Comparative study between Coloured Doppler Ultrasound and angiography in peripheral vascular insufficiency below knee region.

Thesis

Submitted for the partial fulfillment of the Ms. Degree in Radiodiagnosis

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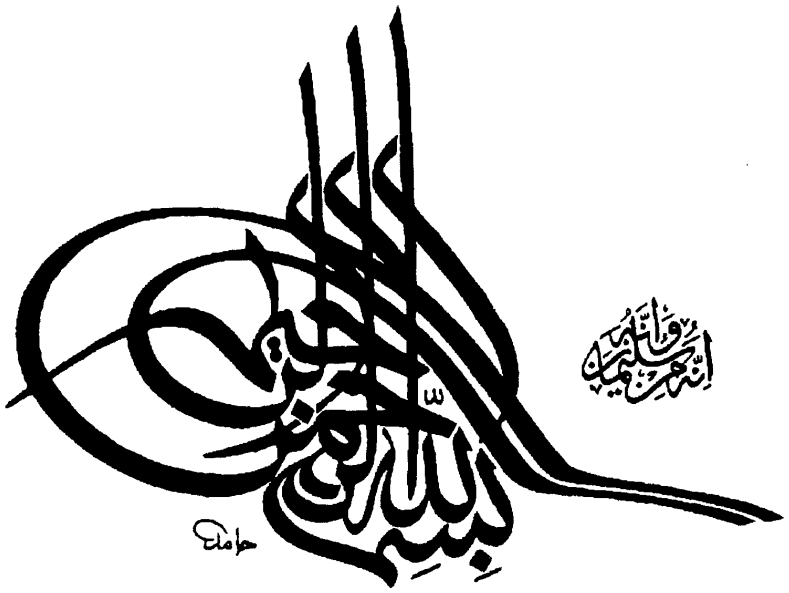
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قَالُوا سُبْحَانَكَ لاَ عِلْمَ لَنَا
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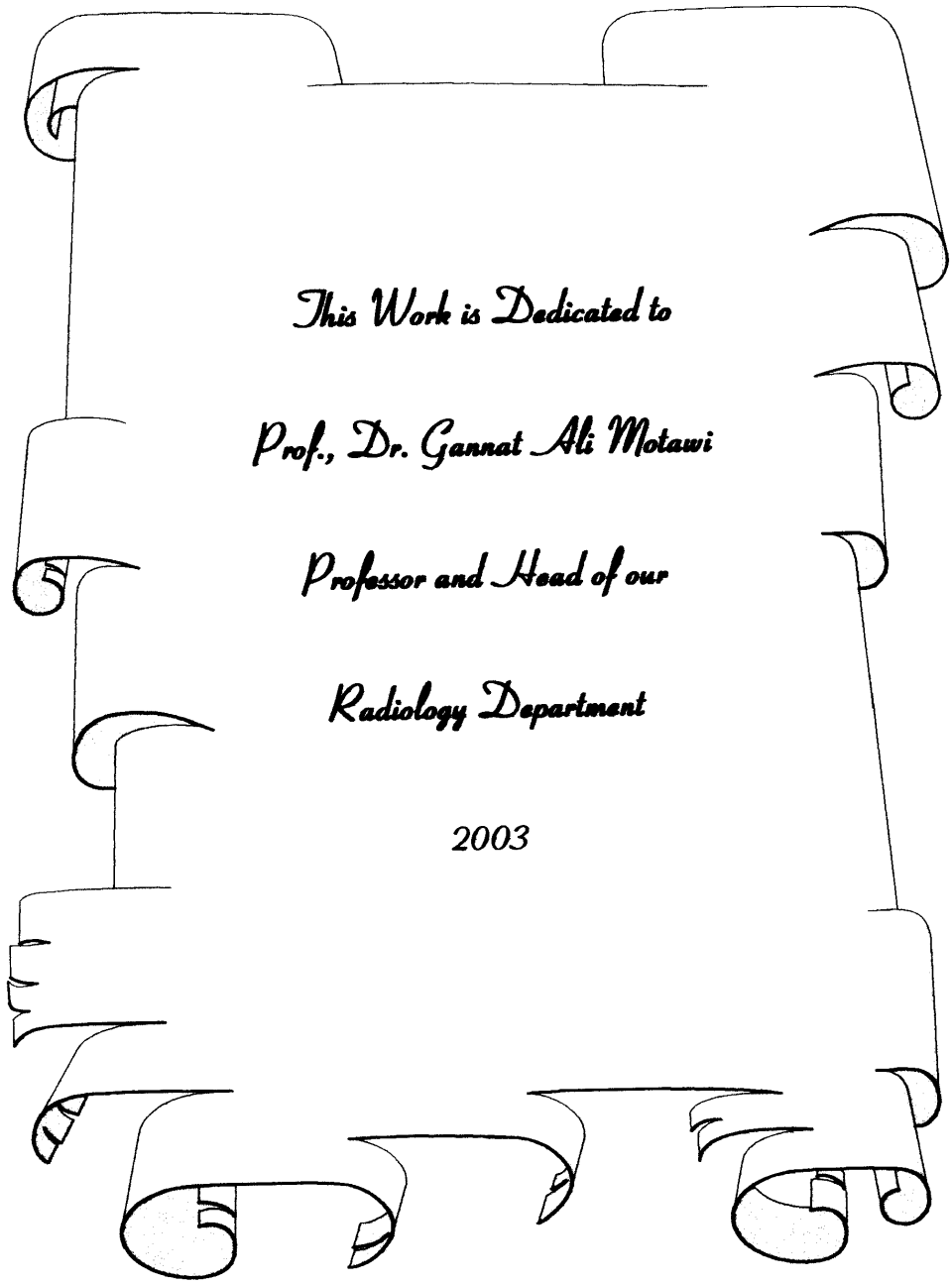
To MY Family


This Work is Dedicated to
Prof., Dr. Gannat Ali Motawi
Professor and Head of our
Radiology Department
2003

Acknowledgment

- *In the name of Allah, the most beneficent and most merciful and peace upon (Mohammed) his kinsmen and companions all.*
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ABBREVIATIONS

- A.T. A. : ANTERIOR TIBIAL ARTERY
- C. F.A. : COMMON FEMORAL ARTERY
- POP.A. : POPLITEAL ARTERY
- P.T. A. : POSTERIOR TIBIAL ARTERY
- S. F.A. : SUPERFICIAL FEMORAL ARTERY
- T. P.T. : TIBIOPERONEAL TRUNK
- P. S.V. : PEAK SYSTOLIC VELOCITY
- S.M.Cs. : SMOOTH MUSCLE CELLS
- L.D.L. : LOW DENSITY LIPOPROTIEN

CONTENTS

Introduction and Aim of the Work

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Introduction and aim of the work

The progression in vascular surgery had changed radically the treatment of peripheral vascular diseases during the last decade. This made early and accurate diagnosis of such diseases an important and urgent need.

Angiography being one of the most accurate techniques remains the standard for diagnosis of peripheral vascular disorders. However, the time, expense, technical factors and discomfort associated with this procedure, all detract it from its routine use as screening or follow up diagnostic procedure.

Within the last decade, non-invasive techniques have been developed to improve the accuracy of diagnosis of peripheral vascular diseases such as color doppler ultrasonography. It represents one of the most useful screening techniques in evaluation of blood flow through arterial tree. The technique is non-invasive, fast, painless and having no immediate or late side effects. It is easy to recognize the normal auscultatory sounds and to distinguish them from abnormal sounds.

(snopek and saunders 1999).

The aim of this work is to compare between the color coded ultrasound findings and angiographic findings in the peripheral vascular arterial disease in below knee region.

Arterial Anatomy Of Lower Limb

Normal Anatomy:-

- ***The common femoral artery*** is the continuation of the external iliac artery at the inguinal ligament Mid-way between the anterior superior iliac spine and the symphysis pubis (Fig 1).

(Gray . 1989).

The common femoral artery gives off a deep branch, the profunda femoris (medial to the neck of the femur).The superficial femoral artery is the continuation of the common femoral artery in the thigh. It runs medial and anterior to the femur.

(Polak, 1997a).

- The upper and middle thirds of superficial femoral artery lies medial to the femur.

In the lower third of the thigh, it runs posterior to pass through the adductor canal to become the popliteal artery and gives off some small muscular branches, the descending genicular or "Saphenous artery".

- ***The profunda femoris artery*** is the most significant branch of the common femoral artery because it serves as the main blood supply to the thigh muscles (Fig 1).

- It is the prime collateral vessel to the leg, and the single most important vessel involved in the collateral

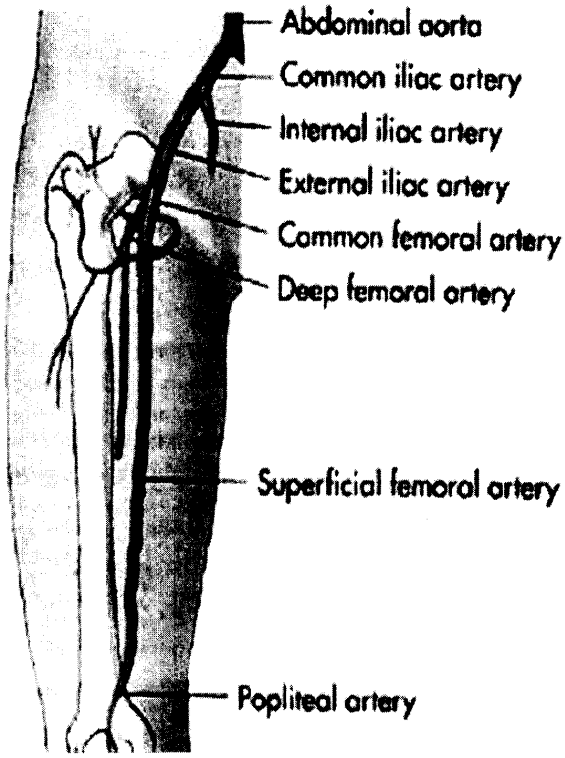

Fig (1) *femoral artery and its branches*

- Network between the pelvis and the lower leg when the superficial femoral artery is occluded.
- It divides rapidly into several branches:

1- Medial circumflex femoral artery.

2- Lateral circumflex femoral artery (divides into the ascending, transverse and descending branches).

3- Four perforating branches (penetrate the adductor Magnus to reach the back of the thigh).

- ***The popliteal artery: -*** is the continuation of the superficial femoral artery. It extends from the inferior border of the popliteus muscle and divides there into anterior and posterior tibial arteries (Fig 2). ***(Morris et al 1960)***.

The course of the artery runs in the deeper layers, it rests first on the femur, then on the capsule of the knee joint, and finally on the popliteus muscle. The popliteal vein superficial and somewhat lateral to the artery. The initial portion of the popliteal artery passes from the medial side to the midline in an oblique direction and descends there after vertically. The length of the popliteal artery is 18 cm, and its diameter is 0.7 cm ***(Gray, 1989).***

Branches of the popliteal artery

- The cutaneous branches.
- The superior muscular branches.

- The sural arteries begin between the upper and middle articular branches.
- The superior genicular artery divides into medial and lateral branches; they wind around the lower end of the femur to form the arterial network of the knee.
- The middle genicular artery pierces the capsule of the knee joint from behind.
- The inferior genicular artery divides into medial and lateral branches; they surround the condyles of the tibia and contribute to the formation of the arterial network.
- The anterior and posterior tibial arteries and their branches.

- The anterior tibial artery: Is one of the terminal branches of the popliteal artery. It starts at the lower border of the popliteus muscle. The course of its projection extends from the mid point of the line between the head of the fibula and the tuberosity of the tibia to a line midway between the two malleoli. The vessel is continued on the dorsum of the foot as the Dorsalis pedis artery. The diameter of the anterior tibial artery is 1.9 to 3.5 mm (Fig 2).

(Gray, 1989).

Branches of the anterior tibial artery:

- The posterior tibial recurrent artery curves back to the knee joint.

- The anterior tibial recurrent artery runs to the arterial network of the knee.
- The muscular branches are distributed to the muscles on either side of the vessel.
- The anterior (medial and lateral) malleolar arteries run to the ankle and participate in the formation of the arterial network around the ankle.
- The Dorsalis pedis artery follows a straight course from the midpoint of the ankle joint to the first interosseous space. It gives branches (lateral and medial) tarsal arteries. The terminal branch of the Dorsalis pedis artery assists in the formation of the deep planter arch.

- ***The posterior tibial artery*** is the other terminal branch of the popliteal artery. It passes in a straight line downwards from the middle of the popliteal space to midway between the medial malleolus and medial tubercle of the calcaneus to divide into branches on the sole. The diameter of the posterior tibial artery is 2.23 to 4.15 mm (Fig 2). ***(Polak J.F. 1997).***

Branches of the posterior tibial artery:

- The circumflex fibular branch which passes around the neck of the fibula.
- The peroneal artery passes obliquely towards the fibula and runs along it to the lateral malleolus. If both tibial arteries are rudimentary, the peroneal artery alone supplies the leg

- The medial and lateral planter arteries arise behind the medial malleolus. The lateral artery is larger, it passes in an arched course medially at the base of the metatarsal bones (Planter arch), and anastomoses with the terminal branch of the Dorsalis pedis artery and also with the deep branch of the medial artery.

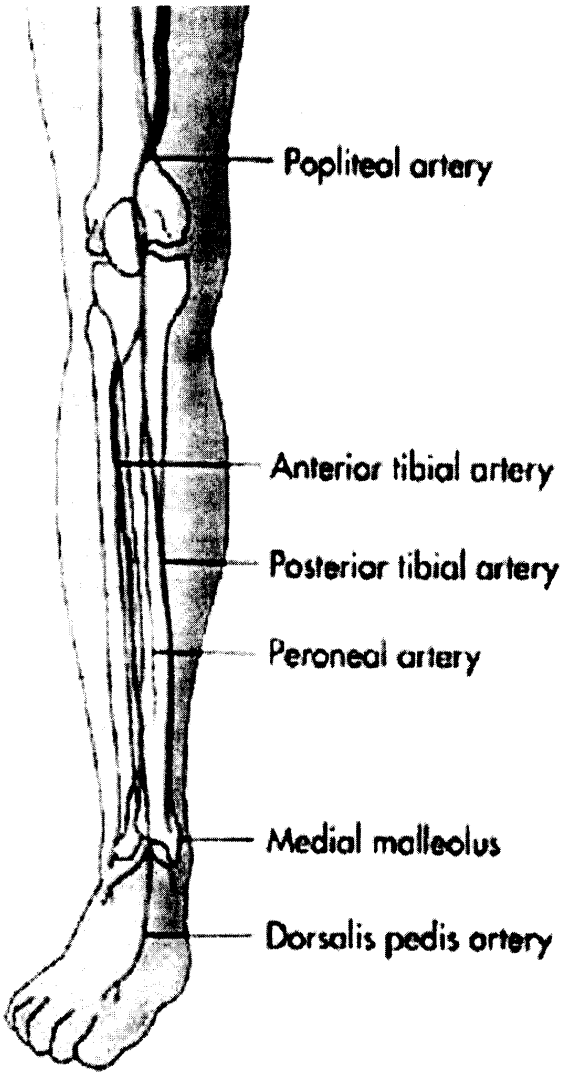

Fig (2) *Right popliteal artery and its branches*

Anatomic variants

1. A persistent sciatic artery ;0.03% of the population the artery originating from the internal iliac artery and extending to the popliteal artery.
2. Duplication of the superficial femoral artery.
3. The profunda femoris artery can arise higher than expected near to the external iliac artery and take medial course.

(Polak, 1997).

Collateral Circulation

At the hip joint:

- The obturator and internal pudendal arteries, which are branches of the anterior division of the internal iliac artery anastomose with the medial circumflex femoral branches of the profunda femoris artery.

- The superior and inferior gluteal arteries, which are posterior division branches, anastomose with the lateral circumflex femoral artery.

- The profunda femoris is anastomosing freely with the popliteal artery branches around the knee via the descending lateral circumflex and the perforating branches.

- ***At the knee level*** when the popliteal artery is occluded, collateral circulation largely comprises small, unnamed branches from medial and lateral genicular, popliteal, superficial femoral and profunda femoris arteries. Branches from medial genicular arteries

tend to reconstitute the posterior tibial artery. Whereas the lateral genicular arteries reconstitute the anterior tibial artery.

- ***At the ankle:*** The peroneal artery may provide collateral circulation to both the anterior and posterior tibial arteries.
- ***At the foot:*** The posterior and anterior tibial arteries may contribute to each other just below the ankle joint.

(Muler, et al.,1997)

Pathology of peripheral vascular insufficiency

Insufficiency (Ischemia), means diminution of the arterial supply to tissues.

Types:

[A] *Acute ischemia:-*

Is occlusion of the arterial Lumen, which may be due to local or general causes.

* *Local causes:*

(a) Thrombosis.
(b) Embolism.
(c) Tourniquet.
(d) Splint.
(e) Vasospasm
(f) Cold injury
(g) Drugs e.g. ergot.

* *General causes:-*

(a) – **Poor blood flow e.g.:-**

- Shock. - Heart failure.

(b) – **Blood dyscrasia e.g.**

* Leukemia – polycythaemia.
* Thrombocythaemia and cold agglutinins.

(Walker W.F. 1988a)

[B] *Chronic Ischemia:-*

(a) *Chronic ischemia due to primary vascular diseases e.g:-*

1- Arteriosclerosis.
2- Thrombo-angiitis obliterans (Buerger's disease).

3- Vasculitis.

4- Primary Raynaud's disease.

5- Congenital arteriovenous malformation and aneurysms.

(b) Chronic ischemia due to secondary vascular lesions:-

1- Connective tissue diseases:-

(a) Scleroderma. (d) Polymyositis and dermatomyositis.

(b) Systemic lupus erythematosus. (e) Sjogren's disease.

(c) Rheumatoid arthritis. (f) Mixed connective tissue disease.

(Duprez A. Daniel 1993).

2- Vasculitis:-

(a) Hypersensitivity Vasculitis. (e) Takayasu's arteritis.

(b) Poly arteritis nodosa. (f) Giant cell arteritis.

(c) Churg – Strauss syndrome. (g) Behcet's disease.

(d) Wegener granulomatosis.

(h) Kawasaki disease (mucocutaneous lymph node syndrome)

(Duprez. Daniel 1993)

3- Vasculopathies:-

a- Ehler's – Danlos syndrome. *b- Fibro muscular dysplasia.*

c- Pseudo-xanthoma elasticum. *d- Marfan's syndrome.*

(Harris E.J. et al., 1995).

4- Drugs and cigarettes

5- Neurogenic: - *paraplegia, poliomyelitis.*

6- Traumatic

7- Cold injury.

8-Vibration vasospasm

(Walker W. F. 1988b).

9- Perino (Erythrocynosis):-

Inflammatory condition induced by cold, consists of angiitis with intimal proliferation and, thickening of the arterial wall.

(Kontos A. Hermes 1996).

Arteriosclerosis

Definition

- arteriosclerosis- a group of diseases characterized by thickening and loss of elasticity of the arterial walls
    - Three forms
        1. atherosclerosis aorta and large branches
        2. Monckeberg's arteriosclerosis Ca^{2+} deposits in the medial part of the artery
        3. arteriolosclerosis small vessels

The Arterial Wall structure

- Intima: single layer of endothelial cells rests on bed of connective tissue
    - When atherosclerotic lesions develop, they form within the intimal layer
- Media: thickest layer of normal arterial wall
    - Separated from intima and adventitia by internal and external elastic laminae, respectively
    - Composed mainly of smooth muscle cells in a matrix of collagen, elastin and proteoglycans
- Adventitia: outermost layer of arterial wall
    - Contains fibroblasts and collagen, as well as blood vessels (vasa vasorum), nerves, and lymphatics

Atherosclerosis

Atherosclerosis is a type of arteriosclerosis. It comes from the Greek words athero (meaning gruel or paste) and sclerosis (hardness). It involves deposits of fatty substances, cholesterol, cellular waste products, calcium and fibrin (a clotting material in the blood) in the inner lining of an artery.

Atherosclerosis can affect the arteries of the brain, heart, kidneys, other vital organs, and the arms and legs. When atherosclerosis develops in the arteries that supply the brain (carotid arteries), a stroke may occur; when it develops in the arteries that supply the heart (coronary arteries), a heart attack may occur.

Atherosclerosis is the leading cause of illness and death allover the world . Despite significant medical advances, coronary artery disease (which results from atherosclerosis and causes heart attacks) and atherosclerotic stroke are responsible for more deaths than all other causes combined.

It is a disease of the arterial intima leading to the formation of fibrous (atheromatus) plaques and to stenosis/ occlusion of the lumen. It involves the proliferation of smooth muscle cells and the accumulation of lipids.

Atherosclerosis affects large and medium-sized arteries. The type of artery and where the plaque develops varies with each person.

Morphology

The American Heart Association Committee on Vascular Lesions has categorized the progression of the atherosclerotic lesion from the first lipid deposit in the intima to the ruptured plaque with thrombosis (Fig. 3). ***(Stary HC et al 1994)***

The type I lesion,

The initial lesion, is the lesion most frequently described in infants and children in all countries. The intima of a type I lesion is infiltrated with microscopic lipid droplets and macrophage-derived "foam cells" macrophages with intracellular lipid deposit). Macrophages take up a limited number of low-density-lipoprotein (LDL) particles; however, once the LDL is oxidized, the macrophage uptake is markedly increased, leading to accelerated foam cell formation.

The type II lesion

Includes fatty streaks, which, on gross inspection, may be visible as yellow streaks, patches, or spots on the intimal surface of arteries. In the type II lesion, foam cells are stratified into layers and there are also more macrophages in the thickened intima, including macrophages without lipid droplets. T-lymphocytes have also been identified in these lesions. In autopsy studies among children aged 2 to 15 years, the majority have type II lesions in the aorta; in general, type II lesions develop in the coronary arteries around age 15 and increase in size and number with aging. ***(Stary HC et al 1995)***

Type III lesions

Type III lesions are an intermediate or transitional lesion characterized by microscopically visible cellular lipid droplets and particles forming pools among the smooth muscle cells in regions of intimal thickening; however, there is no "lipid rich core," a characteristic of the type IV lesion. The type III lesion is still reversible with cholesterol-lowering therapy. When the extracellular lipid pools of the type III lesion coalesce into a lipid rich core, the result is a highly disorganized intima, which is characteristic of the type IV lesion.

The type IV lesion

Characterized by "lipid rich core,", where the extracellular lipid pools of the type III lesion coalesce into a lipid rich core, resulting in a highly disorganized intima, which is characteristic of the type IV lesion. Coronary lesion may still appear normal on an arteriogram, because the plaque initially grows outward (positive remodeling), which does not impede the lumen. This outward plaque growth has been shown using the technique of intravascular ultrasound (IVUS). With use of IVUS, has been shown that sizable atheroma can be detected in coronary arteries that appear normal on an angiogram.

(Yamagishi M et al 1994)

These lesions are clinically significant because they represent potentially high-risk lesions for rupture or fissure. Rupture causing exposure of the lipid core to the circulation frequently leads to thrombosis. Thrombosis and occlusion of an

artery in this stage may be more life threatening than the occlusion of a severely stenotic artery that is often protected by collateral circulation.

The type IV lesion

That ruptures and has thrombosis, hemorrhage, or hematoma is now classified as a **type VI lesion** and is refereed to as a "complicated lesion." After maturation of the thrombus or hematoma in the plaque, the fibrous cap reforms and may eventually calcify, resulting in a fibroatheroma and an occluded or partially occluded artery, characteristic of the type V lesion.

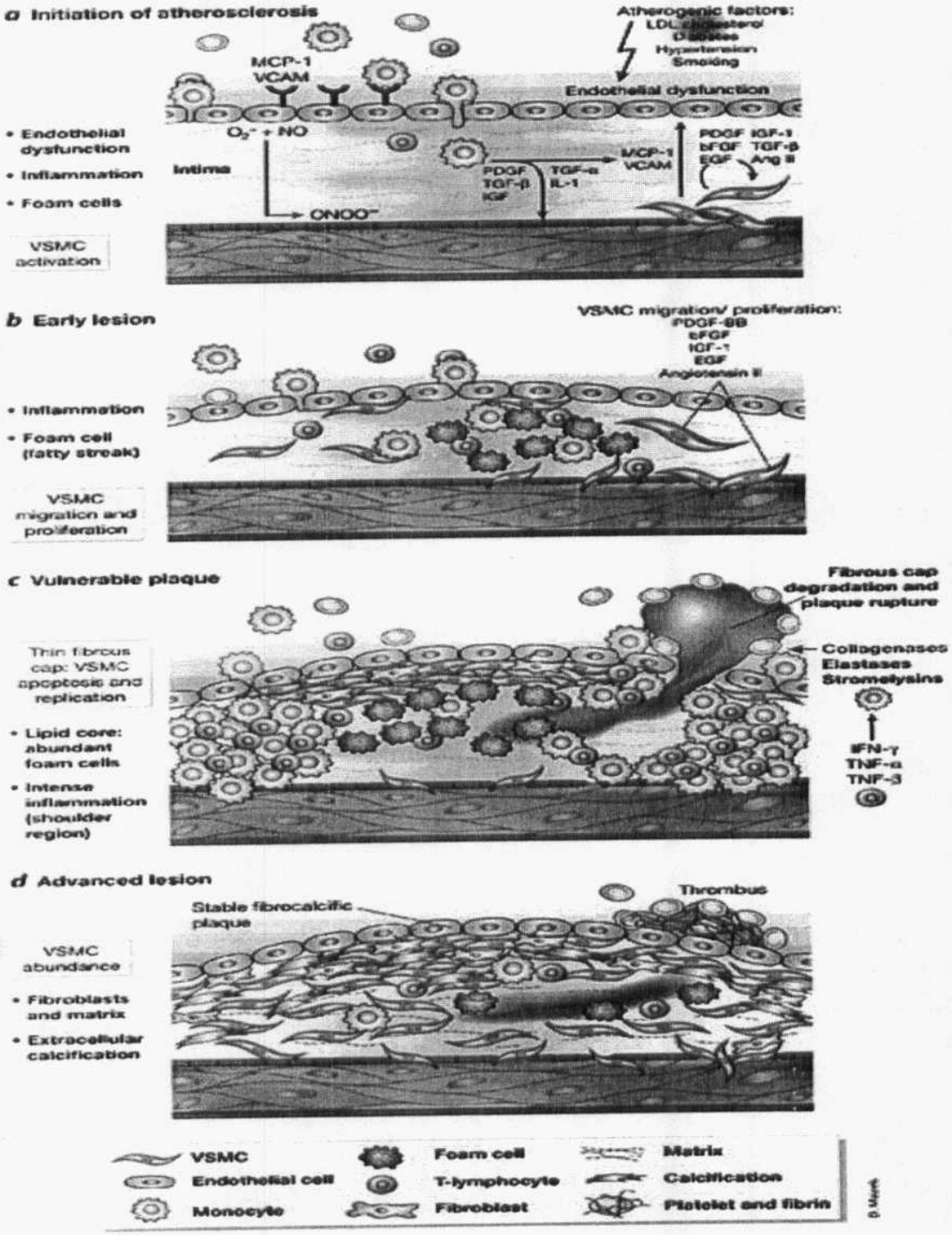

***Fig (3) Stages of atherosclerosis**: early lesion (stagel, II&III) vulnerable plaque (stage IV) & advanced lesions (stage V & VI) from Vascular Proliferation and Atherosclerosis:,*

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Pathogenesis

- NO ONE REALLY KNOWS FOR SURE/ NO ONE HYPOTHESIS
- History?
- Current Hypotheses

1. **Reaction to injury hypothesis**
    - endothelial injury is initiating event
    - there is an increase in permeability that allows passage of plasma lipoproteins, macs/monos, platelets, etc into the sub endothelial connective tissue
    - Even without any stripping of the surface, the monos pass through and become macs
    - Platelets are involved when the injury is severe
    - the Macs and Platelets secrete PDGF and other cytokines
    - the SMCs migrate from media to intima and proliferate in response to PDGF
    - **Major source of lipid- plasma LDL**
    - The LDL is taken up by the macs and SMCs and in turn they turn into foam cells
    - The SMCs in response to the lipid accumulation produce an abundance of collagen, elastic tissue, and Proteoglycans that make up the plaque
2. **Monoclonal Hypothesis**
    - SMCs initiate the lesion
    - THIS HYPOTHESIS IS NOT HEAVILY FAVORED

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- Using isoenzyme studies it was interpreted that all cells in the plaque were derived from the same original cell; benign neoplasm

Pathogenesis of Atherosclerosis

- Endothelial dysfunction: the primary event in atherogenesis in "injury" to the arterial endothelium
- Lipoprotein entry and modification: increased endothelial permeability allows transport of LDL into intima, a process facilitated by an elevated circulating LDL concentration; then LDL oxidation can take place changing it to mLDL
- Recruitment of leukocytes: macrophages become lipid-laden foam cells, the primary constituent of the fatty streak
- Recruitment of smooth muscle cells: transition from fatty streak to fibrous plaque involves migration of smooth muscle cells from arterial media into injured intima, proliferation of smooth muscle cells within the intima, and secretion of large amounts of connective tissue by smooth muscle cells (Fig. 4).

- **Potential Atherosclerogenic factors**
  1. hemodynamic forces
  2. hyperlipidemia
  3. immunological rxns
  4. physical injury
  5. chemical injury
  6. drugs
  7. endotoxemia
  8. viruses

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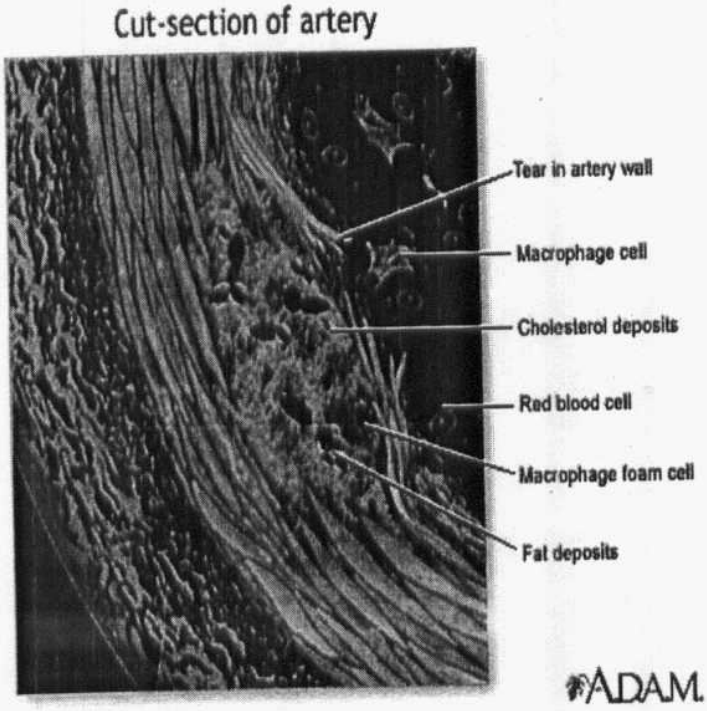

Fig (4) *Atherosclerosis is a disease of the arteries in which fatty material and plaque are deposited in the wall of an artery, resulting in narrowing of the arterial lumen and eventual impairment of blood flow.*

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- **Four major treatable Risk Factors for arteriosclerosis**
  1. Hypertension.
  2. Smoking
  3. Dietary fat
  4. Diabetes mellitus control
- Other Risk Factors
  1. Exercise
  2. Obesity
  3. Stress
  4. Familial predisposition

Table (1) Complications of Atherosclerosis

Complication	Mechanism	Examples
Narrowing and calcification of vessel	Progressive development of fibrous plaque; organization of microthrombi within lesion	Myocardial ischemia; limb claudication
Thrombus formation with occlusion of lumen	Plaque ulceration or rupture; plaque hemorrhage with rupture	Myocardial infarction or unstable angina; thrombotic stroke (cerebral infarction)
Peripheral emboli	Fragmentation and passage of atheromatus material from large proximal vessel to smaller peripheral vessels	Embolic stroke; atheroembolic renal failure
Weakening of vessel wall	Pressure on neighboring medial layer promotes atrophy of muscle cells and loss of elastic tissue	Aortic aneurysms

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Thromboangitis obliterans (Buerger's disease)

-It is a form of progressive arterial occlusive disease that characteristically occurs in young men before 35 years.
(Polak J.F. 1997).

- An excellent analysis of the clinical features was made by Leo Buerger 1908 who published the first series of patients showing the disease. ***(Clement D.L et al., 1993).***

- Buerger's disease is non atherosclerotic, segmental, thrombosing, obliterative, Acute and chronic inflammation of small to medium-sized arteries and veins of the extremities that occur almost exclusively in men who are heavy cigarette smokers.
(***Mc Loughlin, GA et al., 1976).***

- Symptomes are usually confined to the foot or lower legs. Pain at rest, mostly a burning sensation, is the main clinical feature and not exercise-induced intermittent caludication. Involvement of upper extremeties, recurrent thrombophlebitis, Intimal thickening with an inflammatory cell response and preservation of the media are associated with buerger disease. ***(McKusick, V.A et al., 1962)***

Raynaud's Disease and Raynaud's Phenomenon

- Raynaud's disease is an idiopathic vasospastic condition of the small vessels of the extremities that occurs most frequently in young women and is more often symptomatic in the upper than lower extremities. ***(Chait A. 1997).***

- Symptomes include pain, paresthesias, pallor, cyanosis and rubor, and are precipitated by cold and emotion.

- When these symptomes are not associated with other disease, the condition is usually referred to as primary Raynaud's phenomenon or Raynaud's disease and when associated with collagen vascular disorders such as scleroderma, systemic lupus erythematosis, rheumatoid arthritis or other secondary causes like paraplegia, neurovascular compression or drug, it is generally termed secondary Raynaund's phenomenon. ***(Walker W.F. 1988b).***

Polyarteritis Nodosa [P.A.N]

- It is a necrotizing angiitis arterial abnormalitis , most common at bifurcations. ***(Ferris E.J. 1986).***

- The disease results in focal arterial narrowing and dilatation, multiple occlusions and characteristic microanerurysms.

- It especially affects small to medium sized arteries and similar to hypersensitivity angiitis. ***(Ferris Ej, Levine HL 1973).***

- There is preference for visceral abdominal arteries such as those to the kidneys, liver, and small bowel are the most commonly involved vessels. ***(Stanson A W 1990).***

- Microaneurysm formation common in visceral arteries and uncommon in cerebral vessels.

- Rarely, small aneurysms lead to perivascular hematoma may result from weakening or rupture of the wall. ***(Wissler, 1984).***

Ehlers – Danlos Syndrome

- It is an inborn error of metabolism in the collagen construction.

- Described by Ehlers in 1901 and Danlos in 1908.

- It has three classic features:

* Hyperelasticity of the skin.

* Fragility of the skin.

* Hyperextensibility of joints.

Arterial problems are rare in classical syndrome, but as regard peripheral lower limb vessels the syndrome lead to:

- arterial disruption.

- superficial femoral true aneurysm.

- popliteal and posterior tibial arteries pseudoaneurysm.

(Wright, G. B. et al., 1979).

Fibromuscular Dysplasia (F. M. D)

- It is a disease of women usually presenting between the ages of 40 and 70 years. ***(Housten. C. 1979).***

- The female to male incidence is approximatly 4:1 or 5:1. Most patients were their theristies, forties to fifties.

(Abrams, L.A. and Grassi, J. 1997).

- Symptomes most often related to ischemic events 56% of patients.

- The disease can affect:

1- The visceral arteries e.g. renal arteries.
2- Internal carotids arteries.
3- Coronary arteries.
4- External iliac arteries.
5- Femoral arteries. ***(Housten. C. 1979).***

There may be multiple focal asymmetric areas of narrowing due to intimal proliferation possibly secondary to organised mural thrombi .The media is most often involved usually by fibrous thickening. ***(Abrams, L. A. and Grassi J. 1997).***

Other forms of Vasculitis

1- Systemic lupus erythematosus:

Can cause arteriographic abnormalities of small arteries resulting in ectasia at bifurcation, stenosis and occlusions.

(Ferris E.J, 1986).

2- Rheumatoid arthritis:

Associated with arteritis, however ,angiographic abnormalities are usually confined to small arteries in the extremities.

(Stanson A. W. 1990).

3- Takayasu's Arterities:

Vasculitis of medium and large arteries with strong predilection for Aortic Arch (52%) and its branches 12%, most common in young females.

(Hallisey, M.J. et al., 1997).

4- Giant Cell Arteritis:

- Inflammation of medium and large sized arteries.

- The most likely proximal axillary, the brachiocephalic, and the femoral arteries. ***(Stanson A. W. 1990).***

5- Wegener's Granulomatosis :

- A rare form of necrotizing vasculitis.

- Associated with destructive arteritis of blood vessels and granuloma formation.

It may produce disruption of the arterial wall and pseudoaneurysms.

- Commonly the renal artery affected and other aortic branches.

(Abrams L. A. and Grassi C. J. 1997).

6- Hypersensitivity Angiitis:

- Affect the small vessels only so it is called microscopic polyarteritis. ***(Alarcon, 1977).***

CLINICAL PRESENTATION OF PERIPHERAL VASULAR INSUFFICIENCY

Routine history and physical examination will correctly establish the diagnosis of arterial insufficiency of the lower extremity in the majority of patients.

Claudication is pain of severe fatigue produced by exertional ischemia in muscles during or immediately after exercise. Patients will described and relate a history of claudication that highly specific and so characteristic that arterial insufficiency can usually be suspected on the bases of the history alone (Fig. 5) ***(Santos, J.C. Dos, 1974).***

If significant aorto-iliac arterial disease is present, claudication is frequently bilateral. Claudication in the more proximal muscle groups of the lower extremity indicates occlusions or stenosis of the iliac arterial system. The most frequent site of claudication is the calf, suggesting occlusion of the superficial femoral artery with or without popliteal artery occlusion.

Rest pain is most frequently located in the distal portion of the extremity, particularly in the toes or distal foot. Claudication is considered a relative indication for revascularization, depending on the patient's age, the occupation, the need for amputation and the extent of which claudication interfere with daily life.

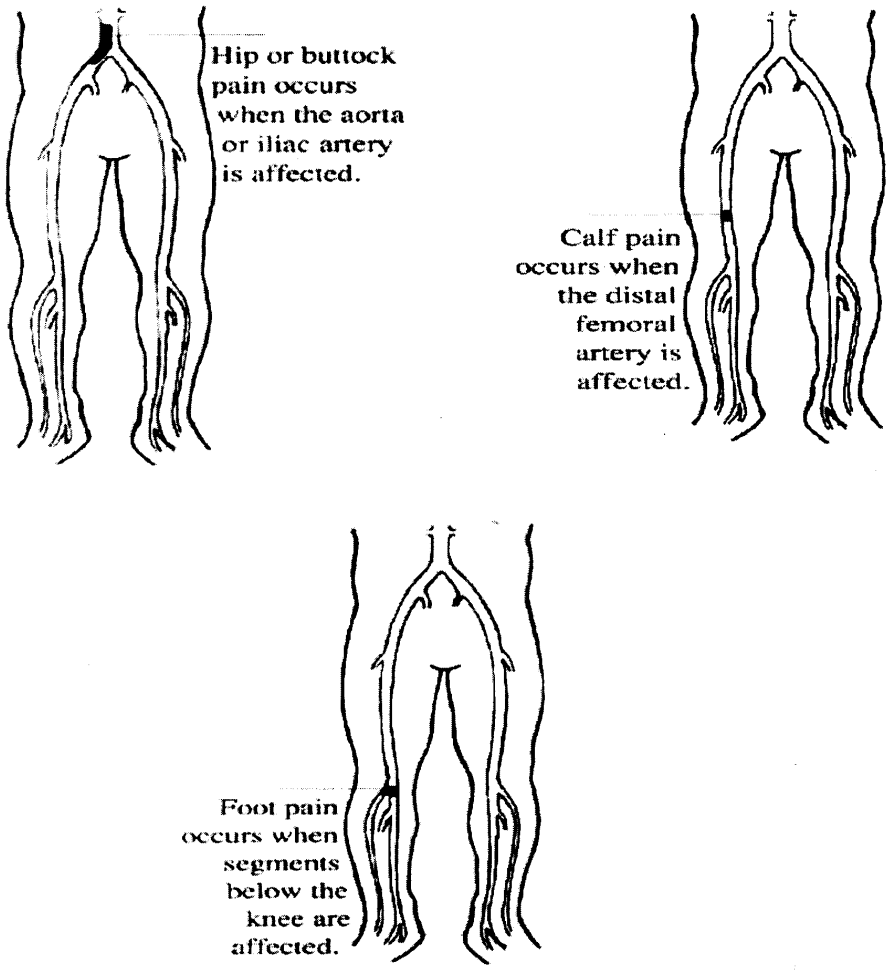

Fig.(5)*Site of occlusion and its presentation*

Physical examination will almost invariably demonstrate lack of tissue perfusion in the lower extremity and thus will corporate the diagnosis, which can be strongly suspected by the history. The pallor after elevation of the limb, the rubor of dependency and the prolongation of the venous filling time, give more clinically relevant information regarding the status of the arterial nutritional perfusion of the distal extremity, than do specialized hemodynamic studies ***(Santos, J.C. Dos, 1974).***

Pallor is also characteristic of acute arterial insufficiency, but rubor of dependency can be demonstrated only in chronically ischemic limbs.

Other physiological findings in patients with chronic arterial insufficiency are atrophic changes, including pedal hair loss, thickened toe nails, thin, shing pedal skin, and atrophy of the calf muscles.

Clinical staging:

Arterial occlusive lesions may be classified according to clinical severity into the following stages.

Stage I: Asymptomatic

Stenosis or occlusion, i.e. none of the symptoms characteristic of chronic arterial occlusive disease are present.

Some patients may exhibit specific symptoms such as a sensation of coldness or a rapid fatigability of the extremity, which

are often not interpreted as due to a clinically disorder. Patients in this stage of the disease often fail to consult a physician.

Stage II: Intermittent claudication

During this stage a segment of stenosis or an occlusion is present, with a collateral circulation which ensures an adequate blood supply during rest; however during effort the circulation is inadequate. Ischemia on effort causes an accumulation of metabolites in the muscles. The patient can walk a certain distance on the level, then the pain in his calf muscles grows so bad that he has to rest for a while-usually only briefly – before the symptoms disappear. The distance which the patient can walk without symptoms is called the claudication or walking distance, and this a useful yardstick for measuring the disproportion between tissue demand and blood supply. For practical reasons, this stage is subdivided into, stage IIa, the milder form of intermittent claudication (walking distance more than 200 meter), and stage IIb (walking distance less than 200 meter), in which the symptoms may be so marked that the patient can be termed as involved.

Stage III: Rest pain

During this stage the blood flow is so much reduced that requisite blood is not even supplied during rest; therefore ischemic pain results. The pain is experienced in the inadequately supplied distal portion of the limb. It is worse with the patient recumbent, when the hydrostatic pressure is eliminated, and especially at night under conditions of reduced systemic blood pressure. The symptoms may be so severe that the patient is deprived of sleep and posses the night sitting up, tortured by violent pain. Rest pain

always occurs in the distal part of the extremities, irrespective of the site of the stenosis or occlusion causing it – in contrast to the pain of the intermittent claudication. In these insufficiently supplied distal areas atrophic changes of the skin, hair and nails ultimately arise. A non-bacterial inflammation of the subcutaneous tissue may occur. Since the patient prefers to keep the affected leg low, edema will developed, favored by the ischemic damage to the capillaries. This pre-gangrenous state gradually posses into stage IV.

Stage IV: Tissue damage

Pre-gangrenous lesions may transform into gangrene, and if a good demarcation of the gangrene occurs, the pains may lessen. However, not every case of gangrene shows good demarcation. Extensive gangrene with proximal spread may be present, often without any tendency to healing. On account of the inadequate circulation, secondary infection which shows little tendency to healing may supervene. Such lesions may be extremely painful, although indolent ulcers do occur in diabetes mellitus.

How is peripheral vascular disease (PVD) diagnosed?

The most common test for PVD is the ankle-brachial index (ABI). Based on the result of an ABI, as well as on the basis of the symptoms and associated risk factors for PVD, the physician can decide if further tests are needed. It the ABI test indicates that the patient might have PVD. ***(Carter SA. 1993).***

Other tests can be used to confirm the diagnosis, including:

- Duplex ultrasound.
- Magnetic Resonance tomography, MR.
- Computed tomography (CT) angiography
- Angiography – Angiogram

Magnetic resonance (MR) tomography

This is a highly sophisticated method of visual investigation of the inner organs of the body, including the blood vessels, using a high-power magnetic field, which is completely harmless to the human body. This method is highly reliable in so far as it can accurately visualize very small details of the structure of a certain part of the body. ***(Rofsky NM, 1998).***

High performance computers attached to this device can rebuild three-dimensional images of any part of the investigated structure, allowing high precision diagnosis and planning for complex medical interventions. Obstructions or dilatations of the arteries can e accurately diagnosed. ***(Owen RS, 1998).***

Computer tomography (CT) angiography

This is another highly sophisticated method of visual investigation of blood vessels using X-rays and concomitant radio-opaque contrast injections to enhance the precision and quality of images obtained.

This allows accurate diagnosis of certain diseases of the blood vessels (mainly of the aorta). ***(Rieker O, et al., 1996).***

In the same way as with MR techniques, the images obtained can be used to reconstruct the structure of a blood vessels three dimensionally, allowing planning for specific surgical interventions.

This is not a completely innocuous procedure, as high doses of X-ray are necessary to perform it. ***(Rieker O, et al., 1996).***

HEMODYNAMICS OF STENOSIS

The basis for the Doppler diagnosis of vascular stenosis is the principle of volume continuity, which states that the velocity of blood flow through a narrowed portion of a vessel will increase if the volume of flow per unit time in the segment is constant. The volume of flow Q is equal to the product of the vessel cross-sectional area A and the average flow velocity v. Assuming the volume of blood remains constant throughout the region of narrowing (Fig 6)

(Burns PN et al., 1995 a).

Q = v1A1 = v2A2;

there fore,

v2/v1 = A1/A2,

and as **A** decreases, **v** increases.

As the residual diameter of a stenosis decreases, there is an increase in resistance and, eventually, a decrease in overall flow and a drop in pressure. From a clinical perspective, a lesion is hemodynamically significant if it causes a perfusion deficit during rest or exercise. The greater the degree of stenosis and the longer its length, the greater the associated pressure decrement. The degree of stenosis beyond which a small increase in severity results in a significant reduction of flow is referred to as a "critical" or "hemodynamically significant" narrowing. This value is generally acknowledged to be 50% of the luminal diameter in the peripheral

arterial system, which corresponds to a 75% decrease in cross-sectional area. This number is somewhat arbitrary in that it is strongly affected by peripheral vascular resistance and the status of the pre- and post-stenotic vasculature

The major criterion for the Doppler diagnosis of arterial stenosis is a focal increase in velocity (peak systolic velocity [PSV]), but there are several other Hemodynamic issues that affect the pulsed Doppler waveform and are therefore useful in waveform interpretation. These are laminar versus turbulent flow, and pulsatile flow.

(Burns PN et al., 1995 a).

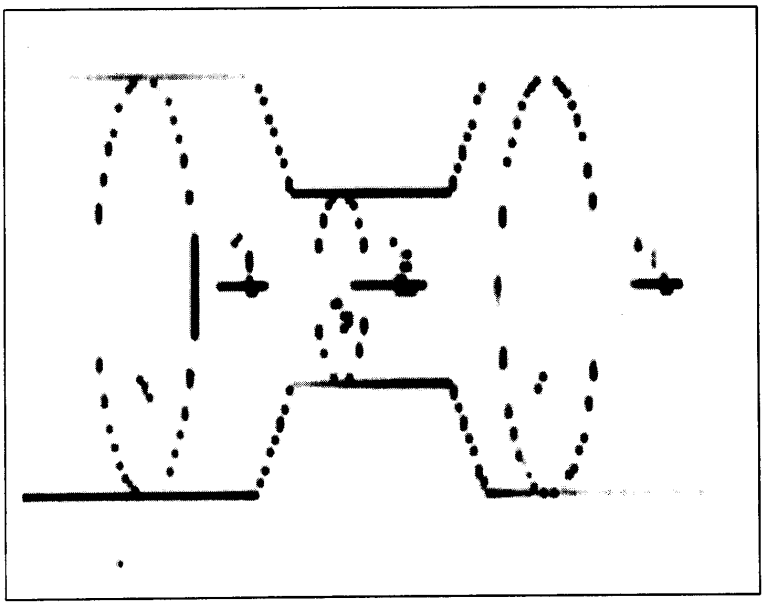

Fig (6)Flow in stenotic artery

(Burns PN et al., 1995 a).

LAMINAR AND TURBULENT FLOW

The flow velocity profile in a straight vessel with a uniform diameter is known as a laminar profile; it is characterized by a smooth, predictable velocity gradient across the cross-sectional area (Fig 7), with the highest-velocity flow at the center and a gradual decrease toward the vessel wall, with an infinitesimally thin layer in contact with the wall having a velocity of zero. The geometry of this flow pattern approximates a parabola and can be conceptualized as a concentrically arranged stack of cylinders moving along a smooth path at differing velocities relative to each other. True parabolic flow exists in the smaller vessels of the abdomen but not usually in the major arteries, where instead there is some flattening in the middle of the velocity profile, which is known as "plug flow ".The pulsed Doppler feature of laminar flow is the presence of a clear "window" beneath the spectrum, indicating that the red blood cells are moving in an orderly manner, with similar velocity and direction (Fig 8).

(Landwehr p. 1995a).

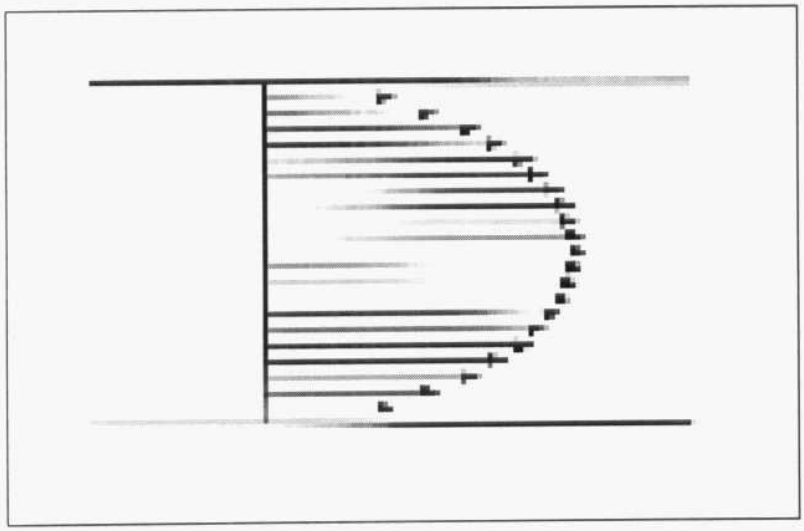

Fig (7) *The Parabolic flow profile is found in larger vessels in diastole and in smaller vessels.*

(Landwehr p. 1995a).

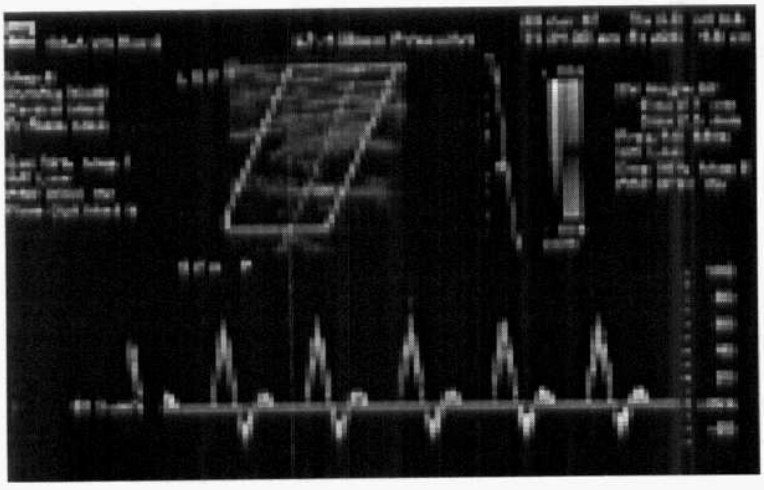

Fig (8) *Laminar flow velocity waveform*

(Landwehr p. 1995a).

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Multiple factors in "real" arteries can focally alter laminar flow, such as vessel tapering, curvature, and bifurcations. Disruption of laminar flow can result in a spectrum of flow abnormalities, ranging from "disturbed" to "turbulent" flow, with the precise distinction between the two being somewhat arbitrary. Flow disturbance comprises a continuum of flow abnormalities ranging from minor irregularities of flow streamlines to completely disorganized, multidirectional flow vectors (Fig 9). The variables that influence the existence of turbulent flow include vessel radius r, the average flow velocity v across the lumen, the density p of the fluid, and the viscosity h of the fluid. With these variables, the Reynolds number (Re) can be calculated by using the equation Re = v2rp/h); a value exceeding approximately 2,000 is generally defined as the critical value for the transition from laminar to turbulent flow. Since a stenosis is associated with elevated velocity, turbulence is usually present within and distal to a stenosis. The color Doppler appearance of turbulent flow is a heterogeneous distribution of different shades of color across the vessel lumen (Fig 10), since the Doppler angles related to individual cells are no longer identical. The pulsed Doppler appearance of turbulence includes spectral broadening (filling in of the window of the spectrum), disorganized simultaneous forward and reverse flow, and fluctuations in flow velocity with time (Fig 11).

(Burns PN et al., 1995 a).

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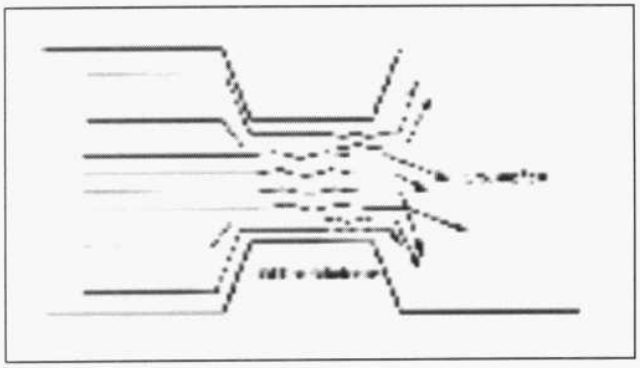

Fig (9) Multidirectional flow vectors

(Burns PN et al., 1995 a).

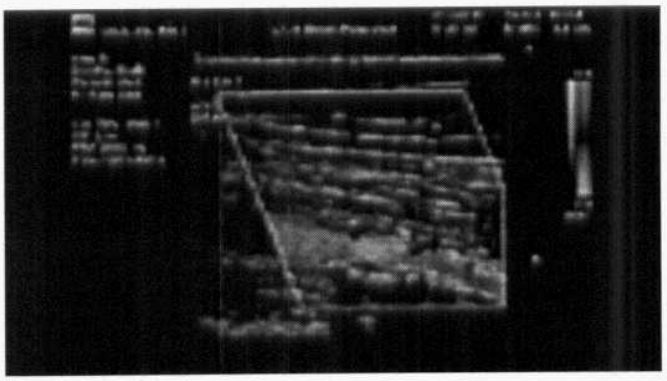

Fig (10) Color Doppler appearance of turbulent flow.

(Burns PN et al., 1995 a).

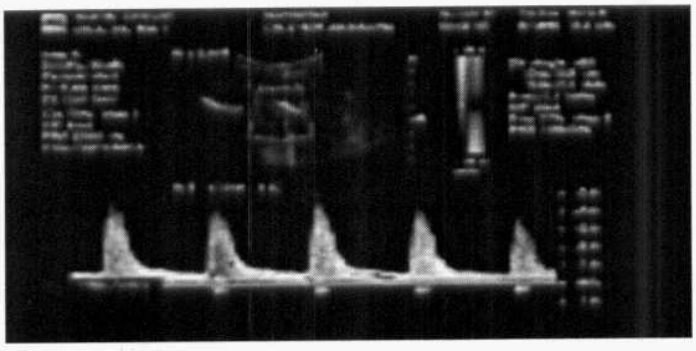

Fig (11) Appearance of turbulence flow velocity waveform

(Burns PN et al., 1995 a).

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PULSATILE FLOW PATTERN

Because of the pulsatile pumping activity of the heart, flow in the arterial system is characterized by alternating phases of acceleration and deceleration. The large pressure amplitude produced by the left ventricle is reduced by the receiving arterial bed, the aorta, and the large vessels. These vessels are sufficiently compliant to store some of the pulsatile energy of the heart, and allow more continuous flow. The degree of the continuous flow component is predominantly a function of peripheral vascular resistance, particularly at the arteriolar level. Reflections of the pressure waves within the arterial tree also influence the flow velocity waveform. These conditions result in two basic forms of the Doppler waveform: high and low resistance. Arteries that supply muscles and skin at rest (extremities, external carotid, penile, and mesenteric when fasting) have a high-resistance Doppler waveform. Lower-extremity arteries are an example of this, and typically have a rapid acceleration to and deceleration from peak systole, a brief reversal of flow in early diastole, and a brief component of ante-grade flow in mid-diastole ("triphasic waveform") (Fig 12). Parenchymal organs such as the liver, spleen, kidney and brain require constant perfusion, in contrast to demand-oriented tissue such as muscle, and have a more continuous, low-resistance flow pattern. The characteristic waveform in a vessel supplying these organs has a significant degree of ante-grade flow throughout diastole, and no reversed flow component (Fig 13).

(Burns PN et al., 1995 b).

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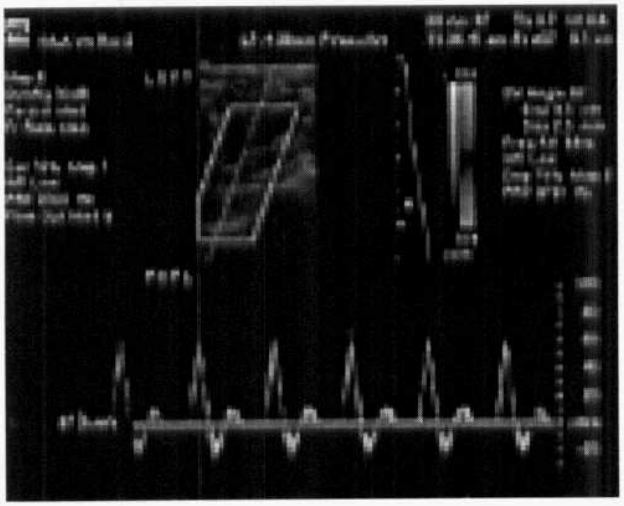

Fig (12) *Triphasic waveform*

(Burns PN et al., 1995 b).

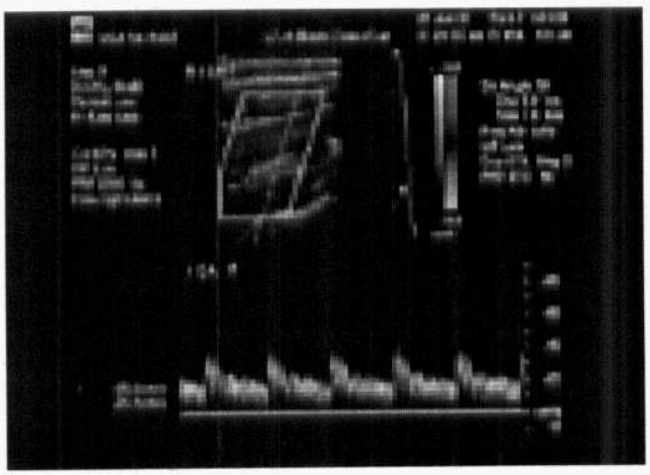

Fig (13) *biphasic waveform*

(Burns PN et al., 1995 b).

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Physiologic or pathologic conditions that alter peripheral resistance can affect the pulsatility and contour of Doppler waveforms. For instance, lowering of peripheral resistance due to a hemodynamically significant lesion or exercise can result in a low-resistance waveform in the femoral artery (Fig 14). Similarly; the usual low-resistance waveform in a renal transplant may convert to a high-resistance pattern due to processes that raise intra-renal resistance, such as acute rejection or renal vein thrombosis. These alterations of waveform can be used to detect changes in peripheral vascular resistance, which may provide important diagnostic information.

(Landwehr p. 1995b).

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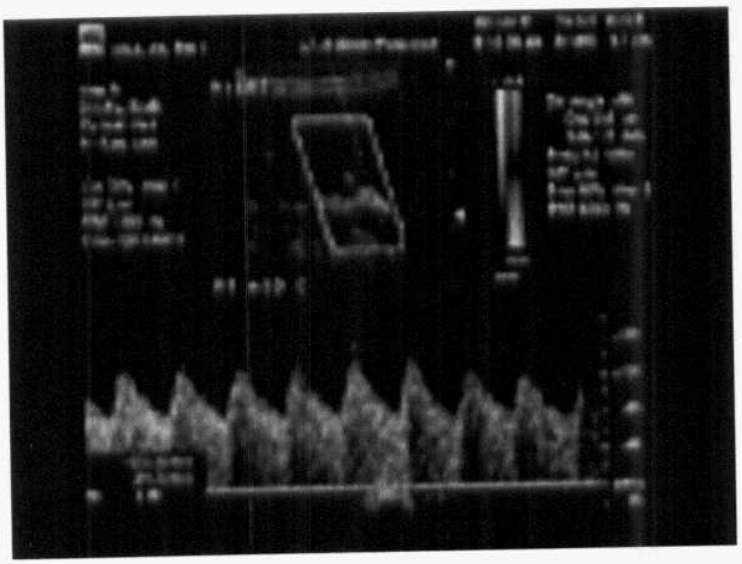

Fig (14) Low-resistance waveform in femoral artery

(Landwehr p. 1995b).

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Principles of Doppler Ultrasound

The Doppler effect is a change in the frequency of a wave, resulting from motion of the wave source or receiver, or in the case of a reflected wave, motion of the reflector. In medicine, Doppler US is used to detect and measure blood flow, and the major reflector is the red blood cell. The Doppler shift is dependent on the insonating frequency, the velocity of moving blood, and the angle between the sound beam and direction of moving blood, as expressed in the Doppler equation (Fig 15)

(Wells PNT 1995a).

$$Df = \frac{2 f v \cos q}{c}$$

where Df is the Doppler shift frequency (the difference between transmitted and received frequencies), f is the transmitted frequency, v is the blood velocity, c is the speed of sound, and q is the angle between the sound beam and the direction of moving blood. The equation can be rearranged to solve for blood velocity, and this is the value calculated by the Doppler US machine:

(Burns PN. 1995).

$$V = \frac{Dfc}{2f\cos q}$$

The angle of insonation q is estimated by the sonographer by aligning an indicator on the duplex image along the longitudinal axis of the vessel, a process known as angle correction (Fig 16).

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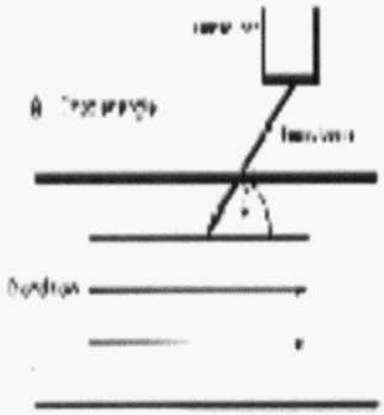

Fig (15) *Velocity of moving blood, and the angle between the sound beam and direction of moving blood*

(Wells PNT 1995).

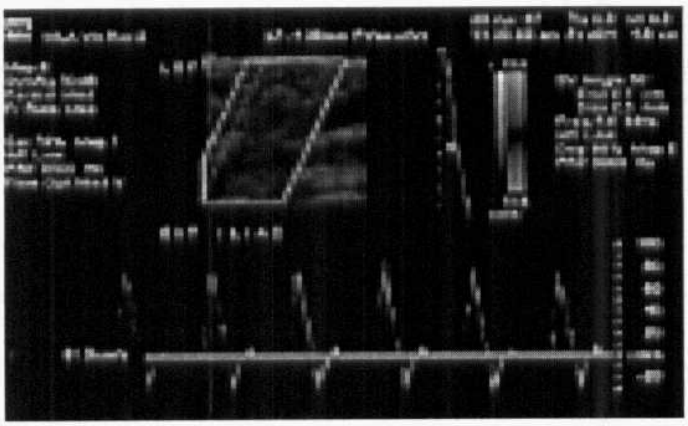

Fig (16) *Angle correction*

(Wells PNT 1995).

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Observing the Doppler equation yields several points that are relevant to the performance of a Doppler examination. First, since the cosine of 90° is zero, if the ultrasound beam is perpendicular to the direction of blood flow, there will be no Doppler shift and a potentially incorrect impression of no flow in the vessel. Second, it is evident that appropriate estimation of the angle of insonation, or angle correction, is essential for the accurate determination of Doppler shift and blood flow velocity. The angle of insonation should also be less than 60° at all times, since the cosine, function has a steeper curve above this angle, and errors in angle correction are therefore magnified ***(Burns PN. 1995a).***

There are several forms of depiction of blood flow in medical Doppler imaging: color Doppler, pulsed Doppler, and power Doppler. Color Doppler US provides an estimate of the mean velocity of flow within a vessel by color coding the information and displaying it superimposed on the gray-scale image (Fig 17).

The flow direction is arbitrarily assigned the color red or blue, indicating flow toward or away from the transducer, respectively. Pulsed Doppler allows a sampling volume (or gate) to be positioned in a vessel visualized on the gray-scale image, and displays a spectrum, or graph, of the full range (as opposed to the mean velocity, as in color Doppler US) of blood velocities within the gate plotted as a function of time. The amplitude of the signal is approximately proportional to the number of red blood cells and is indicated as a shade of gray (Fig 18) ***(Burns PN. 1995a).***

Color Doppler provides a global depiction of blood flow in a region and may be used as a guide for the subsequent placement of the pulsed Doppler gate for

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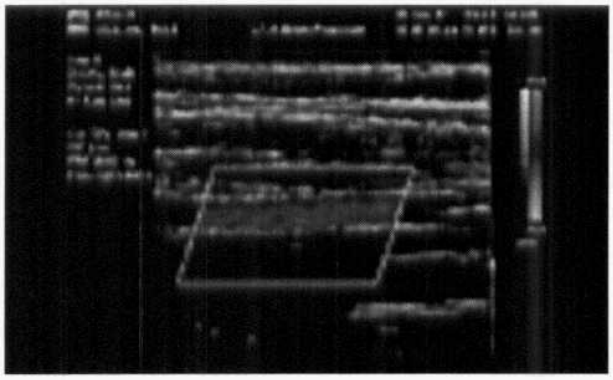

Fig (17) *Color coding the information and displaying it*

(Burns PN. 1995a).

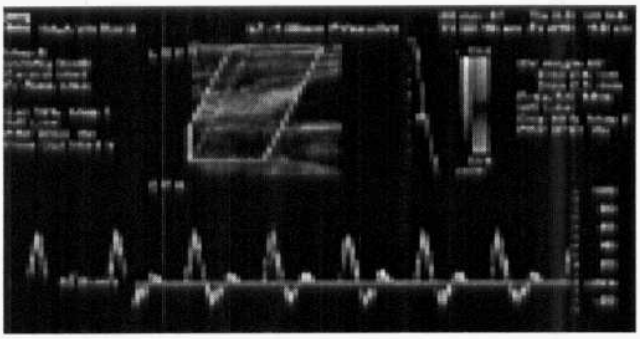

Fig (18) *The normal signal amplitude*

(Burns PN. 1995a).

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detailed analysis at a site of potential flow abnormality. Power Doppler, which is not routinely used in arterial Doppler evaluation of the lower extremity, depicts the amplitude, or power, of Doppler signals rather than the frequency shift. This allows detection of a larger range of Doppler shifts and thus better visualization of small vessels, but at the expense of directional and velocity information.

(Burns PN 1995a)

Artifacts

A detailed overview of Doppler artifacts is beyond the scope of this article, but several artifacts are particularly important for the performance and interpretation of an arterial Doppler examination. Aliasing is an artifact due to an insufficient sampling rate and occurs when the frequency shift to be measured is more than twice the pulse repetition frequency (Nyquist frequency) (Fig 19).

The artifact results in a wraparound of the Doppler spectrum in pulsed or color Doppler US. Aliasing at pulsed Doppler appears as a "folding over" of forward flow in systole in the reverse direction. Aliasing at color Doppler US may manifest as a mixture of colors or as a focus of color in the vessel corresponding to a continuum of colors folded over from the normal flow in the opposite direction within the vessel (Fig 20)

(Burns PN 1995b).

Since aliasing is due to a high-frequency shift or inadequate sampling rate or both, it may be a marker for sites of high-velocity flow, and is therefore a useful artifact for detection of stenosis. During mapping of the arteries with color Doppler US, if a region of aliasing is encountered, it should prompt a more detailed analysis with pulsed

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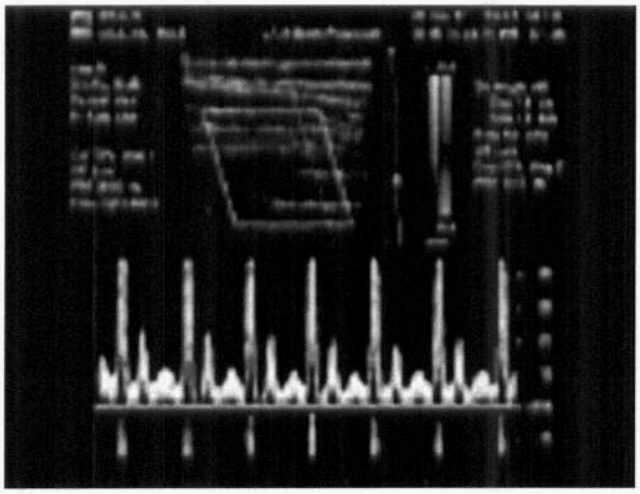

Fig (19) *insufficient sampling rate*

(Burns PN 1995b).

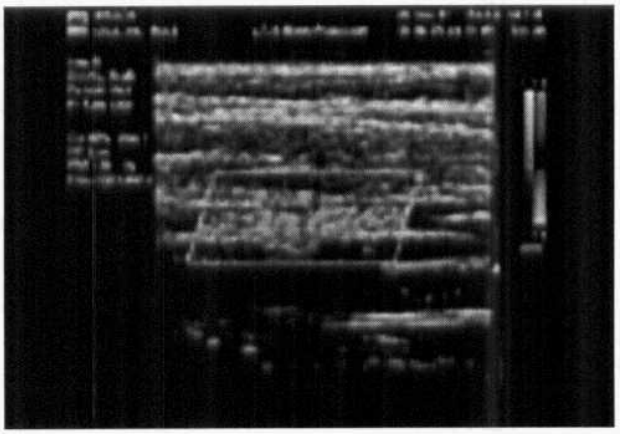

Fig (20) *Colors folded over from the normal flow*

(Burns PN 1995b).

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Doppler to see if an elevated peak systolic velocity ratio is present. Aliasing can be reduced by increasing the pulse repetition frequency or using a lower-frequency transducer, thus decreasing the Doppler shift (Fig 21). ***(Burns PN 1995b)***

Another artifact is "bleeding" of color signal from a vessel into an adjacent area without flow, potentially masking the presence of thrombus or vessel narrowing. This artifact is due to an inappropriately high setting of the color gain. It is important to emphasize the importance of the Doppler angle in interpreting the examination. If the ultrasound beam is perpendicular to the vessel, there may be a spurious impression of no flow (occlusion), or the flow direction may appear to be bidirectional, like a mirror image (Fig 22). This latter artifact is known as the spectral mirror image artifact and is due to the divergence of the Doppler beam in two directions along the long axis of the vessel ***(Burns PN 1995b)***

Finally, it is important to emphasize that the accuracy of angle correction is essential, as inappropriate estimates can result in spurious velocity determinations and potential misdiagnoses (Fig 23) ***(Burns PN 1995b)***

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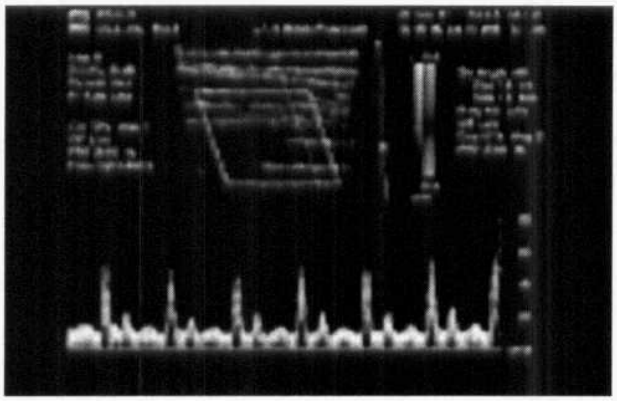
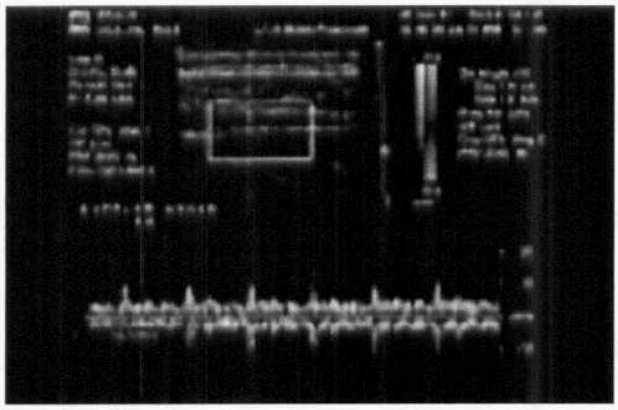


Fig (21) increasing the pulse repetition frequency Reducing Aliasing. ***(Burns PN 1995b)***



Fig(22)spectral mirror image artifact (bidirectional)

(Burns PN 1995b)

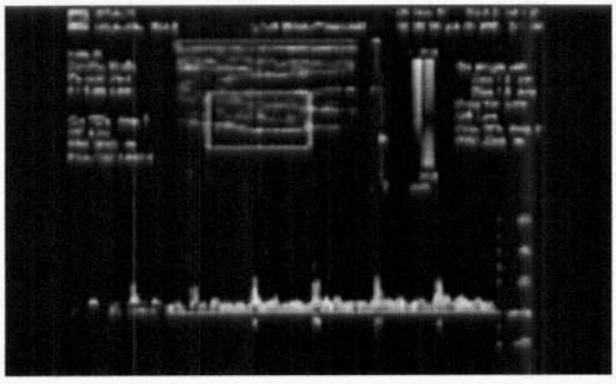


Fig (23) misdiagnoses due to incorrect angle

(Burns PN 1995b)

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Normal Doppler Studies

A normal color Doppler study is characterized by the absence of any hemodynamically significant focal velocity increases and a triphasic or biphasic waveform shape throughout all arterial segments ***(Fig 24).***

Normal peak systolic velocities in the femoral and popliteal arteries vary from 90 to 110 cm/sec in the femoral artery and from 40 to 70 cm/sec in the popliteal artery. The PSV ratio normalizes for this physiologic variation.

(Polak JF 1995).

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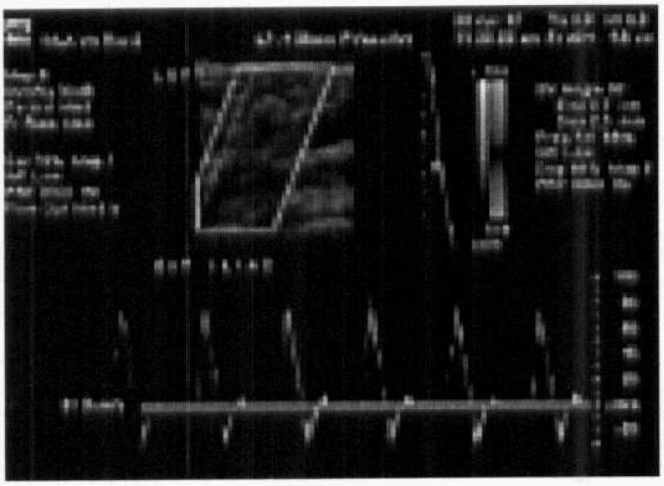

(Fig 24) normal color Doppler study

Polak JF (1995).

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Doppler Diagnosis of Arterial Stenosis and Occlusions

If the lumen of an artery is narrowed, the blood flow velocity increases within the stenosis, as described by the principle of continuity of flow (see the Hemodynamic section) (Fig 25). The principal Doppler criterion for the diagnosis of a lower-extremity arterial stenosis is therefore based on detection of a focal increase in peak systolic velocity (PSV) with pulsed Doppler (Fig 26). Detection of a hemodynamically significant focal increase in PSV involves the ratio of the PSV within the suspected narrowed segment to the PSV in the immediately proximal, nonstenosed portion of the artery.

A ratio of greater than (2) is the criterion for a hemodynamically significant (50% or greater) stenosis, and a ratio of (3.7-4) indicates a (70%) or greater stenosis. **(Polak JF 1995)**

Because of the large variation in velocities within the lower-extremity arteries, depending on location, the use of absolute velocity is less accurate than the PSV ratio, which normalizes for this variability. ***(Burns PN 1995a)***

The examination of the lower-extremity arterial system is performed by using color Doppler US to map the vessels and identify sites of possible stenosis, manifest as aliasing or narrowing of the vessel diameter, although the latter feature is often unreliable. Any site of suspected stenosis at color Doppler US is then interrogated with pulsed Doppler, which provides a spectrum within and proximal to the possible lesion, allowing

(Landwehr P1995b)

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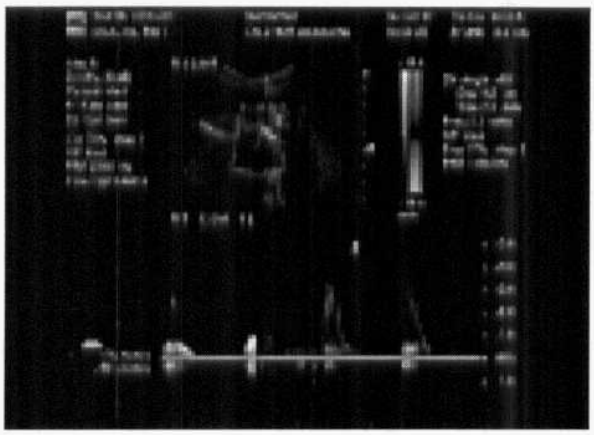

Fig. (25): blood flow velocity increases within the stenosis

(Polak JF 1995b)

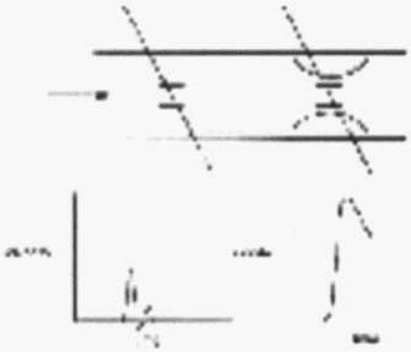

Fig (26) focal increase in peak systolic velocity (PSV) with pulsed Doppler.

(Landwehr P 1995)

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computation of a PSV ratio (***Fig 27***). The use of color Doppler US in conjunction with pulsed Doppler, or color-assisted duplex US, markedly reduces the examination time, generally allowing both legs to be imaged in 30-45 minutes. In addition to the change in velocity due to hemodynamically significant lesions, the contour of the pulsed Doppler waveform is affected by their presence. A normal, resting lower-extremity arterial waveform demonstrates high resistance, having a triphasic form with a rapid acceleration to and deceleration from peak systole, a brief reversal of flow in early diastole, and a small antegrade flow component in mid-diastole (Fig 28). Although the precise relationship between waveform contour alteration and lesion type and location is not well established, certain generalizations can be made. The spectral waveform changes within and immediately distal to a stenosis; in addition to increased PSV, it indicates disturbance of laminar flow and a decrease in pulsatility and loss of the reversed flow component. This disturbance of laminar flow may manifest as spectral broadening, turbulence, and, in severe stenosis, simultaneous forward and reverse flow and indistinctness of the spectral margin (Fig 29). The appearance of the waveform proximal to a lesion is variable and depends on the degree of collateral circulation formation. The waveform may be normal or the systolic velocity may be low but the upstroke (systolic acceleration time and slope) unaffected and pulsatility increased, with absent, reduced, or reversed flow in diastole(Wells PNT 1995)

With an acute occlusion, ineffectual pulsations may be transmitted to the occlusion, producing narrow, low-velocity Doppler signals that do

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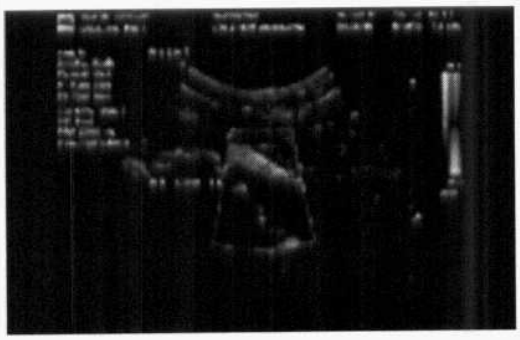

Fig (27) spectrum within and proximal to the possible lesion

(Wells PNT 1995)

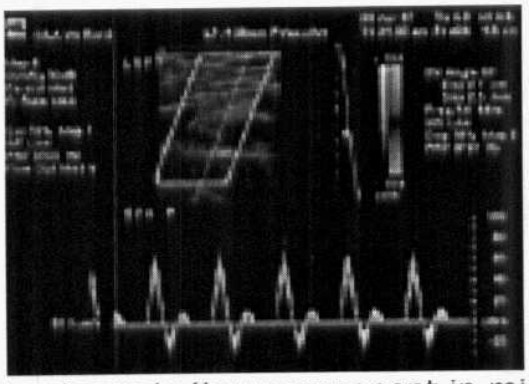

Fig (28) small antegrade flow component in mid-diastole

(Wells PNT 1995)

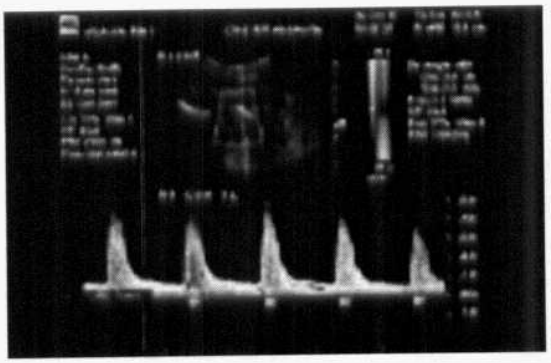

Fig (29) spectral broadening, turbulence, and, in severe stenoses

(Wells PNT 1995)

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Not represent true flow (Fig 30). The waveform shape distal to an obstructing lesion often shows a low-resistance pattern, with loss of flow reversal in diastole and abundant antegrade flow in diastole (Fig 31). The waveform distal to a lesion may also have a delayed systolic upstroke and decreased peak systolic velocity and is sometimes referred to as a " tardus and parvus" waveform (Fig 32).

The decrease in pulsatility is probably due to a combination of factors including ***(Polak JF et al.1990)***

(*a*) Decreased peripheral resistance due to ischemia.

(*b*) Resistance to the reversed flow component related to the stenosis,

(*c*) High level of forward flow throughout the cardiac cycle due to the pressure gradient across the stenosis, and

(*d*) Dampening of the pressure wave with consequent reduction of pulse pressure, resulting in less wave reflection and amplification, which normally contribute to the reversed flow component in diastole.

These waveform contour changes are not the primary diagnostic criteria for arterial lesions but are adjunctive and complementary to the PSV changes. Turbulence is always present within and distal to a stenosis and generally extends a few centimeters downstream. The development of an abnormal waveform contour does indicate the presence of a lesion, but it does not accurately indicate the location of the lesion. Distal to a hemodynamically significant lesion, the waveform often remains low resistance throughout the remainder of the extremity (Fig 33). Waveform abnormalities can probably also be detected at varying distances proximal to a lesion. The conversion from a normal to an abnormal waveform when imaging down an artery either means that an intervening lesion was not detected with velocity criteria or that there is a lesion distal to the point of waveform conversion.

(Allard L 1994)

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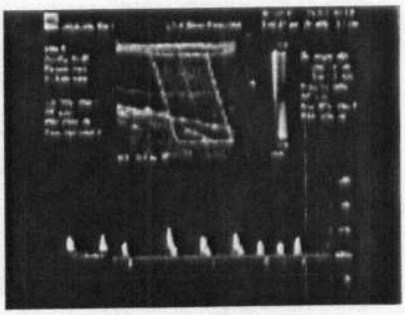


Fig (30) acute occlusion producing narrow, low- velocity ***(Polak JF et al.1990)***

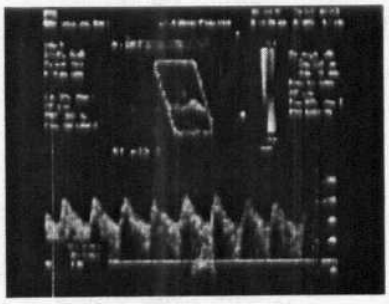
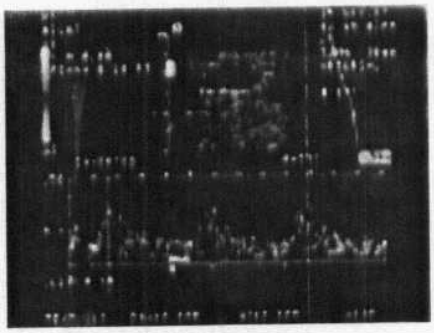


Fig (31) distal to an obstructing lesion ***(Polak JF et al.1990)***



Fig(32) tardus and parvus" waveform

(Allard L 1994)

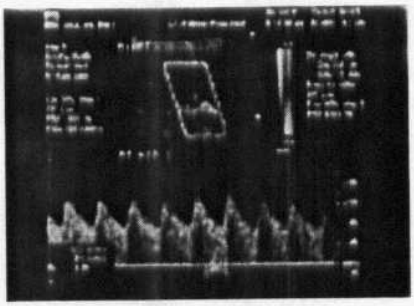


Fig (33) Distal to a hemodynamically significant lesion

(Allard L 1994)

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Doppler diagnosis of an occlusion is fairly straightforward and consists of the absence of color Doppler and pulsed Doppler detectable flow in an arterial segment (Fig 34). It is important to ensure that the lack of detectable flow is not due to technical factors. The Doppler gain should be set at a high level, but short of causing artifacts, and the pulse repetition frequency should be set low enough to allow detection of low-velocity signal from a subtotal occlusion. The settings for low-flow detection can be normalized in a given patient by confirming detection of venous flow **(Carter SA 1993).**

Other potential sources of false-positive examinations include

(*a*) inability to detect Doppler signals deep in the thigh, such as in the adductor canal region;

(*b*) densely shadowing calcified plaque preventing detection of Doppler signal;

(*c*) external compression of the vessel .

(*d*) severe stenosis with very slow flow, below the threshold of detection with the Doppler instrument. A false-negative diagnosis can be due to mistaking high-velocity small arterial collateral vessels parallel to the occluded segment for a patent, stenosed artery. ***(Burns PN. 1995b)***

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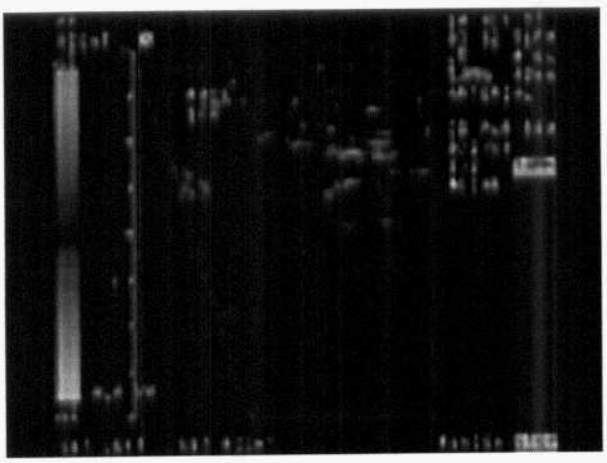

Fig (34) absence of color Doppler *(Burns PN. 1995b)*

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INTRODUCTION TO ANGIOGRAPHY

Indications

Angiography include diagnosis of primary vascular disease, diagnosis and localization of small vascular tumors, preoperative definition of vascular anatomy, diagnosis and treatment of vascular complications of disease or surgery, Percutaneous vascular interventional procedures.

(Snopek and Saunders. 1999).

Contraindications

Include medically unstable patients with multi-system dysfunction, recent myocardial infarction, serious arrhythmia, electrolyte imbalance, serious past contrast reaction, impaired renal status, coagulopathies, inability to lie flat on the table due to congestive heart failure, respiratory pathology, residual barium from previous study, and pregnancy.

(Saadoon Kadir and Decker 1991).

Equipment Considerations

General

Angiography rooms or suites are specially adapted so that they can be used for minor surgery as well as for angiography procedures. In many cases they are located near standard operating arenas in case of an emergency during a special procedure. Patients are often more unstable or need more

monitoring equipment during special studies because of potential complications from the procedure itself.

(Irwin et al 1990).

Exposure Factors

70 KVp is appropriate for cerebral, thoracic, and abdominal angiography. Lower KVp can be used for peripheral angiography. Higher KVp (85) may be needed for lateral abdominal radiography. Using the shortest possible exposure time will reduce motion blur on the images. Short exposure times require higher mA stations. Technologists have to be able to calculate tube loading to avoid overloading the x-ray tubes.

Carbon fiber table tops are suggested for digital angiograph. Tables need to "floal" and "step" during procedures. Other helpful features include variable height for ease in getting patients on/off the table and for magnification. The ability to tilt or oblique the table may be useful during some procedures.

(Snopek and Sounders 1999).

Image Capture

Most of the useful information during angiography is observed in motion during the procedure itself, but frequently documentation is necessary. Options include: rapid serial changers, magnetic recording devices, laser optical devices (videodisc), large-format serial spot film devices, cinefluorography, and digital image storage devices.

(Saadoon Kadir and Decker 1991).

Injectors

Automatic injectors deliver the contrast at a more reliable and consistent rate than possible with hand injection. In general, larger vessels (aorta) require higher pressure and higher rates of flow than smaller vessels (coronary arteries). In addition to the vessel size and flow rate, factors that influence the appropriate setting on an automatic injector include the viscosity of the contrast, catheter length, catheter diameter, and injection pressure. Automatic injectors include a device to heat the contrast to make it less viscous. The injector holds the syringe with the plunger end up during the power injection to reduce the likelihood of air being injected into the catheter. All connections must be airtight and the settings double-checked before the injection run is made. ***(Saadoon Kadir and Decker 1991).***

Subtraction Technique

Subtraction technique reduces the visibility of bone and other nonessential parts of an image and enhances the visibility of contrast material in an image. Subtraction images are actually images of the "differences" between two other similar images, one without any contrast material and one with contrast material.

Digital subtraction angiography (DSA) has made traditional subtraction techniques obsolete. But the basic principles of subtraction technique are still being used in some circumstances.

Film A is made before any contrast is injected. The patient can not move between this exposure and the rest of the series. Film B is made after contrast injection. Next make a "negative" of

Film A (radiopaque areas will now be dark, etc.) This negative is Film C and is called the "mask". Next superimpose Film C on Film B. The two images must be in perfect registration. If the patient moved between the two exposures, the non pertinent anatomy will not be "subtracted" on the final image.

Last, make a copy of Film C superimposed on Film B. This copy is called Film D. Film D will show all the surrounding soft tissue, bone, etc. only faintly and the contrast will be very prominently displayed. ***(Saadoon Kadir and Decker 1991).***

Digital Subtraction Angiography - DSA

DSA converts the analog data from the image intensifier and converts it into digital data that can be manipulated by the computer. DSA has several advantages over conventional angiography:

Imaging of low contrast structures is improved data can be stored for analysis and manipulation later information is processed quickly and reviewed without delay diluted contrast agents can be used

(Saadoon Kadir and Decker 1991).

Digital Subtraction Angiography can be performed more safely than regular angiography because a computer digitizes the image to generate images of contrast filled vessels even though less contrast material has been injected in the patient. This means that during intra-arterial injections significantly less contrast can be injected, and that arterial images can be obtained following venous injections.

Venous punctures and injections have fewer risks than arterial punctures and injections. Another advantage is the decrease in the number of films required because only the most informative images are processed.

Along with the usual angiographic equipment, DSA requires computer support, a high resolution image intensifier, and a high quality television monitor. Images of the anatomy before and after contrast enhancement of the vessels are stored, digitized, and subtracted from one another to produce real-time subtraction images.

Generally DSA patients need to be alert with reasonably good cardiac output and renal function. It is reserved for vessels and organs that can be isolated from superimposed structures (examples include carotid and vertebral arteries, extremity vessels, and major abdominal vessels.) Patients with diabetes mellitus, pulmonary hypertension, multiple myeloma, coronary artery disease, and poor renal function may be more safely studied with intraarterial DSA because the volume of contrast required is greatly reduced. ***(Snopek and Saunders 1999).***

Accessories and Supplies

Needles

Most needles used during angiography are common venipuncture needles (Angiocath). Needles with larger gauge numbers have smaller lumen. Specialized needles used during angiography and special studies include arterial puncture needles (Amplatz), long skinny needles (PTCA - Chiba), translumbar

aortography needles, and butterfly needles. Potts-Cournand and Seldinger are special needles used for venous or arterial puncture. The lumen of a needle may be filled with a blunt obturator or a sharp stylet to prevent tissue from accumulating in the lumen as the needle is pressed through the layers of the body to reach a vessel. ***(Saadoon Kadir and Decker 1991).***

Dilators

Dilators are made of a smoothly tapered Teflon material more durable and rigid than catheters.

They are inserted through the tissue into the vessel lumen over the guidewire. Dilators are the same size or slightly smaller than the size of the catheter which will be used to prevent excess peri-catheter bleeding. ***(Snopek and Saunders 1999).***

Guide-wires

Guide-wires are used to maintain access to the vascular system and to guide the catheter to the vessel of interest. Guide-wires have a stainless steel wire core with a tightly wound outer stainless steel wire wrap. The core can be fixed or movable. The tip is flexible to maneuver in sclerotic or tortuous vessels.

(Snopek and Saunders 1999).

Catheters

Catheters are long, hollow polyurethane tubes that fit inside vessels. Catheters with larger French numbers have larger lumen. Catheters permit better visualization of remote vessels while using relatively small amounts of contrast because the contrast does not

get diluted on its way to the vessel of interest. Catheters are slightly radio-opaque, and come in a variety of shapes to match the course of specific vessels. Some catheters can be custom shaped during a procedure. Catheters have single end holes or multiple side-holes. Some catheters are highly specialized with dilatation balloons or shaving devices for angioplasty.

(Snopek and Saunders 1999).

Contrast Materials

Angiography requires positive (radio-opaque) contrast (iodinated) to be injected into vessels. Other special studies may use negative (radiolucent) contrast (air) injected in to a body cavity. We would NOT inject air into a vessel.

Iodinated contrasts can be ionic or nonionic. Renografin is an example of an ionic contrast. Ionic contrasts are subdivided into those with high osmolality and those with low osmolality. Ionic contrasts are less expensive but cause more complications including patient discomfort during procedures. Nonionic contrasts are used in angiography to reduce the heat sensation and provide more comfort during injection. Nonionic contrast materials include Metrizamide (Sterling Winthrop), Iopamidol (Squibb), Iopromide (Berlex), and Iohexol (Sterling Winthrop).

(Snopek and Saunders 1999).

Some patients will "react" to an iodine contrast injection. Unfortunately, reactions are not predictable, so baseline vital signs and assessment are necessary and all contrast patients have to be monitored closely. Approximately 70% of reactions occur within 5

minutes of injection, 16% occur more than 5 minutes post-injection, and 14% occur more than 15 minutes post-injection.

Contrast reactions are considered adverse drug reactions and are sometimes described as "allergic reactions." Some of the symptoms are attributed to the hyperosmolality of the contrast agent and some are attributed to the chemotoxicity of the contrast. Reactions can be classified as 1) overdose reactions,2) anaphylactic reactions,3) cardiovascular reactions,4) psychogenic reactions, and 5) activation system-triggering reactions.

(Snopek and Saunders 1999).

Patient Prep for Angiography

Laboratory Results

Patients with BUN levels greater than 30 mg/dl and creatinine levels greater than 1.5 mg/dl may have poor renal function and may not be good candidates for contrast injection, because their kidneys could not "clear" the contrast from the bloodstream. PT, PTT, platelets, etc. are also checked.

Pre-angiographic Orders

No solid food 6 - 8 hours prior to procedure, to reduce risk of aspiration and to prevent overlapping gas shadows on abdominal films. Patient should be well-hydrated, IVs will be used if necessary, NPO only if general anesthesia is required atropine may be given to reduce vasovagal reactions. Diazepam (Valium) may be given to reduce anxiety. Aspirin may be given to reduce platelet adhesiveness .Shave and prep the groin or axilla.

Possibly discontinue anticoagulant therapy to reduce risk of excessive bleeding. ***(Irwin et al., 1990).***

Puncture Site Prep

Compare pulse strength on both sides of patient, both sides should be prepped in case of emergency mark pulse points distal to the puncture site for comparison after the procedure patient assessment for cold, shiny, hairless skin, obvious lesions, infections, etc.

(Irwn et al., 1990).

Locate puncture site

shave if necessary using warm, soapy water

clean with povidone solution in circular pattern, inside to outside, do not retrace path

clean with alcohol in circular pattern, inside to outside, do not retrace path

drape patient with sterile vignette drapes, extra layers in expected wet areas

cover puncture site with sterile towel

The Angiography Procedure - What Happens?

Needle in vessel (single wall vs. double wall puncture)

Stylet or obturator out

Blood return

Guidewire in through needle lumen

Needle slipped off guidewire

Dilator in to separate tissue

Guidewire advanced to location for injection

Guide wire position verified with fluoro-Catheter slipped over guide wire

Catheter advanced to location for injection

Catheter position verified with fluoro

Guide wire removed from lumen of catheter

Catheter position verified with fluoro

Test contrast injection

Contrast injection with filming

Preliminary evaluation of images

Catheter removed while pressure is applied to the puncture site

(Irwin et al., 1990).

Pressure on puncture site

Percutaneous puncture sites include femoral, axillary, brachial, carotid, and Translumbar. The femoral approach is used most often, with anti-coagulant solution immediately before they are used and every 1-2 minutes while they are in the body.

Filming during an arteriogram shows progressive filling of the arteries, then capillaries, then veins.

The arterial phase requires the fastest filming rate because blood flow is most rapid during this phase.

After the procedure, some references suggest using a gloved hand for compression without any gauze so that any bleeding will be immediately obvious. The middle finger should be over the puncture site, the other fingers should press along the course of the vessel. Compression should be hard enough to stop bleeding

from the puncture site, but not hard enough to close peripheral vessels ***(Brown and Company 1987).***

Compression is usually maintained for 10 minutes without lifting the fingers, but this is variable depending on patient coagulation, size of puncture site, longevity of the procedure, amount of manipulation of the catheters, etc. Protamine sulfate may be injected after the procedure if prolonged bleeding at the puncture site is a problem. Never release compression suddenly. If re-bleeding occurs, recompress for 20 additional minutes. After compression, a dab of antibiotic ointment and a plain Band-Aid should be applied over the puncture site. Heavy dressings could mask re-bleeding after the procedure.

(Brown and Company 1987).

Post Angiography Procedure Care

Retroperitoneal and external hematoma formation is possible. Fluoroscopy or overhead radiography of the bladder following the procedure documents renal function and may reveal displacement from pelvic hematoma.

After the procedure, the following should be checked:

Puncture site for signs of bleeding, internal hematoma, infection

Every 30 minutes for four hours

Every hour for four hours

If groin hematoma does form, trace it with unwashable ink to track its enlargement compare blood pressure and distal pulses with pre-procedure measurements

Patient ability to void - may need urinary catheterization

The patient should be on bed rest for 8 hours following the procedure. Patient must keep the punctured leg straight. Log rolls are acceptable. The patient may resume a normal diet and follow previous orders. It is important for the patient to rehydrate after the contrast injection. ***(Brown and Company 1987).***

Technique of lower limb arteriography

- Puncture and catheterization of the lower limb can be performed by:

[1] Retrograde femoral artery approach:

- Percutaneous retrograde transfemoral catheterization is the common method for evaluating the aorta and lower extremity, arteries.

[2] Antegrade Femoral Artery Approach:

- Has gained popularity with the increased performance of femoral, popliteal and infra popliteal interventions.

[3] Axillary or Brachial Artery Approach:

When both femoral pulse are absent

Less common approaches:

[4] Graft punctures approach.

[5] Translumbar approach .

[6] Direct popliteal approach.

[7] Trans-Venous Approach:

Through the basilic vein or through the internal jugular or common femoral veins can be chosen for intravenous digital subtraction angiography. Now replaced by direct arterial access with smaller-diameter catheters ***(Polak J. F. 1997b).***

Technique of lower limb arteriography:-

- Femoral arteriography is usually performed by puncturing the common femoral artery if it is palpable using the seldinger's technique as demonstrated in the following sequences:-

    - The artery is palpated to select the site of puncture before local anesthetic is injected. Various anatomical descriptions are given regarding the site at which to puncture, best place is usually the point where the artery crosses the pubic bone it is also the easiest point at which to achieve haemostasis afterwards. After local anesthesia, a small scalpel incision is made in the skin. A pair of fine artery forceps is inserted into the incision and used to create a tunnel through the subcutaneous tissues down to the artery.

This maneuver is particularly important in large or obese patients, for it not only facilitates catheterization but it reduces the risk of a post-puncture haematoma.

The artery is felt with the middle and index fingers at one hand and insert the needle (held in the other hand) between the two palpating fingers, the needle is held angled forwards and passed right through the artery the centeral stylet is then withdrawn Fig (35). The needle angled slightly more towards the horizontal and withdrawn at even rate, assisted by gentle rotatory movements to avoid any sudden jerking. When the tip of the needle is safely in the arterial lumen, there will be a free, spurting back flow of blood from the hub. While the needle is held steady

with one hand, the soft tip of a guide wire is threaded through the needle into the artery Fig (36).. When sufficient length of wire is inside, the needle is removed and firm manual pressure maintained on the puncture site until the needle is exchanged for a catheter of dilator, the guide wire is removed when the tip of catheter is in a satisfactory position Fig (37). and catheter is then flushed free of blood with heparinized saline.

Contrast medium is injected by pump or hand over 3-4 seconds is normally adequate for femoral arteriogram, but if a lower aortic injection is being made through a catheter, a pump injection of nearly double contrast over 4-5 seconds will be necessary (smaller volumes of contrast is needed when using Digital Subtraction Angiography (D.S.A). ***(Modic et al., 1983).***

It is often very important for the vessels of the whole extremity to be visualized and if moving top table or moving stand is not available, multiple injections may be necessary for this purpose. The timing of the radiographic exposure is important and will often need to be tailored to the individual case, to allow for the considerable variations in flow that exist in different patient with arterial disease. ***(Modic, et al., 1983).***

Many vascular surgeons prefer the radiologist to avoid puncturing the femoral artery at a point that may shortly be the site of vascular graft or other surgical procedure, in such cases and in those where the femoral artery is not palpable or information about more proximal vessels is also sought, a catheter study from the opposite leg to show the aorta, iliac vessels and both lower

extremities is preferable, through intravenous digital subtraction angiography may give the necessary information in many cases.

Where both femoral arteries are impalpable, a Translumbar aortogram or catheter study using an axillary or brachial approach can be performed if intravenous D.S.A is unavailable or inadequate for the purpose. ***(Dawson P., 1988).***

It is important to obtain plain radiographs of the limb before injecting contrast medium, as any calcifications present in the arteries may be invisible on the post injection films. Failure to demonstrate calcified areas can preliminary films in this way may lead to serious errors of interpretation as such areas can be mistaken for contrast medium on the injected study.

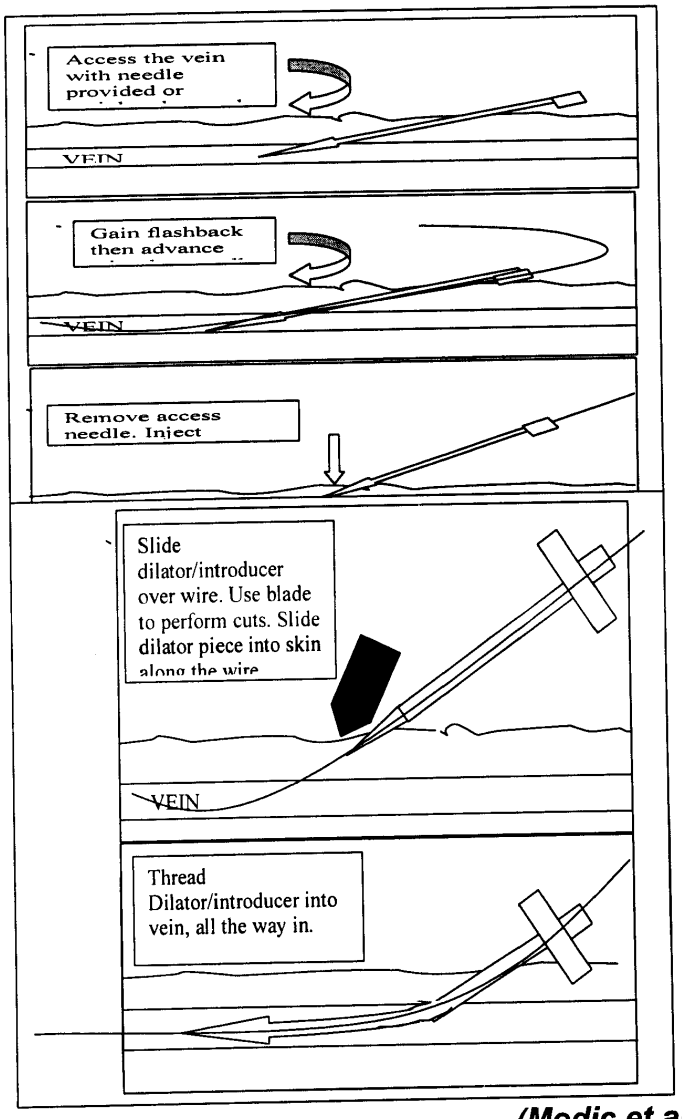

Fig (35): ***(Modic et al., 1983).***

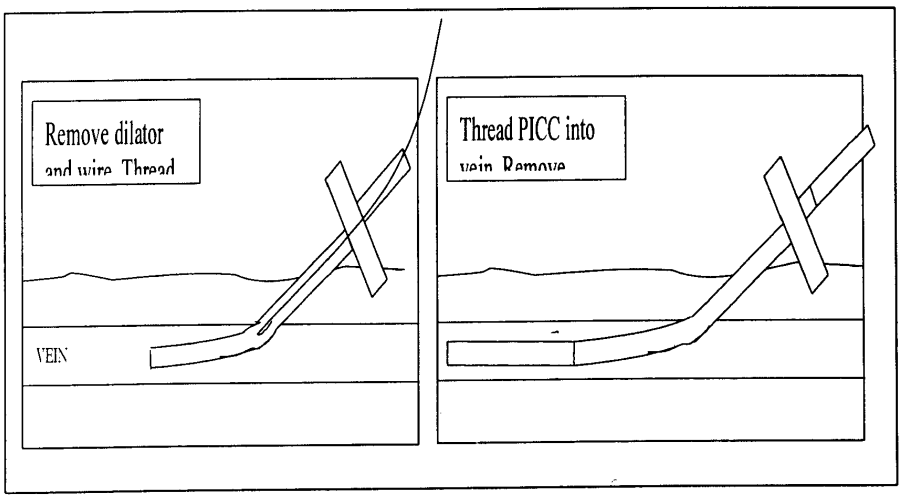

Fig (36).

(Modic et al., 1983).

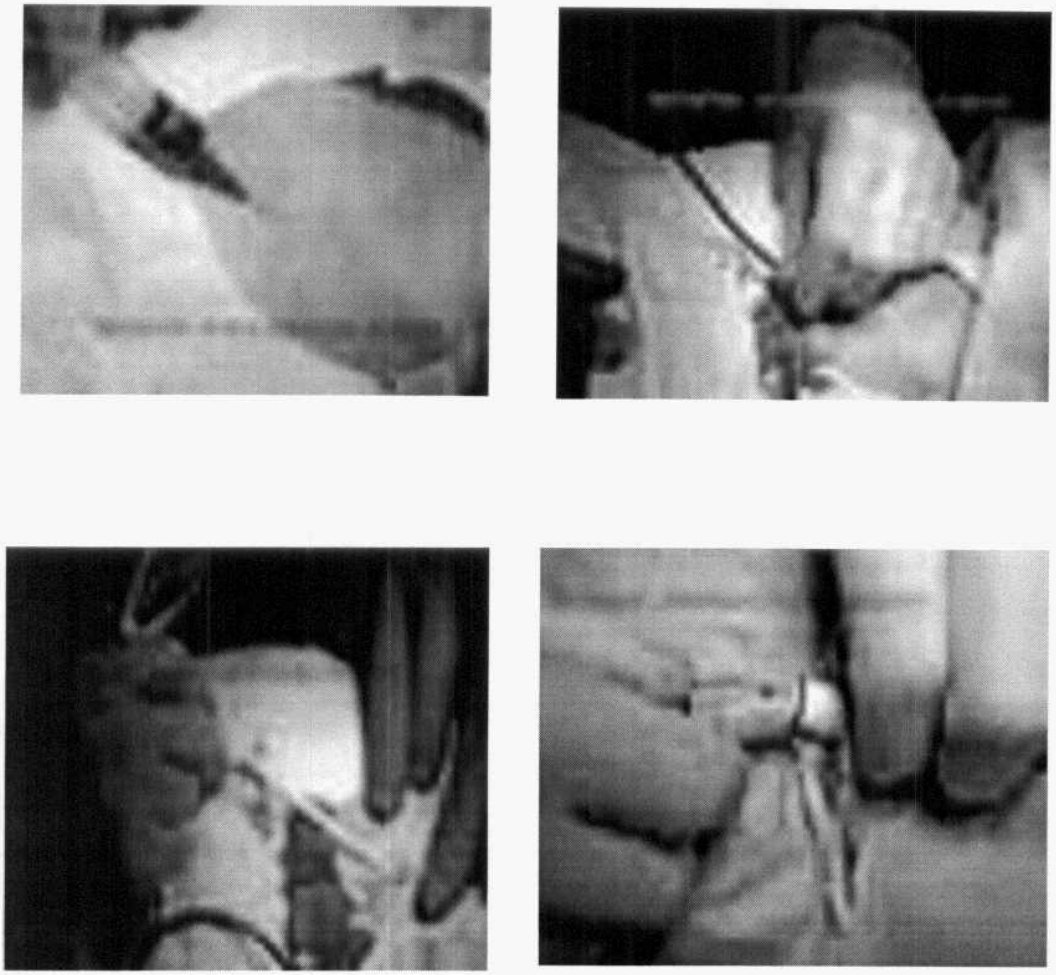

Fig (37):

(Modic et al., 1983).

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Specific Complications of Angiography

Adverse Reaction to Contrast Material

More thorough discussion of patient reactions to contrast materials is found elsewhere in your resources. The combination of poor hydration and impending or renal failure will complicate a patient's response to contrast materials. Using DSA to reduce the amount of contrast needed, using nonionic contrast materials, and hydrating patients before the procedure will all reduce the contrast reaction complications from an angiographic procedure.

Hematoma Formation

Hematoma formation at the puncture site is the most common complication. It is usually caused by inadequate post-procedure compression. Multiple traumatic punctures, large diameter catheters, prolonged or excessive catheter manipulation, or perforation of a retroperitoneal artery also causes it. While they may be unsightly and painful, they are usually self-limiting. Serious complications include inability to stop bleeding, compression of adjacent nerves, bladder or trachea displacement. Protamine sulfate, vitamin K, and plasma are used to encourage clotting. ***(Snopek and Saunders 1999).***

Absent Distal Pulse

Arterial spasm or thrombus may cause the pulse to disappear at or distal to the puncture site.

Diseased vessels or damaged intimas may occlude following the procedure. Distal pulses and limb response are vital to

determine if the distal limb is receiving sufficient blood supply, or if surgical intervention is necessary.

Vessel Wall Dissection

Vessel wall dissection will occur when the catheter is not fully in the lumen of the vessel or if the jet from the catheter tip damages the wall during injection. Using specially designed catheters and vessels with large lumen (aorta) for high pressure injections reduces the likelihood of these complications.

Embolus

Platelet aggregates adhere to the surface of a foreign body such as a catheter, resulting in a thrombus. This accelerates the formation of thromboplastin, thrombin, and eventually a fibrin network, which incorporates RBC to form a complete thrombus. The thrombus may dislodge with the catheter in place or be stripped off as the catheter is withdrawn. The dislodged thrombus travels with the blood as an embolus and becomes lodged in a distal site (usually a site with a narrow lumen.) Embolization can be reduced with expeditious procedures, regular catheter flushes, avoidance of arterial trauma and spasm, and avoidance of wedging the catheter tip position. Patients may be systematically anti-coagulated or the external catheter surface can be treated with a thrombo-resistant material. If the procedure takes more than one hour, the major effects of heparin will have diminished. Emboli can also be created by air, dislodged particles of atheromatus plaque or cholesterol, or foreign bodies.

(Saadoon Kadir and Decker 1991).

Infection

Medullary Shock

- happens during aortic injections
- caused by low blood flow rate (congestive heart failure, Valsalva, hypotension, etc.)
- contrast pools and flood spinal branches of intercostals and lumbar arteries
- Uncontrolled, painful, spastic contractions of the lower extremities, which last minutes to hours
- relieved by IV injection of Valium
- must monitor vital signs

Other Complications at Puncture Site

- False aneurysm
- AV fistula
- Retroperitoneal hematoma

Complications from Translumbar Approach

- Perinephric abscess
- Pneumothorax, hemothorax, chylothorax
- Periaortic hematomas
- contrast reactions

(Snopek and Saunders 1999).

Guidewire Complications

- Punch biopsy of the vessel wall if the fit between the guidewire and the catheter is too loose.
- The flexible tip can be pulled off the guidewire if the fit between the guidewire and the catheter is too tight.

- Flaking or stripping of the Teflon coating.
- Ventricular Fibrillation
- due to improper electrical grounding

(Snopek and Saunders 1999).

Material and Methods

A symptomatic 20 patients with lower limbs ischemia who were admitted to Sayed Galal Hospital. They had not previously undergone surgical revascularization of the lower limbs.

They were examined (whole lower limb) first by color doppler ultrasound followed by digital subtraction angiography.

- Below knee region (The scope of study) divided into the following segments:
- Distal popliteal artery segment.
- Tibio-peroneal trunk segment.
- Proximal, mid, and distal anterior tibial artery segments.
- Proximal, mid, and distal posterior tibial artery segments.
- Peroneal artery.
- Dorsalis pedis artery.

- All vascular ultrasonographic examination was done with:

1. Philips SD 800 apparatus
2. Esaote Biomedica AU 3 apparatus.

- A.7.5 MHz linear array transducer was utilized for vessels of the lower limb study.

- Examination was performed with the patients in supine position with external rotation to get the best delineation of the leg arteries.

- On scanning popliteal, tibio-peroneal trunk and proximal posterior tibial arteries, they were best visualized with the patients in prone position.

- Each segment was imaged transversely to size the colored flow in the lumen with respect to the arterial walls for assessment of lumen diameter, and longitudinally by gray scale for measurement of arterial wall thickness, presence of calcification, atheromatus plaques, thrombus and to determine the site of stenosis.

Then use color flow imaging measurement of peak systolic velocity (P.S.V.) from Doppler spectrum.

Relative narrowing of the lumen if present was graded as percentage of lumen narrowing.

The grade of stenosis was based on determination of peak systolic velocity at the stenosis compared with measurements of peak systolic velocity in the arterial segment proximal to the stenosis.

Occlusions were diagnosed when no flow was demonstrated despite the attempts to maximize sensitivity to show flow, by increasing Doppler gain, decreasing scale and increasing sample volume.

- ***Arteriography was performed by:***

AXIOM Artis MP, SIEMENS MEDICAL SYSTEMS, ERLANGEN, GERMANY, 2001.

- Non-ionic contrast media, Iopromid (ultravist) was used with the varied dose according to the situation ranging between 50 – 100 ml.

- In all patients, arteriography was done in frontal plane.

- 16- Patients underwent right direct femoral arteriography.

- 4- Patients underwent left direct femoral arteriography.

- Vasodilator was given to the patient before examination to role out arterial spasm

- **the segments being examined by both techniques were classified into**

Group (A) 50 % stenosis.

Group (B) 50 % - 70 % stenosis .

Group (C) 70 % - 99 % stenosis.

Group (D) Total occlusion

Results were tabulated and analyzed by gross table the sensitivity of the color doppler were calculated.

Case (No. 1)

CLINICAL PRESENTATION;

A diabetic female patient 60 years old, Complaining of claudication pain at both lower limbs more marked on right side.

History of left big toe amputation.

On examination:

- Trophic changes are noted at both legs with loss of hair and pallor.
- Absent PTA, ATA, and D.PA pulsations at right lower limb.

Below knee Color Doppler, study of right lower limb:

- **Distal popliteal artery:** shows No significant abnormality.
- ***A.T.A.:***

- Weak color flow pattern with monophasic waveform pattern, indicating proximal obstruction or high-grade stenosis.

- ***P.T.A.:***

- No color flow or spectral waveform could be detected along the entire coarse of the artery.

- ***Peroneal:***

- Difficult to examined.

- ***Dorsalis pedis:*** ;

Patent with attenuated flow.

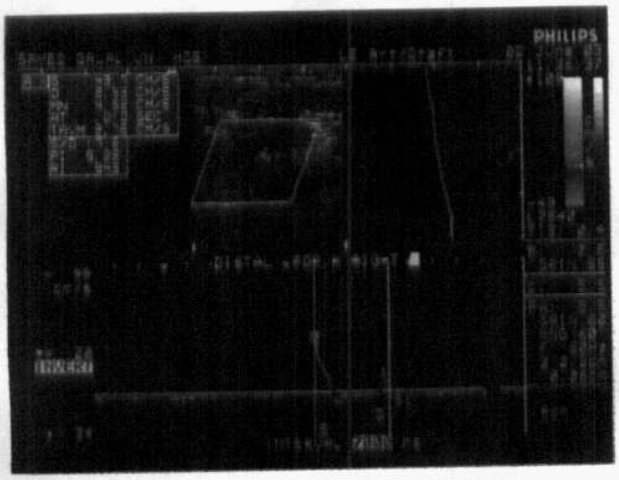
- **Arteriographic study revealed:**

It concides with the color Doppler study with additional information's in term of:

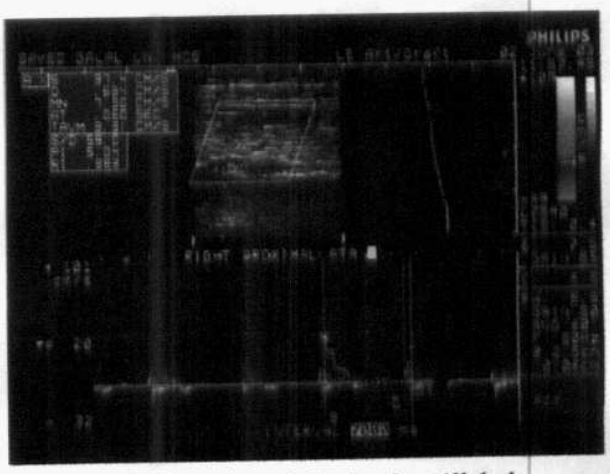
- Severe attenuation at stem of trifurcation of popliteal artery, which could not be demonstrated on Color Doppler study.
- Patent uppermost extent of posterior tibial trunk with marked narrowing of its lumen and markedly attenuated flow.

Case (No1)

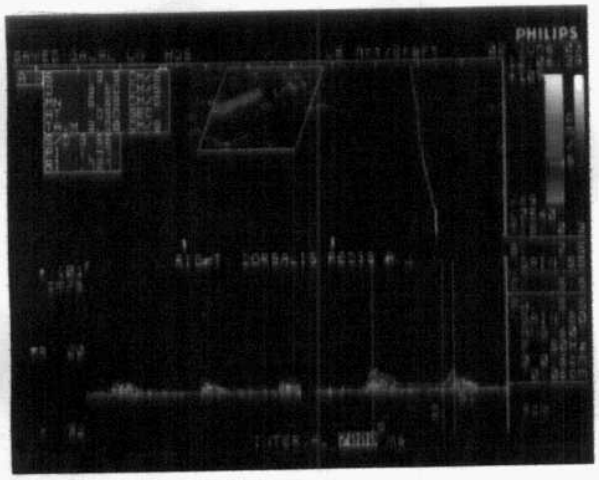
Below knee Color Doppler, study of right lower limb:



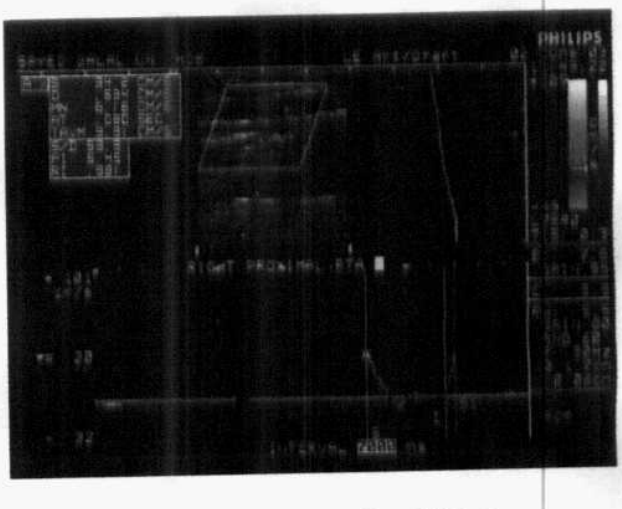
a) Popliteal Artery P.S.V.



b) Proximal Anterior tibial Artery P.S.V.



c) Dorsalis pedis artery PSV.



d) Proximal posterior tibial artery

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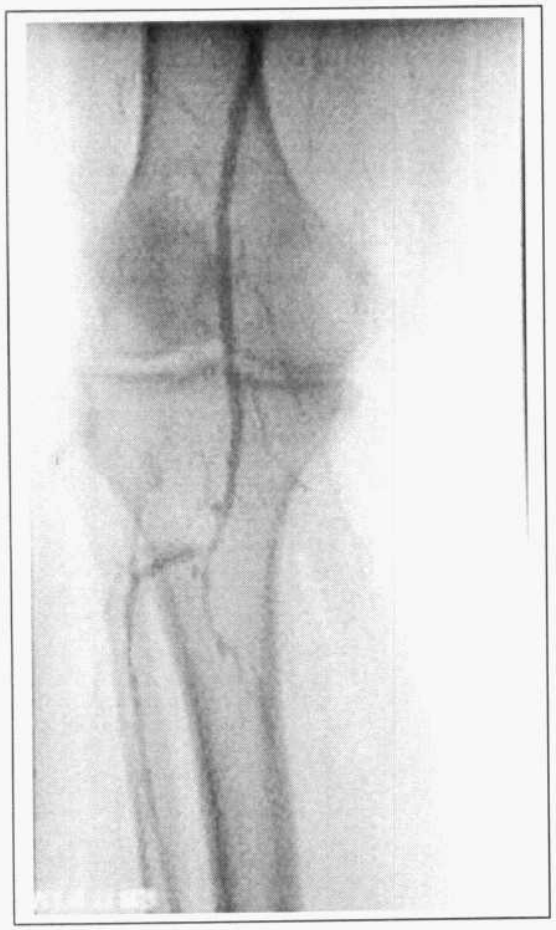
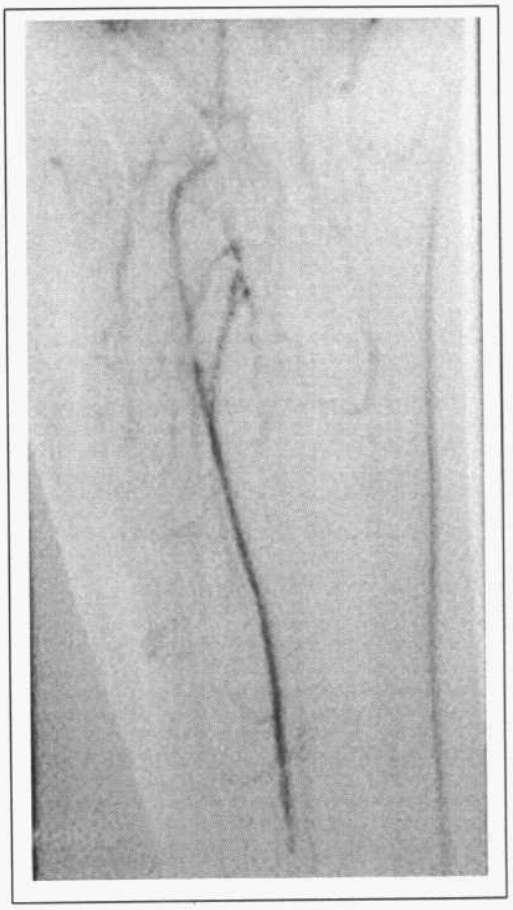
Arteriographic study revealed



a) POP. A. and its trifurcation



b) Opacified A.T.A

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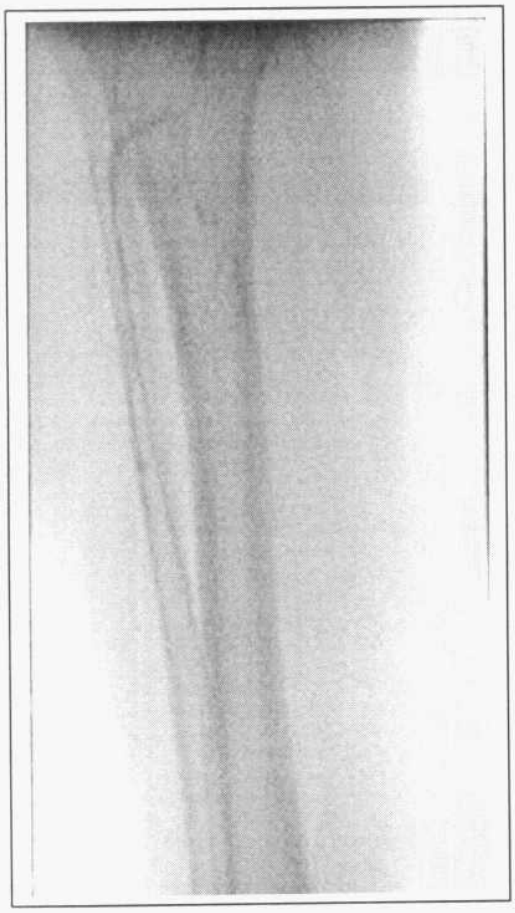
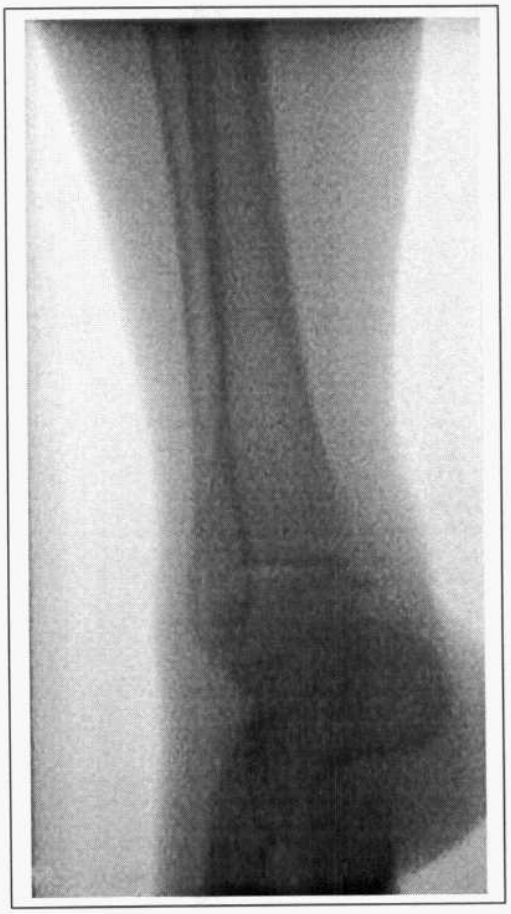


c) Opacified A.T.A
Absent PTA. & peroneal



d) Opacified A.T.A
Absent PTA. & peroneal

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Case(No. 2)

Female patient 55 years old.

Complaining of claudication pain at left lower limb.

On examination:

- Trophic changes of left lower limb with loss of hair and pallor.
- Absent, PTA, ATA and D.P arteries pulsation.

Below knee *Color Doppler*, study of left lower limb:

- ***Distal popliteal artery***: shows no significant abnormality.
- **A.T.A.:**

- Proximal, middle and distal segments are patent with damped waveform, indicating obstruction or high-grade stenosis at its uppermost extent..
- ***P.T.A.:*** ;
- Proximal, middle and distal segments show no color flow or spectral waveform.

- **Peroneal:**

- No color flow or spectral waveform could be noted .
- ***Dorsalis pedis:*** ;

Patent with diminished blood flow velocities

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- **Arteriographic study revealed:**
- ***It concides with the color Doppler study with additional information in term of;***

- High grade stenosis of the uppermost extent of the anterior tibial artery.
- Severe attenuation of proximal posterior tibial (75% - 99%).
- Severe attenuation of peroneal (75%-99%).

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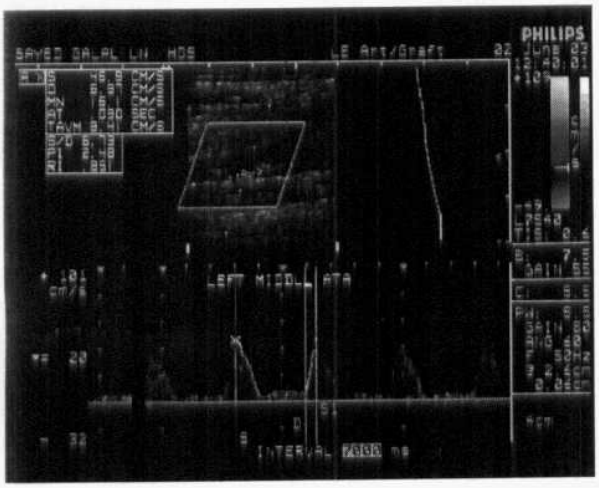
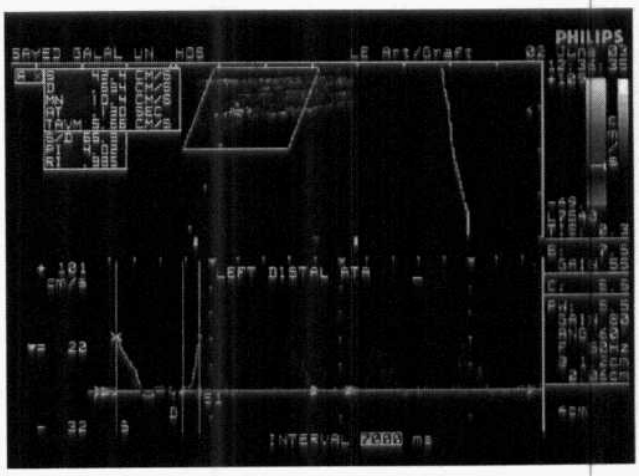
Case (No. 2)

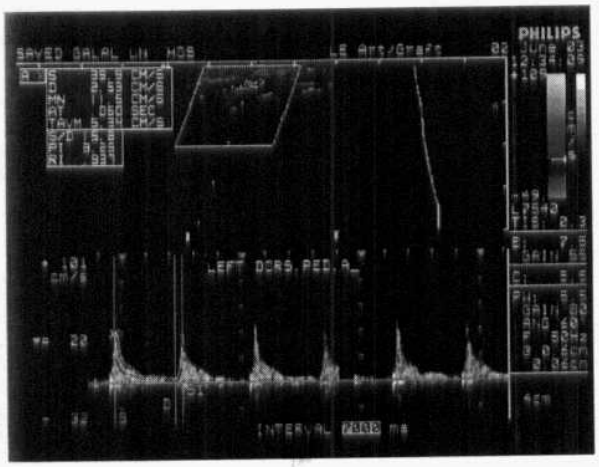
Below knee Color Doppler, study of left lower limb:



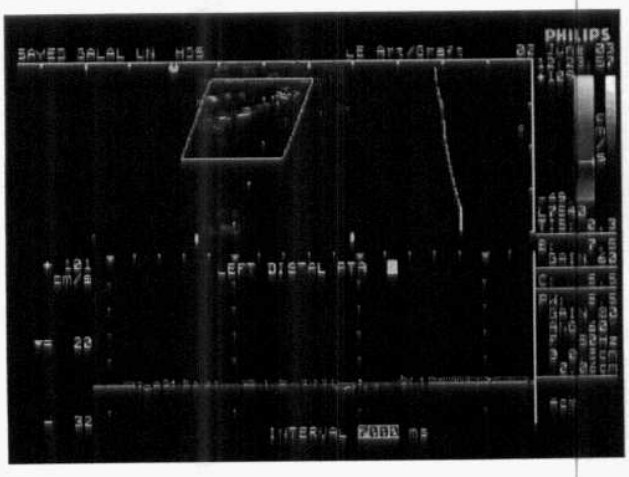
a) Middle ATA



b) Distal ATA



c) Dorsalis pedis



d) Distal PTA

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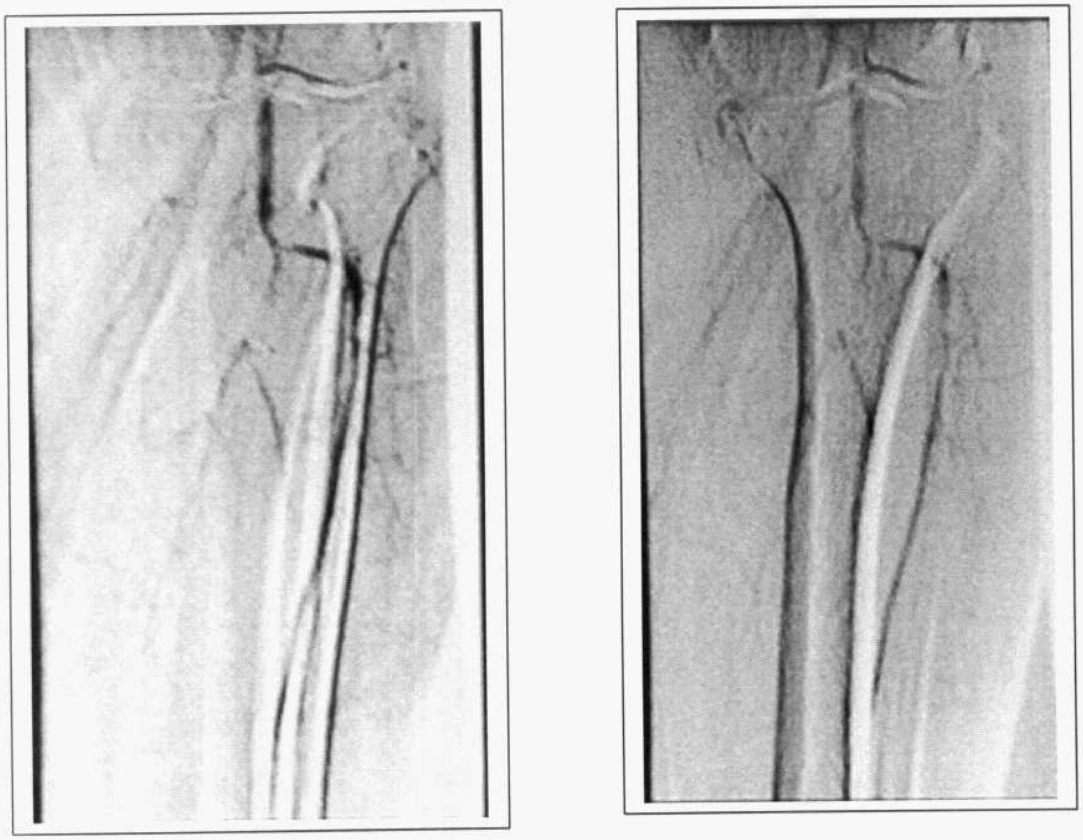
Arteriographic study revealed:



a) POP. A. and its trifurcation

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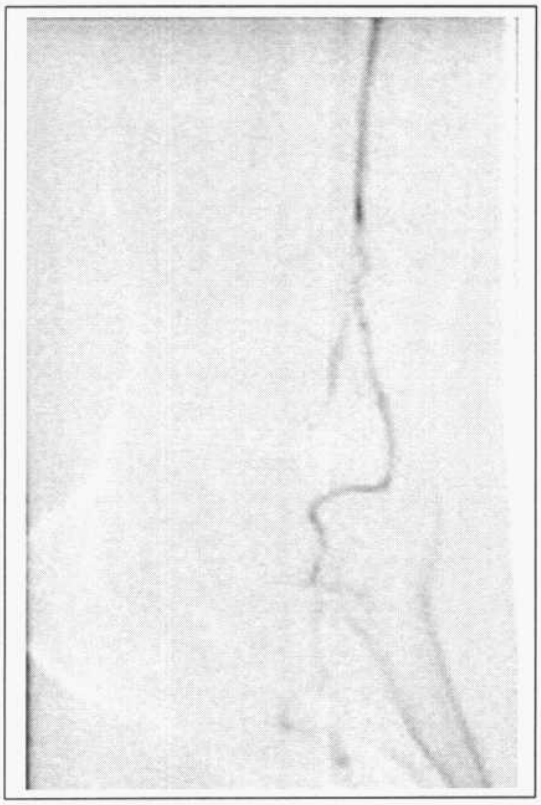

b) Distal ATA &DORSALIS

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Case (No. 3)

Male patient, 52 years old.

Complaining of ischemic manifestation in left lower limb.

on examination:

- Paller of left lower limb .
- Absent, PTA, ATA, and D.P arteries pulsations of left lower limb.

Below knee Color Doppler, study Left lower limb:

Distal popliteal artery shows no color flow or spectral waveform.

A.T.A.:

- Markedly diminished color flow is noted along its proximal portion with damped waveform pattern and markedly diminished blood flow velocities. There is no color flow or spectral waveform could be detected at its middle and distal segments.

P.T. AND PERONEAL ARTERIES:

- No flow could be detected along the course of the artery.

Dorsalis pedis:

- Diminished color flow velocity with biphasic waveform.

- **Arteriographic study revealed:**

It concides with the color Doppler study:

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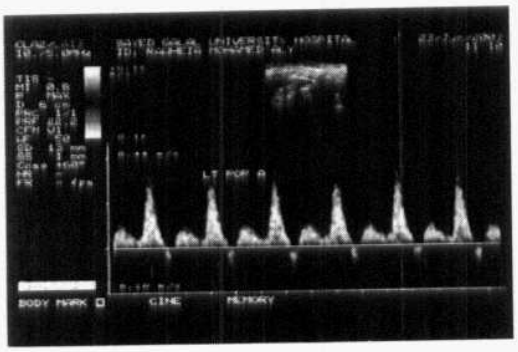
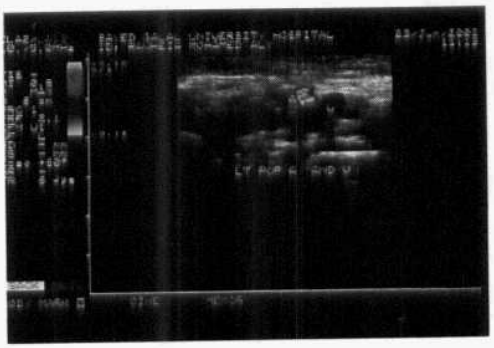
Case No. 3

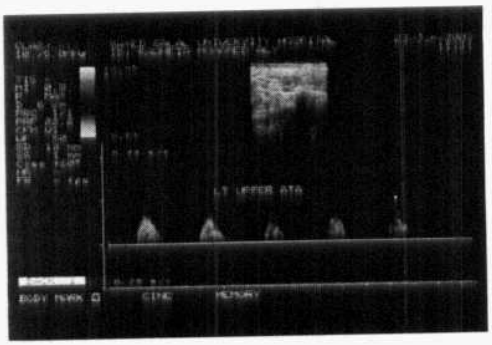
Below knee Color Doppler, study Left lower limb:



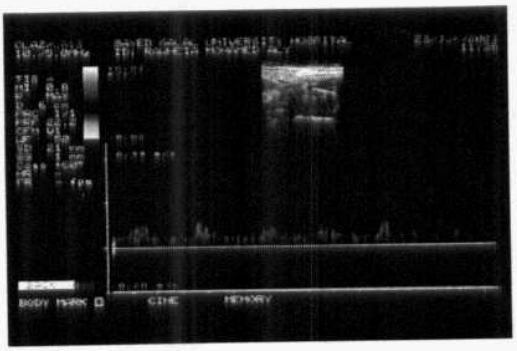
a) Popliteal artery



b) Popliteal artery occlusion



c) ATA biphasic



d) PTA biphasic

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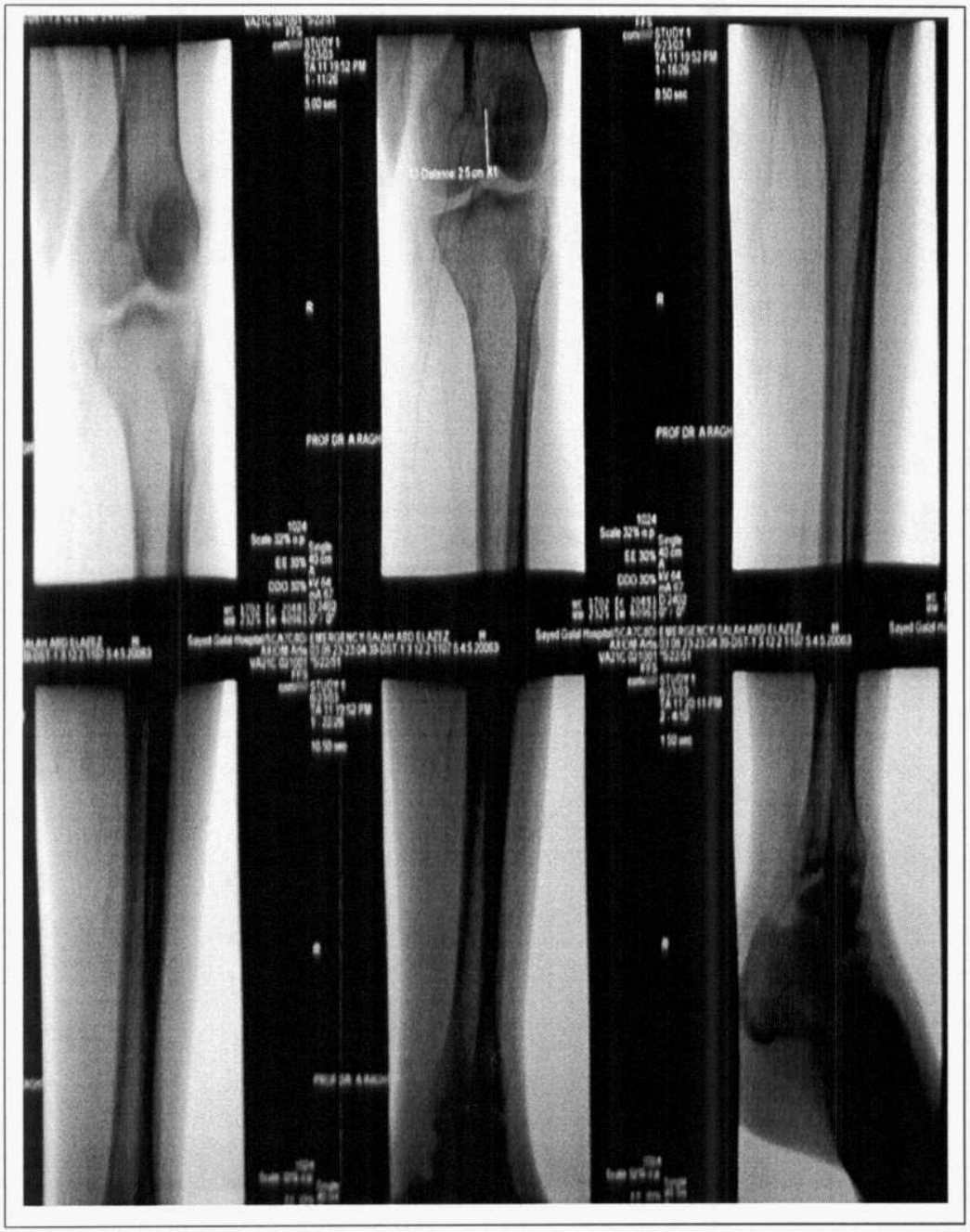
Arteriographic study revealed:



A) Occlusion POP. Artery

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Case (NO. 4)

A male patient, 55 years old.

Complaining of claudication pain in left lower limb.

on examination:

- Trophic changes of left lower limb, loss of hair, paller.
- Absent, PTA, ATA, D.P pulsation of left lower limb.

Below knee *Color Doppler study of* Left, lower limb:

- **Distal popliteal artery** shows no significant abnormality.

- **A.T.A.:**

- Average color flow is noted, however, biphasic waveform is obtained .This might be related to arteriosclerosis or mild to moderate stenosis at its origin.

- **P.T.A.:**

- Shows week color flow with biphasic waveform pattern and diminished blood flow velocities, suggestive of its marked stenosis with arteriosclerotic changes.

- **Peroneal A.:**

Diminished color flow with diminished blood flow velocities.

- **Arteriographic study revealed:**

- Irregularity of distal popliteal artery is seen however good contrast opacification is noted.

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- Anterior tibial artery shows multiple short segmental stenotic areas seen just distal to its origin and middle third with appreciable flow seen in the distal segment and continues as Dorsalis pedis artery.
- Peroneal artery shows good opacification of its proximal one third with absent flow at its distal tow thirds.
- Posterior tibial trunk is occluded with small segmental run off seen with attenuated flow noted in its distal third with week opacification of planter artery.

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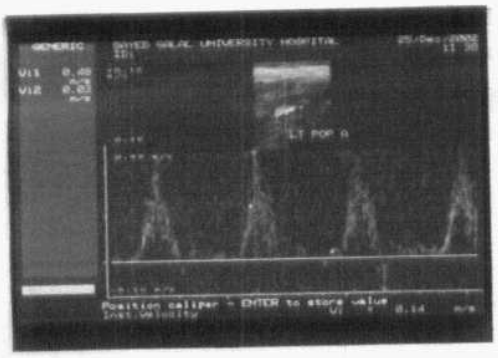
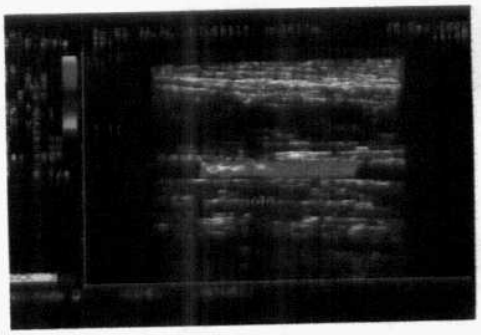
Case No. 4

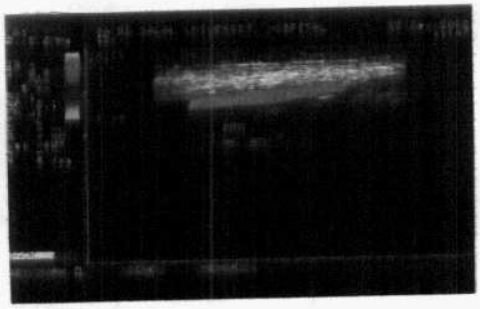
Below knee Color Doppler study of Left, lower limb:



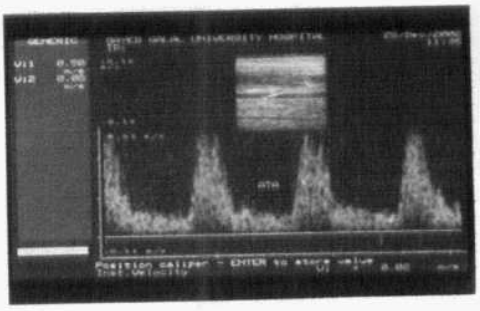
a) POP artery



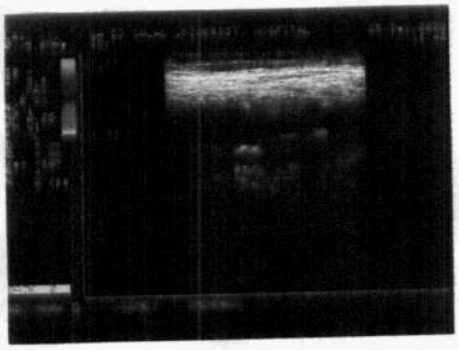
b) ATA color flow



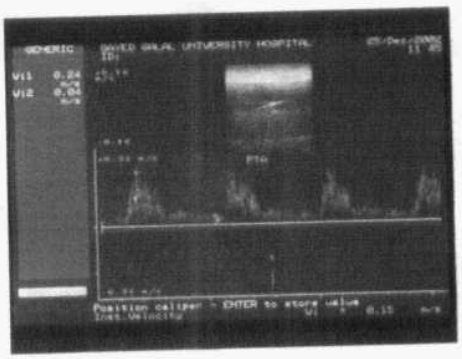
c) Dorsalis pedis color flow



d) ATA



e) PTA color flow



f) PTA biphasic

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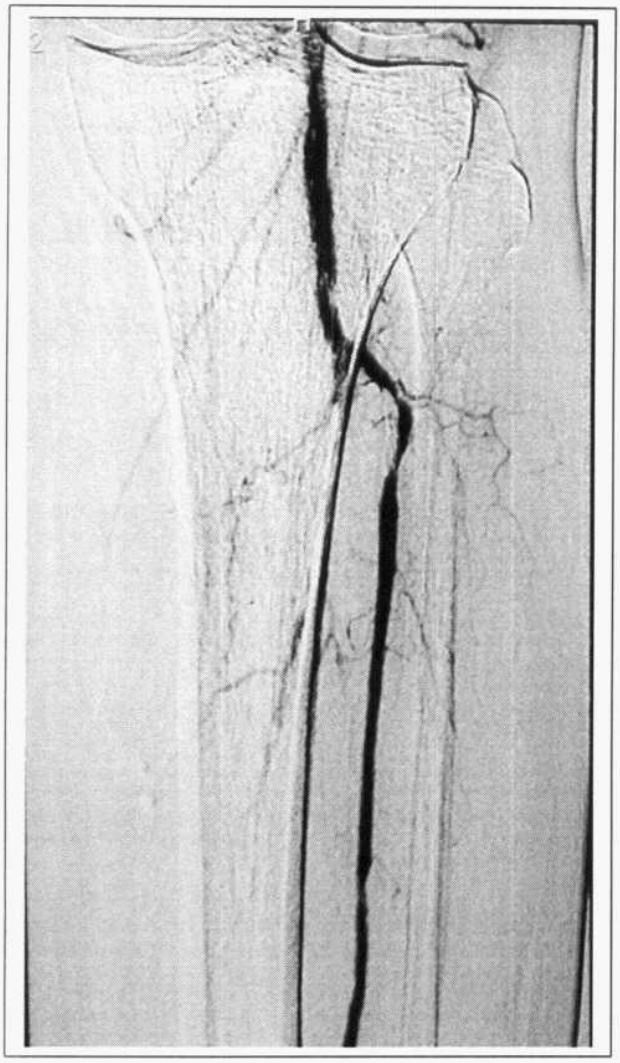
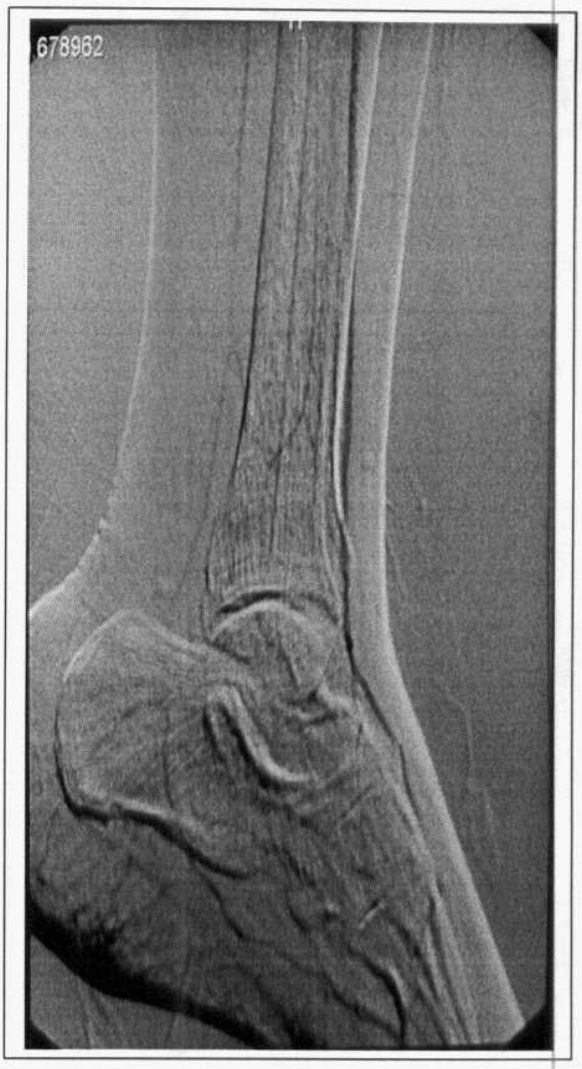
Arteriographic study revealed:





A) *Opacification of popliteal and tibial arteries*
B) ?

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Case 5

A male patient 45 years old.

Complaining of swelling at the upper part of left leg after trauma.

on examination:

- Pulsatile swelling at the upper part of left leg.
-Trophic changes of left lower limb, loss of hair and paller.
- Absent, PTA, ATA, D.PA pulsation of left lower limb.

Below knee *Color Doppler, study of left lower limb:*

GRAY SCALE

A well defined thin walled pulsatile cystic swelling is noted at the popliteal fossa .

COLOR FLOW

The swelling is presenting diffuse filling with blood with color aliasing. The swelling appears feeded from the popliteal artery and draining into the popliteal vein.

SPECTRAL ANALYSIS

Spectral aliasing is noted at the swelling; popliteal and, tibial veins and arteries.

These findings might be related to arterio-venous fistula.

- **Arteriographic study revealed:**

Aneurysmal sac was seen originating from popliteal artery at its posterior aspect with narrow neck and immediate filling of the popliteal veins during arterial phase with lobulated sac related to the venous side. these changes represents pseudo aneurysm of popliteal vessels with arteriovenous shunt.

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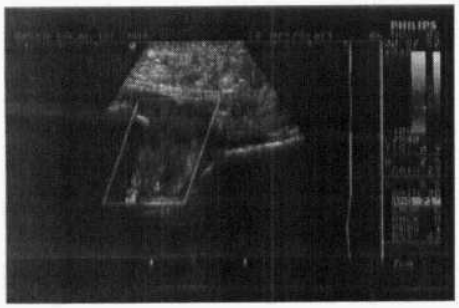
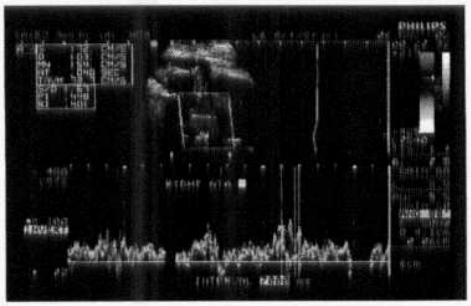
Case No. 5

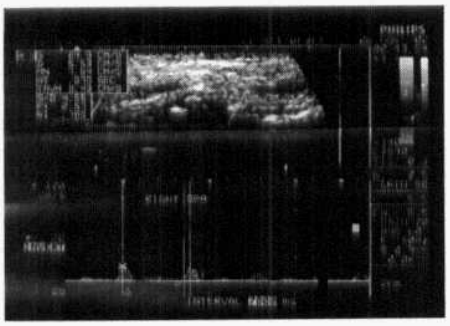
Below knee Color Doppler, study of left lower limb:



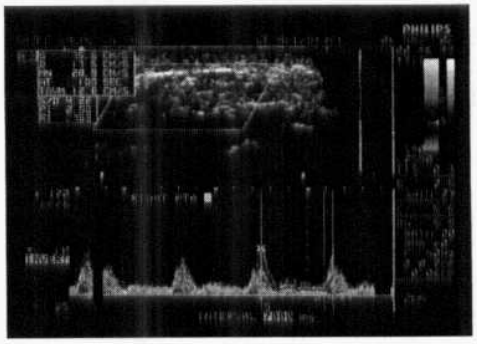
a) Aneurysmal sac



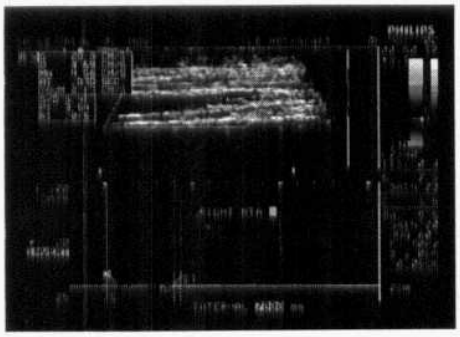
b) Proximal ATA



c) Distal ATA



d) PTA normal flow



f) Dorsalis pedis artery

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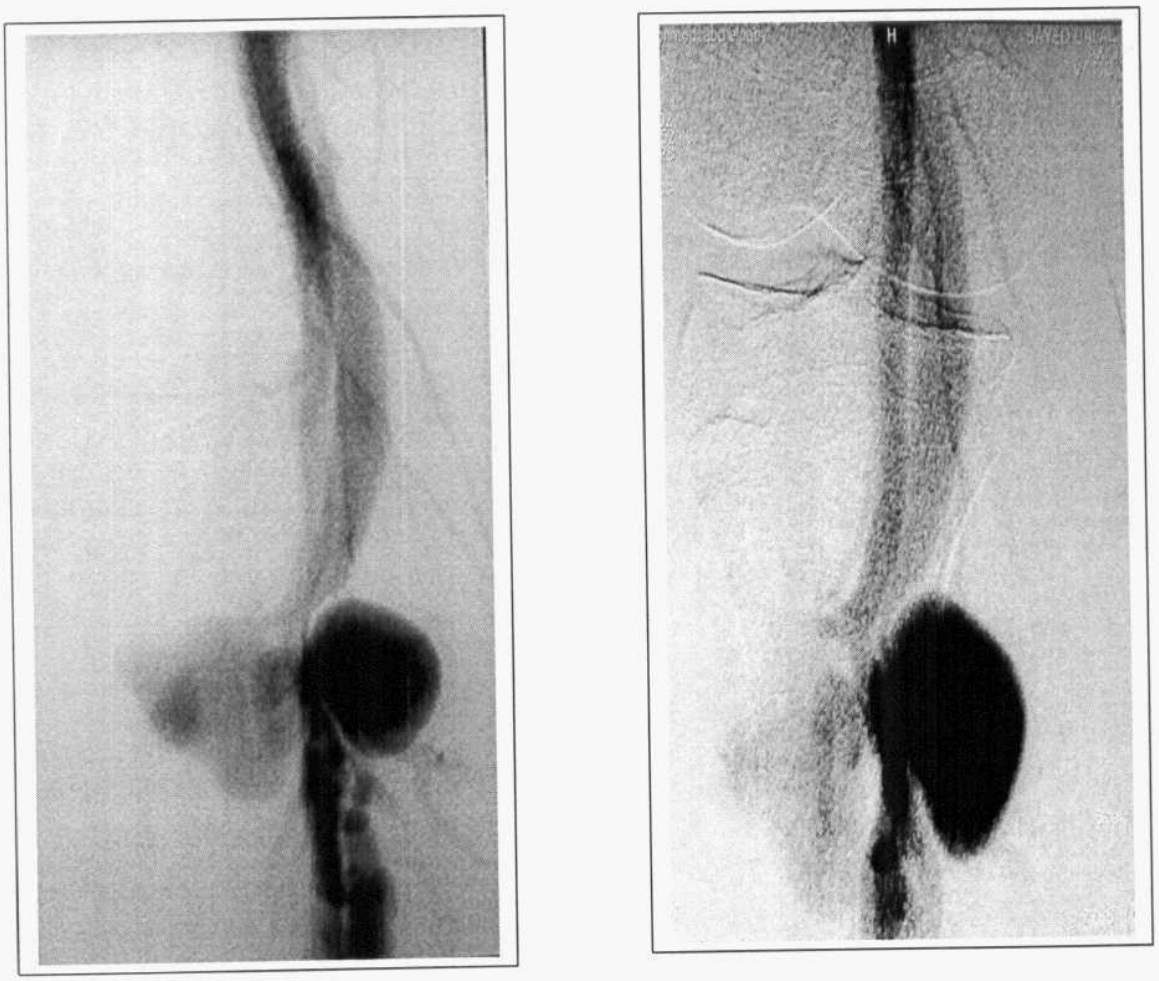

a) Aneurysm & Arterio venous fistula

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Case 6

Male patient 55 years old.

Complaining of recurrent cluodicaation pain in both lower limbs

Which Increase with walking in both sides of lower limbs.

There is history of diabetes.

RIGHT LOWER LIMB

on examination:

- Trophic changes, loss of hair and paller at left lower limb.
- Pulse was in PTA, ATA and D.P of both lower limbs.

Below knee *Color Doppler study of Right, lower limb:*

POP.A., A.T.A., P.T.A., Peroneal A., Dorsalis pedis A.:

shows diffuse arteriosclerosis with no evidence of stenosis or changes of spectral waveforms.

- **Arteriographic study revealed:**

It concides with the color Doppler study except:

- Saver stenosis of anterior tibial artery proximal and totally occluded middle and distal.
- Saver stenosis of posterior tibial artery; proximal and middle segments.
- Dorsalis pedis artery refilling from planter arch.

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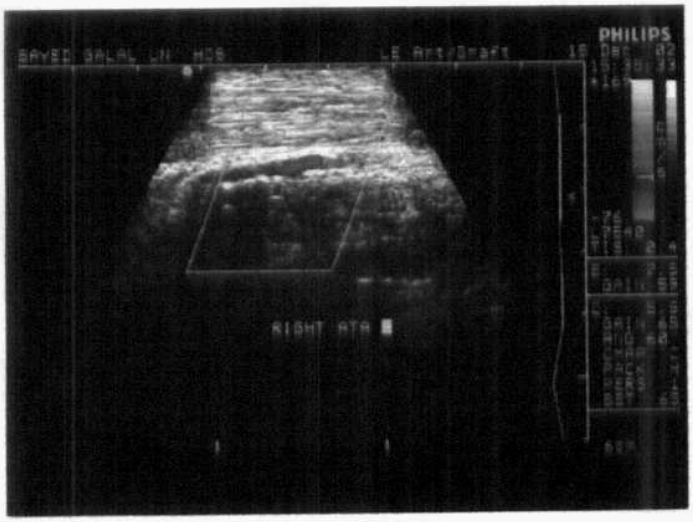
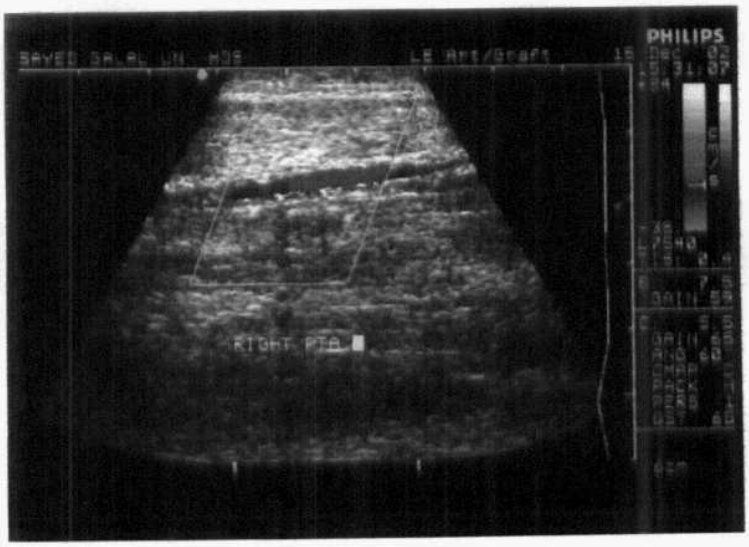
Case No. 6

Below knee Color Doppler study of Right, lower limb:



a) ATA color flow



b) PTA color flow

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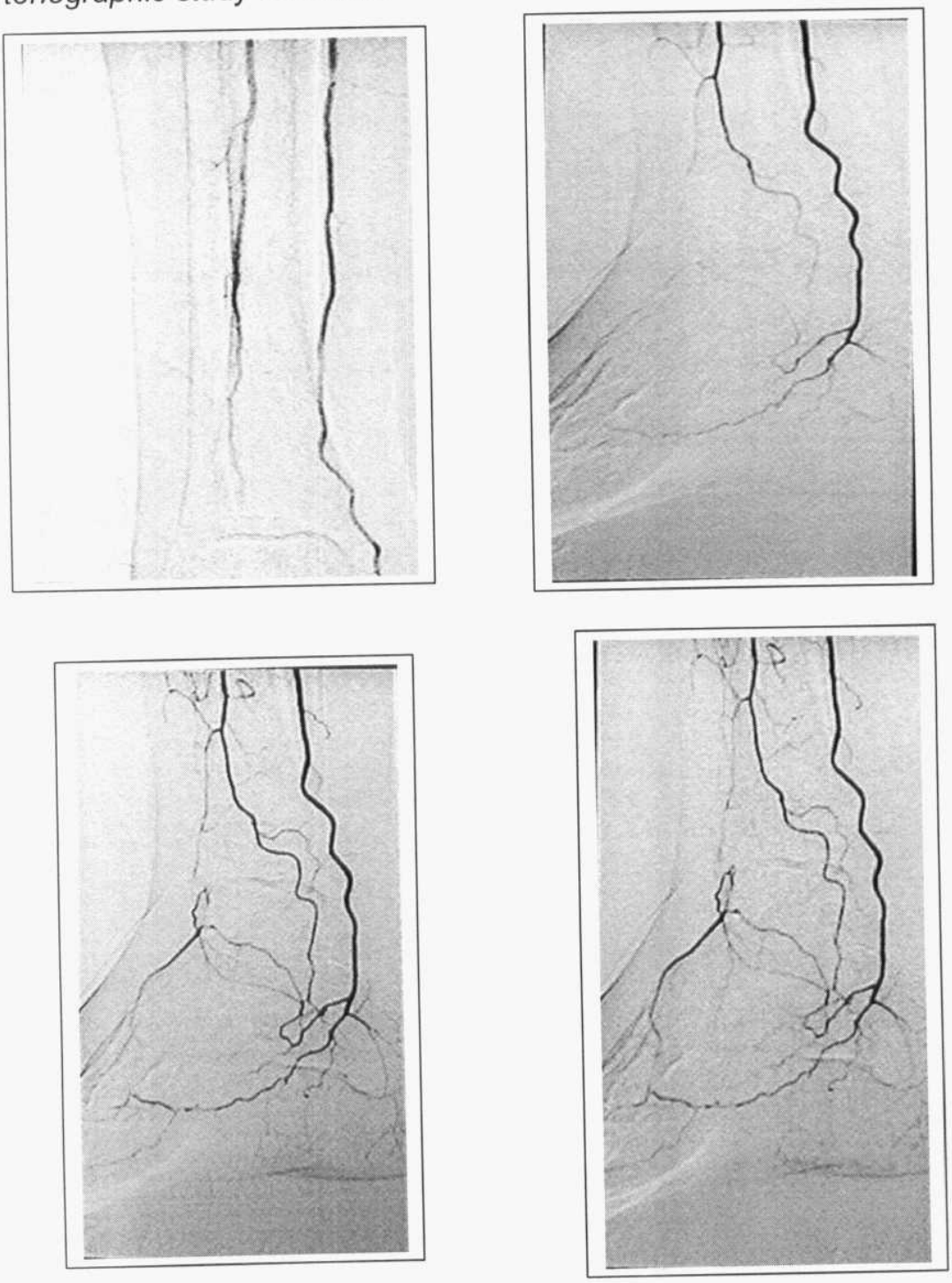
Arteriographic study revealed:



a) Dorsalis pedis artery refilling from planter arch.

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Case (No. 7)

Male patient 28 years old.

Complaining of right leg ulcers, 7 years duration after motor car accident with history of vascular injury treated by plastic surgery.

On examination:

- Chronic ulcers above ankle joint of right lower limb.
- Pulsation was absent at Dorsalis pedis artery of right lower limb.
- Trophic changes, loss of hair and paller at right leg.

Below knee Color Doppler study of Right, lower limb:

Distal popliteal artery was patent with no stenosis and normal waveform.

A.T.A. was no color flow.

P.T.A. was patent with no stenosis and normal waveform.

Peroneal : was patent with no stenosis and normal waveform

Dorsalis pedis patent with no stenosis and dumped waveform.

- **Arteriographic study revealed:**

It concides with the color Doppler study except:

- Occlusion of anterior tibial artery 2cm from its origin .
- Distal segment of anterior tibial artery is refilled from collateral arteries with occlusion of Dorsalis pedis artery.

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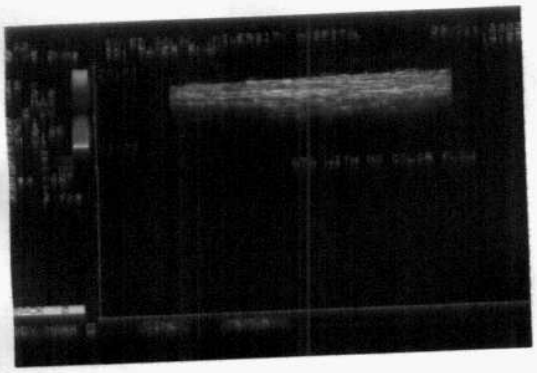
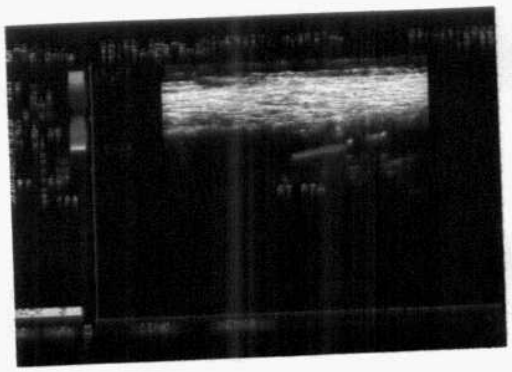
Case No. 7

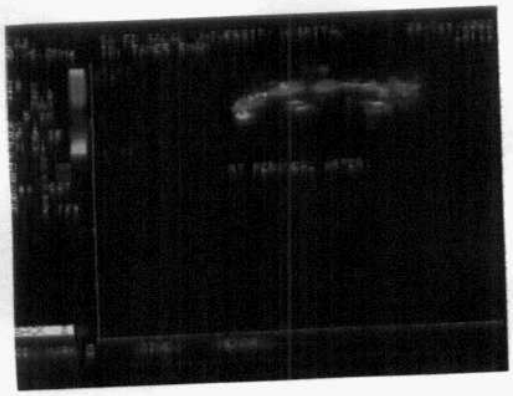
Below knee Color Doppler study of Right, lower limb:



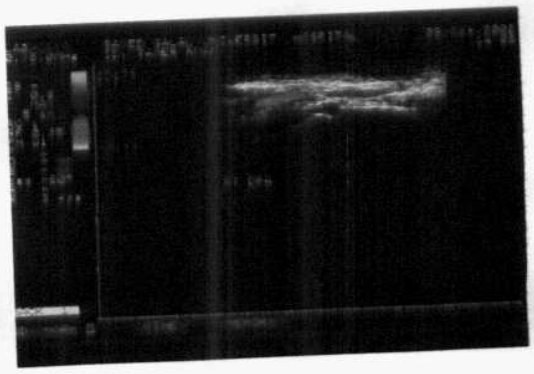
a) No color flow of ATA



b) Color flow PTA



c) Color flow of peroneal



d) Color flow of dorsalis pedis

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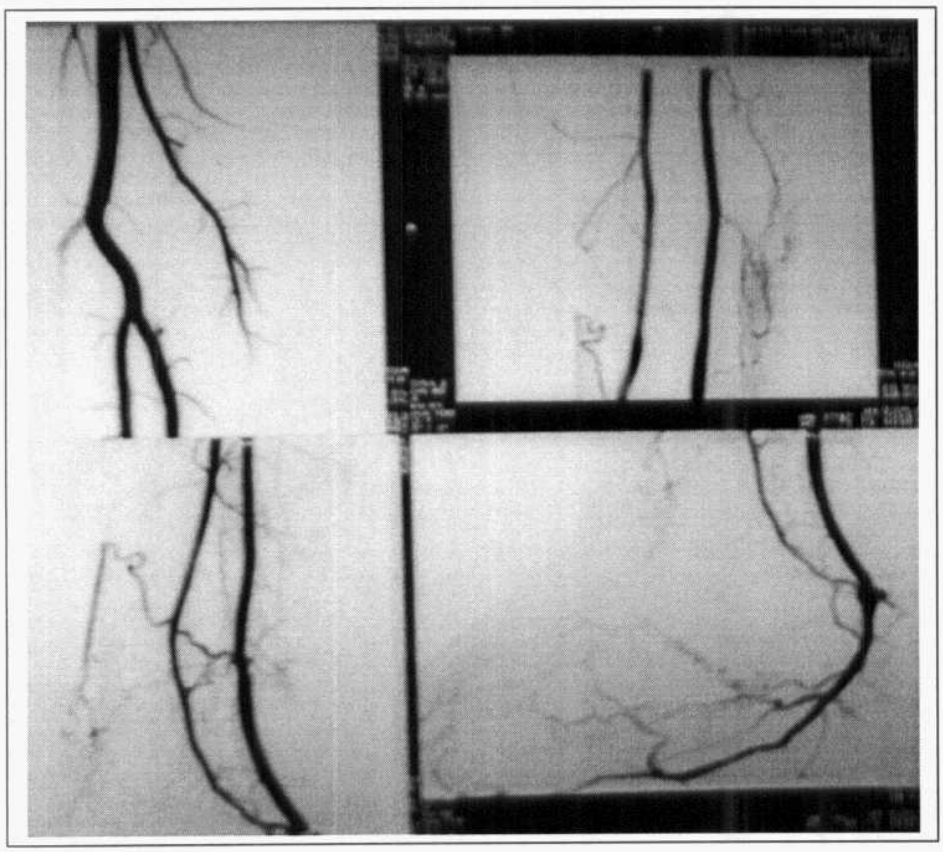
Arteriographic study revealed:



a) Distal segment of anterior tibial artery is refilled from collateral

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Case (No. 8)

Male patient 60 years old .

Complaining of recurrent claudication pain in both lower limbs .

Increase with walking in both sides of lower limbs.

On examination:

- Trophic changes of both lower limbs, loss of hair and paller.

Below knee Color Doppler, study of Left lower limb:

Distal popliteal artery patent with adequate color flow and biphasic waveform.

A.T.A. and **P.T.A.** are patent with biphasic waveform

Dorsalis pedis shows increased peak systolic velocity (P.S.V).biphasic waveform.

- **Arteriographic study revealed:**

It concides with the color Doppler study except:

- Popliteal, anterior tibial, posterior tibial arteries show no stenosis with good opacification.
- Middle segment of posterior tibial artery shows mild stenosis (<50%).

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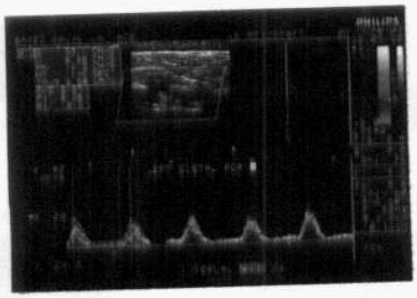
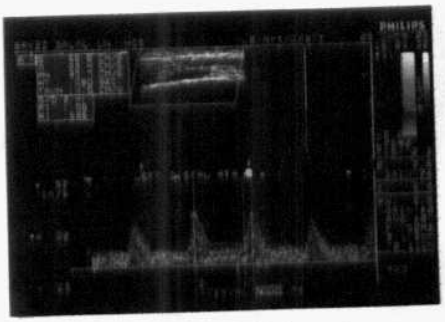
Case No. 8

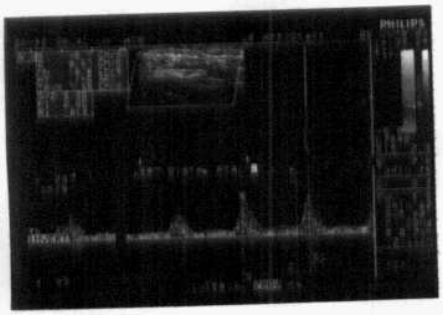
Below knee Color Doppler, study of Left lower limb:



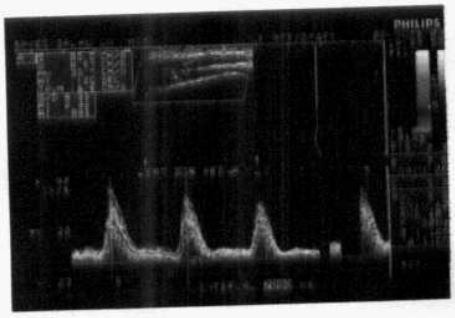
a) POP artery biphasic



b) ATA biphasic



c) PTA biphasic flow



d) Dorsalis pedis artery

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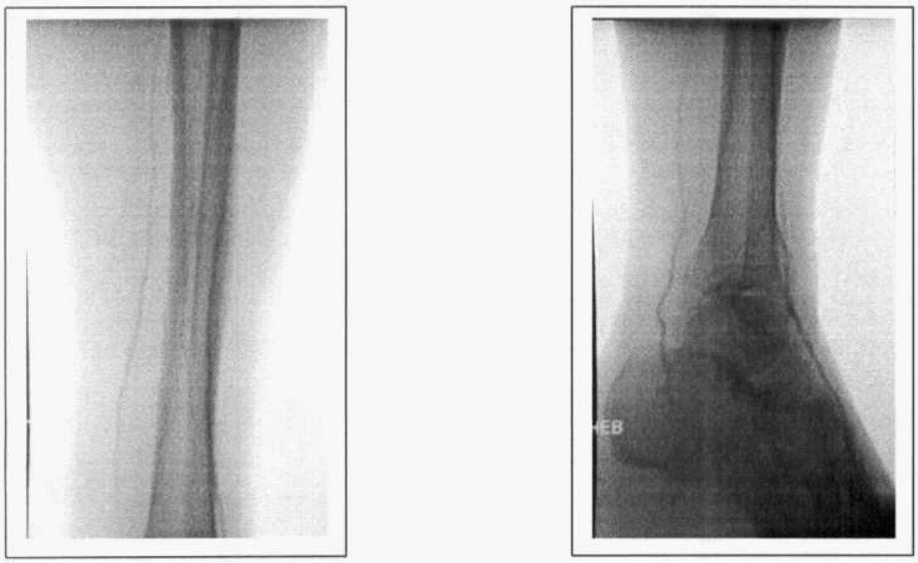
Arteriographic study revealed:



a) posterior tibial artery mild stenosis

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RESULTS

Distal popliteal portion:

Color Doppler Ultrasound over estimated (1) segment as complete occlusion which arteriography detecting it as (70%-99%).

Color Doppler Ultrasound under estimated (1) segment as (70%-99%). which arteriography detecting it as (<50%).

Anterior Tibial Artery Segments

(a) Proximal segment of ATA:

Duplex studies overestimated (3) segments out of (26) examined segments of A.T.A proximal segment detecting them as (complete occlusion) where arteriography classified them as (70 % - 99 % stenosis) .

(b) Middle segment of ATA:

Also duplex overestimated (2) segments out of (25) segments of A.T.A. middle segments to have (50% - 70% stenosis) and overestimated another (2) segment detected to be (70 % - 99 % stenosis) which arteriography detecting them as less than (<50% stenosis) and (complete occlusion) respectively.

Color Doppler ultrasound overestimated (2) segments classified them as (50 % - 70 % stenosis) while arteriography detect them as (<50% stenosis)

And also overestimated (3) segments in (70% - 99% stenosis) to be (<50% stenosis)

Color Doppler underestimated (2) segments detecting them to be (70% - 99 % stenosis) with flow seen within them where arteriography detecting them as complete occlusion.

(2) In Tibio – Peroneal Trunk Segment

Color Doppler overestimated (1) segment to be complete occlusion where arteriography classified it as (70 % 99 % stenosis)

(3) In Posterior Tibial Artery Segments

a) Proximal Segment:

Only (1) segment out of (26) segments was overestimated by color doppler to be (70 % - 99 % stenosis). See tables.

B – Middle Segment:

Color Doppler overestimated (1) segment as (50%-70% stenosis) where arteriography detect it (<50% stenosis).and underestimated (2) segments as complete occlusion where arteriography detect them (70%-99% stenosis).

c- Distal segment:

Color Doppler ultrasound overestimate (1) segment (70%-99% stenosis) where arteriography (50%-70% stenosis).

Color Doppler ultrasound overestimate (1) segment (70%-99% stenosis) where arteriography (< 50% stenosis)

(4) In The Peroneal Artery Segment

Color Doppler has (5) Segment out of (25) Segment not feasible to be studied.

The Sensitivity of duplex in the examination was:

85 % in lesion < 50 % Stenosis .

95 % in lesion From (50 % - 70 % stenosis)

95 % in lesions from (70 % - 99 % stenosis)

90 % in lesions of (complete occlusion) .

(B) on comparison of both techniques regarding detection of the possible cause of the arterial stenosis

Table (2): Frequency and percentage of segments not feasible to be studied by both arteriography and color assisted Duplex

	ATA (D)	PTA (D)	PER	Total
Arteriography				
No. of examined segments.	22	27	25	74
No. of segment not feasible to be studied.	0	0	0	0
Percentage.	0%	0 %	0 %	0%
Color flow Duplex				
No. of examined segments.	22	27	25	74
No. of segment not feasible to be studied.	0	0	5	5
Percentage.	0 %	0%	20 %	6.75 %

Table (3): Distribution of the studied cases according to their degree of stenosis as detected by both arteriography and Color Doppler in the below knee region

Degree of Stenosis	POP(D)*		ATA (p*)		ATA(M)*		ATA(D)*		TPT*		PTA (P)*		PTA (M)*		PTA (D)*		PER*	
	A	**D**	**A**	**D**	**A**	**D**	**A**	**D**	**A**	**D**	**A**	**D**	**A**	**D**	**A**	**D**	**A**	**D**
< 50 % Stenosis	10	12	15	15	12	10	10	5	13	13	9	9	8	7	11	10	11	9
50 % - 70 % Stenosis	5	4	-	-	3	5	6	8	2	2	-	-	2	3	6	5	7	7
70 % - 99% Stenosis	6	4	5	2	1	3	-	5	3	2	2	3	-	2	2	4	2	2
Complete Occlusion	4	5	6	9	9	7	6	4	7	8	15	14	14	12	8	8	5	2
Not feasible to be studied	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
Total (225 segments)	**25**	**25**	**26**	**26**	**25**	**25**	**22**	**22**	**25**	**25**	**26**	**26**	**24**	**24**	**27**	**27**	**25**	**25**

* ATA (P) Anterior tibial artery proximal segment.
* ATA (M) Anterior tibial artery middle segment.
* ATA (D) Anterior tibial artery distal segment.
* TPT Tibio peroneal trunk segment.
* PTA (P) Posterior tibial artery proximal segment.
* PTA (M) Posterior tibial artery middle segment.
* PTA (D) Posterior tibial artery distal segment.
* PER Peroneal artery segment.

Table (4): Distribution of the studied cases according to the possible cause of stenosis as detected by both arteriography and Color Doppler in the below knee region.

Causes	POP(D)*		ATA (p)		ATA(M)		ATA(D)		TPT		PTA (P)		PTA (M)		PTA (D)		PER	
	A	D	A	D	A	D	A	D	A	A	D	D	A	D	A	D	A	D
No Stenosis	4	4	3	3	2	2	3	2	3	3	3	3	2	2	3	3	4	3
Stenosis plaques	15	13	13	12	13	15	10	16	16	14	8	9	9	11	12	14	15	15
Embolic occlusion	2	1	1	1	-	-	2	-	1	1	1	1	-	-	-	-	-	-
Acute thrombotic occlusion	1	2	1	1	-	-	1	-	1	1	1	1	-	-	1	1	-	-
Chronic occlusion	3	5	8	9	10	8	6	4	4	6	13	12	13	11	11	9	6	2
Not feasible to be studied	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
Total of examination segments = 225	**25**	**25**	**26**	**26**	**25**	**25**	**22**	**22**	**25**	**25**	**26**	**26**	**24**	**24**	**27**	**27**	**25**	**25**

Table (5) . Color Doppler sensitivity in detecting the degree of arterial stenosis in cases of the lower ischemia (below knee region) regarding the arteriogram is gold standard (100%).

Degree of stenosis / Arterial segments	<50 %	50%-70%	70%-99%	Complete occlusion
popliteal portion	95 %	75 %	82 %	96 %
Infra-popliteal portion	85 %	95 %	95 %	90 %

Tale (6) Color Doppler sensitivity to detecting the possible cause the arterial stenosis of the lower limb (below knee region) regarding arteriography sensitivity 100 %.

Possible cause of stenosis / Arterial segments	No stenosis	Stenotic plaques	Acute embolic occlusion	Acute thrombotic occlusion	Chronic occlusion
popliteal portion	Equal with arteriography	92 %	Equal with arteriography		97 %
Infra-popliteal portion	95 %	95 %	Equal with arteriography		90 %

Discussion

The words arterial insufficiency and ischemia are used to indicate inadequate arterial circulation

Peripheral vascular disease is a condition in which the arteries that carry blood to the arms or legs become narrowed. This interferes with the normal flow of blood.

Peripheral vascular disease affects about 1 in 20 people over the age of 50, or 10 million people in the United States ***(Stary HC et al.1995).***

More than half the people with peripheral vascular disease experience leg pain, numbness or other symptoms — but many people dismiss these signs as "a normal part of aging" and do not seek medical help. Only about half of those with symptoms have been diagnosed with peripheral vascular disease and are seeing a doctor for treatment. .

Atherosclerosis is the leading cause of illness and death allover the world. Despite significant medical advances, coronary artery disease (which results from atherosclerosis and causes heart attacks) and atherosclerotic stroke are responsible for more deaths than all other causes combined. ***(Stary HC et al.1995)***

Angiography is one of the important techniques for the diagnosis of peripheral vascular diseases .Since its discovery dates back to the 1923 , where Berberich and Hirsch filled the veins of the lower limbs with contrast material, and Brook in 1924 who first worked in the area of femoral arteriography. Although at that time, it was a risky procedure.

Nowadays ease of performance and availability of equipments rendered it a relatively safe and easy procedure..

Peripheral arteriography play important role in the diagnosis and management of a wide variety of disorders, arteriography is often regarded as expensive, hazardous technique.
(Egglin T.K., et al , 1995)

The color doppler ultrasound is non-invasive procedure used to detect the velocity of blood flow in the vascular tree in order to replace angiography procedures and to avoid its side effects, where angiography is not mandatory.

We are faced with some difficulties during angiography to visualized the below knee vasculature specially in patients with arterial occlusive disease affecting the superficial femoral or proximal popliteal arteries due to insufficient amount of contrast reaching the distal leg arteries around the ankle joint, while , duplex US is beneficial in detecting flow signals , patency and wave form even it is not triphasic.

The following data was obtained After examination of (25) lower limbs of (20)patients

Popliteal artery we examined (25)segments

Anterior tibial artery we examined (73) proximal ,middle and distal segments

Posterior tibial artery we examined (73) proximal ,middle and distal segments

Peroneal artery we examined (25)segments

Color Doppler sensitivity to detecting the possible cause the arterial stenosis of below knee region (25 lower limbs) regarding arteriography sensitivity 100 %.

Stenotic plaques lesions(95%)

Acute embolic and thrombotic occlusion equal with arteriography

Chronic occlusion lesions (90%)

Occlusive arterial diseases affect males (16) more than females (4). Smoking (16) appears to be a contributing factor. Gangrene of the lower limbs was encountered in (5) of the patients especially those affected by diabetes mellitus (14).

Arteriosclerosis (15) cases, this group of patients formed the main bulk of our work; they are (15)patients of the total number of cases. All of them suffered from peripheral ischemic changes. On clinical examination, there were trophic changes in most of the cases in the form of ulceration, loss of hairs and mails,

and gangrene. The pulses of the lower extremities either are usually absent or markedly diminished. Occlusions were suspected clinically in (12) patients.

These clinical data, although essential in the diagnosis, should be complemented and confirmed by other diagnostic methods to choose the correct line of treatment.

Acute thrombotic disease (3) cases associated with hypercoagulabilaty states

Arterio venous communication (2) cases, this group of patients had history of trauma was found in most of the cases as knife trauma.

Color doppler ultrasound and arteriographic examinations revealed the same results in the diagnosis of the presence of fistulas communications, yet arteriography can reveal exactly the site, also of communication, the nature of the underlying disease, and bony affection features which are lacking with the ultrasonic examination. In addition, it can help in the differential diagnosis of the disease.

As regarding collaterals, arteriography was more accurate in detection of the number, anatomical location and caliber of the collaterals than duplex

This work aims at evaluating the patients with peripheral vascular diseases by color doppler ultrasound and comparing those results with angiography

Disadvantage Color Doppler scanning

Difficult visualization of the proximal part of the tibial vessels and the tibio – peroneal trunk. We found that it is easier to scan the tibial vessels distally at the level of malleoli and trace them proximally up to popliteal trifurcations. This approach solved many problems in scanning the anterior tibial artery and posterior tibial artery. But we were challenged by the peroneal artery being deep, it was the most difficult to be scanned.

Indirectly (not directly) asses the efficiency of collateral vessels by the receiving the Doppler spectral wave in the vessel distally.

Its most significant limitation is the inability to see particular vessel well enough to obtain accurate velocity measurement. Visualization can be limited by vascular calcification, bowel gas, vessel tortuosity and slow flow.

Another major drawback that it is operator dependent, the obtained data depend to a great extent on the operator's skill's

Advantage of color doppler ultrasound

Externally applied transducer which does not injured or operate the skin. The technique is painless and has not been accompanied by side effects.

The color doppler ultrasound may be used regularly with success to evaluate arterial signals from the level of external iliac artery to the pedal arteries.

The color doppler ultrasound is small, compact, and easily carried to the desired location. A paramount advantage of this instrument is the ease with which it can be employed in evaluating the results of reconstructive arterial surgery. The instrument may be taken to the operating room, the recovery room or the patients bedside to assess the operative results.

The color doppler ultrasound is of great value in infants, patients in shock and patients having induced hypotensive anesthesia (Quoted by Strandness). Also it could detect pulses of extremities in the presence of obesity and edema.

Color Doppler sensitivity in detecting the degree of arterial stenosis in cases of ischemia below knee region regarding the arteriogram is gold standard (100%)

(.85 %) in lesion (< 50 % Stenosis) .

(95 %) in lesion From (50 % - 70 % stenosis)

(95 %) in lesions from (70 % - 99 % stenosis)

(90 %) in lesions of (complete occlusion) .

CONCLUSION

As diagnostic testing for vascular disease continues to evolve, the borderline between noninvasive and invasive techniques has become blurred. For example, contrast angiography is clearly an invasive procedure, and methods based on ultrasound are generally considered noninvasive, but computed tomographic angiography, which relies on the use of ionizing radiation and intravenous contrast material, might be regarded as minimally invasive. Intravascular ultrasound combines invasive catheterization techniques with the ability to evaluate vascular abnormalities by noninvasive imaging. Similarly, the distinction between diagnostic and therapeutic approaches has become less clear with recent advances in the field of catheter-based interventional techniques. Current therapeutic options include not only, conventional balloon angioplasty, but also atherectomy, stenting, catheter-directed thrombolysis, and intravascular grafting. The invasive techniques of contrast arteriography and venography are now used primarily as adjuncts to intervention, since they are no longer required solely for diagnostic purposes .

Arteriography while remaining the diagnostic standard for lower limb ischemia has some major limitation. It's cost, discomfort and risks preclude its morphologic images do not provide the physician with physiologic assessment of hemodynamic impairment associated with vascular disease.

On the other hand, Color Doppler sonography is accurate, noninvasive, commonly used method for evaluating lower-extremity peripheral arterial disease.

In recent years, refinements in MR imaging and CT slip-ring technology have allowed the development of MR and CT angiography.

Although there has been less clinical experience with these modalities (especially CT angiography) relative to US and pressure measurements, studies have reported similar sensitivities and specificities to those of US

(Rofsky NM 1998).

Advantages of conventional angiography relative to US are shorter examination time, less operator dependence, and anatomic depiction similar to that of MR and CT angiography

Currently, the choice of noninvasive technique depends on available equipment and expertise and acceptance by vascular surgeons of the newer tests. US currently remains an important modality in the evaluation of peripheral arterial disease, it be used as screening modality in patients with risk factors (smoking, diabetes, hypertensive and hyperlipidemia) US will likely continue to have a role in many settings, such as for targeted questions (e.g., post angioplasty assessment, pseudo aneurysms), in portable examinations, for patients unable to cooperate for angiography

imaging, and where expensive CT and MR equipment are not available. ***(Rieker O 1996)***

Duplex is able to determine not only the presence but also the location and the severity of vascular disease with an accuracy that equals arteriography in the lower limb arterial tree.

Since the ultimate goal of non-invasive vascular studies is to replace arteriography without sacrificing accuracy. Duplex studies aim to limit the number being done and to apply arteriography for more selective indications particularly if surgery is contemplated.

Arteriography allows perfect mapping for the arterial tree and visualized the status of distal run-off. This last information has a great value for the surgical outcome.

Thus we recommend that for any patient with lower limb arterial complaint must undergo, close history taking, proper physical examination and then color assisted Duplex ultrasonography preceded by segmental systolic pressure studies.

Lastly according to the preceding data judgment must be taken whether arteriography is indicated or not.

SUMMARY

Technological progress in the design and performance of the ultrasound scanners has greatly expanded the role of the ultrasonography in the diagnosis of vascular process, where arterial diseases can be located and quantitated to some extent by Color Doppler studies.

For a long time arteriography had a remarkable role in studying the vascular system referred as the golden standard but now Color Doppler ultrasound with its high resolution imaging and being non invasive provide a new unique modality for studying the peripheral vessels.

In this work we tried to evaluate the role of each modality in assessment of the arterial disease of lower limb

We have studied 20 patients with lower limb ischemia by both Color Doppler ultrasonography and contrast arteriography, the results were correlated and revealed the promising and excellent role of Color Doppler ultrasound in studying the lower limb arterial tree from the knee joint down to dorsalis pedis in comparison to arteriography

No significant difference between it and arteriography in most of cases.

Both were found to have almost the same sensitivity to exclude the presence of lower limb ischemia in most of cases.

Great agreement between both modalities was found. We suggest that any patient with lower limb ischemia, should first be assessed by Color Doppler scanning as a non-invasive technique, and gives a great idea about vascular hemodynamics.

Still arteriography is superior to Color Doppler regard the spatial resolution of the arterial tree; however, Duplex has its essential role.

With the modern advances in ultrasound technology, the Color Doppler studies are not only a merely preliminary method upon which arteriographic studies are tailored but in some situations it may completely replace lower limb arteriography.

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Arabic Summary

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الملخص العربي

لعب التصوير الشرياني بالصبغة الدور الأساسي في تشخيص أمراض الأوعية الدموية الطرفية وخاصة شرايين ما تحت الركبة في الطرف السفلي.

إلا أن التطور التقني الذي حدث في تصميم وصنع أجهزة الموجات فوق الصوتية قد أدي إلي توسع كبير في استخدامها في تشخيص أمراض الأوعية الدموية الطرفية.

أصبح الدوبلر الملون الأن الفحص الأمثل باعتباره أنه غير هجومي ويعطي فكرة جيدة عن فسيولوجية وميكانكية سريان الدم خلال الأوعية الدموية مما ساعد في التشخيص.

وبفضل التحسينات الحديثة التي طرأت على أجهزة الدوبلر الملون التي جعلت فحص الشرايين بالموجات فوق الصوتية هو الإجراء الأول لدراسة أمراض شرايين ما تحت الركبة بالطرف السفلي بل من الممكن أن يكون كافياً ويغني عن إجراء التصوير الشرياني بالصبغة في بعض الحالات.

في عملنا هذا نقيم دور الدوبلر المزدوج ودور التصوير الشرياني بالصبغة في دراسة أمراض شرايين ما تحت الركبة بالطرف السفلي وقد قارب الدوبلر الملون من دقة تشخيص التصوير الشرياني بالصبغة.

ومن ثم نوصي بان يجري فحص الدوبلر المزدوج الملون لكل مريض يشكو من قلة الامداد الدموي بالطرف السفلي.

وبالرغم مما سبق فان التصوير الشرياني بالصبغة حتي الأن يبقي متفوقاً على فحص الدوبلر الملون خصوصاً في شرايين ما تحت الركبة.

جامعة الأزهر
كلية الطب — بنين
قسم الأشعة التشخيصية

دراسة مقارنة بين الدوبلر الملون وأشعة الشرايين في قصور الأوعية الدموية الطرفية تحت الركبة

رســـالـــة

توطئة للحصول على درجة الماجستير في الأشعة التشخيصية

مقدمـــة مـــن
الطبيب/ عبد السلام أحمد أحمد العشري
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