, there is a rise of the diastolic flow in this artery. A peak systolic velocity (PSV) > 225 cm/sec and/or an end diastolic velocity (EDV) > 60 cm/sec indicate a stenosis of the SMA > 50%. The threshold values in normal cases have been found to be: PSV 275- 300 cm/s and EDV 45-55 cm/s. The increased diastolic velocity best relates to the stenosis of the SMA > 50%. The specificity and accuracy of DS of the CTr and SMA is > 80%. The influence of the collateral circulation or stimulation test with a meal is unknown; the administration of a high calorie meal (600 Kcal) transforms the high-resistance small bowel into a low-resistance organ and consequently the US wave is altered from three-phase to two-phase. However, if there is stenosis of the SMA, an increased flow after eating would exaggerate the SPV and consequently expand the spectrum. All meal types (mixed, carbohydrates, fats or protein) increase the flow velocity and diameter (and therefore blood flow). Water and isotonic solutions of sodium chloride do not increase blood flow. Alterations of the flow parameters are at their clearest approximately 60 mins. after eating a mixed meal.

A recent metanalysis reports several conditions that can interfere with flow velocity in the visceral vessels.

In patients suffering from intestinal inflammatory diseases, flow velocity and blood volume are increased (celiac disease in the adult and child and in Crohn's disease). Mesenteric flow is also increased in cirrhotic patients in whom, however, the response to a meal in the SMA is comparable to that of healthy subjects. An increased flow with a drop in mesenteric resistance has been described in children successfully operated on for aortic coarctation. Amongst the physical-pathological conditions or drugs, in addition to meals, intestinal inflammatory diseases also increase systolic and diastolic flow in the SMA. Thyreotoxicosis and glucagon only increase systolic flow, whilst hypotension and hypotensive hypovolaemia (head-up tilt) increase diastolic flow and reduce systolic peak. Vasopressin reduces systolic peak, leaving diastolic flow unaltered.

Portal Vein and Superior mesenteric vein

The study of visceral venous vessels is mainly of internist interest (ultrasound of the upper abdomen). The assessments mainly concern flow pattern (presence or absence of flow, arterial-venous shunt), the presence of flow inversions and collateralisation in the event of thrombosis or portal hypertension.

Postoperative control

In open surgery the reconstruction of the SMA is carried out generelly using a bypass graft from the subrenal aorta. Many surgeons, however, anastomise the prosthesis into the segment of the supraceliac aorta or a branch of the celiac trunk, whilst others re-implant the mesenteric artery on the aorta (generally subrenal). In some cases, splenic-mesenteric anastomosis are used.

At present, in most patients, percutaneous angioplasty is performed with or without stents. After open repair or stenting, haemodynamic parameters fall back to normal ranges, there is a reduction of maximum velocity at the level of the treated segment and a return to modulation of flow downstream.

Turbulence in the dilated segment, particularly with the presence of a stent, with regularisation of the flow signal immediately downstream does not indicate restenosis but rather is an expression of disturbed segment movement.

For a correct diagnostic interpretation and to assess the clinical results, it is crucial to know which revascularisation technique was used.

Recommendations

The celiac trunk (CTr) and superior mesenteric artery (SMA) are unfrequently affected by atheromatous type steno-obstructive disease and even when they are, patients remain free from symptoms for a long time due to the presence of a rich collateral circulation between CTr, SMA and IMA and between those vessels and the aortic circulation, through gastric and haemorrhoidal branches.

CDS of the SMA and CTr is recommended in patients with symptoms of chronic celiac mesenteric insufficiency.

Recommendation 1 Grade C

CDS of the SMA and CTr is reccommended in patients with an epigastric and or mesogastric vascular bruit.

Recommendation 2 Grade C

CDS of the SMA and CTr is recommended in patients who have undergone revascularisation of the visceral arteries.

Recommendation 3 Grade C

Angio-CT or angio-MR are complementary to CDS and recommended in the study of aneurysms and/or lesions of the visceral vessels that are difficult to assess by ultrasounds, or in pre-operative assessment where CDS is not deemed sufficient, except where endovascular treatment can be foreseen if diagnostic angiography is performed during endovascular procedure.

Recommendation 4 Grade C

Angiography is only recommended in doubtful cases, in patients with symptoms for whom a better definition of the disease is required or in view of revascularisation if AngioMR or AngioCT do not provide sufficient indications, or if vascular catheterization is indicated anyway for other diagnostic needs, also in view of the high incidence of cholesterol emboli following angiography.

Recommendation 5 Grade C

REPORTING PROPOSAL FOR DUPLEX SCANNING OF THE VISCERAL VESSELS

Surname, Name..... age
date...../..../...../
The examination is performed with
– Equipment.....
– Probe type.....

Description of the celiac trunk wall and profile and the segment of the hepatic and splenic artery for exploration:
– .....
– Stenosis of the.... % localised.....
– Aneurysms YES NO ø maximum artery aneurysm ..... cm
Description of the wall and profile of the superior mesenteric artery: .....
– Stenosis localisation: ostial YES NO, in tract YES NO, length of stenosis... cm
– Aneurysms YES NO
– ø maximum aneurysm CTr... cm - SMA... cm - Hepatic... cm - Splenic... cm
Description of the vein flow and wall profile
– compressibility
– flow pattern

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Color-coded duplex scanning of the renal artery

Renal arteries are identified directly at the origin from the aorta or in the pre-parenchymal segment.

They normally do not originate from the aorta at the same level, hence the arteries of each side must be studied separately on different planes. The right renal artery presents a longer extension than the left due to its anatomical position. The renal parenchyma presents a low flow resistant arterial district, hence Doppler PW findings obtained from the renal artery, in the proximal, medial and distal segment, are characterised by a high diastolic flow component.[1-22]

In the normal subject, peak systolic velocity (PSV) is approximately 100±20 cm/sec and velocity levels are similar in both renal arteries. The ratio of peak systolic velocity of the aorta as compared with that of the renal artery (Renal-aortic - RAR ratio) is normally <3.5 [23]; stenosis of below 60% of the diameter involves a PSV >180 cm/sec and an RAR <3.5 whilst stenosis greater than 60% is characterised by a PSV >180 cm/sec and RAR >3.5 [24]. This ratio is valid when the aorta is not aneurysmatic, diffusely ectatic or atheromatous with tortuosity. In such case, RAR sensitivity is significantly reduced [25].

The analogy of the flow signal of the renal artery with that of the carotid vessels, and particularly of the internal carotid has allowed for the application of many velocity parameters and spectrum analysis of the Doppler signal already used for the supraortic trunks. Those parameters include the IS (Index of Stenosis according to Arbeille and Pourcelot)[25, 26].

The assessment of stenosis of the renal artery shows high sensitivity and specificity when applying some of those parameters.

The renal artery must be assessed at an ostial, post-ostial and hilar level.

The individual distal assessment at the renal hilum or at the parenchyma level does not allow for the diagnosis of ostial or post-ostial stenosis equal to or less than 70-75% of the lumen, due to the normalisation of the flow signal in the event of remote assessment of the stenotic area.

Peak Time in these cases looks to be within normal limits (less than 0,07 seconds).

The search for the ostial segment must always be attempted, also exploiting oblique, lateral or coronal projections, which, in particular at the right renal artery, allow for better insonation and often reduce the need for extreme corrections of the Doppler angle.

Another parameter to be measured in this district is the resistance index (RI): (1-[end diastolic velocity/maximum systolic velocity] x 100).

The RI shows the capacity of the parenchymatous vessels to supply a constant, low impedance flow to smaller calibre vessels representing the majority of the arterial-capillary circulation.

Normal RI values of the renal vessels range from 0,55 to 0.75-0.77, in the same way as for the carotid district. Raising of the RI, by 0,80 or greater, measurable at the ostial level of the renal artery, and which is maintained or increased in its intermediate, hilar and intraparenchymal segment, is seen in the event of parenchyma or post-renal disease.

The presence of high RI associated with stenosis of the renal artery does not allow to predict the efficacy of PTA stenting of the artery [27,28].

A significant decrease, below 0,55, may be seen in severe ostial or post-ostial stenosis or occlusion of the renal artey, with downstream "dumped" type flow signal (high Peak Time,

reduced systolic peak, high diastolic flow).

Another condition with such a decrease is seen in intraparenchymal A-V fistula, a condition where the renin-angiotensin system may also be activated, with signs of renovascular hypertension.

Kidney transplant

More and more frequently, an assessment of the vessels of patients submitted for kidney transplant is required.

The site of the entry of the transplanted renal artery onto the iliac axis represents the new renal ostium and in a normal-functioning kidney shows a typical mono-phase flow along the entire artery.

The iliac axis must be studied with CDS prior to surgery. A stenosis of the iliac axis upstream of the entry to the transplanted renal artery may result in renal ischemia with the activation of the renin-angiostensin system. Treatment by angioplasty of the iliac in this case is indicated kidney [29,30].

Assessment of stenosis of this segment is performed using the same criteria as for the native artery.

The assessment of the RI is extremely important in the early stages of transplant and during follow-up.

Increased RI is related to early rejection or altered kidney function sometime after transplant.

Recommendations

Stenotic disease of the renal arteries, in patient suffering from peripheral arteriopathy, appears with an incidence ranging from 30-40% and progression of stenosis is seen in approximately 20% of cases. Bearers of stenosis of the renal artery are not always hypertensive.

CDS of the renal arteries is recommended in patient with systo-diastolic hypertension, with early-onset hypertension or with impairment of the kidney function.

CDS of the renal arteries is supplementary and complementary to patients suffering from early onset of peripheral arteriopathy and in those with aneurysm of the abdominal aorta.

Recommendation 1 Grade C

CDS of the renal arteries is indicated in patients subjected to open surgical renal repair or stenting.

Recommendation 2 Grade CCDS of the renal arteries is recommended in pre- and post-operative control in cases of kidney transplant.

Recommendation 3 Grade C

Angiography is the most effective means to show a lesion of the renal arteries.

Recommendation 4 Grade C

REPORTING PROPOSAL FOR DUPLEX SCANNING OF THE RENAL ARTERY

Surname, Name.....age.....
date...../...../.....
The examination is performed with
Equipment.....
Probe type.....
Description of the renal wall and profile, from the ostium to the hilum
.....
.....
– Stenosis localisation: ostial YES NO, in tract YES NO, length of stenosis.....cm
– Aneurysm YES NO, localisation YES NO in tract YES NO, hilar YES NO, intraparenchymal YES NO
– Features.....

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Guidelines for the assessment of the vasculogenig erectile dysfunction

Investigations

— Color-coded duplex scanning (CDS)
— Penile tumescence test
— Spontaneous nocturnal tumescence
– Visual sexual stimulation tumescence
— Standard radiography (Xray)
— Dynamic cavernous measurement (perfusion pressure, venous return, diameter changes of cavernous body)
— Digital subtraction angiography (DSA)

Complementary investigations

— Neurological assessment
— Electromyography of the sphincters
— Electromyography of the cavernous bodies
— Cortical evoked potentials from dorsal nerve of the penis

Unsuitable studies

— Erection drug test without CDS, since it does not provide aetiological indications in the non-responder patient
— CW Doppler exam, since the theta angle is not known, it does not measure the velocity of systolic peak

Procedures

The diagnosis of erectile dysfunction (ED) is a clinical diagnosis that should be made by an andrologist – urologist – sexologist.

History and physical examination should always be done before laboratory investigatioms.

History should be medical and psychological. Many common diseases are associated with ED, such as arterial hypertension, diabetes mellitus, myocardial diseases, lipoidoproteinoses - hypercholesterolemia, renal insufficiency, hypogenitalism, neurological diseases, psychiatric diseases, previous rectal and vascular, genital/urinary operations, anti-hypertension and psychotropic drugs, alcohol abuse, marijuana, codeine, meperidine, methadone and heroin, previous radiotherapy.

Physical examination should always be performed on

every patient, particularly assessing the endocrine, vascular, neurological and genital/urinary tract.[1, 2]

Several blood laboratory tests are recommended (glycaemia and testosterone in most patients; lipidic profile, prolactinemia, and PSA may be required based on the physical examination.[3-5]

In ED assessment the complexity of reaching erection and the possible causes of deficit, which are many and often associated, should be kept in mind: adrenergic hypertone, psychogenic, congenital or acquired anatomic penile alterations, neurological, iatrogenic, arteriogenic, veno-occlusive, dysglandular, secondary to other organic disease or abuse or involuntary intake of toxic substances.

The frequency of ED is rather high today (from 35 to 52% of patients) and is continuously rising.

The media's enormous interest in this topic and the availability of drugs that can be taken orally are all factors that complicate diagnosis and correctly resorting to laboratory investigations and treatment.

The frequency of ED increases with age, even if it is impossible to define a threshold age between physiological aging and real ED.

Treating ED with drugs currently available for oral intake is effective. The laboratory investigations should therefore be simple and prompt, aimed at an early treatment.

The erection drug test (ICI test), performed with intracavernous injection of Alprostadil 10 micrograms, is a very simple, quick, low-cost, low invasive and almost painless study. If the patient responds positively to the ICI test, a significant arterial or venous disease can be ruled out, and the patient can start medical treatment. If the patient is a non-responder, it is necessary to repeat the test associated with the CDS to assess the vascular condition and possible lesions.

The dynamic penile CDS (associated with the intracavernous injection of Alprostadil 10 micrograms) is the first (and often the only) useful or necessary instrumental investigation. It can prove the arterial hemodynamic normality and is the first choice investaigation for the arterial disease.[6, 7]

It also provides informations about veno-occlusion, even if with little specificity.

It is a quick study. Low-cost and low invasive. Some risk of priapism is to be kept in mind. It depends on the dose of thr injected drug (which can be reduced in connection with the history, the young age of the patient and the morphology of the penis), concerns the younger patients, with a risk of permanent lesions only in exceptional cases.

The nocturnal penile tumescence test measures the changes of penis circumference and is a useful diagnostic parameter to distinguish ED of psychological origin from that of organic nature.[8]

The limitations of this test are the accuracy of measurement and the definition of the cut-off between lack of rest tumescence and erection.

The penile tumescence caused by visual sexual stimulation test measures the changes of circumference of the penis during visual excitement. Compared to the nocturnal test it has the advantage of being quicker, but has the strong limitation of requiring an isolated and private environment hard to find in a hospital. The emotional response to an erotic film can then be variable; in some cases it is a source of embarrassment.

Dynamic cavernous measurement is carried out with the dynamic infusion of fluids and then a contrast medium. It simultaneously measures the perfusion pressure in the cavernous bodies, the morphology of the cavernous bodies, the changes of its diameter and the venous return. Useful for measuring the maximum perfusion pressure of the cavernous arteries, it is considered the "gold standard" examination to detect anomalies of the venous occlusion.

It is currently the only way to monitor the functional state of smooth muscle fibres, as it can identify the complete relaxation of the cavernous bodies.[9, 10]

DSA is used to investigate both the arterial bed and venous return. It can be performed by selective and bilateral catheterization of the internal iliac arteries or by direct injection into the cavernous arteries. In both cases the exam requires injecting also a vasoactive drug in order to induce reduction of the peripheral resistances. Owing to its invasiveness, this study is replaced by CDS.

The only remaining indication is the diagnosis/treatment of those rare cases of high flow priapism, because treatment by embolization of the arterial-venous fistulas can be obtained in the same procedure.

Penile color- coded Duplex scanning

Instruments

Color-coded Duplex scanner Transducer: 5-10 MHz

Procedure

1. Patient's position: supine
2. Probe position: placed on the back of the penis

transversal scanning to assess the echostructure and dimensions of the cavernous bodies

longitudinal scanning to identify the cavernous arteries, their patency and their hemodynamics. Assessment of the echostructure and dimensions of the cavernous bodies.

3. Intracavernous injection.

A standard dose of vasoactive drug that reduces the peripheral resistances is injected in a cavernous body.

The increased cavernous flow is seen within 2-4 minutes, mostly around 4-5 minutes.

Alprostadil 10 micrograms is currently used. The dose has to be standardized in order to provide a comparison of hemodynamic parameters with the values currently provided in the literature. This dose can be reduced in young patients (< 40 y).

The patient is observed until the end of the drug induced erection period.

Complete erection (the penis cannot be bent), which appears within 10 minutes and lasts at least 30 minutes, on its own is proof of a normal arterial and venous function of the penis (11).

4. CDS assessment of the cavernous bodies.

Transversal and longitudinal scanning allows assessment of:

— the dimensions and shape of the two cavernous bodies

— the echostructure. The presence of widespread hyperecogenic nodules is to be described, providing their dimensions and iconographic documentation

— the presence of plaques due to Peyronie's disease. The plaque is to be described regarding its site, dimensions and echogenicity. If the plaque is hyperecogenic with shadow, the cavernous arteries are to be studied above and below the plaque, showing their patency and hemodynamics.

5. Hemodynamic assessment

It is necessary to assess the cavernous arteries with lon-

gitudinal scanning and define their course and complete patency with the color flow map or with Power Doppler.

Any presence of significant connections between dorsal and cavernous artery is to be described as well as of a thin arterial lumen with irregular diameter and/or occlusions, specifying their site.

Hemodynamic parameters. Pulsed Doppler recording on a sample volume as small as possible can start as early as 3 minutes after the ICI test, and it should be completed within 15 minutes. The scanning plane must fathom a long section of thecavernous artery. In its most proximal section and with the theta angle as small as possible, several velocitograms entirely similar should be clearly recorded in order to measure precisely:

— velocity at the systolic peak
— telediastolic velocity
— resistance index

The systolic peak velocity is crucial to define normality of the arterial flow.

Presently the cut-off value between normality and anomalies is a systolic peak velocity > 30 cm/s in both cavernous arteries.

The telediastolic velocity varies depending on the time between the ICI test and the recording of CDS.

The telediastolic velocity increases during the ICI test, but then gradually drops until it reaches values even <5 cm/s depending on the gradual increase of the veno-occlusion peripheral resistances. However there are not currently defined normal values in the literature.

Assessment of venous occlusion and possible venous leaks should not be done by CDS, but with the cavernous pressure measurement.

The resistance index: A > 0.8 value is currently considered normal.

6. Observation of the patient after ICI test.

The investigation requires 15-20 minutes. If the patient does not reach a complete erection within this time period the observation can be stopped.

In case of complete and lasting erection, the patient should be controlled until it clearly recedes. The risk of drug induced priapism is rare, but possible.

To make the erection recede, it is useful to:

— make the patient work the muscles of the lower limbs (bending the legs, or go up and down the stairs).

— insert a 19G needle under local anesthesia to aspirate the blood and reduce the pressure in the cavernous bodies.

This simple method is usually enough for the penis to become flaccid.

— If after emptying it, the penis becomes rigid again, it is necessary to inject Phenylephrine at the initial dose of 200 micrograms every 5 minutes, increasing it up to 500 micrograms if the response is insufficient.

— Several cases of priapism that resist these procedures are described in literature.

If a patient has had an erection for too long a time after the ICI test, it is not possible to predict the risk of having the same problem in subsequent ICI tests. The dose of drug to be injected must be reduced anyway [12-14].

Recommendations

An instrumental vascular investigation is indicated only if there are symptoms identified as ED according to the definition of the NIH of the European Association of Urology

Recommendation 1 Level A

History and physical examination of genital/urinary, endocrine, vascular and nervous system as well as recent measures of glycaemia and testosterone should always be done before laboratory investigations.

Recommendation 2 Level A

CDS is "first choice" for the assessment of an arterial vascular disease. It can be also instrumental for assessing the effectiveness of the veno-occlusion.

An intracavernous injection of a vasoactive drug (Alprostadil 10 micrograms) is needed. It is a quick, low-cost, low invasive and non-painful test.

The only risk is drug induced priapism, which occurs rarely and more frequently in patients < 40y.

Recommendation 3 Level A

The intracavernous injection of a vasoactive drug is to be done with Alprostadil 10 micrograms in a standardized way for comparison with normal values.

Such dose can be reduced in patients < 40 y. The possibility of priapism, though rare, is to be kept in mind. When the ICI test induces complete erection the patient should be observed until it recedes.

Recommendation 4 Level A

Both the nocturnal and visual sexual stimulation penile tumescence tests may prove useful for the patient with psychological ED that presents a normal response to the test. A lack of response does not define the cause of ED because it may also be caused by the embarrassment created by performing the test.

Recommendation 5 Level B

Dynamic cavernous measurement is an invasive radiological investigation. It measures the perfusion pressure of the cavernous bodies and shows the venous return. It is considered the "gold standard" for assessing a penile veno-occlusion anomaly as a cause of ED.

Recommendation 6 Level B

Selective DSA is an invasive investigation almost entirely replaced by CDS. The only remaining indication is the diagnosis / treatment of rare cases of high flow priapism, allowing embolization of the arteriovenous fistulas.

Recommendation 7 Level A

REPORTING PROPOSAL FOR ASSESSMENT OF VASCULOGENIC ERECTYLE DYSFUNCTION

Surname ..... First name .....
age ..... date .....
The investigation is carried out with
– device
– probe

The intracavernous injection test (ICI) was carried out with Alprostadil 10 micrograms (specify if a different dose was used).
The ICI test induced: erection, turgor, lack of response (specify)

Hemodynamic assessment
Right systolic peak velocity ..... cm/s
Left systolic peak velocity ..... cm/s
Right telediastolic velocity ..... cm/s
Left telediastolic velocity ..... cm/s
Right resistance index .....
Left resistance index .....

CDS assessment
– concise description of the cavernous bodies
– presence of widespread hyperecogenic nodules
– plaques due to Peyronie's disease, specifying whether this entrains occlusion of the arteries.

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Guidelines for the assessment of male varicocele

Varicocele is caused by a disorder of the venous drainage of the testicle with consequent formation of varicose veins of the pampiniform plexus surrounding the testicle inside the scrotum. It is generally divided into a front and rear portion. These small veins gradually anastomose to form larger venous branches. The internal spermatic vein (one or more) runs inside the spermatic funiculus and then on the rear side of the peritoneum. It opens into the renal vein on the left side and into the inferior vena cava on the left. Other veins originating lower down, immediately extrascrotum, flow into the saphenous, femoral, inferior epigastric or external iliac veins of each side [1-5-13-15].

The incidence of varicocele is roughly 10-15% in the overall population and 20-40% in infertile men. The left side is involved in 85% of the cases. Varicocele mostly appears with puberty and is multifactorial in nature. There is a family component since a "weakness" of the venous valves is inherited, which can also be the cause for haemorrhoids and varicose veins of

the lower limbs. Those diseases are often present in brothers and parents. There is also an embryogenetic development that may lead to the absence or incompetence of the valves along the spermatic veins. Another factor may be compression of the left renal vein by the superior mesenteric artery on the aorta [6-7-12].

Due to this altered venous return, varicocele can entrain poor testicle growth during puberty and/or poor fertility in the adult. The real key to the problem seems to be hyperthermia. In presence of varicocele the temperature of the testicle rises beyond the physiological values. Moreover, vasoconstrictive adrenal hormones reach the testicle and reduce its oxygenation. Lastly the build-up of toxic waste continues when it should instead be washed away.

Such abnormal stimulations on the testicle due to the venous drainage defect change its structure and damage the production of sperm in the long run, the result being ingravescent hypofertility up to cases of sterility due to azoospermia.

Hence it should be emphasized the need for an early diagnosis of varicocele during childhood or adolescence, since that the histopathological analysis of testicles carried out on adult patients shows irreversible damage which can not be recuperated even by surgical correction.

Symptoms and evolution

In many cases varicocele presents asymptomatically. In some cases it is accompanied by a sense of inguinoscrotal heaviness on the side involved, which is worse in evening hours and enhanced by standing a long time or after physical exertion.

In most cases, particularly in young adults, varicocele is identified during workups undertaken for infertility. The seminal examination shows: reduction of sperm motility and number plus changes of their morphology. Damage to fertility is slowly progressive. According to some studies, varicocele increases the risks of early abortion if his partner becomes pregnant anyway. This is due to complex biochemical factors that alter the "unwrapping" of the chromosomes from the head of the sperm.

There are various varicocele classifications [1-2-9]:

— a general classification as primitive or idiopathic and secondary,

— a clinical classification as: subclinical - varicocele is not clearly distinguishable, but is found only with laboratory investigations; grade I - varicocele that can be detected only with the Valsalva manoeuvre; grade II – which can be detected with palpation without the need for the Valsalva manoeuvre; grade III – which can be detected just by looking, in so far as venous distension causes an evident lack of definition of the hemiscrotum).

It should however be kept in mind every classification of varicocele has neither a correlation with the degree of damage nor with the possible improvement after correction.

In patients with varicocele hypotrophy of the testicle is found in approximately 40% of cases. It can be assessed using orchidometers or more precisely using testicular ultrasound, a definitely necessary method mainly for very young boys for whom a spermiogram may be difficult to obtain [14-16].

Diagnosis

It should be done as early as possible.

The assessment of varicocele is based on two investigations: the CDS of the spermatic vessels, which is the only safe device to show the venous reflux necessary for defining varicocele and the spermiogram, i.e. the quantitative and qualitative analysis of sperm.

The testicular US investigation measures the testicular volumes and also shows distension of the veins of the pampiniform plexus. CDS allows the varicocele condition to be defined measuring the venous reflux.

Supplementary studies are:

— Examination of the seminal liquid

— Basal plasmatic hormonal measurements (FSH, LH, PRL, T, free T, 17betaoestradiol)

— Testicular biopsy

— Phlebography, used only as a preliminary stage to endovascular treatment

The studies today unsuitable or obsolete are:

— CWD without scrotum ultrasound because it does not assess the echostructure and any possible testicle hypotrophy

— Testicular ultrasound alone because distension of the scrotum veins is not identified with the presence of reflux

— Scrotum thermography.

The assessment aims to detect and measure a significant reflux in the internal spermatic veins (by far the most involved) and/or in the external spermatic veins or in the cremasteric veins (exceptionally involved) associated with a possible testicular hypotrophy [1-7-13-14-16].

Demonstration of a "significant" reflux is crucial to label infertility as secondary to a varicocele [1-2-7].

Testicular hypotrophy homolateral to left varicocele is associated in 25-93% of patients with infertility. A volumetric reduction on one side of at least 20% is deemed significant [6]. The testicular hypotrophy test is most important in the peripuberal phase, when it is impossible or complex to resort to examination of the semen [16].

Spermatic color-coded Duplex scanning

Instrument: color-coded Duplex scanner with 7-10 MHz linear transducer.

Patient position is supine while studying the testicles and the epididymes, but always and only in ortostatism for the hemodynamic assessment of the reflux.

The examination is carried out after inspection and palpation of the testicles and of the veis of the plexus.

The presence of venous distension, enlargement and elongation while standing allows to identify a varicocele. The diameter of the veins must be equal to or greater than 3 mm.

The presence of palpable veins both while standing and in the supine position should lead to consider a varicocele as secondary to venous obstruction of the left renal vein or of the inferior vena cava.

Palpating the testicles is helpful to direct the testicular US investigation towards testicular hypotrophy, epididymal cysts or other diseases.

Longitudinal, transversal and oblique scan should to be done to get exaustive imaging of testis and epididymis. Longitudinal CDS is used for assessing the reflux in the veins of the pampiniform plexus and in the internal spermatic veins.

By US investigation of the testicles the volume of the two testicles is measured. A reduction of more than 20% is significant for hypotrophy when associated with venous reflux. An alternative is to measure the gonadal diameter, but there is no agreement on significant changes of this parameter. Including the body and tail of the epididymis in the measurement of the testis is to be avoided [12-15].

Assessment of the reflux is done by measuring the duration of the venous reflux under basal conditions and during the Valsalva manoeuvre.

Flow through the veins is not detected in the normal patient in the standing position, but occasionally a low-velocity intermittent centripetal flow may be seen.

The presence of continuous venous reflux under basal conditions is proof of a complete valvular incompetence is significant for venous orthostatic hypertension.

An intermittent venous basal reflux in expiration is significant for an initial venous incompetence.

A venous reflux only during the Valsalva manoeuvre suggests valvular only during rising of the abdominal pressure. This type of reflux is significant only if it lasts more than 2 seconds. Several authors still doubt such relevance. Remember that the person performing the CDS must carefully and patiently search and optimally detect the vein where to take the sample volume. For this purpose it is essential to use the compression/relaxation manoeuvre carried out on the veins of the distal pampiniform plexus.

Treatment

There is no medical treatment for this ailment but in those cases where reflux was corrected but oligospermia remains 3 months after the procedure. In such cases it is advisable to stimulate the testicle to produce a larger number of sperm (functional resumption) by subcutaneous administration of the purified Follicle Stimulating Hormone (FSH, a hormone naturally in control of stimulating spermatogenesis) [12-16].

The treatment, to be decided case by case based on age, anatomic condition, seminal and hormonal data, and on previous treatments undergone, is open surgical (selective ligature of the spermatic vein) or endovascular (percutaneous catheterization and sclerosis of the spermatic vein).

Successful treatment of varicocele during puberty brings testicle growth back to normal, whereas in the adult a varying degree of improvement of the semen is achieved with improvement of fertility.

Recurrences of the disease after correction are rather similar amongst the various techniques: 5 to 20% of the cases.

A follow-up at one and six months is adviced to complete or correct treatment, when needed.

Recommendations

The magnitude of the varicocele has no equivalence with the severity of the reflux.

Recommendation 1 Level A

There is correlation between the length of time the testicles are exposed to the reflux and the impairment of spermatogenesis. Diagnosis and treatment must be early.

Recommendation 2 Level A

The ultrasound measurement of the volume of the testicles is mandatory: a reduction > 20% is considered significant for hypotrophy.

Recommendation 3 Level B

"Significant" spermatic venous reflux is detected with the patient in the standing position and under basal conditions. It is a high velocity reflux that proves complete valvular incompetence of the spermatic vein.

Recommendation 4 Level A

Bilateral investigation and report in mandatory.

Recommendation 5 Level B

Spermatic phlebography is no longer recommended as first level study. It has been replaced CDS.

Recommendation 6 Level A

REPORTING PROPOSAL FOR SPERMATIC VEIN COLOR-CODED DUPLEX SCANNING

Surname.....Name.....age.....
date.....
The examination is carried out with
– device.....
– probe type.....

Presence of venous ectasias of a diameter equal to or greater than 3 mm YES NO

Description of the venous reflux
left
right
– presence of basal reflux YES NO
– intermittent, expiratory YES NO
reflux caused by the Valsalva manoeuvre lasting..... seconds

testicle volume
– testicular hypotrophy > 20% YES NO
– right testicular volume.....
– left testicular volume.....
Description of any morphological abnormality of the testicles or of the epididymes.

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Guidelines for the assessment of female pelvic congestion syndrome

Varicocele in women, better defined as pelvic venous insufficiency, was for the first time described by Taylor in 1949 [21]. He introduced the term " pelvic congestion syndrome " (PCS), consisting of pelvic pain, dyspareunia, dysmenorrhoea, dysuria, vulvar congestion with or without vulvar varicose veins, but the hemodynamic definition of PCS and the attention paid to this case of chronic venous insufficiency should be attributed to Hobbs [8].

"Chronic pain" of the pelvis – mainly in a young multipara woman – and varicose distension of the ovarian veins with valvular incompetence is not rare. Their reflux causes the PCS with pelvic varicose veins, vulvar and perineal communicating with ectopic varicose veins of the thigh [19].

Commonly found are recurring varicose veins in patients who have already undergone operations to correct varicose veins of the lower limbs, evidence of the reflux coming from the ovarian or hypogastric plexus [22-23].

Unlike male varicocele, in ovarian varicose veins fertility disorders are never found.

Diagnosis is made with the presence of the chronic pelvic pain, with exacerbations during ovulation and menstruation and the presence of varicose veins in the thigh with atypical distribution, generally on the posterior and parainguinal areas.

Closure of the incompetent ovarian veins will carry a considerable improvement of chronic pelvic pain in at least 70% of the cases, and a considerable reduction of the extrapelvic peripheral varicose veins in roughly 90% of the cases.

Another symptom still underrated is dyspareunia, for the most part associated with the perivaginal and vulvar varicose veins. Decompression and closure of the dilated veins is beneficial in more than 80% of the cases [2-4].

Despite presenting in about 15% of women aged 18 to 50, the PCS is often overlooked in the differential diagnosis of abdominal pains [1].

Conversely it should be considered for both new non-invasive diagnostic and new treatment perspectives [2-7].

Chronic pelvic pain involves 10% of the gynaecological population and it is defined as an abdominal or pelvic pain, non-cyclic, lasting at least 6 months.

It is felt in the lower abdomen, continuous or intermittent. It may intensify at the end of an intense workday, or for long periods of standing or during the menstrual cycle. It can be irradiated to the buttocks and thighs. It can be accompanied by dyspareunia, symptoms of bladder spasm or of abdominal constipation.

Because of the close connection of various systems in the pelvic area, because of the overlapping of symptoms between various diseases and because of the inadequacy of diagnostic techniques, laparoscopy was broadly used as a diagnostic tool. As many as 33% of the laparoscopies were performed for chronic pelvic pain. This method however drew a high percentage of false negatives.

Moreover this technique does not allow to identify all the causes that might lead to chronic pelvic pain [9-10].

The physiopathology of the PCS has not been completely explained yet. Many believe that incompetence of the ovarian veins progressively leads to varicosity in the broad ligament and in the retrouterine plexus, which are associated with pelvic pain that in turn is worsened by increased intraabdominal pressure, as occurs during walking or long standing [13-14].

Venous drainage of the ovaries runs through a venous plexus that communicates with the uterine plexus in the broad ligament. The corresponding vein – single or multiple branch – comes out of the ovarian plexus and goes up along the psoas muscle to run into the left renal vein on the left and into the inferior vena cava on the right. Postmortem studies have shown that the valves may be absent in the cranial segment of the vein in 15% on the left and in 6% on the right. The valves may be incompetent in 35% of women, with higher frequency in multipara women [11].

The diameter of the ovarian veins in non-pregnant women, in fertile age, is not well-defined in the literature. Approximately the diameter of 6-8 mm should be the minimum for defining varicocele [4-19].

Diagnosis

Diagnosis is established by the transvaginal CDS, which completely depicts the pelvic veins and the anastomosis with the abdominal veins and lower limbs with a high degree of reliability.

Multi-layer angioCT and angioMRI are able to display the retro-ovarian and periuterine veins of increased diameter, but these second level studies are justified only for differential diagnoses with other diseases of the pelvis (e.g. expanding ovarian formations etc.). They and do not measure the entity of reflux [17-19].

A rare PCS with associated varicose veins in the lower limbs is caused by compression of the left renal vein between the superior mesenteric artery and the aorta and it is known as "Nutcracker Syndrome". It should be suspected in women with PCS and haematuria and can be confirmed by angioMRI or angioCT [20].

Endovascular treatment using stents has been.

Using a transabdominal approach, the pelvic vascular structures are hard to assess by US owing both to their distance from the probe and to their variety and range of anatomic structures.

The method of choice is therefore the transvaginal CDS performed with high frequency (5-7.5 MHz) endocavitary probes.

The investigation is carried out with the patient in the gynaecological position, with the bladder empty, in a slight anti-Trendelenburg in order to allow the veins to fill.

Once the uterus is displayed as the landmark, the probe is turned about 90° to the right and the uterine artery is displayed, then the iliac artery, and lastly the periuterine venous plexus. The same manoeuvre is made to the left. The periuterine venous plexus of the ovarian veins are assessed bilaterally.

Then the probe is moved toward the vaginal walls to assess the perivaginal veins and the internal iliac vein.

Any reflux - basal, during gentle abdominal compression and with the Valsalva manoeuvre – is assessed using the pulsed Doppler.

It should be kept in mind that the diameter of the intra-abdominal veins may vary for different reasons, including the hormonal situation and the cycle phase. Diameters greater than 6-8 mm are considered pathological.

It is crucial to identify exactly the collector of the enlarged veins, in view of the indications for endovascular treatment [6-12-16-18].

Treatment

Treatment consists of interrupting the reflux.

Medical treatment (eliminating the ovarian function, pain killers) plays a palliative role. Surgery, with its wide range of solutions (total histerectomy, ligature of the ovarian veins and the secondary branches) can be applied successfully. But it carries scars, some morbidity, the use of general or epidural anaesthesia and a brief hospitalization of [15]. Laparoscopy techniques cam be considered but they have not reduced morbidity and costs [14].

The first choice treatment today is percutaneous endovascular catheterization and sclerosis that can be performed with transbrachial access, like in men. The procedure is performed under local anaesthesia, in day hospital [6-12-16-18].

Recommendations

History and physical examination should include the gynaecological assessment of a specialist expert with the problem

Recommendation 1 Level C

CDS is a fist level test, but angioMRI and angioCT are essential for studying high refluxes.

Recommendation 2 Level C

REPORTING PROPOSAL FOR TRANSVAGINAL COLOR-CODED DUPLEX SCANNING

Surname.....Name.....age.....
date.....
The examination is carried out with
– device.....
– probe type.....
Venous ectasias of a diameter equal to or greater than 6-8 mm YES NO
Site:
– ovarian YES NO
– hypogastric external iliac perineal
– vulvar
– haemorrhoidal inguinal
– suprapubic

Features of the venous reflux.

Reflux caused by the Valsalva manoeuvre lasting..... seconds

Then state if there is:
– Saphenous incompetence
– Incompetence of cross side effects
– Previous resection of great saphenous vein

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Guidelines for the assessment of the arterial circulation of the lower limbs

Investigations

— Continuous wave Doppler (CWD)
— Duplex scanning (DS)
— Color-coded Duplex scanning (CDS)
— Standard radiography (Xray)
— Angiography by computed tomography (AngioCT)
— Angiography by magnetic resonance (AngioMR)
— Digital subtraction angiography (DSA)
— Transcutaneous O_2 tension/CO_2 tension ($TcPO_2$ - $TcPCO_2$)
— Plethysmography (PG)
— Laser Doppler (LD)
— Near infrared spectroscopy (NIRS)

Procedure

In addition to the clinical assessment, the first test is CWD measuring the systolic pressure at the ankle and the ankle-brachial pressure index (ABI**)**.

The ABI is important not only to assess the severity of the arterial disease, but also as an easy detection method (can also be carried out by nurses and technicians), and as a pathology marker, mainly for cardiovascular mortality in the elderly.[1] The ABI is less reliable in diabetic patients owing to the calcifications and sequential stenoses. Some authors report a 70.6% sensitivity with an 88.5% specificity.[2]

Therefore, measurement of the pressure of the toe and calculation of the toe-arm pressure or "toe index" (TI) is indicated for these patients and those with renal insufficiency or with other arterial diseases with severe calcifications of the tibial vessels.[3]

Measurement of the segmentary pressures may be useful to suggest the site of the obstructive lesions.[4]

The pressure indexes can be determined after a treadmill test

The CDS is used for the morphological study of segments of the lower limb arteries. It is a precise non-invasive study as emerges from a meta-analysis of 14 studies regarding various arterial segments compared to angiography, and can sometimes replace angiography in deciding the treatment strategy,[5] even if surgeons still find it hard to accept

it in the peripheral district. It is particularly indicated in studying the deep femoral artery and the femoral junction.

Fourteen studies comparing CDS with angiography in the femoral-popliteal district report a sensitivity varying between 82% and 95% and a 96% specificity for diagnosing stenosis equal to or greater than 50%, and a sensitivity between 90% and 95%, with 96-97% specificity, for diagnosing occlusion, depending on the different levels of methodological quality of the study.

In the infragenicular district, the diagnosis of occlusion presents a 74% sensitivity and a 93% specificity, whereas for stenosis greater than 50% or occlusion the sensitivity is 83% with 84% specificity.

From another study conducted on 613 patients it resulted that the CDS is superior to DS (P=0.022), so the addition of the color flow imaging to the duplex increases the diagnostic reliability in thearterial diseases of the aorta-iliac femoral-popliteal axis.[6]

The accuracy of a clinical decision based on the sole ultrasound description is still rather variable (82-95% in a double-blind study conducted on the decisions of 5 surgeons and one radiologist [7]), even if the differences are probably due to the different attitudes the individual surgeons have towards a lesion. Even at the level of the lower limbs the DS alone does not lead to a correct treatment planning in all patients, and must be integrated with other imaging methodos.[8] However one should not forget the deep-rooted habit of setting the therapeutic indication based on a general display of the vascular axis, which makes both a morphological and functional "interpretation" possible, with analysis of the collateral circulation in its entirety and above all in the emergency and re-entry sites.

Using a US amplifier increases reliability and quality of the ultrasound image with regard to angiography. However, it must still be verified if it is enough for treatment planning or if it is an economically sound proposal, considering that in any case it is necessary to resort to other X-ray studies in a certain number of cases.

The CDS is still the examination of choice in follow-up and in monitoring the patient who has undergone invasive treatment, whether surgical or endovascular.

Specifically, the CDS is extremely reliable in testing patients carrying femoral-popliteal bypasses, both in vein and in prosthetic material, since it is able to assess the state of the anastomosis, of the graft, and of the inflow and outflow vessels, and to detect the stenoses that might lead to occlusion of the bypass.

In those patients undergoing endovascular treatment, the CDS is just as effective, even if there are no studies that establish the velocimetric and hemodynamic parameters suggestive of intrastent restenosis.

AngioCT and/or AngioMR (second level examinations) are indicated only to complete the US investigation in determining the site and nature of the lesion, and in assessing the wall pathology, in the arteries upstream and downstream of the lesion, particularly when there are mixed steno-obstructive and aneurysmatic lesions, in a perspective of surgical or endovascular approach.

AngioCT is taking an increasingly important role as a second level examination for patients with peripheral arterial disease. It is essentially associated with rapid technological development and the possibility to carry out a complete study of the entire circulatory tree with subcentrimetric scans in just a few seconds. There are no perspective studies specially built to assess the accuracy of AngioCT compared to the other methods. However, the data available today report encouraging results, with a 90.9% sensitivity and a 92.4% specificity as compared to angiography.[9, 10] Actually, the agreement between AngioCT angiography is maximum in the iliac-femoral and above knee femoral-popliteal area, with a marked advantage for the AngioCT in the planimetric assessment of proximal lesions, whereas it drops significantly in assessing the below knees and distal vessels.[11] This is why the most recent guidelines [4] suggest using AngioCT in patients who are candidates for revascularization when AngioMR is contraindicated or unavailable.

In a number of centers angioMR has become the method of choice for the diagnosis and treatment planning for the patient with peripheral arterial disease.[12] The sensitivity and specificity levels, compared to angiography, run around 94-97% in the various series, slightly higher at the iliac and femoral level, and slightly lower at the crural level.[13]

AngioMR can be carried out with paramagnetic contrast medium (contrast-enhanced) or without contrast (time-of-flight technique). Today the AngioMR with contrast medium provides better results in so far as with 1.5V devices and movable table, it is possible to perform a study of the entire body in a few minutes. The excellent results in terms of sensitivity, specificity and accuracy compared to angiography, and its superiority compared to the CDS described in recent studies, ensure that more and more authors consider AngioMR as the first choice method in a candidate for invasive treatment. The current limitations are not only the contraindications to perform a magnetic resonance, but also the possibility of overestimating the steno-obstructive lesions and the difficult display of the flow when there are intravascular stents.

DSA should be restricted to patients with multilevel arterial disease, or to candidates for surgery in whom non-invasive studies are considered insufficient.

At present the possibility of performing femoral-distal revascularizations without angiography is not accepted by everyone. Actually, the AngioMR currently offers images that can replace angiography in almost all areas, with a lower operating cost and in a non-invasive way, so it can be foreseen that in the near future AngioMR will replace DSA in a high percentage of cases. Recent studies proved that in the presence of a technically adequate AngioMR, DSA provides additional information helpful for treatment planning only in 10% of cases.

The most recent international guidelines [3, 4] also confirm that non-invasive methods, used separately or together can replace DSA in patients with peripheral arterial diesease. On the other hand, angiography still plays a well-defined role as the intraprocedural method of choice during invasive treatment, whether it is open surgical or endovascular.

The assessment of the microcirculation is mostly carried out measuring the transcutaneous pressure of oxygen ($TcPO_2$) and of carbon dioxide ($TcPCO_2$), which offer data more useful for a metabolic assessment.

Laser Doppler (LD) is seldom used for diagnostic clinical purposes; it is mainly reserved for research.

Near infrared spectroscopy (NIRS) or percutaneous spectroscopy is performed with waves having a frequency close to infrared and is used mostly in assessing cerebral perfusion during carotid surgery, heart surgery or neurosurgery and in intensive care. It was recently used to assess muscular perfusion of the lower limbs, at rest and after exercise, in sports medicine and in patients with peripheral arterial disease, and to investigate compartmental syndromes.

At rest, the muscular oxygen saturation in claudicants

is the same as that of healthy controls, whereas it significantly drops after exercise both as an absolute value and as a percentage of drop over baseline values. The time period for reaching 50% of the baseline T(50) and the period of complete recovery T(100) are significantly longer than in healthy patients. A T(50) >70 seconds identifies a peripheral chronic arterial disease with 89% sensitivity and 85% specificity.[20]

The pulse wave amplitude was used mostly with digital plethysmography to investigate the endothelial function.[21]

With this method it is possible to attain an accuracy of more than 95% in identifying and locating significant occlusive lesions, particularly in diabetic patients with widespread parietal calcifications.

Measurement of the systolic pressure at the ankle and ABI

It is done with CWD and special cuffs positioned at the ankle that assess the pressure in the pedal artery and in the posterior tibial artery. It is always advisable to detect the presence of a signal in the peroneal, at the external malleolus because in many cases it is the only artery that supplies the foot. The pressure at the ankle is compared to the brachial systolic pressure.

The ratio between ankle pressure and systemic pressure of the upper limb is called ankle-brachial index (ABI), or Winsor index.

It would be ideal to measure the two pressures at the same time owing to the high variability that can be found in the first few minutes of reading otherwise, it is advisable to measure the brachial pressure at the beginning and end of the measurements in order to assess their shift and/or to mediate the data. One can also determine the ratio between the mean of the pressures detected at the anterior and posterior tibial and the mean of the pressures of the brachial artery.[22]

Unless it is done with accuracy the ABI may present a fairly high interobserver variability.[23]

In patients with non-compressible arteries the measurement of the systolic pressure at the toe should be used to calculate the toe index (TI). A special small occlusion cuff with flow sensor is used. It is similar to that used during digital plethysmography, and is applied in the proximal segment of the hallux or, if there are trophic lesions, of the second toe. The toe systolic pressure is about 30 mmHg lower than that at the ankle. The physiological value of the toe index is therefore greater than or equal to 0.70.

Measurement of the segmentary pressures at the thigh, calf and ankle, compared to the arm, can be useful to assess the significance of every stenosis-occlusion in patients with multilevel disease, but a multi-segment measurement with this technique is possible in no more than 78% of the limbs.[24]

Treadmill test

The laboratory should report two variables: the speed the treadmill and the angle of inclination of the surface on which the patient walks. Constant speed and inclination are used for diagnostic testing.

A speed of 2.5-4 km/h and a 12-15% inclination are usually recommended. The patient must walk until pain appears or for at least 5 minutes or until muscular exhaustion is reached. As a screening test for claudication, some authors suggest using the treadmill with constant speed and progressively increasing the inclination.[25, 26] In all case, the speed and inclination must be adapted to the clinical conditions of the patient.

Appropriate patient instuction is essential. He must repeat the exercise at least three times before being able to perform a correct test.

The parameters to be detected are:

— systolic ankle-arm pressure before and immediately after the exercise is stopped;

— relative free walk interval: appearance of initial muscular pain;

— absolute free walk interval: need to stop the exercise;

— recovery time: time necessary to recover a usual walking ability.

Since the stress test may cause myocardial ischemia or severe arrhythmias, the treadmill test must follow a cardiological assessment and should be carried out with cardiac monitoring in a room equipped with a defibrillator.

Arterial Duplex scanning of the lower limbs

The patient lies down. The arteries are explored with the duplex probe starting from the common femoral artery to get transversal scans of the vessel, then exploration continues distally and the superficial femoral-deep femoral bifurcation is assessed. *Description and recording*

Assessment of the disease using color-flow imaging to better define the profile of the walls of the vessel.

Longitudinal sections of the vessel. Description and documentation of the parietal morphology. Use of color-flow imaging with velocimetric assessment and measurement of any turbulence making samplings with pulsed Doppler.

Exploration commences distally, obtaining transversal sections of the superficial femoral and then longitudinal sections along the entire axis of the vessel.

Use of color-flow imaging to point out any turbulence and outline the parietal profile of the vessel.

Use of pulsed Doppler with samplings at various levels and recording of any blood-flow velocity anomalies.

For an optimum assessment of the popliteal and tibial arteries, the patient lies down with his/her feet raised in a way such as to keep the leg partially bent. When this is not possible due to physical problems, the patient is kept lying down with the leg bent and the probe positioned from below at the level of the popliteal cavity.

The popliteal artery and tibial bifurcation are explored with transversal, then longitudinal, sections following the various vessels, if possible, along the entire course.

Information about the walls of the vessels and their content is obtained.

Color flow imaging is used to assess the lumen of the vessel and any turbulenceof the flow.

Information about the flow velocity is obtained by sampling with pulsed Doppler.

To detect an entrapment of the popliteal artery, the popliteal region is explored, again with the patient lying down and limb extended. The patient is asked to actively bend the arch of his foot against a rigid surface. The compression and arrest of flow both in the artery and in the popliteal vein must be assessed. The vessels can also be assessed during dorsal bending of the foot. The manoeuvre can also be carried out with the patient standing. It is how-

ever necessary to consider that the positive result of the tests has an extremely high prevalence and reaches 80% in the healthy population. This positive result is mostly secondary to pseudocompressions of the popliteal cavity, muscular hypertrophy or ligamental laxity.

The DS shows the anatomy of the vessels and their morphology, atherosclerotic plaques and other vascular anomalies as well as surrounding tissues and allows a spectral Doppler analysis of the entire vessel.

Scanning in B-mode with the help of color-flow-mapping provides high reliability. The blood velocity information is added to the morphological assessment The non-invasive diagnosis of the femoral-distal district suggested by Schneider *et al*., and based on the comparison with angiography are reported in Table I.

Transcutaneous oxymetry

It is possible to measure the arterial pressure of oxygen (PaO_2) of the capillary blood in a non invasive way using an electrode on the skin (transcutaneous oxygen tension = $TcPO_2$).[23] This electrode has a platinum cathode surrounded by a silver anode wrapped in a spiral that acts as the heating element. When a 630 mvolt polarizing voltage is applied to the cathode, oxygen drops to generate a current directly proportionate to the PaO_2. Since transcutaneous diffusion of the O_2 is greatly reduced at the normal skin temperature, the element contained in the electrode ensures that the area in question is heated to a temperature higher than body temperature (usually 45 °C, as this temperature offers the best correlation between $TcPO_2$ and PaO_2). Moreover, the heat causes local vasodilatation of the dermal capillaries, with consequent local arterialisation of the capillary blood, liquefaction and disorganisation of the solid crystalline structure of the horny layer, which provides quicker diffusion of the gas from the vessels to the electrode and facilitation of the dissociation of the oxyhemoglobin with increased local supply of oxygen.

Measurement of the basic $TcPO_2$, expressed in mmHg, especially under exertion, is a simple and sensitive non-invasive diagnostic test to be considered as an addition and supplement to other methodos.

The $TcPO_2$ measurement is included in the parameters defining a condition of critical ischemia (value equal to or less than 10 mmHg).

Regional Perfusion Index (RPI) is also used in studying peripheral arterial disease. It is the ratio between each value recorded on the limb and that on the chest because it obviates the effects of the cardiopulmonary function on the local $TcPO_2$ as it is independent from the changes of the systemic distribution of oxygen.

$TcPO_2$ is used in assessing the level of amputation [3] and in predicting healing of the stump [28] since it accurately reflects the degree of ischemia in the segment by way of the quantitative determination of oxygen present on the dermal and epidermal level.

The mean values in mmHg of $TcPO_2$ in normal patients and in various stages of peripheral arterial disease [29] are provided in Table II.

The measurement on the chest is an index of the systemic perfusion and is valid as a reference.

The differences between the various stages following exercise consisting of bending-extending the foot for 3' or until pain appears are particularly significant. The peculiar behaviour of every single stage after exertion with a progressive increase of recovery time is noted gradually while changing from the mild stages to the most severe ones (Table III).[30, 31]

Measurement of the basic $TcPO_2$,[3] is a simple and sensitive non-invasive test particularly useful to distinguish between pain induced during exercise by vascular causes from that caused by other diseases. The behaviour observed in patients with claudication with normal $TcPO_2$ at rest is typical. A sudden decline of the $TcPO_2$ recorded at the leg or at the back of the foot is noted immediately after exercise, and returns slowly to the basic value. On the contrary, $TcPO_2$ values taken before, during and after exercise in patients in which pain in the limbs had no ischemic basis did not show differences with the $TcPO_2$ values measured in healthy patients.

The threshold value of 35 mmHG reflects the actual minimum tissue perfusion required for healing since it al-

TABLE I.—*Systolic velocity peak and spectral analysis.*

Reduction of the lumen diameter	Features of the systolic velocity peak and of the spectral analysis
None	– Not defined normal PSV, usually <120 cm/s – triphasic wave
<50%	– PSV on the stenosis / proximal PSV <2; keeping the reversed flow and slight broadening of the spectrum
50-79%	– PSV on the stenosis / proximal PSV >2; reverse flow absent – post-stenotic turbulence right after the stenosis – broadening of the spectrum – monophasic wave right after the stenosis with reduced PSV – possible normalisation of the waves distally to the stenosis – PSV 120-250 cm/s
80-99%	– PSV on the stenosis/proximal PSV >2 – reverse flow absent – post-stenotic turbulence right after the stenosis – Full broadening of the spectrum – Monophasic wave right after stenosis – PSV >250 cm/s
Occlusion	– No flow in the displayed artery – Monophasic wave, pre-occlusive proximal to the occlusion – Distal monophasic wave with reduced velocity

TABLE II.—*Absolute values (+/- S.D.) of $TcPO_2$ in healthy and arteriopathic patients.*

Sites	Healthy	Stage II	Stage III	Stage IV
Chest	78 ± 4	73 ± 5	69 ± 2	69 ± 3
Thigh	75 ± 2	69 ± 2	58 ± 1	50 ± 2
Leg	76 ± 3	58 ± 3	50 ± 3	40 ± 4
Foot	75 ± 3	50 ± 3	35 ± 2	28 ± 1

TABLE III.—*Percentage changes of the $TcPO_2$ values during tests of limb raising and lowering out of bed in patients with sclerotic and diabetic arteriopathy.*[30]

	Raising the limb		Lowering the limb	
	Sclerotic	Diabetic	Sclerotic	Diabetic
Stage II	-16.4%	-40.3%	+9.7%	+3.7%
Stage III	-56.8%	-65.5%	+48.4%	+55.5%
Stage IV	-64.2%	-79.3%	+74%	+82.3%

lows granulation tissue to be formed and provides good resistance to infections.

The postural test [28] is also useful in assessing the patient with chronic arterial disease. The values are given in Table III. It is noted that the greater $TcPO_2$ fluctuations are seen in patients with diabetic arteriopathy, a condition in which there is maximum baroreceptor damage and therefore the arterial districts behave like vessels without any reactive capacity.

Measurement of the $TcPO_2$ is indicated in selecting patients with critical ischemia that cannot be revascularized, who might benefit from hyperbaric treatment. Increased $TcPO_2$ of the tissues ≥10 torr) assessed after the hyperbaric chamber makes it possible to select patients who might respond to this treatment,[32] unlike those whose increased oxygen tension is <10 torr, who probably will not benefit from it.

Recommendations

In addition to clinical assessment, the first test is CWD measuring the systolic pressure at the ankle and calculating the ABI.

Recommendation 1 Level A

In patients with ankle arteries that cannot be compressed, the assessment should be made by measuring the systolic pressure at the hallux and with calculating the TI.

Recommendation 2 Level B

Calculating the pressure indexes after exercise in the treadmill test and estimating the claudicometry on flat surface (second level examinations) are indicated only in clinical studies and in cases with dubious symptoms.

Recommendation 3 Level C

To perform a correct stress test or a correct claudicometry, appropriate patient instruction is essential. He must repeat the exercise at least 3 times before being able to perform a correct test.

Since the stress test may cause myocardial ischemia or severe arrhythmias, the treadmill test must follow a cardiological assessment and should be carried out with cardiac monitoring in a room equipped with a defibrillator.

Recommendation 4 Level C

The DS with color-flow mapping is the first level examination for the investigation of the arteries of the lower limb. It is particularly indicated for the femoral bifurcation and the superficial and deep femoral arteries

Recommendation 5 Level C

The DS is often complementary to other methods in patients with critical ischemia who need an invasive treatment open surgical or endovascular.

Recommendation 6 Level C

The DS is recommended for monitoring patients who undergo repair by open surgery.

Recommendation 7 Level A

The DS is recommended for monitoring patients who undergo endovascular treatment

Recommendation 8 Level B

AngioMR (second level examination) is indicated only to complete the ultrasound studies in defining the site and nature of the lesions and in assessing the arterial bed upstream and downstream of the lesion, particularly when there are mixed steno-obstructive and aneurysmatic lesions, in anticipation of an open surgical or endovascular approach.

Recommendation 9 Level B

AngioCT (second level examinations) is indicated only to complete the ultrasound studies in defining the site and nature of the lesions, and in assessing the arterial bed upstream and downstream of the lesion, particularly when there are mixed steno-obstructive and aneurysmatic lesions, in anticipation of an open surgical or endovascular approach as substitution of AngioMR when it is contraindicated or unavailable

Recommendation 10 Level B

Angiography (DSA) is indicated only for patients with multilevel arterial disease, or for candidates to surgery when non-invasive studies are considered insufficient (10-15% of cases.

Recommendation 11 Level B

Measuring the $TcPO_2$ is helpful in defining the tissue perfusion in patients with critical ischemia.

Recommendation 12 Level B

$TcPO_2$ is used in assessing the level of amputation and in predicting healing of the injury since it accurately reflects the degree of ischemia at the dermal and epidermal level.

Recommendation 13 Level C

Measuring the $TcPO_2$ is complementary when studying organic and functional peripheral arterial diseases.

Recommendation 14 Level C

REPORTING PROPOSAL FOR CW DOPPLER OF THE LOWER LIMBS

Last name, Name ..... age date ...../...../...../
R brachial artery P..... R ant. tibial artery P..... ABI....
R post. tibial artery P..... ABI....
R brachial artery P..... L ant. tibial artery P..... ABI....
L ant. tibial artery P..... ABI....
Conclusion:.....

REPORTING PROPOSAL FOR TREADMILL TEST

Last name, Name..... age date...../...../...../

	Base	End of exercise		Base	End of exercise	After 5'
R brachial artery P			R ant. tibial a. PA			
			R post. tibial a. PA			
L brachial artery P			L ant. tibial a. PA			
			L post. tibial a. PA			

	1st exercise	2nd exercise	3rd exercise
Relative free walk interval	metres	metres	metres
Absolute free walk interval	metres	metres	metres
Recovery time	seconds	seconds	seconds

Test carried out at the speed of _____ km/h and with an inclination of _____%
Conclusion:.....

REPORTING PROPOSAL FOR ARTERIAL DUPLEX SCANNING OF THE LOWER LIMBS

Last name, Name..... age
date...../..../...../
The examination is carried out with
– Device.....
– Probe type.....
Femoral:
– Common (underneath the inguinal ligament)
  – Profile, wall and diameter description
  – Stenosis of....% (of diameter); length of stenosis... cm
– Deep
  – Profile, wall and diameter description
  – Presence of stenosis of....% (of diameter); length of stenosis... cm
– Superficial
  – Short occlusion / stenosis (cm)
  – Profile, wall description
Popliteal
– Aneurysm (diameter, site, length)
– Stenosis of....% (of diameter); length of stenosis... cm
– Entrapment compression R yes no - L yes no
Tibial (upon completion of diagnostic testing for revascularization)
Description.....
– Diameter and description of the wall of the tibial posterior to the malleolus and pedal

Measurement of the pressure index

R brachial artery	P.....	R ant. tibial artery	P..... ABI....
		R post. tibial artery	P..... ABI....
L brachial artery	P.....	L ant. tibial artery	P..... ABI....
		L ant. tibial artery	P..... ABI....

Femoral-distal bypass check:
– proximal anastomosis
  – morphology, wall profile .....
  – stenosis...% of the diameter,
  – dilatation – aneurysm
– distal anastomosis
  – morphology, wall profile .....
  – stenosis...% of the diameter,
– dilatation – aneurysm
  – description of the morphology of the entire prosthesis.....
– midgraft PSV..... cm/s, EDV.... cm/s;
– Power Doppler assessment .....
– Assessment with US amplifier .....
Conclusion: .....

REPORTING PROPOSAL FOR TRANSCUTANEOUS OXIMETRY

The basal values recorded on standard recording points and their modifications after dynamic tests are recorded for each limb.

Chest ..... mmHg
Thigh R ..... mmHg L ..... mmHg
Leg R ..... mmHg L ..... mmHg
Foot R ..... mmHg L ..... mmHg

If there are trophic lesions:
10 cm from the lesion.....mmHg
5 cm from the lesion.....mmHg
near the lesion.....mmHg

		R ± %	L ± %
Basic value...	- After exertion....	Modification	
Basic value...	- After postural test.....	Modification	

The plots are to be attached

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Guidelines for the assessment of diagnosis of superficial vein thrombosis and diagnosis of deep vein thrombosis

Diagnosis of superficial vein thrombosis

If the purpose of the instrumental examination is to diagnosis a saphenous vein thrombosis, establishing its presence is not enough. It is necessary to verify its cranial extension.

In the most frequent case of a localization at the great saphenous vein, the thrombosis can stop at the pre-ostial valve without affecting the ostial collateral veins, or it can extend up to the edges of the ostial valve with the elevated risk of a femoral vein thrombosis. This morphological information can be obtained only from the echo-color-Doppler. The C.W. Doppler does not have to be used in this study, but neither does the echo-Doppler offer satisfying information compared to the color Doppler.

The thrombus 3 cm away from the saphenous crosse is considered at risk.

The same problem and the same diagnostic procedure are proposed for the superficial vein thrombosis of the calf.

Plethysmography is not suited to this type of verification because it does not reveal any thrombus and becomes positive only in cases of complete thrombosis of the deep venous axis.

Phlebography does not have a well-grounded indication in this clinical doubt. It allows the deep venous axis to be studied, but provides less information about the incomplete thrombosis of the superficial veins.

Diagnosis of deep vein thrombosis

The symptoms of DVT are non-specific and variable, so the clinical diagnosis is unreliable. In spite of this, the clin-

ical-anamnestic data are highly important because they allow a reliable assessment of the clinical probability of DVT. Assessment of the clinical probability for TVP according to Wells' criteria allows patients to be classified in three categories with different probabilities of having a DVT: high risk (75% of probability of having a TVP), intermediate risk (17% probability) and low risk (3% probability).[1-18]

There are 4 types of patients with suspected DVT:

1. symptomatic outpatient;
2. symptomatic hospitalized patient;
3. high risk asymptomatic patient;
4. patient with suspected thrombotic recurrence.

Symptomatic outpatient

Presently there are 4 diagnostic strategies that can be used in diagnosing DVT in the outpatient:

1. complete echo-color-Doppler study of the lower limbs and of the caval iliac district: As it is a diagnostic strategy not as validated as the others, it is recommendable in vascular diagnostic centers that have highly expert operators; the anterior tibial veins can be excluded from the study as they are not subject to isolated thrombosis.

2. serial CUS: according to this strategy, the patient is primarily subjected to CUS to the extent of the proximal veins (femoral veins and popliteal vein). A positive result requires treatment to be introduced, whereas a negative result requires that the examination be repeated 7 days later; treatment is introduced only if the second result is positive. This procedure is effective, but compels a high number of repeated controls: only 2% of patients prove positive with the second examination.[11, 12]

3. determination of pre-test probability: according to this strategy, the patient is primarily classified according to his pre-test probability of DVT (the history and clinical objectivity contribute to establishing the probability of a patient having a DVT, according to standardized criteria);[9] the patient is then subjected to CUS. Low pre-test probability and negative CUS rule out DVT; intermediate pre-test probability and negative CUS (discrepancy) force the CUS to be repeated 7 days later; high pre-test probability and negative CUS (discrepancy) require phlebography or CT venography-MRI venography or a CUS check-up 2-3 days later. In light of the latest studies, the positive CUS always requires treatment. Unlike the former, this approach allows the examination to be repeated only with a limited number of patients with negative CUS (the patients sent by the Emergency Room to the diagnostic outpatient clinics with a low pre-test probability are about 50% of the total).[18] Determining the pre-test probability was afterwards simplified so as to divide the patients into only two groups: patients likely and unlikely to have DVT.[33]

4. using the D-dimer: according to this strategy, the patient is primarily subjected to CUS study with echo-color-Doppler. Patients with negative CUS are subjected to measurement of the D-dimer (degradation product of the fibrin that forms when there is thrombosis). If this is normal, no other control is needed. The negative predictive value of the D-dimer is very high if dosage is carried out no later than 15 days from when the symptoms begin. If the D-dimer is positive, it is necessary to repeat the CUS examination a week later. With this strategy, the number of patients needing to repeat the examination drops to about 30% of the total.[19]

5. In the outpatient practice, we suggest that clinical assessment of pretest probability of DVT, rather than performing the same test in all patients, should guide the diagnostic process for a first lower extremity DVT. This is also what is recommended by the 9th edition of the ACCP guidelines 2012.[34] So the diagnostic strategies should be used in the following way:

I. patients with low pre-test probability: simplified CUS is sufficient in these patients;

II. in patients with intermediate and high clinical pre-test probability, we recommend the complete Echo Color Doppler examination not only of the proximal veins, but also of the distal veins (of the calf) in diagnostic vascular centre having expert staff. Even if not as validated as the others,[23] this latter strategy has in actual fact already come into use in the larger vascular diagnostic centres and a recent trial has also confirmed its accuracy and feasibility.[22] In the diagnostic outpatient clinics where there are no experts operators in studying distal veins, the diagnostic strategies based on CUS + D-dimer are preferable.

As even a recent review [24] showed how patients with suspected DVT with negative D-dimer and a low clinical pre-test probability do not seem to need an ultrasound examination, we recommend to use this diagnostic approach only when it is not possible to carry out an echo-Doppler examination (for example, during the weekend). Even if the recently published guidelines [34] of the American College of Chest Physicians suggest not to perform further diagnostic testing on these patients, we consider useful to do a simplified CUS examination within 48 hours from the clinical-laboratory assessment. In addition to give further diagnostic confirmation, the ultrasound examination also allows the diagnosis e of pathologies that enter into differential diagnosis with the DVT (Baker's cysts, muscular hematomas, etc.).

Symptomatic hospitalized patient

Symptomatic hospitalized patients include subjects on the average at a higher pre-test risk. The approach with D-dimer can not be used because it has been demonstrated that approximately 70% of patients hospitalized have a high D-dimer (the D-dimer can, in fact, also rise simply due to an infection, the presence of a hematoma, etc.).

This is why the only diagnostic strategy validated in these patients is the one that uses the clinical pre-test probability combined with CUS.[20]

High risk asymptomatic patients

The diagnosis with the CUS is less accurate because the thrombi are smaller and often confined to the subpopliteal level. Routine ultrasound testing is not recommended in these patients.

In particular conditions the ECD proves helpful: diagnosis of DVT in asymptomatic patients with high risk who have not been able to follow a correct prevention of thrombosis, or in selected patients with very high risk (previous DVT, two step increase D – dimer).

Patient with suspected thrombotic recurrence

The symptoms of DVT recurrence – mostly edema and pain in the leg – appear in one-third of patients who have suffered from DVT despite appropriate anticoagulant treatment.[26] The clinical diagnosis is inaccurate for distinguishing a new episode of DVT

from post-thrombotic syndrome or other causes of edema or pain in the leg. It is highly important to use a diagnostic method because even in the case of suspected DVT recurrence, it has been proven that two-thirds of patients do not have an acute venous thrombosis.[27]

The results of the most widely used test, CUS, remains altered 1 year after the thrombotic event in 50% of patients.[28]

However, when a comparison with a previous ultrasound examination is available, a new thrombosis can be diagnosed owing to the presence of a new non-compressible venous segment or to the increase of the residual thrombus of 4 or more mm.[29] If the residual thrombus has not increased or if its increase is less than 2 mm compared to the previous examination, the presence of proximal recurrence of DVT is ruled out. However, in these patients proving negative at the first examination as well, when a detailed study of the subpopliteal veins is not possible, it is necessary to repeat the ultrasound study 2 and 7 days later.[30] To reduce repetition of the CUS examinations, also in this case one can resort to D-dimer dosage,[31, 32] even if clinical studies in patients with suspected recurrence of DVT are few compared to patients with suspected first episode of DVT.

Dosage of D-dimer can be useful also in cases in which the ultrasound examination is not diagnostic (increase of the residual thrombus between 2 and 4 mm): a negative D-dimer would rule out the recurrence of DVT in these cases.[32]

Lastly, dosage of D-dimer is useful in the cases – unfortunately not rare – in which a previous CUS examination is lacking.

There are no truly safe criteria for distinguishing recently formed thrombi from old thrombi in the same site, even if they normally differentiate for these characteristics: a recently onset thrombus is characterised by being not very echogenic, occlusive and more voluminous (increases the venous diameter). A thrombus of an old date instead has the features of being hyperecogenic with signs of recanalization inside and with diameter of the vein involved that can even be smaller than the native vein due to partial sclerosis of the vein.

When the result of the previous ultrasound examination is unavailable, it will then be necessary to refer to the thrombus ultrasound characteristics (even if the diagnostic accuracy has never been demonstrated with reliability), together with the D-dimer dosage and, if necessary, phlebography. However, phlebography has many limitation because in addition to being invasive, costly and operator-dependent, it may not be diagnosed due to the persistency of venous segments obliterated by the previous DVT. We therefore recommend to repeat CUS 7 days later if the D-dimer is negative. On the other hand, an anticoagulant treatment is to be started if the D-dimer is positive and the clinical and ultrasound characteristics are in favour of a recent onset DVT. But there is lower – quality evidence available do guide diagnosis of recurrent DVT: in fact in this last case the latest ACCP guidelines [34] suggest venography (grade 2C).

For all these reason is recommended an ultrasound check-up at regular intervals of all the patients who have suffered from an episode of DVT (6 months; annual check-up when the thrombus has completely recanalized or when thrombotic residue has stabilized, which remains unaltered during the last 2 check-ups) and accurately measuring the diameter of the residual thrombus. Only in this way can a precise diagnosis of thrombotic recurrence be made.

Instrumental examinations to diagnosis a DVT

The first diagnostic instrumental procedure is ultrasound with echo-color-Doppler. The entire deep venous axis must be assessed with this examination in search of complete or incomplete thrombosis. It should be kept in mind that the most validated manouvre is compression with the probe on the common femoral and on the popliteal, the so-called CUS.[7-13, 23]

The C.W. Doppler examination, like the plethysmography with venous occlusion, must no longer be used because they prove positive only in the thromboses with occlusion of the venous lumen and venous hypertension in clinostatism. They are studies that assess only the hemodynamics. They are usually negative in deep thromboses without complete occlusion of the venous lumen.

Venography is still considered by some as being the instrumental examination of reference in this pathology. In actual fact, it is being performed less and less, in parallel with the improvement of the Echo Color Doppler equipment. One advantage of phlebography is the panoramic nature of the image. On the other hand, phlebography is still an invasive examination, and also operator-dependent.

Elective indications for phlebography are:

— need to discriminate doubtful or conflicting results (*i.e.*, positive clinical and negative US);

— diagnosis of recurrence;

— search for concealed embolic sources in patients with serious or recurring EP;

— SItuations of particular clinical complexity (malformation pictures, vasal or extrinsic compressions, thrombus monitoring).

An important alternative to venography are CT scan and MRI.

The scintigraphic methodologies are no longer used in studying deep venous thromboses due to the high incidence of false positives, but are still used for diagnosing pulmonary embolism.

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Guidelines for the assessment of the venous circulation of the lower limbs

Investigations

— Continuous wave Doppler (CWD)
— Duplex scanning (DS)
— Color-coded duplex scanning (CDS)
— Intravascular ultrasound (IVUS)
— Standard radiography (Xray)
— Angiography by computed tomography (AngioCT)
— Angiography by magnetic resonance (AngioMR)
— Plethysmography (PG)
— Photo-plethysmography (PPG)
— Venography (VG)
— Radionuclide techniques

Procedure

The purpose of the examination is to verify a reflux or a superficial and/or deep venous thrombosis. The investigations are different in the two cases.

The deep venous circulation should always be assessed.

Verification of a reflux

The methods of first choice are the ultrasound examinations or photo- plethysmography (PPG). The two types of study should be considered complementary and not alternatives.

CDS is presently the most useful and reliable means for studying the venous system of the lower limbs.

Its sensitivity and accuracy are close to 100% in all pathological conditions, both acute and chronic.[1-11]

The morphological data, which with the more recent devices presents a resolution power of 0.3 mm, highlights the finest features of the vascular wall and of the valves.

Adding the hemodynamic data, the examination provides information that is static, but mainly dynamic in short periods of time.[2]

The ultrasound examination allows to detect a reflux, its origin, its entity and to evaluate its oriented direction and which veins are interested.[5, 18, 20, 24]

It allows to investigate the single superficial or deep vein, identifying it based on its anatomic site, and allows the origin and axis of the reflux to be completely demonstrated.[15, 16]

This technique also provide repeatable and reliable quantitative data (*e.g.*, the length of time of the reflux during the Valsalva maneuver performed under standard conditions; the measure of the reflux peak velocity RPV). Venous outflow obstruction is also studied by duplex ultrasound and chronic changes in deep and superficial veins following deep venous thrombosis may be noted.[18]

The computerized quantitative photo-plethysmography (PPG) with the venous pump test, with dorsal extension of the tibio-tarsal joint maneuvers, and air plethysmography assess the overall function of the muscular pump and the valvular competence of the veins.[26]

The advantage of the PPG is that it is able to obtain quantitative data (the venous refilling time) that globally describes any impairment of the venous return secondary to reflux in a matter of seconds.

One PPG limitation should be kept in mind: it may be difficult to differentiate a superficial venous reflux from a deep reflux and/or from a reflux in incompetent perforating veins.[24]

Venography has been replaced by CDS; however it should be reserved for patients with previous phlebothromboses or prior operations, or in patients with dubious CDS findings. In very specific cases VG is still indicated (recurrences after surgery, complex post-thrombotic syndrome, dysplasias).

Varicography is occasionally indicated for studying post-surgery or post-sclerotherapy recurrences, particularly in the popliteal region or incompetent perforating veins, mainly if they are multiple.

Methods

CDS of the venous system of the lower limbs is based on the morphological and hemodynamic findings obtained with the systematic examination of the deep and superficial vessels.[8, 16, 17, 24]

Sectorial or linear probes with frequencies from 7.5 MHZ to 10 MHz are currently used since the veins are relatively superficial.

The investigation of the iliac veins and of the inferior vena cava is performed with probes ranging from 3.5 to 5 MHz, as they are deeper.

The examination must be done comparatively, bilaterally, in static and dynamic conditions, and in transversal and then longitudinal sections with multiple scans. It is useful to first assess the part deemed healthy, operating the different adjustments of the device, particularly the gain and the PRF (Pulse Repetition Frequency). A PRF that is too high can lead to non-visualization of an endoluminal flow since the venous flow is normally at low velocity.

The probe must be gently moved over the skin without exercising the slightest pressure. The patient, in a room at constant temperature and placed in a comfortable position, should be as relaxed as possible so as to prevent pressure on the veins due to muscular contractions.

The investigation of the deep veins is carried out with the patient lying with his/her back raised 45%. This is to allow for optimum venous relaxation.

Side scans should be used for studying the deep veins of the abdomen in order to reduce the difficulties created by intestinal gas, scars, ascitic liquid and obesity.[24]

Mainly the components that should be included in a complete Duplex scanning examination are four: visibility, compressibility, venous flow, including measurement of the duration of reflux, and augmentation.

Asymmetry in flow velocity, lack of respiratory variations in venous flow, and waveform patterns at rest and during flow augmentation in the common femoral veins indicate proximal obstruction.[8]

The examination starts with assessment of the inferior vena cava and iliac veins in the abdomen. Then the common femoral vein is explored by placing the probe so as to get a transversal section of the lumen. Many operators start the examination with longitudinal scanning. There are no substantial differences. Both are methodologically correct.[16, 24]

The sizes of the vessels are assessed to precise any segmentary enlargement, lumen, parietal changes (wall thickening and irregularity, valvular structure) and the valvular function. Compression maneuvers with the probe are carried out in order to assess the compressibility of the vessel. The phases of the basal venous flow are assessed with the pulsed Doppler. Then the patency and competence of the entire venous axis is studied with light pressure of the segments proximal and distal to the probe.

The same procedure follows with the probe in longitudinal projection.

Any blood reflux will be displayed with color reversal (blue-red), or with the reversal of the wave when assessment is performed with the pulsed Doppler. This assessment is usually made every time the valvular competence in a segment and the hemodynamic changes have to be established.

Then the veins of the lower limb are studied. The saphenous-femoral junction is assessed, followed by the superficial femoral-deep femoral bifurcation. Next comes the common femoral with a transversal projection with sequential compression with the probe to assess its patency.

The popliteal vein can be assessed with the patient lying down and the limb bent slightly. A better position would be prone or lying on the side. The popliteal vein is assessed with transversal projections and serial compression. To assess the valvular competence, proximal and distal compression is carried out with analysis of the color and flow while seated or standing.

With the patient seated and leg partially bent, with the foot resting on a support, the patency of the calf vessels are studied, usually moving from top to bottom, with transversal projections and serial compression. This allows the muscles to relax and the veins to fill better, resulting in a better display of them. Assessment of the deep veins is essential and preliminary to the study of the superficial veins.

To investigate the superficial veins the examination is performed with the patient standing, possibly resting on supports with the weight of his/her body shifted alternatively onto the limb not being examined.[1, 2, 8, 16, 24]

After the morphological study of the wall, the compress-

ibility of the veins is assessed with a light external compression with the probe repeated along the course of the vessel.

It is possible to follow the saphenous veins along their entire course up to the junctions. The greater saphenous vein (GSV) is identified at the groin with the probe moved downward and medially. It ends up close to the anteromedial wall of the common femoral vein where it is often possible to assess its main branches (circumflex vein, anterior and posterior collateral veins, external pudenda veins). The lesser saphenous vein (LSV) is seen in the posterolateral position in the popliteal region. It starts in the median site along the posterior side of the leg. Given the frequent anatomical changes of the saphenous-popliteal junction, with the knee slightly bent the probe must be slowly moved upwards and downwards in the popliteal region until the junction is found.

When present, the Giacomini vein (intersaphenous vein) can be assessed. It is the continuation of the LSV in the thigh that often ends in a posteromedial tributary of the GSV or in the superficial femoral vein.

Lastly, not to be forgotten is the study of The Leonardo vein is (posterior arch vein) found behind the GSV. It is rather important owing to its connections with the Cocket perforating veins.

Then the hemodynamic parameter is assessed positioning the sample volume or via the changes of color and the duration of the reflux during the maneuvers: reflux can be elicited in two ways: increased intra-abdominal pressure using a Valsalva maneuver for the common femoral vein or the SFJ, or by manual compression and release of the limb distal to the point of examination.

An orthostatic reflux greater than 1 second is considered pathological.[5, 7, 11, 16, 24] Recently 500 ms as the cutoff value for saphenous, tibial, deep femoral, and perforating vein incompetence, and 1 second for femoral and popliteal vein incompetence have been recommended.[8]

Even if the presence or the absence of reflux and its duration are good parameters for the assessment of venous pathology, recently velocity and reflux peak velocity (PRV) have been considered better indicators for evaluating reflux intensity. The duration of valve reflux time (or valve closure time) cannot be used to quantify severity of reflux and is purely a qualitative measurement. The PRV and the rate of reflux appeared to better reflect the magnitude of venous incompetence,[22] and have demonstrated to be related with the disease's clinical severity,[26] both for saphenous vein alterations and worsening or [19] for proximal deep veins: the presence of a high reflux peak velocity may be considered an independent predictor of advanced symptoms of post thrombotic syndrome.[25]

The reflux is assessable in all the veins. It is possible to follow the vein distally, identifying the direction of the reflux and defining its length. This holds true if all of the vein being examined present valvular incompetence, or only a part of it or a collateral branch.

It is important for making treatment decisions.

The perforating veins, normally invisible, appear as transverse branches to the main saphenous truks when dilated, and are examined with the patient seated or standing. Once identified, a 90° rotation of the probe allows to assess them in longitudinal section.[4]

The diameter of clinically relevant "pathologic" perforators (*e.g.*, beneath healed or open venous ulcer) may predict valve incompetence. The SVS/AVF Guideline Committee definition of "pathologic" perforating veins includes those with outward flow of 500 ms, with a diameter of 3.5 mm, located beneath a healed or open venous ulcer (CEAP class C5-C6).[8]

Where the venous anatomy is variable it is advisable to perform longitudinal scans to precise more accurately the relationships between the veins.

CDS provides additional information on GSV, such as its diameter and direction of flow, the collateral veins and any accessory saphenous veins, display of the ostial and pre-ostial valve and the origin of the reflux from thigh, leg or from pelvic veins.

In assessing the reflux of the LSV CDS allows to define the anatomy of the popliteal muscles, the exact level of junction with the popliteal vein or with the superficial femoral vein, the competence of the Giacomini vein or an origin of reflux from the popliteal perforating vein.[2, 10, 14, 15]

Exploration of the gastrocnemious and soleus veins should also be done.[8, 24]

Normal ultrasound findings

The veins appear as anecogenic channels delimited by a thin flexible border. They are not very mobile and show modifications of their diameter associated with respiratory movements. In the supine position, the venous lumen appears longitudinally flattened and ovaloid in transversal section; it appears dilated in the seated or standing position, with a round image in transverse section.[1, 2, 6]

In normal conditions the veins easily and totally collapse when compressed and immediately return to their normal diameter when compression is released. This vein property is one of the most important criteria for identifying venous thrombosis and occlusion.

Performed with longitudinal and transversal sections and with multiple scans, the examination can show the venous valves and their movement. They appear as hyperecogenic structures, at times with "metallic luminosity", protruding in the vasal lumen with the typical fluttering movement and greater visibility while open.

In proximity to venous junctions or valves, spontaneous or triggered stagnation (extrinsic compression, varicose veins), endoluminal echoes are seen with the "wreaths of smoke" or "snowstorm" image, consequent to low blood velocity and turbulence, which can easily be differentiated from the endoluminal echoes of thrombotic origin due to their mobility and disappearance with the dynamic manoeuvres. Endoluminal positioning of the pulsed Doppler sample volume and the representation in spectral analysis point out a spontaneous flow, phasic with respiration, non-pulsatile, altered by the activation manoeuvres (proximal and distal compression, flexo-extension of the foot, Valsalva). These features are more evident in the large deep veins, as their spontaneous flow is lost in the leg and popliteal muscle.

The forced inspiration and Valsalva manoeuvres can be performed to assess the parietal distension and elasticity and the hemodynamic pattern of the inferior vena cava, iliac and common femoral vein.

By regularly performing compression on the skin with the probe it is possible to recognise with confidence whether the vessel is a vein, but also whether or not there are pathological endoluminal echoes.

Pathological findings

In cases of chronic superficial venous insufficiency, the vessels appear increased in diameter, meandering, with

irregular walls although still compressible with the probe in the standing position. When there are large varicosities it is possible to note increased echogenicity inside the lumen due to agglomerates of erythrocytes. In this case a seesaw movement of the content of the varices due to respiration is seen, with vortex images if a muscular contraction or activation manoeuvre is carried out.[3]

The incompetent valves are more echogenic, thicker, sometimes with irregular deposits on their surfaces, not very mobile and at times with poor or no movement of the flaps.

Due to enlargement of the vein the edges of the valvular cusps remain apart with persistent reflux. Sometimes prolapse of the valves is seen, with jerky movement of the cusps during the Valsalva manoeuvre or during activation manoeuvres.

It is possible to study all of the superficial and deep veins in addition to assessing the state of the perforating veins. This complete study is the base of the so-called venous "mapping" as a stage preliminary to surgery.[4, 20]

With CDS anatomic anomalies are easily diagnosed such as saphenous, popliteal and femoral duplication or anomalous junctions, mainly that of the LSV.

Measurements of the diameter of the veins are also essential, particularly of the saphenous-femoral and saphenous-popliteal junctions in case of varicose veins.

Those data play considerable role allowing the surgeon to reach all of the anatomic information needed for a correct strategy.

Special attention should be paid to the relationships between GSV and LSV and their tributary branches and connections various levels.

For post-surgery recurrences, CDS detects their causes, showing anomalous saphenous collateral veins, neo-cross or cavernomas. "Neo-cross" defines an inguinal recurrences with a long saphenous stump and expansion of the untreated saphenous collateral veins. Occasionally that segment becomes 2-3 cm in diameter and is called "cavernomas".

In assessing recurrence, it is important to point out the size of the "neo-cross" vessels, which are often small prior to surgery, and the position of a residual saphenous vein (subcutaneous or subfascial) and the connections with the other deep and superficial veins. In some cases the "recurrence" is really a "residual" saphenous vein when it has not been removed (for crossectomy, proximal crossectomy and distal ligature, proximal and distal ligature, true double saphenous along its entire course, hemodynamic operations, etc.) and is found in almost its entire course.

Beside the chronic insufficiency of the superficial veins caused by valvular incompetence, cases of obstructed deep venous drainage or deep valvular incompetence can be identified.[17]

Chronic deep veins obstruction and deep valves incompetence

Chronic deep venous obstruction of the lower limbs may generally be described as a blockage of the

outflow of blood from the lower extremity. Poor recanalization following acute deep vein

thrombosis is the most common cause of severe chronic venous blockage. Remaining obstruction is the principal cause of symptoms in approximately one-third of PT limbs. The post-thrombotic syndrome is the most common complication of venous thromboembolism occurring despite optimal anticoagulant therapy in 20-40% of patients within the first 1-2 years after deep venous thrombosis (DVT) of the lower limb.[9, 12, 13]

Recanalization with valves damage of one or more segments of the deep veins generally follows deep venous thrombosis resulting in mixed morphological pictures of prevalent obstruction or recanalization with incompetence of the valves detectable with ultrasound examination. It appears that obstruction of the iliac vein is particularly important and results in more severe symptoms than more distal segmental blockages. Approximately 20% of these iliac veins will completely recanalize on anticoagulation treatment, while the remaining veins recanalize partly and develop different degrees of obstruction and collateral formation. Femoro-popliteal venous obstruction appears to be better compensated by collateral formation than obstruction of the iliac and common femoral veins.[21] Obstruction or partial venous blockage may occur also due to external causes: so called non-thrombotic iliac vein lesions (*i.e.*, May-Thurner syndrome or Cockett's or 'Iliac vein compression' syndrome) may be more important in the expression of non-thrombotic CVD.

For non-thrombotic iliac vein lesions has been suggested the term "permissive lesion", which does not become clinically significant until other components of the venous circulation of the lower limb fail. Correction of a permissive lesion may be surprisingly resolved with venous stenting.[24]

An incompetence of the perforator veins and in turn hypertension in the superficial veins may be associated with chronic benous obstruction.

No accurate invasive or noninvasive test for the evaluation of obstruction is available

Although The diagnosis of outflow obstruction has to be made by morphological investigations.

Positive tests may support further investigation and intervention, but a negative test does not exclude clinically significant venous outflow obstruction.

Even if ultrasound scanning allows to detect a reflux, its origin and its axis in the cranio-distal direction, but is under development for the iliac vein because still lacks the adequate accuracy to detect partial obstruction or occlusion. In fact, it is not known what degree of venous stenosis should be considered hemodynamically "critical" and which is the better investigation available. Thus, currently it is impossible to detect borderline obstructions of potential hemodynamic significance.

Plethysmographic tests (hand-foot pressure differential, hyperaemia-induced dorsal foot venous pressure increase) are global hemodynamic tests and may suggest obstruction to the venous outflow at any anatomic site and level, but significant blockage may exist in the presence of normal result.[22, 26] A positive hemodynamic test may indicate haemodynamic significance, a normal test does not exclude it.

Antegrade transfemoral venography is unable to show haemodynamic impact of visualed lesions even if allows to identify the distribution and nature of the morphological changes of the femoro-ilio-caval outflow (occlusion, stenosis and the presence of collateral circulation). Ascending venography usually visualizes the iliac vein to assess any obstruction of that segment, but not sufficiently.

Like ultrasound scanning, none of these tests have been validated.

IVUS is considered superior to venography in detection of the extent and type of morphological lesion of the vein.[22]

It is probably the most accurate test for this application and should be used to validate findings of other morphological imaging methods. IVUS may better show morpho-

logical intraluminal details (trabeculations, webs) and assess venous. An external compression with the resulting deformity of them venous lumen or post thrombotic remodelling can be directly visualized. By the measurement of the cross-cut areas and diameters of the normal and compressed or diseased veins the degree of stenosis can be precisely calculated using the software built into the IVUS apparatus. IVUS represents a crucial aid to guide stent insertion too.

REPORTING PROPOSAL FOR THE ASSESSMENT OF VENOUS REFLUX OF THE LOWER LIMB BY CONTINUOUS WAVE DOPPLER AND COLOR-CODED DUPLEX SCANNING

CONTINUOUS WAVE DOPPLER

Surname, Name..... age date...../.... /...../
The examination is carried out with
– Device.....
– Probe type.....
Description of the superficial veins (GSV, LSV) and reflux.....
– reflux present yes or no
– origin of the reflux (mainly for the site of the junction of the LSV)
– duration of the reflux during Valsalva, in seconds:
  – reflux < 0.5 sec. .....
  – reflux > 0.5 sec. < 1.0 sec.....
  – reflux < 1.0 sec. .....
– axis of the reflux, defining the distal extension of the valvular incompetence
– reflux in the superficial femoral vein
– valvular incompetence of other veins (Giacomini vein, Leonardo vein.....
– refluxes in incompetent perforator veins
– reflux present yes or no
– duration of the reflux, in seconds
– site of the perforator vein(s)
(for the Cockett perforator veins, it is helpful to specify the distance from the sole of the foot in cm)

COLOR-CODED DUPLEX SCANNING

– Brief description
– Duration of the reflux during Valsalva, in seconds:
  – reflux < 0.5 sec. .....
  – reflux > 0.5 sec. < 1.0 sec. .....
  – reflux < 1.0 sec. .....
– axis of the reflux, defining the distal extension of the valvular incompetence .....
– Assessment of the refluxes in standing position
– Description of the site and extension of the valvular incompetenc to other veins (Giacomini vein, Leonardo vein)
– Diameter of the vein at the ostial and preostial valve
– incompetence of perforator veins
– Site of the perforator vein(s) - (for the Cockett perforator veins, it is helpful to specify the distance from the sole of the foot in cm)
– Duration of the reflux, in seconds

Pre-op mapping of the perforator veins is to be done when explicitly requested for surgical purposes (usually

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Guidelines for the surveillance of patients with stents

Stenting was introduced for treating obstructive lesions of the peripheral or visceral vessels both as a primary procedure and after percutaneous angioplasty. Stents are of different sizes and materials, with a metal structure having a closed mesh (closed cells), open mesh (open cells) or variable geometry (hybrids), cylindrical or conical, bare or covered with synthetic material, final or reabsorbing, premounted on balloon or self-expandable. This feature is of particular concern for intra-procedural assessment of the stenting in those cases in which this assessment when the procedure is performed without angiography.

Some old steel stents cannot be assessed by AngioMR. On the other hand, the conformation and the materials stents can change the velocity of endoluminal flow, the adhesion to the vessel wall and the anatomic pattern of the vessel more or less significantly.

Investigations

— Standard radiography (Xray)
— Color-coded Duplex scanning (CDS) basal and after administration of US amplifier
— Angiography by computed tomography (AngioCT)
— Angiography by magnetic resonance (AngioMR)
— Digital subtraction angiography (DSA)
— Intravascular ultrasound (IVUS)

Advantages and disadvantages are described in the chapter about monitoring patients aortic endoprostheses.

The sole purpose of the X-ray is to assess the position of the stent or its dislocation or its structural alterations and rupture.

CDS alone is practically adequate to assess the stents positioned in all peripheral or visceral areas. Both the angioCT and angioMR are used in those districts where CDS is unable to provide exhaustive answers to the questions required by a "complete" check.

DSA is used only in checking the stenting intraprocedurally or in subsequent endovascular operations.

The parameters of a "complete" surveillance of a stenting procedure are:

— In the site of the stent
  – Complete opening and patency of the stent
  – Complete coverage of the lesion
  – Presence of material inside the stent (the lesion protruding from the mesh of the stent, new atheroma, hyperplasia/restenosis, thrombus)
  – Adhesion of the stent to the wall of the vessel
  – Dissecations/Rupture of the vessel wall
  – Structural modifications of the stent
  – Thrombosis of the vessels
  – Presence of angulations (kinking) or other modifications of the anatonomy of the vessel
  – Coverage/occlusion of bifurcations and/or collateral circulation
  – Migration of the stent
  – Intrastent flow velocity (PSV – EDV)
— Downstream of the stent
  – Micro/macro embolism
— At the site of percutaneous access
  – Thrombosis
  – Dissection
  – AV fistula
  – Pseudoaneurysm
  – Hematoma
  – Lesions due to the mechanical closing systems

The assessment at the puncture site is the same for all types of access vessels and the nearly exclusive method is CDS. External iliac vessels may require multi-layer imaging techniques that display retroperitoneal hematoma.

Parietal thrombus or complete occlusion will appear with minus images or with total absence of flow and the presence of hypoecogenous material in the early post-procedural hours, a material that becomes hyperecogenous during the following days.

The presence of a double lumen divided by a mobile septum is typical dissections.

A turbulent, pulsating endovenous flow with a considerable diastolic wave associated with reduction of arterial flow downstream and the recording of flow-jets near the passage, at times also identifiable in b-mode suggest an AV fistula.

An ovalar shade with sharp edges, hyperecogenous, located near the vessel wall, with thrombus inside of it and a pulsating flow, shows a pseudoaneurysm due to the leakage of blood from the hole in the vessel wall. Disarrangement of the subcutaneous tissue, without sharp edges and without pulsating core will identify a simple hematoma.

There are several differences in the assessment methods depending on the peripheral or visceral vessels involved by stenting.

Carotid stent

The stent considerably alters the Peak Systolic Velocity (PSV) and End-Diastolic Velocity (EDV) inside of it, and therefore the velocimetric criteria normally used for assessing the stenosis cannot be applied in the immediate and long-term followup. The intrastent restenoses make an impact in percentages varying between 4 and 21% within the first 2 years.[1-18] Studies in the literature are sufficiently consistent to confirm increased velocity within the stent and in restenoses (Table I).

Such increase is due to several factors: different compliance between native vessel and stented segment;[18] remodelling of the artery induced by expansion of the stent;[19] considerable parietal rigidity of the stent/arterial wall [20] and a significant reduction of the distensibility coefficient of the stented zone compared to the upstream vessel. All of this entails hemodynamic modifications of carotid and of the Peterson's elastic module of the stented vessel.

TABLE I.—*Surveillance schedule.*

Degree of stenosis	Asymptomatic stenosis	Symptomatic stenosis
<50%	Follow-up at 1 year	Follow-up every 6 months
50-70%	Follow-up at 6 months, then every year	Follow-up every 3 months
>70% or non-echo or ulcerated plaques	Surgical treatment Follow-up at 3-6 months, then every year	Surgery

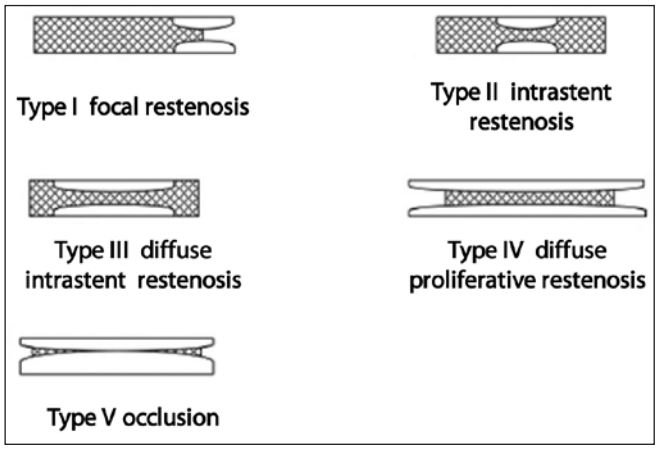

Figure 1.—Different types of intrastent restenosis in accordance with Lal.[11]

In turn those factors modify the shear stress of the wall with a consequent endothelial dysfunction that causes hyperplasia and restenosis.[21-23]

When there are contralateral carotid occlusions [24] or stenosis ≥50% [25] there is an additional increase of the blood volume in the stented carotid with consequent overestimation of the restenosis.

Studies on animal models seem to indicate that the increased velocity varies considerably not only with the structure of the stent, but also with the dimensions of the cells (open or closed), with the shape (cylindrical or conical), and with the geometry and material.[26] It also seems that oversizing of the stent produces minor effects on the hemodynamic parameters (Piamsomboon).

Probably the velocity profiles change also according to the time elapsed from when the stenting being higher on the days right after the procedure.[11]

In the study Timaran carried out in 2007 it is highlighted that there are velocity differences in intrastent restenoses between men and women, but limited to the PVS: for restenoses falling between 50 and 69%, the PVS is 224 cm/s in women and 194 cm/sec in men; for stenosis >70%, the PVS is 422 cm/s in women and 400 cm/s in men.

Based on the extension of the restenosis (more or less 10 mm), the classification in five types of intrastent restenosis can be adopted (Figure 1).

In a carotid stenting surveillance program a study of the cognitive performance of the patients, should be carried out with appropriate neuropsychological tests [27, 28] and a diffusion-perfusion MR to detect the number, extension and site of the new brain lesions, homo-lateral and contralateral, caused micro-embolisms.[29, 30]

Timing of postoperative assessments

Restenoses are the most frequent complication following carotid endarterectomy (CE) and carotid artery stenting (CAS) and are mostly concentrated in the first 12-18 months (restenosis caused by myointimal hyperplasia due to a particular hyper-reactivity of the patient, technical errors, residual atheromas, extension and increase of the plaque in common carotid). Restenoses due to the recurrence of atherosclerosis appear a few years later, mainly in patients with non corrected risk factors; the incidence of restenosis between 1 and 2 years varies from 9% to 33%.[31]

Restenosis is due to many risk factors, to the female sex and to the type of treatment. Some subgroups are at an annual risk of severe restenosis greater than 6% (patients with hyperlipidemia, diabetes mellitus, current smokers, coronoropathies, the female sex, young age), in which the cost of follow-up monitoring would correspond to higher effectiveness requirements.[32] As far as surgical treatment is concerned, application of a patch significantly reduces the incidence of restenosis and consequently the need for assessments performed at follow-up.[33]

Based on the literature and on the experience of the Working Group of this Society for the guidelines, the following surveillance schedule is proposed in Table II.

Post-stenting assessment

The post-stenting assessment should be made after 3-6-9-12-18 months, and then every year. If the contralateral carotid is stenotic, it is necessary to carry out the assessments according to the protocol for natural stenoses.

Peripheral stents

The intravascular ultrasound (IVUS) provides a transversal tomographic image of the vessel and of the stent so that an assessment of the diameters and of the expansion of the stent (complete or partial) can be accurate. A stent causes the external elastic lamina to be compressed and no longer visible,[34, 35] however intrastent restenosis would is mainly caused by myontimal hyperplasia, partial endoluminal thrombosis and arterial remodelling, and much less by the compression on the wall by the stent.

On the iliac arteries intrastent restenosis varies widely between 6.7 and 63% of the vasal lumen, average 22%, and myointimal hyperplasia appears along the entire length of the stent, with preferential site at the centre of the stent in only 52% of cases. The myointimal thickness is also on the average 1.19 ± 0.61 mm (0.4-2.5 mm).[36]

The stent expansion is complete in 90% of the cases, *i.e.*, when the ratio between minimum lumen and maximum intrastent lumen is 0.8 along the entire stent. An elliptical conformation of the stent is usually caused by parietal calcifications in all those cases where the radial force of the stent is insufficient to overcome the wall resistance due to calcium.

The intra and inter-observer variations of this method are not significant and where estimated at 4.9 and 5.4%, respectively.

CDS of the subclavian stents has a 57% sensitivity and a 100% specificity, as it is strongly limited by obesity, emphysema and tachypnea or by diffuse calcifications of the vessel (37). CDS is also limited by the difficulty to see the entire subclavian, mainly in its first segment, where obstructive lesions are frequent.

AngioMR is impossible in patients with pacemakers and in claustrophobic patients, and is highly conditioned by the type of stent used (material and conformation). [The gold standard in these cases is still the CT angiography].

Restenoses in the superficial femoral artery at one year are still rather high at about 40-60%.[38-41] Moreover the fractures and structural alterations of the stents are at about 50% of the cases at one year, with consequent restenoses or pseudoaneurysms caused by the rupture of the wall of the vessel.[42] In this area standard X-ray is definitely needed.

The PSV value and the intrastent PSV (at the site of maximum stenosis) to PSV outside the stent ratio are also

TABLE II.—*Parameters of Doppler ultrasound velocity in intrastent restenosis, according to various authors.*

Author	Degree of stenosis	PSV cm/s	EDV cm/s	ACI/ACC
AbuRahma (5)	≥30%	>154	>42	>1.5
AbuRahma	≥50%	>224	>88	>3.4
AbuRahma	≥80%	>325	>119	>4.5
Armstrong (6)	<50%	<150		<2
Armstrong	50-75%	>150	<125	> 2
Armstrong	>75%	>300	>125	>4
Chahwan (7)	Normal	30-118	18-60	
Chahwan	20-50%	137-195		
Chi (8)	50-70%	>240		>2.45
Chi	>70%	>450		>4.3
Cumbie (9)	≥50%	≥195	≥75	≥2.2
Cumbie	≥80%	≥205		≥2.6
Kwon (10)	≥50%	200		>2.5
Lal (11)	<20%	<150		<2.15
Lal	20-49%	150-219		
Lal	50-79%	220-339		≥2.7
Lal	80-99%	≥340		≥4.15
Levy (12)	<60%	<200		
Levy	≥70%	≥250		≥2.8
Peterson (13)	Normal	<170	<120	
Peterson	≥70%	≥170	≥120	
Robbin (14)	Stenosis	>125		>3
Setacci (15)	<30%	≤104		
Setacci	30-50%	105-174		
Setacci	50-70%	175-299		
Setacci	>70%	≥300	≥140	≥3.8
Stanziale (16)	50-70%	≥225		≥2.5
Stanziale	>70%	≥350		≥4.75
Zhou (17)	≥70%	≥300	≥90	≥4.0

measured during CDS. PSV > at 140 cm/sec and PSV ratio ≥ 2.4 suggest a restenosis of at least 50%.[43]

The US investigation of the peripheral stent should always be completed by calculating the ABI also for comparison with the preprocedural value or one of the previous assessments.

Renal stents

Restenoses for stents in the renal arteries vary between 6.4 [44] and 30% of the cases.[45]

DSA is still today the gold standard, although it presents considerable limits: complications at the site of percutaneous catheter introduction (hematoma, infection, pseudoaneurysm); contrast-induced nephropathy; renal embolism; two-dimensional view that cannot assess precisely any restenosis or its degree; overestimation of the stenosis in cases post-stenotic dilatation.[46] The angiographic cut-off for intrastent restenosis is 50%.[47]

AngioMR has increasingly become reliable with its 1.5 Tesla equipment, the 3D volumetric acquisition technique with gadolinium and measurement of the pressure gradient, mainly for primary lesions. Unfortunately checking steel stents is practically impossible due to the lack of the intrastent signal.[48-51]

AngioCT certainly offers clear reconstructed 3D images, but presents known problems: ionizing radiation, reaction to the contrast medium, nephrotoxicity and high cost.[52, 53]

CDS is the only reliable method for the hemodynamic assessment of a restenosis, with a significant restenosis cut-off at 60%. The most reliable parameter is the intrarenal resistance index (RI) whose value is ≥0.05, and for unilateral stenosis it corresponds to a diametric angiographic stenosis of at least 70%.[54-56] In the case of bilateral restenosis, the acceleration time (ac) is to be assessed. For angiographic restenosis ≥ 70% it is >at 0.07 s.[57] The RI and ac parameters are shown in Figure 2.

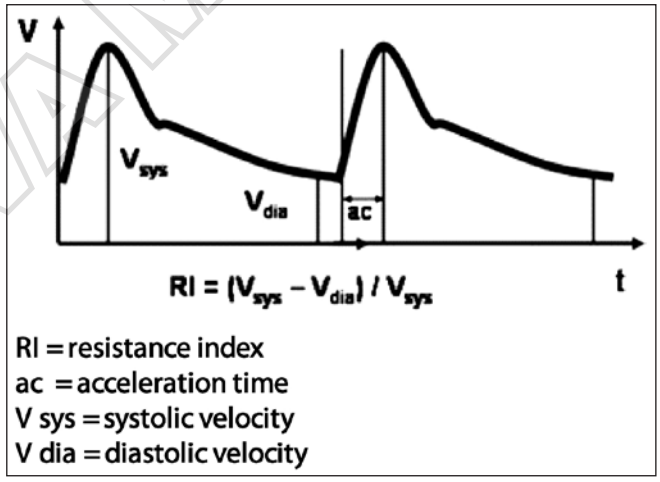

Figure 2.—The measure of resistance index (RI) and acceleration time (ac) to evaluate intrastent restenosis of renal artery.

PSV >200 cm/s, or the renal/aortic flow velocity >3.5, correspond to an angiographic restenosis falling between 50% and 60%, but not as specific.[54]

When the native renal artery has a diameter less than or

equal to 5 mm, there is the risk of hemodynamic restenosis even when it is just higher than 20%.[58] Indeed, the incidence of intrastent renal restenosis progressively increases as the diameter of the renal native artery reduces (14% for renal arteries ≥at 7 mm; 20% for 6 mm arteries; 42% for 5 mm renal arteries and 57% for renal arteries of between 3 and 4 mm. On the other hand, this ratio is not evident in simple post-angioplasty restenoses.

Color-coded duplex scanning for surveillance of patients with stents

Instruments: color-coded duplex scanner with 2-3.5 MHz transducer, with sectorial phased array probes for deep arteries; 7-10 MHz transducer with linear probes for the superficial arteries.

Procedure

Same as for native arteries. It should be emphasised that the presence of steel stents, or covered stents, can make assessment of blood velocity inside the stent more complex.

REPORTING PROPOSAL FOR DUPLEX SCANNING IN PATIENTS WITH STENTS

Last name: ..... First name: ..... age: .....
date:.....
Examination performed with:
– Device -
– Probe type -
Features of the stent (to be repeated for each stent):
– site:
– dimensions
  – length:
  – Diameters: prox interm. dist.
– structural features:
  – complete expansion of the stent (minimum lumen/maximum lumen ratio > 0.8)
    no yes

Ratios with the stented vessel:
– coverage of the lesion: complete partial
– adhesion to the wall: complete partial
– dissecations/rupture of the vessel wall
– anatonomy of the stented vessel
– coverage of the collateral vessels:
  no yes presence of coils

Material inside the stent:
– protrusion of the lesion through the mesh of the stent
– hyperplasia
– new atheroma
– thrombus
– restenosis: site
  focal diffuse

PSV
EDV
PSV ratio

Only for renal stents:
RI (resistance index) ac (acceleration time)
Compared to the previous assessment, the stent is migrated:
no yes
Contralateral arteries:

At the site of percutaneous access
– Thrombosis
– Dissection
– AV fistula
– Pseudoaneurysm
– Hematoma
– Lesions due to the mechanical closing systems

Only for peripheral stents:
– Ankle-brachial index right left
– Brachial pressure
– Posterior tibial pressure
– Anterior tibial pressure
– Ultrasound amplifier
– Power Doppler

Any difficulties run into while performing the examination:

Indication for other complementary examinations:
– Standard Xray
– angioCT
– angioMR
– DWI
– Cognitive tests (only for carotid stents)

Conclusion:
Next check-up:

Recommendations

PSV and EDV and the PSV ratio are modified by a stent and their values cannot be compared to those of the non-stented vessels

Recommendation 1 Level A

CDS is first choice for monitoring a stent

Recommendation 2 Level B

AngioCT and AngioMR are alternative techniques when CDS is inadequate or incomplete, or a complication with indication to treatment is suspected.

Recommendation 3 Level B

DSA should be restricted to those cases where a new endovascular procedure is indicated due complications at the same site.

Recommendation 4 Level B

Timing of the check-up of a patient with a stent must envisage a post-op check-up within 30 days from the procedure, one every 3 months afterwards for the first year, and one every 12 months for the following

Recommendation 5 Level C

Occlusion of the arterial vessels involved in positioning the stent, whether necessary or accidental, always entails close instrumental check-ups pertaining to the circulatory district involved.

Recommendation 6 Level C

CDS can be used as the sole intra-operative monitoring during peripheral stenting.

Recommendation 7 Level C

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Guidelines for the surveillance of patients with prosthesis or aortic-iliac-femoral endograft

Arterial repair for aortic-iliac-femoral diseases can be done by:
— aorto-aortic implant
— aorto-bisiliac implant or bypass
— aortic bifemoral bypass
— aortic endoprosthesis
— aortic-bisiliac endoprosthesis
— aorto-uniliac endoprosthesis, with possible association with femoro-femoral crossover bypass.

Those procedures may include additional bypasses or open or covered stents for the simultaneous repair of the "visceral" branches (renal, celiac trunk, superior mesenteric) and internal iliac artery.

Timing of checks varies according to the type of treatment and its possible complications.

Investigations

— Continuous wave Doppler (CWD)
— Color-coded duplex scanning (CDS)
— Angiography by computed tomography (AngioCT)
— Angiography by magnetic resonance (AngioMR)
— Digital subtraction angiography (DSA)
— Standard radiography (Xray)
— Gastroduodenoscopy (GDS)
— Tc99m labelled leucocytes scintigraphy (SG)

CDS, basal and after administratiom of US amplifier (echo contrast). High-definition 2-5 MHz sectorial ultrasound probes should be used, resorting to second harmonic, second generation US amplifier by bolus injection or by slow infusion in an antecubital vein of the arm, and preparing the patient with an adequate diet and drugs to reduce the bowel air. Using the tissue harmonic would seem to be essential in order to increase sensitivity of the echo contrast, provide longer scanning periods, and reduce the of false positives secondary to the blooming artefacts.[1] Continuous US amplifier infusion provides a broader "window" of study (up to 28 minutes) and allows a more attentive search for small and low-flow endoleaks (EL). It also makes it easier scanning patients with excessive endoabdominal gas and with a high corporeal mass.[2] The only contraindication for an US amplifier is an allergy to galactose, though very rare. CDS is certainly the patient's favorite since it is entirely atraumatic and devoid of complications, even with an US amplifier. CDS cannot be carried out in 5% of cases, mainly in obese patients or in those with extremely tympanitic abdomens.[1, 3, 4] Comparisons between CDS and multi-layer AngioCT confirmed a good correspondence (near 100%) for the data of the two methods, mainly as far as the measurement of the diameters and detection of endoleaks are concerned. CDS also provides hemodynamic data and informations on the movement of the arteries and of the sac, absolutely non-obtainable with an Xray. CDS is particularly valuable in identifying the direction of flow of an endoleak, which is not as easily recognized by AngioCT. A further advantage of CDS is its high sensitivity in detecting the perigraft jets, or tiny areas of color flow, near the graft (type III endoleaks) that may not be detected by angioCT. CDS, however, is limited by the long time it takes to complete the investigation and by its dependence on the skill of the examiner.

Measurement of the ankle-brachial index (ABI) with CWD, 8-10 MHz probe, at the pedal and/or posterior tibial arteries. Extensive calcific lesions may distort the pressure measurements at the ankle. It provides only information about reperfusion of the distal arterial bed.

Multi-layer AngioCT is the "reference standard" in for patients with an endoprosthesis as it provides images, even 3D, of all the endoabdominal structures mainly if it is triphasic, in the early (arterial phase) and in the late phase (venous phase).[5-9] Rapid acquisition of data and high reproducibility and accuracy are all remarkable advantages of this method. The layers to be examined and rebuilt three-dimensionally must however be thin (1-3 mm). AngioCT is expensive and employs ionizing radiation with some risk due to high dosage, particularly if repeated and close over time. Table I was drawn by the U.S. Food and Drug Administration to assess the consistency of the radiant phenom-

TABLE I.—*Diagnostic procedures.*

Diagnostic procedures	Actual dose in milliSieverts (mSv)	Equivalent number of chest X-rays	Time necessary for an equivalent dose coming from "natural" rays (3mSv/year)
Chest RX	0.02	1	2.4 days
Cranium RX	0.07	4	8.5 days
Spine RX	1.3	65	158 days
Urography	2.5	125	304 days
Esophago–gastro– duodenography	3.0	150	1.0 year
Barium enema	7.0	350	2.3 years
Cranium CT	2.0	100	243 days
Abdomen CT	10.0	500	3.3 years

enon.[10] Repeated exposure to ionizing radiation is of lesser concern in the typically elderly population of patients with aortic aneurysms than in younger individuals. It always needs a contrast medium (120-200 mL), which can nephrotoxic, so that its use in patients with renal insufficiency is dangerous, and it can trigger serious allergic reaction.

AngioMR *is* also performed with basal scans and following administration of paramagnetic contrast (gadolinium). Serious nephrotoxicity associated with this type of contrast have been reported in recent years.[11] Its imaging is fairly similar to that of angioCT, provided machines of at least 1.5 Tesla with appropriate software are used. Sensitivity and specificity were even higher than angioCT as far as type II endoleaks are concerned. Actually angioMR was more sensitive than angioCT for detecting type II endoleaks, with a sensitivity of 100% and specificity of 82%. Blood-pool and cine magnetic resonance techniques may make angioMR even more sensitive. Moreover, cineMR may be used to quantify aneurismal wall motion, which has been associated with persistent perfusion of the aneurysm. The magnitude of change in the diameter of the wall correlates with the type of endoleak, with the antegrade flow of a type I leak producing a greater pulsatile change in diameter than the retrograde flow of a type II leak or no endoleak at all. In quantifying pulsatile change in aneurysm size between systole and diastole, cineMR potentially provides a means to measure the force being exerted on the aneurismal wall and a possible corollary gauge of the risk of continued expansion and ultimate rupture of an aneurysm. AngioMR has advantages over angioCT related to safety. AngioMR, which uses less toxic gadolinium compounds, is particularly appealing to patients who cannot tolerate the contrast medium used for angioCT because of renal dysfunction or allergy. AngioMR also does not expose stent-graft patients (who must undergo periodic imaging for the rest of their lives) to repeated doses of radiation. Many stent-graft systems are not currently compatible with MR due to their ferromagnetic, stainless-steel composition. Not only must the graft be compatible for an optimal examination, but the patient should also be suitable — without a pacemaker, intracranial aneurysm clip, ferromagnetic implant, claustrophobia, or inability to lie flat and still. Further potential disadvantages of angioMR related to its technical limitations include a small field of view, poor visualization of vascular calcifications, and difficulty visualizing and quantifying the size of the outer margins of an aneurysm on sequences that are typically fat suppressed).

DSA is now used only during endovascular procedures carried out to correct complications (infusion of fibrinolytics, mechanical recanalization, positioning of free or covered stents, percutaneous angioplasties). Nephrotoxicity and possible onset of allergic reactions are to be stressed.

Standard radiography (Xray) may be used in patients with stent-graft with a metal structure, but only for checking that the materials are intact as they may incur "fatigue" and rupture and for checking their position over time. Only the presence of abundant calcifications in the wall of the sac will make it visible and will allow the inter-parietal diameters to be measured.[12]

If an infection involving the prosthesis and/or endothoracic, retroperitoneal or endoabdominal structures are suspected, Tc99m labelled leukocytes scintigraphy (SG) can be used. The positive result of this study may be distorted by infections arising shortly after the implant. What is to be noted is that the semiotics of the AngioCT ability for detecting infections is increasingly, mainly if there are retroperitoneal collections, if the bowel is involved or if there are germs that develop gas.

The possible involvement of the bowel may require a gastroduodenoscopy (GDS) down to the Treiz to investigate aorto-duodenal fistulas particulatly with the third portion of the duodenum.

Surveillance of patients submitted to open surgery

The major, early and late complications in patients a Dacron or PTFE graft in the aortic-iliac area are listed below with percentages gathered from the international literature:

— Thrombosis (2-5%)
— Dilatation of the graft (2.5-38%)
— Rupture (fewer than 100 cases in all international literature)
— Anastomotic aneurysm (0.25-12.5%)
— Infection (0.5-6%)
— Aortic-enteric fistula (0.4-4%)

The percentages provided above are different for biological prostheses, which are rarely used in this area and only in cases of re-operations due to infection.

Low impact in percentage is that of:

— hemorrhage
— embolism/microembolism
— lymphorrhoea
— cancerogenicity (angiosarcomas)

Most of those complications arise within the first two years from the operation and 50% of them within the first 12 months though they may appear even 10 years after the implant. Their incidence is between 1.5% and 7%. In re-

viewing the experience of the Mayo Clinic, Haller wrote in J Vasc Surg of 1997, "This 36-year population-based study confirms that the vast majority of patients who undergo standard surgical repair of an abdominal aortic aneurysm remain free of any significant graft-related complication during their remaining lifetime".[13]

Those considerations ensure that the timing of the surveillance of patients with a graft in the aortic-iliac area can be 3, 6, 9, 12 and 24 months after the implant. Subsequent investigations years may be restricted to any "clinical" onset of complications.

CDS is first choice, without the use of echo contrast, and must include identification of the sites of anastomosis and their morphological and hemodynamic assessment, measurement of the diameters of the graft (main body and branches), of the native aorta and the iliac arteries beyond the anastomosis, assessment of good function of any other bypass graft for the visceral branches and their patency, identification of any periprosthesis collections or collections inside the aneurysmal sac (sutured around the prosthesis). The investigation should be completed with a measurement of the ABI: if it is decreased more than 1.5, compared to the previous tests, suspicion should arise of circulatory impairment of the limb due to micro/macro-embolism or to progression of the atherosclerosis. Only the detection of complications, which might require reoperation - open or endovascular – necessarily requests futher studies. AngioCT in generally indicated.

TABLE II.—*Intraoperative complications.*

Complications associated with the device
– Impossible progress
– No or incorrect positioning
– Modifications following positioning
– Torsion
– Stenosis
– Occlusion
– Migration
Arterial complications
– Perforation
– Dissection
– Rupture
– Stenosis
– Obstruction (thrombosis)
– Distal embolism

TABLE III.—*Postoperative complications.*

Complications associated with the device
– Migration
– Stenosis
– Thrombosis
– Bleeding
Arterial complications of the limb
– Bleeding
– Hematoma
– Pseudoaneurysm
– Thrombosis
– Embolism
– Claudicatio intermittens
– Neuralgia
– Infection

Surveillance of patients submitted to endograft implantation

Successful repair of an aneurysm of the abdominal aorta (EVAR)The positioning of an endoprosthesis for aortic-iliac aneurysm, followed with success, requires exclusion of the aneurysmal sac from any blood supply with the resulting reduction of endoluminal pressure and loss of pulsatility, rearrangement of the endoluminal thrombus and reduction of the diameters. Technologies for studying the intrasac pressure with implantable sensors are currently being tested, but as of today they are not very reliable while they are very expensive instead.[14]

Lack of reduction of the aneurysm diameters and residual pulsation suggest that the sac is being supplied with blood, a phenomenon that is defined as "endoleak".

Endoleaks are divided into four types according to the White classification:[15]

— TYPE I (A): no or incomplete expansion of the anchorage stents, proximally on the level of the aortic neck and/or distally on the level of the iliacs.

— TYPE II (B): sac supplied by the vessels emerging from it, with reversed flow (lumbar, inferior mesenteric, accessory renal).

— TYPE III (C): loss of cohesion of the structural components of the endoprosthesis (extension cuffs, branches for the iliacs.

— TYPE IV (D): permeabilization or rupture of the wall of the endoprosthesis.

White's classification also includes a TYPE V (E), which is named "endotension". It is distinguished by persistence of pressure inside the aneurysm, which prevents its reduction of diameters or even entails its growth, without evident signs of leaks. With more refined techniques all of endoleaks will probably be detected, therefore "pure endotension" is bound to disappear. Monitoring patients with an endograft should be done immediately after implantation in the operating room, during the post-op course (within 30 days) and for the entire follow-up course.

The incidence of endoleaks varies from 10% to 45%.[16] Monitoring is required for the remaining lifetime for its early detection and necessary treatment.[17] Even in the most recent studies the endoleak average runs around 20%.[18]

Surveillance of patients after EVAR is focused on early detection directly of complications.

Tables II and III show those complications based on the time of onset and on the district involved.[19]

All of the complications, including endoleaks arising in the intraoperative phase, can be detected by DSA during or at the end of the procedure. Leaks may also be "late" during the follow-up and appear months or years after EVAR.

Complete assessment should verify:

— patency of the endograft;

— position and structure of the endograft;

— diameters/volume and pulsation of the aneurysm;

— endoleaks;

— patency and integrity of the vessels upstream and downstream;

— perfusion of the visceral arteries;

— evolution of the untreated lesions;

— infections;

— presence of an aortic-enteric fistula.

The patency of the endoprosthesis, of the proximal aorta, of the distal and visceral vessels can equally be assessed with ECD and CTA. Use of a CWD is to be restricted only upon completion of the clinical examination for measuring segmentary pressures of the limbs that might be involved in an embolic and/or thrombotic peripheral artery episode.

TABLE IV.—*Reliability of CDS for detecting endoleaks.*

Author	Year	Sensitivity	Specificity	Pred - value	Pred + value
Sato (28)	1998	97	74	98	66
Thompson (29)	1998	100	100		
Wolf (30)	2000	81	95	90	94
Zannetti (31)	2000	91.7	98.4	99.4	78.6
d'Audiffret (32)	2001	96	94		
Pages (33)	2001	48.3	93.8		
Mc Lafferty (34)	2002	100	99	100	88
Mc Williams (1)	2002	25	82		
Golzarian (35)	2002	77	90		
Giannoni (36)	2003	62.5	93.4		
Raman (37)	2003	42.9	96.0		
Arko (38)	2004	96	94	98	90

The % of sensitivity and specificity of CDS is obtained by the relation with angioCT imaging.

Xray can only to assess the change of position and structural damage of the endograft with a structure at least partially metallic.[20]

Both CDS and AngioCT correctly show the relationships of the endograft with the near structures, any dislocation and/or torsion/angulation. The fractures of the stents are not clearly depicted by CDS.[21]

Measurement of the diameters of the aneurysmal sac in EVAR patients is still rather unsatisfactory either with CDS and AngioCT due also to intra and inter-observer variability.[22] Actually the measurements are easier with the tomographic scans, are more precise and can be standardized. The scanning plane however is not always perfectly perpendicular to the prosthesis or to the aneurysmal sac, something that instead can easily be obtained with the CDS. Hence the measurements of the diameters with AngioCT may be uncorrect and a correction of imaging angulation must be performed. Only in this way the measures of the changes in diameter become reliable and significant.[22] The diameters of the aneurysm decrease from 6 to 14 mm (8 mm average) within the first 18 months (24). Some authors doubt that the measurement of the diameters of the sac allow to exclude endo- leaks and suggest to resort to volumetric measurement.[25-27]

Reperfusion of an aneurym after EVAR may prevent shrinking of the sac and its pulsation to disappear. AngioCT images detect both blood supplies to the aneurysm by the endoleaks and the lack of decrease or increase of the diameters. Reliability of CDS as compared to AngioCT in detecting endoleaks is reported in Table IV.

In recent years the reliability of CDS reached 100%. This was achieved with techological improvements, such as the study of the second harmonic and of the "pulse inversion harmonic" (39) and with the use of echo contrast.[40] AngioCT is still a "static" examination that not always is able to identify the origin and severity of an endoleak.[41] With CDS even in basal conditions, but possibly also after injecting US amplifiers,[1] it is possible not only to learn the origin of an endoleak, but also to identify its velocity and direction inside the sac. Such study is particularly adequate in checking type II endoleaks that, in most cases, do not require additional treatment when they proceed to spontaneous resolution, but that must anyway be checked repeatedly until they disappear. [The assessment of the spectral Doppler analysis allows us to recognize the type II endoleaks that spontaneously may recede (direction of flow – Parent,[42] Peak Sistolic velocity – Arko).[38]

CDS with M-mode function is an effective means for assessing the pulsation of the sac, well beyond the simple measurement of its diameters.[24] The pre-op pulsatile wall motion varies from 0.8 to 1.3 mm (1.0 average). Following adequate exclusion, it drops to 16-37% of the basal value (25% average), as this reduction is lower (50% of the basal value) when there is an endoleak. DSA provides intraoperative confirmation of an endoleak and shows the ways to correct it.

Graft infection is often a difficult diagnostic problem; sometimes confirmation comes only from surgery. Periprosthetic collections shown by post-op investigations might be associated with hematic or sero-hematic collections that do not necessarily indicate an infective process.[43] Their first appearance shortly after the procedure should always arise suspicion of an infection.

CDS is unable to distinguish between blood collections and those of other materials unless a disruption of a vessel or of an anastomosis is detected.

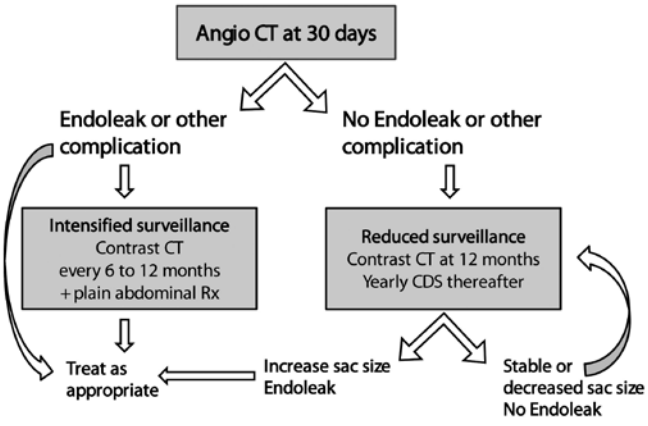
AngioCT may differentiate absorbing contrast medium from the long-standing thrombotic formations, liquid collections or collections containing air.[44]

Scintigraphy leucocytes labelled wtih Tc99m or 111In would ideally represent the most reliable marker of an infective cellulomediate collection: their deposit in the site of anastomosis or along the prosthesis would indicate infection.[45] Unfortunately negative or uncertain findings of this exam cannot exclude infection, whereas scintigraphy made too early after open surgical or endovascular procedure may be falsely positive.

TABLE V.—*Recommendations for surveillance after endovascular aneurysm repair and tailored to underlying renal function (University of South Florida).*[50]

Renal function	Testing modalities
Creatinine <1.5 mg/dL	3-phase contrast CT (6 mo) or CT alternated with implanted pressure measurement (6mo) or CT alternated with CDS
Creatinine >1.5 - <2 mg/dL	3-fase contrast CT 2nd or 3rd interval with non contrast CT, CDS, or pressure measurement (6mo)
Creatinine >2 mg/dL	CDS or pressure measurement (6 mo) plus noncontrast CT (2ys)

TABLE VI.



Graft infection is a multimedial diagnosis made on the basis of clinical judgement, laboratory evidence, imaging and in some instances an echo- or CT-guided biopsy.[46]

Gastro-duodenoscopy can identify a gap in the duodenum wall (usually in its third portion), sometimes associated with bleeding, in an aortic-enteric fistula. This is owing to decubitus of the proximal stent of the endograft, first at the aneurysm wall and at the intestinal wall afterwards.[47]

CDS is not very helpful unless there are dehiscences of the aortic anastomosis, whereas angioCT is fully able to define the fistula and the perigraft collection.[48]

The evolution of the untreated obstructive lesions can be monitored with CDS and with angioCT in case of multilevel lesions. Measuring ABI will suffice for evaluating the stability of pre-existing obstructive lesions.[49]

In patient with EVAR, after the post-op period, the timing of the subsequent check-up should be concentrated in the first 24 months: every three months during the first 12 months and then every six months in the absence complications. The highest number of adverse events seems to occur during this time span. In the following years the incidence of the complications drops significantly and the assessments based on the cost to benefit ratio recommend checking the patient every year.

As a principle to proceed with an AngioCT should be decided also on the base of the renal function. The guidelines of the University of South Florida condition the use of AngioCT to the blood levels of creatinin [50] (Table V).

Another study protocol was provided by the Zenith multicenter trial (Cook Inc, Bloomington, IN, USA) that was held in the United States in 2008 [51] (Table VI).

In order to reduce health costs it was suggested above a priority check-up with CDS, associated with an X-ray of the abdomen. The target is to save more than $ 16000 per patient for a three-year follow-up, as shown in Figure 1.[40]

The following scheme of checks for patients with EVAR is recommended:

— angiography is to be used for intraprocedural DSA: it is used during the first treatment and in subsequent operations;

— multilayer AngioCT should be done in the immediate post-op phase, mainly for a comparison with CDS, and should be repeated only if CDS is inadequate or shows complications needing treatment.

— AngioMR can replace AngioCT if there are no contraindications;

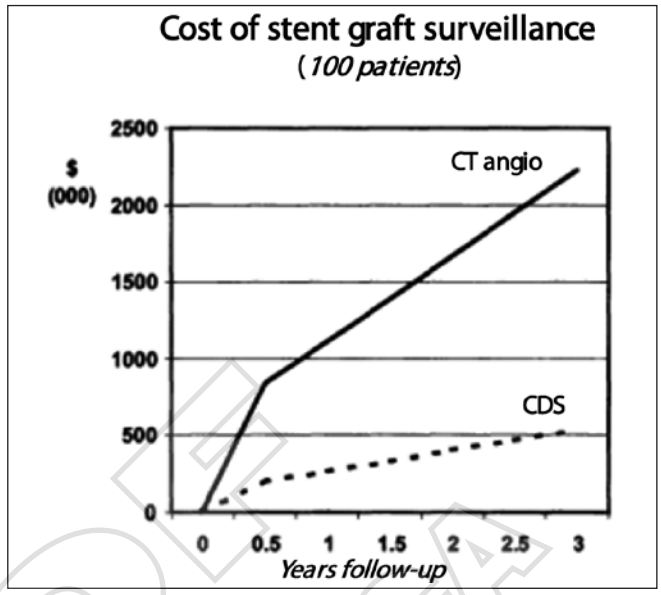


Figure 1.—Cost of stent graft surveillance.

— all patient check-ups should be done with CDS, with US amplifier, and should be associated with an Xray of the abdomen to show structural damage of the endograft.

Color-coded Duplex scanning of the aortic prostheses and endografts

Instruments

— Color-coded Duplex scanner
— 2-3.5 MHz transducer with phased array sectorial probes.

Procedure

Patient in supine position. The examination is to be performed after three days of preparation with an adequate diet to decrease gas in the bowel. For a more satisfactory study of the iliacs a full bladder is also advisable to create a window of low ultrasound attenuation.

The patient should be fasting for at least six hours.

In the beginning the probe is placed right underneath the xifoid process of the sternum, across it, in order to get a transversal scan of the subdiaphragmatic aorta, above the implant site of the prosthesis or proximal stent of the endograft (in some cases the stent is placed above the ostium of the renal arteries, but in most cases it corresponds to the "neck" of the aneurysm in the subrenal aorta. The diameters are measured first at this level since after the implant the neck can run into dilatation with consequent migration of the proximal stent. The prosthesis or the endograft are explored thoughout their course with multiple transversal or longitudinal scans assessing structure, continuity of the various segments, torsion, coiling or kinking.

The distal anastomoses or landing stents of the endograft on the common iliac or on the external iliac arteries should be checked. The exclusion from the direct flow of the internal iliac artery covered by the endograft, and pre-

viously occluded at the origin with spirals or other endoluminal stuff, is also to be checked.

The blood flow inside the prosthesis or endograft is displayed with the color module and with power Doppler using an average PRF, and a Doppler sampling close to the main trunk and in its branches is done. Similar measurements are made in the aorta above the prosthesis and downstream of the implant to point out the patency, the blood flow velocities and any turbulence or alterations of the flow parameters induced by the anastomosis or stents.

As far as the aneurysmic sac is concerned, patients submitted to open surgery will present it latter immediately around the prosthesis (it is actually sutured to protect the prosthesis and its anastomoses as to prevent an aorto-duodenal fistula). After EVAR the maximum antero-posterior and latero-lateral diameters of the sac must be assessed, indicating the anatomic landmark where they are measured. The residual systo-diastolic expansion can also be measured with A-mode method. The presence of endoluminal thrombus and any abnormal increases of the thickness of the wall will be noticed.

The presence of endoleaks will be assessed with the color module and Doppler, specifying their number, type, supplying vessel for type II leaks and the direction of flow.

The base examination will be completed with the study of any visceral vessel involved by the endograft and of the femoral arteries, site of introduction of the main body of the endograft and of the additional iliac branches.

The need to extend the investigation to the arteries of the lower limb, associating the measure of ABI, may arise when distal microembolism, obstructive or pseudoaneurysmal lesions are suspected.

The base examination may be followed by an investigation of the endograft blood flow and endoleaks following slow intravenous administration of 20-400 mg of US amplifier diluted in saline solution.

REPORTING PROPOSAL FOR DUPLEX SCANNING IN PATIENTS WITH AORTIC OR AORTIC-ILIAC-FEMORAL PROSTHESIS

Last name: ..... First name: ..... age: ..... date: .....
Examination performed with:
Device -
Probe type -
Aorta above the proximal anastomosis
Diameter (mm):
Anastomosis
Proximal site flow
Distal sites flow
Prosthesis
Main trunk diameter branches
Patency of arteries
Visceral:
Iliac: common - external - internal -
Femoral:
Periaortic retroperitoneal collections:
Ankle-brachial index right left
Brachial pressure
Posterior tibial pressure
Anterior tibial pressure
Power Doppler
Difficulties during the examination:
Indication for further investigation:
Conclusion:
Next check-up:

REPORTING PROPOSAL FOR DUPLEX SCANNING IN PATIENTS WITH EVAR

Last name: ..... First name: ..... age: ..... date: .....
Examination performed with:
Device -
Probe type -
Aortic neck
Diameter (mm):
Position of the proximal stent:
Endograft
Type: linear bifurcated aortouniliac
Patency:
Position:
Structural defects:
Aneurysm sac
Maximum diameters (mm):
— antero-posterior
— latero-lateral
PWM (wall motion in mm):
Thrombus: Seroma:
Endoleak
Type: I (A) proximal distal
II (B) lumbar inferior mesenteric other
III (C)
IV (D)
Flow pattern:
Patency of arteries
Visceral:
Iliac: common - external - internal -
Femoral arteries
— Pseudoaneurysm
— endoluminal lesion
Check of any complementary procedures:
— embolization:
— occlusion
— bypass:
Periaortic retroperitoneal collections:
— Ankle-brachial index right left
Brachial pressure
Posterior tibial pressure
Anterior tibial pressure
Ultrasound amplifier
Power Doppler
Difficulties during the examination:
Indication for further investigations:
Conclusion:
Next check-up:

Recommendations

AngioCTA is the gold standard for patients with EVAR. It should be carried out in the immediate post-op phase and when complications due to the endograft are detected.

Recommendation 1 Level A

CDS should be used in association with AngioCTA immediately after positioning an endograft and can be used alone during follow-up in all uncomplicated cases and when it is exaustive.

Recommendation 2 Level B

DSA is restricted to those cases in which a new endovascular procedure is indicated due to complications.

Recommendation 3 Level B

The timing of the check-up for a patient with EVAR should envisage a post-op check-up (within 30 days from the procedure), one every 3 months afterwards for the first year, and one every 12 months for the following years.

Recommendation 4 Level C

Type I and III endoleaks require an immediate procedure, possibly endovascular. Type II endoleaks are to be checked repeatedly assessing the arteries involved, the flow, the direction of the leak, and the features of the aneurysm.

Recommendation 5 Level B

Type II endoleak should preferably be corrected by endovascular or laparoscopic procedures.

Recommendation 6 Level C

Failure to find endoleaks with CDS when there is no decrease of diameters and persistent pulsation of the aneurysm requires further investigation aimed at explaining the endotension.

Recommendation 7 Level B

Occlusion of the arteries involved by the endograft, whether necessary or accidental, always entails close monitoring adequate to that particular arteries.

Recommendation 8 Level C

CDS is first choice for patients with an aortic or aortic-iliac/femoral prosthesis implanted with open surgery. Other techniques are indicated only complications and/or when considering another operation.

Recommendation 9 Level B

The timing of the check-up for a patient with an aortic or aortic-iliac/femoral prosthesis should envisage a post-op check-up (within 30 days from the procedure), followed by one every 6 months for the next two years.

Recommendation 10 Level C

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Guidelines for assessment of the lymphoedema of the limbs

These guidelines arise from the need everyone who works in lymphatic pathology has seen to single out some methods for gathering clinical and instrumental observations of patients with lymphoedema in a uniform and shared manner, based on the evidence found in literature and on a comparison with various professional experiences.

This necessity is also justified by the fact that after reaching a validation of the various methods, randomized and controlled multi-centre clinical studies – necessary for getting high levels of proof in this vascular pathology sector as well – can be developed. This will naturally also have significant repercussions on the socio-economic aspects of the sector (the possibility to prescribe rehabilitative techniques, to get reimbursement for braces, operator availability, crediting of diagnosis and therapy centres, etc.).

Investigations

— Measurement of the dimensions and morphology of the limbs
  — Ultrasonography
    – Ultrasound of soft tissues
      – Color coded duplex scanning (CDS)
  — Nuclear medicine imaging:
    – Lymphoscintiscan
  — Tonometry
  — Non-invasive X-ray imaging
    – CT
    – MR
  — Invasive X-ray imaging
    – Limphography
  — Bioimpedenziometry

The level of evidence of the clinical studies on the results of the various lymphoedema of the limbs treatments today is still very low. This is largely determined by the lack of unanimous agreement on the methods for evaluating various characteristics of the limb and of the lymphoedema tissue.

The possibility of precisely, reliably and repeatably measuring these characteristics is a condition necessary in order to carry out a comparison between the results obtained by the various Centres.

Measuring the dimensions of the limb

A precise and repeatable measurement of the dimensions of the limb suffering from lymphoedema is necessary

in order to both define the degree of the lymphoedema and to monitor its development, with regard both to the natural progression of the pathology and to the results given by the various treatments (medical, physical, surgical).

Various measurement techniques are proposed in the literature. One first consideration is to be made on the methods of evaluating the dimensions of the limb. Some authors make an evaluation based on measuring the circumferences at various levels of the limb, taking them into consideration separately or by adding them together. This position is criticised by other authors who instead stress the need to evaluate its volume in order to better highlight the real dimensional changes, considering the limb as a 3D solid.

This consideration is backed by the fact that the major international scientific companies define lymphoedema as an increased volume – whether absolute or in percentage – of a limb consequent to lymphatic insufficiency.

From a review of the literature it results that out of 43 clinical trials published concerning the evaluation of the effectiveness of various peripheral lymphoedema, 14 (42%) took only the centimetre data into consideration (to compare measurements in pre-defined points or as a summation of circumferences), whereas 19 (58%) evaluated the change of volume of the limb (as direct or indirect methodology).

The volume of the limb can be obtained with direct or indirect measurements.

Direct measurements of the volume of the limb

Water measurement of volume

This methodology measures the volume of the limb directly by immersion in water. The limb is immersed up to a specific level inside a container previously filled with water and the volume of water displaced by the limb is measured. The measurement is taken by measuring the rise of the water level inside the container or collecting and measuring the water that has spilt over it after the limb is immersed.

This technique has shown good reproducibility and elevated accuracy (intra-observer change 0.7%, inter-observer change 1.3%). The water temperature modestly affects the measurement. A 1.4% change was seen in the measurement of volume of the hand using water at temperatures of 5 °C and 45 °C, whereas significant differences were not detected for temperatures between 20 °C and 30 °C.

On the other hand, it has some defects. Precise measurement requires a lot of time, adequate space, rather costly equipment. It also demands considerable patient collaboration and good motility to place the limb inside the container, and so it cannot be used if there are prominent functional limitations as in the case of secreting skin injuries. It requires that the materials be thoroughly cleaned with disinfection of the container before being used by another patient. It supplies an estimate of the volume of the entire segment of immersed limb, without however providing information about the spatial distribution of the edema.

In short, the measurement of volume in water is the methodology to be considered as gold-standard for measuring the volume of the limb, but the logistical difficulties tied to its use make it difficult to use as routine in clinical practice (optimal examination).

The most advisable uses are:

— for measuring the volume of the hand or foot, the indirect centimetre measurements of which are more difficult and less precise; the assessment in water of these areas presents fewer problems than that of the entire limb.

— for the sake of scientific research, where knowing the absolute volume of the limb is necessary, for comparisons with other measurement techniques.

Procedure

The container is filled up to a pre-defined level (point 0) or up to the edge of the overflow slit. The limb is slowly and gradually immersed inside the container up to the pre-defined level marked on the skin. The rise of the water level is measured, or the volume of water flowing over is measured. A reverse measurement of volume can be made with a similar technique, by filling a container in which the limb has already been put inside with water. After taking the limb out, the amount of water necessary for again filling the container is measured.

Some technical aspects must be specified in order to make the measurement as accurate as possible:

— the limb immersion level must always be the same; to do this, it is necessary that the point of skin projection of a bone marker (*e.g.*, the stylohyoid process of the cubitus) or a pre-defined graphic marker on the skin (e.g. 15 cm above the epicondyle) be taken as reference for the water level;

— during the examination, the patient must remain absolutely immobile so as to allow the water level to stabilise;

— in using containers with water overflow, in which the overflowed water is collected in another container, the time when water collection is to be stopped must be standardised, since dripping from the outlet spout lasts for several minutes; some authors recommend stopping collection of the overflowed water when the time between one drop and the next is longer than 5 seconds;

— some authors recommend executing a mean on 3 consecutive measurements in order to increase measurement accuracy

Pyrometer

Evaluates the volume of the limb using infrared source of light that, aimed at the limb at a right angle, generate shadows that allow specific sensors to plot very precise circular sections of the limb. This technique has proven to be extremely precise. It is all but superimposable with the water measurement of volume as far as accuracy and repeatability is concerned, and better than it as far as ease of use is concerned. On the other hand, it is very expensive and presently not sold in Italy.

Indirect measurements

Measurement with tape measure

The volume of the limb can be indirectly calculated starting with a precise measurement of the circumferences of the limb at various levels using a tape measure. Compared to direct measurements, this measurement boasts the advantage of being quick, low cost, and performed with means easy to find and within everyone's reach. It also has the benefit of also showing the spatial distribution of the oedema, comparing the measurements of the various limb segments.

Measuring the volume with this technique has demon-

strated, water measurements being equal, excellent inter-rater and test-retest reliability, but the values obtained can not be compared with the absolute values of volume measured with direct methodologies (mean error: 6%). With this technique the volume is calculated by applying formulas for calculating volumes of geometric solids, to which the various limb segments are assimilated. Obviously the more the shape of the various limb segments diverges from that of the theoretical solid the formula is based on, the greater the error will be.

The limb circumferences can be measured at 4, 7, 10-cm spaces, or in pre-defined points by measuring the distance between them (*e.g.* metacarpophalangeal joint, wrist, 10 cm distally and 15 cm proximally to the epicondyle). The choice of restricted measurement spaces is based on the concept that accuracy of the calculation also depends on the distance (hence the total number) of measurement points. When changing the distance between the measurement points from 4 to 10 cm, the value of the volume of 30 upper limbs suffering from lymphoedema was highly superimposable, concluding that measuring every 4 cm in clinical practice is unnecessary unless there are seriously dysmorphic limbs in which evaluation every 10 cm runs the risk of being imprecise owing to the presence of redundant skin folds.

Method of measurement

The tape measure has to be flexible and short in height to stay well-adhered to the skin. No traction in any way whatsoever must be performed in order to avoid minimum compression of the tissues. The tension with which the operator stretches out the tape measure while measuring can in fact considerably alter the result, and this is particularly easy when taking measurements on oedematose limbs. Compared to water measurement, a bigger error has indeed been proven when measuring oedematose limbs (8-12%) compared to limbs of healthy patients (6.1%) and even more so compared to stiff limbs of manikins.

Even the placing of the tape when measuring can be a source of error if it is not placed perfectly at a right angle to the longitudinal axis of the limb.

Once identified, the measurement points must be marked on the skin with an indelible felt-tip pin with fine tip. When taking the measurement, the edge of the measure must always and unfailingly be positioned below or above the mark. The operator's accuracy in reading the measurement is essential. Rounding off (*e.g.*, to the previous or subsequent half centimetre) must therefore be avoided.

In order to guarantee reproducibility of the measurement, it is necessary to identify all the various measurement points with certainty and repeatably. Since the various measurement points are identified starting from an initial point called point 0 (usually located on the wrist for the upper limb and on the ankle for the lower limb), it is essential that this point be absolutely and precisely identifiable. It would be essential to use a bone marker point as the first point (*e.g.*, the stylohyoid process of the cubitus, the apex of the medial malleolus of the tibia). However, a precise identification of the skin projection of these markers is not easy in strongly oedematose limbs unless there is the possibility of an identification with other methodologies (*e.g.*, marking the skin close to the bone marker identified with echotomography). This is why it is often more expedient to use a skin fold as the first point of reference (*e.g.*, first palmar fold at the wrist), or the acral extremity of the limb (*e.g.*, tip of the 2nd or 3rd digit of the hand or foot). The points after the first one must be identified going along the axis of the limb and not along the skin surface, namely plotting an ideal line between two extremities of the segment in question and measuring the various distances that identify the subsequent measurement points on it (*e.g.*, from point 0 at the wrist to the elbow or to the acromion-clavicular apex for the upper limb, from point 0 at the ankle to the medial or lateral condyle of femur to the anterior superior iliac spine or to the trochiter for the lower limb).

Procedure

To perform an assessment of the oedema's evolution in limbs without significant distortions, the most accurate and quickest technique is measuring the circumferences at points 10 cm from each other. In the case of limbs with significant distortions, it is instead necessary to reduce the distance between the various measurement points to 4 cm.

The circumferences obtained this way can be added together to get a total value that is the expression of the overall size of the limb. For a volumetric evaluation it is instead necessary to apply the formulas provided above to calculate the volume of the various limb segments, which are to be added together. If possible, the accuracy of the measurement is increased by the evaluation of the volume of the extremities (hand or foot) by immersion in water

In addition to the total value (centimetre or volume), spatial assessment of the circumferences obtained is very useful in order to better point out the change of the dimensions of the various sectors of the limb.

It is necessary to note that if identification of the measurement points at pre-defined and fixed distances provides a comparison of the data obtained in the same patient over time (*e.g.*, the effectiveness of a treatment for that patient), if it should prove to be of interest to compare the data obtained between different patients, this methodology presents a fundamental error constituted by the fact that a pre-defined distance transferred on limbs of different sizes identifies also very different limb segments (*e.g.*, the same distance from the wrist can locate the measurement point at the III superior of the forearm in one patient and at the III inferior of the arm in another patient). This is why it is advisable to choose points identified by dividing limb segments into similar equal parts as a reference for the centimetre measurements.

The methods indicated are those more feasible and practical:

For the upper limb

Patient seated or laying down on his back, with limb abducted at 90° and not supported. The circumference of the hand close to the base of the 1st finger and the distance between the first palmar fold at the wrist and the base of the 3rd finger is measured.

Point 0 at the wrist, at the centre of the first palmar fold, is identified and is marked with a graphic marker. The main skin fold of the elbow is identified, and from its centre point (point 2) an imaginary line is plotted up to point 0. Halfway along this line point 1 is identified. The acromial apex (point 4) is identified and an imaginary line is plotted up to point 2. Point 3 is identified at the centre of this line. Then the circumferences close to points 0 (wrist), 1 (mid forearm), 2 (elbow) and 3 (mid arm) and the distance between point 0 and 1, 1 and 2, 2 and 3 are measured. It is possible to calculate the volume of the limb with these measurements. In this case, calculation is more complex as

the limb segments have different heights, but the various points are comparable between patients of different soma.

If the limb is greatly dysmorphic, it is necessary to increase the measurement points by dividing the distance between points 0 and 2 and between points 2 and 4 into 3 or 4 parts instead of half.

If the limb does not present a marked oedema, it is possible to bone saliences instead of using skin folds as marker points. Therefore, the stylohyoid process of the cubitus is assumed as point 0, the epicondyle as point 2 (to plot line 0-2) and the epitrochlea as point 4 (to plot line 2-4).

For the lower limb

Patient standing. The circumference of the foot in the central point is measured (the length of the foot from the heel to the tip of the 1st toe is measured).

Point 0 at the apex of the medial malleolus is identified. Point 3 medial is identified at the medial condyle of femur, and an imaginary line is plotted from here to point 0. This line is divided into 3 equal parts and points 1 and 2 are identified. Point 3 lateral is identified at the lateral condyle of femur, and point 6 at the trochiter. An imaginary line is plotted from point 3 lateral to point 6, and this line is divided into 3 equal parts, identifying points 4 and 5. Then the circumferences close to points 0 (ankle), 1 (third inferior of leg), 2 (third superior of leg) and 3 (knee, transmalleolar line), 4 (third inferior of thigh) and 5 (third superior of thigh) and the distance between the various points are measured. With these measurements it is possible to calculate the volume of the limb and the various points are comparable between patients of different soma.

If the limb presents a marked oedema that does not permit precise detection of the bone saliences, it is necessary to use points at pre-established distances as references.

In this case it is advisable to use a rule placed beside the limb of the patient on which points at a distance of 10 cm (for limbs not too dysmorphic) or 4-5 cm (for strongly dysmorphic limbs) are identified, starting from the ground.

For a rapid assessment of the unilateral oedema of a limb for the purpose of staging, it is possible to evaluate the difference of volume between the two limbs in a precise point by simply measuring the circumference in the corresponding point of the 2 limbs and using the formula $E2- S^2/S^2$ %, where E is the circumference of the oedematose limb and S is the circumference of the healthy limb. With this technique it is possible to quickly find out the percentage of edema of the hand, forearm and arm.

Monitoring the edema

Unilateral oedema: after having calculated the volume of the two limbs, it is possible to get the relative volume of the oedematose limb compared to the healthy limb (Vpat/Vsan) and the volume of the edema (Vpat-Vsan/Vsan).

In monitoring therapeutic results, repeated measurements of the limbs must be taken. In order to be comparable, the measurements must always be taken with superimposable methods (same methodology, same procedure, same time, same time elapsing since treatments carried out, etc.).

It is then possible to calculate:

— the initial percentage of edema: (Li-Ni)/Ni * 100

— the final percentage of edema (Lf-Nf)/Nf* 100

— the difference in the percentage of edema (Lf/Nf – Li/Ni) * 100

— the percentage of change of the edema [(Lf-Nf)-(Li-Ni)]/(Li-Ni) * 100

(where Li and Lf: initial and final volume of the limb with lymphoedema, Ni and Nf: initial and final volume of the healthy limb).

In the case of surgical operations with lymphadenectomy, it would be advisable to take pre-op measurements of the limbs, to be assumed as reference for calculating the volume of the oedema.

In the case of bilateral oedema, the only possibility is to compare each limb with itself over time, as it is not possible to use a limb as control.

Ultrasonography

Ultrasound of soft tissues

The ultrasound study of the patient with lymphoedema provides information about the structural tissue characteristics (supra- or sub-fascial distribution of the oedema, presence of ectasias of lymphatic collectors, of lymphatic lakes, connective conditions, thickness of the various skin layers).

The normal appearance of the skin is well-definable owing to the presence of layers having a different echostructure. It is, in fact, possible to distinguish the two layers making up the skin: epidermis derma and subcutaneous tissue. The first layer is distinguished by a hyperecogenic "incoming echo" represented by the reflection of the ultrasound beam due to the different acoustic impedance between the layer of gel put on the skin and the horny epidermis layer, a hypoecongenic layer represented by the papillary derma, and a hyperecogenic layer, the reticular derma. The derma present in a healthy patient has a thickness varying between 1 and 4 mm.

The demarcation between dermis and subcutis is distinct owing to the different acoustic impedance of the two structurally heterogeneous tissues. The subcutaneous tissue is hypoecogenic due to the presence of adipose lobules interposed in connective shoots and vascular lacunae. The thickness of the subcutis is quite variable (from 5 to 20 mm), depending on the corporal seat and soma of the patient. The muscular fascia is a hyperecogenic structure separating the subcutis from the muscular tissue running parallel to the skin layer. Thanks to their current axial and lateral resolution capacity, instruments today allow even the lymphatic vessels in healthy patients to be seen. Whereas the lymphatic capillaries forming a polygonal network close to the reticular dermis and the lymphatic precollectors forming a plexus in the context of the connective septa of the subcutaneous adipose tissue, having a calibre of 50-100 µ, cannot be seen, the lymphatic collectors in the deepest part of the subcutis – forming a network parallel to the axis of the limb in the superficial epi-aponeurotic area, having a calibre greater than 500 µ– are visible as linear echo images (in lymphatic vessels with virtual lumen) or as double binary images (in ducts with patent lumen). The lymphatic vessels can be seen not only in the subcutaneous area, but also in proximity of lymph nodes (afferent and efferent lymphatic vessels).

The morphological characteristics of the various skin layers change in lymphoedema, in terms of both echogenicity and thickness. There is possibility to use compression of tissues to study tisuttal composition

Alterations of the echogenicity

In the dermal layer, the echogenicity is lower in lymphoedema than in healthy controls. The reduction of the echogenicity, expression of interstitial oedema, is widespread both in the superficial portion of the dermis (papillary) and in the deep portion (reticular). This homogeneous distribution differs from that found in lipodermatosclerosis (in which the reduced echogenicity is mostly located on the superficial dermis) and in heart failure, in which the oedema is mostly in the deep dermal portion.

The subcutaneous layer instead has an anecogenic network with polyhedral links that compresses the surrounding hyperecogenic adipose tissue. This network is the expression of the progressive ectasia of the various anatomic levels of the lymphatic system. In the initial stages, especially the lymphatic collectors for the most part located in the epifascial layers and in the proximity of the superficial venous vessels appear ectasic. Then the pre-collectors dilate in the subcutis and lastly, the lymphatic network reaching the more superficial layers up to the reticular dermis (expression of the so-called Dermal Back Flow). The compression made with the probe empties the lymphatic network that fills again very slowly when pressure is released.

When the fluid collects outside the lymphatic collectors, actual "lymphatic lakes" form, creating a fragmented anecogenic network without noticeable walls that does not respond to compression with the probe. These alterations bring about the progressive disappearance of the normal reticular appearance of the subcutis. A progressive increase of the echogenicity of the subcutis and dermis is indicative of development towards a fibrosclerosis. It should be emphasised that these alterations can be seen in all situations in which there is an oedema, even of non-lymphatic origin (post-traumatic, venous, renal, cardiac, infective, neoplastic), stressing the involvement of the lymphatic system in all the forms of oedema.

Even the muscular tissue presents a structural alteration, increased echogenicity and loss of the normal fascicular structure, but this condition is for the most part associated with the presence of a venous insufficiency with involvement of the deep venous system (e.g. venous thromboembolism).

Changes of thickness

In lymphoedema, all the layers (dermal, subcutaneous and muscular) appear increased in size.

Today assessment of the thicknesses seems to be an essential study procedure for monitoring development of the lymphoedema and for evaluating the effectiveness of the various treatments. The thickness of the dermis is measured from the skin surface to the dermis/subcutis interface; the sucutis is on the other hand measured from the dermis/subcutis interface to the muscular fascia. In a more simplified manner, it is possible to measure the subcutaneous dermis thickness from the skin surface to the muscular fascia.

Procedure

Study of the lymphatic system requires scans having a high image quality standard, equipped with electronic probes having a high ultrasound beam emission frequency (from 10 MHz up – 7.5 MHz probes offer a sufficient study of the subcutaneous layer, but not of the dermal layer). The probes must be linear, such as to provide an improved viewing range and support surface.

The presence of a range area close to dark for the reflections due to the transducer/skin interface, even in high frequency probes, requires the use of spacers able to remove the dark area from the skin layers closer to the surface. These non-attenuant synthetic material spacers must be thin, but with a large surface, in order to make the support geometry of the probe with respect to the area to be studied more favourable.

An alternative to the spacer could be using an abundant layer of gel in contact with which the probe is placed. The probe must not, however, come into direct contact with the skin surface.

The pressure of application of the probe must be minimum in order to prevent causing the coaptation of the lymphatic structures closer to the surface.

The study is to always be conducted comparing the homologous contralateral regions and performing both longitudinal and transversal scans.

The ultrasound evaluation must first of all be aimed at the clinically evident areas of oedema in order to define their morphological characeristics and extension.

The thicknesses of the various skin layers (dermis and subcutis) must be measured in pre-defined points. The major difficulty is identifying standardized observation points. The bone structures are not a suffiently stable and precise marking for repeatable and systematic evaluations. It is therefore advisable to make these evaluations close to the circumference measurement levels, on both the medial and lateral sides of the limb.

The study must include examination of the radix of the limb in order to point out the number, dimensions and echostructure of the lymph nodes.

Color coded Duplex scanning

An assessment of the state of the arterial and venous circulation of the limbs is always made with Doppler (probe and appropriate procedures, as described by the relevant guidelines) in order to rule out non-lymphatic pathologies and to check for the presence of pathological conditions co-existing such as to depict treatment contraindications, such as recent arteriopathies or venous thromboses.

Nuclear medicine imaging

Lymphoscintiscan

The lymphoscintiscan is a simple methodology that offers not only an anatomic study of the subaponeurotic lymphatic vessels, but also a function assessment.

The technique is based on using radioactive isotopes in radium preparations that when introduced into the organism issue radiations possible to detect, record and measure with special gamma cameras.

The tracer (colloid with a high molecular weight) is injected at the distal extremity of the limb. The colloid injected subcutaneously is collected by the clasmatocytes in the interstice by phagocytosis (not by passive filtration). It is essential that the colloidal particles have optimum dimensions, because if they are too large they would stay in the injection area and if they are too small they would not be held back by the lymph nodes. 2 mCi of micro 99m Tc

colloid sulphur (SN) is injected into the 1st or 2nd interdigit space of each limb, and the head of the gamma camera is positioned on the district to be examined. In studying the lower limbs, the patient is laid down on the bed and the gamma camera detector is interfaced with a computer that acquires the data dynamically at 1 frame/15" x 30', then allowing the identical areas of interest (ROI) to be selected on the legs to generate activity/time curves. Afterwards, static measurements are taken on the legs, thighs and pelvis to display the lymphatic routes and lymph node stations.

Then the patient (according to some protocols) walks at a regular stride for 60' or 120', and when he returns, the static late acquisitions on the same districts examined are performed.

The normal picture envisages displaying broadbands of tracer transport along the legs and thighs up to reaching the major inguinal, iliac and loin-aorta chain lymph node stations; at times the liver may show up.

In the study on the upper limbs, the protocol is the same, with injection between the 1st and 2nd interdigit space on the back of the hands and subsequent measurements taken on the forearm, arm and chest, both dynamically and statically. The muscles are activated by having a tennis ball or the fist squeezed rhythmically. Then the scans are made on the same points.

The normal picture contemplates the tracer going back up like a thin band of radioactivity that climbs along the medial and internal region of the arm until it reaches the armpit, where the lymph node bundle is seen, but the separate lymph nodes are not identifiable.

The anatomic evaluation in the p with lymphostasis shows a slow removal of the tracer from the injection point; dermal back-flow; reduced display of the inguinal and iliac lymph nodes, which become more visible only after active movement.

In primitive lymphoedema, there is poor definition of the lymphatic routes with delayed appearance of the regional lymph nodes and possible tracer overflow in the case of hypoplasia, whereas in the case of aplasia there are no lymphatic routes and lymph nodes are not displayed. In secondary lymphoedema, we see failed removal of the tracer or a dermal back-flow; formation of collateral circulation; no display of the lymph nodes due to proximal obstruction with development of collateral circulation; tracer overflow in a lymphocoele; lymphangiecstasias; lymph node varices.

Tonometry

The tonometer is an instrument proposed by Piller and Clodius in 1976 that is used to determine the tonicity of the dermal and subcutaneous tissue. Tonicity is defined as the degree of tissue resistance to mechanical compression, and is therefore a objective measurement of the subjective parameter expressed as compressibility of the oedema. Basically, it precisely and repeatibly measures the degree and change over time of the compressibility of the tissues subject to the action of a standardised weight.

Some authors have conjectured they are able to get information about the biochemical characteristics of the oedematose tissue by studying the absolute value of the compressibility of the oedematose tissue and deformability of the tissue. Certainly, even if tonometry still does not have sufficient studies, it seems to be a good methodology for quantitatively and objectively evaluating characteristics of the oedema assessed up until now only semi-quantitatively and subjectively, as the fovea and consistency of the tissue.

Procedure

The deepening of the tissue forced by a 200 g weight 5 seconds after tonometer application and after 2 minutes is evaluated. When executing the examination, the tonometer must be keep motionless on the point in question and with a slope on the horizontal plane less than 20°.

Non-invasive X-ray imaging

CT and MR

These examinations are able to clearly study the skin, subcutaneous and muscular compartment, identify its density, thickness and morphological characteristics (presence of thickened or fibrotic interlobular septa). These expensive examinations not devoid of side effects and contraindications are recommended for complicated patients or for research purposes.

Invasive X-ray imaging

Lymphography

It is a contrast graphics methodology that Kinmonth introduced to clinical practice in 1952. It consists of injecting a lipo-soluble contrast medium inside the lymphatic vessel so that the lymphatic network and the lymph nodes can be seen with X-rays. It provides data regarding the number, calibre, course of the lymphatic vessels, the flow methods and the lymphatic-venous connections. It makes a morphological evaluation of the lymphatic circulation possible. With local anaesthesia, a cutaneous incision is made near a skin area where a lymphochromic test has been performed. A lymphatic vessel is then identified and is cannulated; the contrast medium is injected. After the injection, a scan is made that shows the lymphatic vessels full of contrast (filling phase). It is possible to see the lymphatic stations a few hours later (adaptation phase). The technique is burdened by many complications: pain during the examination, lymphangitis, dermatitis, thrombophlebitis, fever, headache, vomiting, diarrhea, up to more grave situations such as pulmonary, cerebral, renal, hepatic embolism or anaphylactic shock. The clinical picture sometimes appears worsened after the examination due to the lymphatic damage caused by the contrast medium. An indirect lymphography can be made by injecting a water-soluble lymphotropic contrast medium intradermally. Owing to the contrast characteristics, only lymphatic collectors close to the injection area are seen, whereas it would be better to see the lymph nodes.

Lymphography today is recommended only when studying the lymphatic circulation in preparation for a lymphatic micro-surgical operation.

Bioimpedance

It is a non-invasive method mostly used for estimating body composition based on the electrical conductive properties of various tissues.

Commonly known as BIA, it involves the use of low frequency (tipically 50 KHz) electrical currents traveling through the extracellular fluid and tissues.

This technique is able to identify, even in a segmental setup, and qualify the fluids in arm and limbs the test is high sensitive and specific (ref.)*, but it can suffer low repeatability if the test is not correctly standardized.[1-44]

Recommendations

A precise and repeatable measurement of the dimensions of the limb suffering from lymphoedema is necessary in order to both define the degree of the lymphoedema and to monitor its development, with regard both to the natural progression of the pathology and to the results given by the various treatments (medical, physical, surgical).

Synthesis 1

The measurement of volume in water is the gold standard, and is the optimum examination for measuring the volume of the limb, but the logistical difficulties tied to its use make it difficult to use as routine in clinical practice.

Recommendation 1 Level B

Measurement of volume in water is recommended for measuring the volume of the hand or foot, or for scientific research purposes, where it is necessary to learn the absolute volume of the limb for comparisons with other measurement techniques.

Recommendation 2 Level C

Measuring the circumferences of the limb with a tape measure is the most highly recommended for a routine assessment of the dimensions of the limb, with simple centimetre finding at different levels of the limb or as calculation of the volume by applying mathematical formulas regarding geometric solids (cylinder or frustum), to which the various limb segments are assimilated.

Recommendation 3 Level B

In the case of unilateral lymphoedema, after calculating the volume of the two limbs the volume regarding the suffering limb with respect to the healthy limb and the volume of the oedema must be calculated.

Recommendation 4 Level B

In the case of surgical operations with lymphadenectomy, it is advisable to take pre-op measurements of the limbs, to be assumed as reference for calculating the volume of any secondary lymphoedema.

Recommendation 5 Level C

In the case of bilateral oedema, it is necessary to compare each limb with itself over time, as it is not possible to use a limb as control.

Recommendation 6 Level B

The ultrasound study of the limb with lymphoedema provides information about the structural tissue characteristics (supra- or sub-fascial distribution of the oedema, presence of ectasias of lymphatic collectors, of lymphatic lakes, connective conditions, thickness of the various skin layers).

Synthesis 2

The ultrasound evaluation must be aimed at the clinically evident areas of oedema in order to define their morphological characeristics and extension. The thicknesses of the various skin layers (dermis and subcutis) must be measured in pre-defined points.

Recommendation 7 Level C

An evaluation of the state of the arterial and venous circulation of the limbs must always be made with Doppler to rule out non-lymphatic pathologies and to check for the presence of pathological conditions co-existing such as to depict treatment contraindications.

Recommendation 8 Level C

The lymphoscintiscan offers evaluation of the lymphatic system from a morpho-functional point of view. It is recommended if the diagnosis is doubtful or for scientific research.

Recommendation 9 Level C

Tonometry precisely and repeatably measures the compressibility of the tissues. It is a recommended though not very popular examination.

Recommendation 10 Level C

CAT and MRI examinations are recommended only for research purposes.

Recommendation 11 Level C

Lymphography today is recommended only when studying the lymphatic circulation in preparation for a lymphatic micro-surgical operation.

Recommendation 12 Level C

REPORTING PROPOSAL FOR ULTRASOUND EXAMINATION OF THE SOFT TISSUES

Evaluation form

Progressive number Sex Date
Surname and name
Address
Phone
ID number of centre
Initials
Date of birth
Anthropomorphic data
weight height
BMI
Oedema familiarity ❑ Yes ❑ No
habits work ❑ yes ❑ sedentary ❑ active work ❑ no
non-working activity ❑ sedentary ❑ active

oedema area skin appearance	❑ smooth	❑ verrucose	❑ dystrophic
	❑ dyschromic	❑ lymphorrhea	❑ ulcerated
	❑ eryspelas	❑ lymphangitis	
acute infections	❑ bacterial	❑ mycotic	
chronic infections	❑ no	❑ minor	❑ marked
reduced motility	❑ yes	❑ no	
pain sensitivity	❑ normal	❑ reduced	❑ absent
Recommended treatment			
❑ diet	❑ presso-therapy	❑ brace	
❑ mobilizing physical therapy	❑ lymph drainage	❑ bandage dressing	❑ medical treatment

basic pathology associated pathologies drugs
❑ hormone treatment
❑ calcium antagonist
❑ trauma
❑ other

Treatments carried out:
❑ pharmacological
❑ elastocompression ❑ bandage ❑ standard brace ❑ custom-made
❑ motor rehabilitation ❑ DLM ❑ cyclic pressotherapy
❑ pressotherapy at home ❑ use of electric medical devices

measurements	right	left	Difference
Upper (Lower)			
armpit (hip)			
arm (thigh)			
elbow (knee)			
forearm (leg)			
wrist (ankle)			
hand (foot)			
Tone forearm (leg)			

Scan
forearm (leg)
Inspection:
Check sheet
ID number of centre progressive number
Anthropomorphic data
weight height BMI
habits work ❑ yes ❑ sedentary ❑ active work ❑ no
non-working activity ❑ sedentary ❑ active
complications ❑ phlogosis ❑ trauma
❑ disuse ❑ other
Treatments carried out:
❑ pharmacological
❑ elastocompression ❑ bandage ❑ standard brace ❑ custom-made
❑ motor rehabilitation ❑ DLM ❑ cyclic pressotherapy
❑ pressotherapy at home ❑ use of electric medical devices

Scan
forearm (leg)
Inspection:

oedema area skin appearance	❑ smooth	❑ verrucose	❑ dystrophic
	❑ dyschromic	❑ lymphorrhea	❑ ulcerated
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pain sensitivity	❑ normal	❑ reduced	❑ absent
Recommended treatment			
❑ diet	❑ presso-therapy	❑ brace	
❑ mobilizing physical therapy	❑ lymph drainage	❑ bandage dressing	❑ medical treatment

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ABBREVIATIONS

ABI	Anle-brachial index
ACA	Anterior cerebral artery
ACAS	Asympomatic carotid atherosclerosis study
ACoA	Anterior communicating artery
AEF	Aorto-enteric fistula
AICA	Antero-inferior cerebellar artery
AngioCT	Angiography by computed tomography
AngioMR	Angiography by magnetic resonance
AVF	arteriovenous fistula
BA	Basilar artery
BFI	B-flow imaging
BIA	Bioimpedanziometry
CAS	Carotid artery stenting
CC	Common carotid artery
CDS	Color-coded duplex scanning
CE	Carotid endarterectomy
CIA	Common iliac artery
CM	Capillary microscopy
CS	Carotid siphon
CT	Computed tomography
CTr	Coeliac trunk
CWD	Continuous wave Doppler
DS	Duplex scanning
DSA	Digital subtraction angiography
DWI	Diffusion weighted immaging
EC	External carotid artery
ECST	European carotid surgery trial
ED	Erectile dysfunction
EDV	End diastolic pressure
EEG	Elettroencephalography
EIA	External iliac artery
EVAR	Endovascular aortic aneurysm repair
FDG	Fluorodesoxyglucose
FMD	Flow mediated dilatation
FSH	Follicle stimulating hormone
GDS	Gastroduodenoscopy
GSM	Gray scale median
GSV	Greater saphenous vein
HDL	High density lipoprotein
HITS	High intensity transient signals
IC	Internal carotid artery
ICAROS	Imaging carotid angioplasty and risk of stroke
ICI	Intracavernous injection test
IIA	Internal iliac artery
IMA	Inferior mesenteric arety
IMT	Intimal-media thickness
LD	Laser Doppler
LDL	Low density lipoprotein
Lf	Final volume of a limb with lymphoedema
LG	Lymphography
LH	Luteinizing hormone

Li	Initial volume of a limb with lymphoedema
LRR	Light reflection rheography
LSG	Lymphoscintigraphy
LSV	Lesser saphenous vein
MCA	Middle cerebral artery
MES	Microembolic signal
MLD	Minimum lumen diameter
MR	Magnetic resonance
NASCET	North american symptomatic carotid endarterectomy trial
Nf	Final volume of contralateral healthy limb (in a p. with lymphoedema)
Ni	Initial volume of contralateral healthy limb (in a p. with lymphoedema)
NIRS	Near infrared spectroscopy
NNT	Number need to treat
NPV	Negative predictive value
OA	Ophtalmic artery
PCA	Posterior cerebral artery
PCoA	Posterior communicating artery
PCS	Pelvic congestion syndrome
PET	Positron emission tomography
PFO	Patent foramen ovale
PFR	Pulse repetition frequency
PG	Plethysmography
PICA	Postero-inferior cerebellar artery
PPG	Photoplethysmography
PPV	Positive predictive value
PRL	Prolactine
PSV	Peak systolic velocity
PTA	Percutaneous transluminal angioplasty
PTFE	Polytetraphluoroethylene
PWD	Pulsed waves Doppler
PWV	Pulsed wave velocity
RAR	Renal-aortic ratio
RI	Resistance index (intrarenal)
ROC	Receiver operator characteristic
SAT	Supra-aortic trunks
SEPs	Somatosensorial evoked potentials
SG	Scintigraphy
SIDV	Società Italiana di Diagnostica Vascolare (Engl. Italian Society of Vascular Investigation)
SMA	Superior mesenteric artery
SPECT	Single photon emission tomography
SPREAD	Stroke prevention and educational awareness diffusion
TCD	Transcranial Doppler
TCDS	Transcranial duplex scanning
TcPCO2	Transcutaneous carbon dioxide tension
TcPO2	Transcutaneous oxygen tension
TEDS	Transesophageal duplex scanning
TI	Toe index (or toe-brachial index)
TIA	Transient ischemic attack
TOS	Thoracic outlet syndrome
TR-LIFS	Time-resolved laser-induced fluorescence spectroscopy
US	Ultrasound
VA	Vertebral artery
VG	Venography
Xray	Standard radiography