ONE YEAR STUDY OF COMPARISON OF DIAGNOSTIC ACCURACIES OF COLOUR FLOW DOPPLER WITH CONTRAST ENHANCED MAGNETIC RESONANCE ANGIOGRAPHY (M R ANGIOGRAPHY) AND WITH INTRAOPERATIVE FINDINGS IN 30 PATIENTS WITH OBSTRUCTIVE ARTERIAL DISEASE OF LOWER LIMBS PRESENTING AT KLE HOSPITAL,BELGAUM

Submitted by

Dr. Santosh.B.Chikaraddi

DISSERTATION

Submitted to the
KLE University,Belgaum.

In partial fulfillment

Of the requirement for the award of the

MASTER DEGREE

IN

GENERAL SURGERY

Under the guidance of

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I hereby declare that this dissertation entitled **"ONE YEAR STUDY OF COMPARISON OF DIAGNOSTIC ACCURACIES OF COLOUR FLOW DOPPLER WITH CONTRAST ENHANCED MAGNETIC RESONANCE ANGIOGRAPHY (M R ANGIOGRAPHY) AND WITH INTRAOPERATIVE FINDINGS IN 30 PATIENTS WITH OBSTRUCTIVE ARTERIAL DISEASE OF LOWER LIMBS PRESENTING AT KLE HOSPITAL,BELGAUM."** is a bonafide and genuine research work carried out by me under the guidance of **Dr. A.C.PANGI. M.S**, Assoc professor, Department of general surgery. J.N Medical College, Belgaum.

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Dr.Santosh.B.C

List of Abbreviations used

ATA-Anterior tibial artery.

BL-Both lower limbs.

CFA- Common femoral artery.

CFD - Colour flow doppler

CIA-Common iliac artery

CLI-Critical limb ischemia.

DM- Diabetes mellitus.

EXA-External iliac artery.

F- Female.

HPL-Hyperlipidemia.

HTN-Hypertension.

IC-Intermittent claudication.

IP. No – In patient number.

IRA-Infrarenal Aorta.

LL-Left lower limb.

LLAD - Lower limb arterial disease

M - Male.

MRA - Magnetic resonance angiography

N-Normal arterial diameter

OAD- Obstructive arterial disease

PA-Popliteal artery.

PNA-Peroneal artery

PFA-Profunda femoris artery.

PTA-Posterior tibial artery.

RL-Right lower limb.

SFA-Superficial femoral artery.

SMA-Small arteries

SMK-Smoking.

Sr.No – Serial Number.

TPT-Tibioperoneal trunk.

Abstract

Background - MR angiography has been considered the "GOLD STANDARD" for the investigation of obstructive arterial disease of lower limbs.The development of Colour Flow Doppler has extended the scope of non-invasive assessment of lower limb arterial disease.

Aim - To prospectively compare the diagnostic accuracy of Doppler with MR angiography and with intraoperative findings in detecting hemodynamically significant lesions in patients with obstructive arterial disease of lower limbs

Settings and design - This comparative study was designed in the department of general surgery , J.N.Medical college , Belgaum.,Patients were subjected to Doppler and MRA to evaluate the aorto-iliac and femoro-popliteal vessels.

Materials and methods - 30 patients of obstructive arterial disease of lower limbs formed the subjects and their affected lower limbs evaluated with Doppler and MRA and findings compared with intraoperative findings

Statistical analysis - Sensitivity and specificity calculated and chi-square test used for calculation of P value . A P value of < 0.05 is considered statistically significant

Results - There was good statistical agreement and sensitivity and specificity of Doppler ranged from 70-90% and 100% in different arterial segments. Sensitivity and specificity of MRA ranged from 90-95% and 100% in different arterial segments.

Conclusion - Colour doppler has grown from an ancillary diagnostic aid to a critical component in non-invasive diagnostic workup for patients with obstructive arterial disease of lower limbs , with the potential of displacing MRA as the initial investigation of choice.

Key words - Peripheral arterial occlusive disease ; Colour Flow Doppler ; Magnetic resonance angiography ; Lower limb arterial disease

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INTRODUCTION

The lower limb arterial disease is common disorder with variable morbidity and mortality. This disorder commonly affects men and women over the age of 50years. It affects nearly 10 million people.

The common symptom associated with lower limb arterial disease is intermittent claudication. The other symptoms may be rest pain, chronic ulcer, and appearance of gangrene suggestive of critical limb ischemia. Some people are however asymptomatic.

More than 70% of patients experience no change or have an improvement in the symptom after 5 to 10 years of conservative management. But 20 to 30%of patients progress to more severe symptoms that require intervention. Less than 10% of patients require amputation.

Most of the lower limb arterial disease are because of underlying atherosclerosis which is also systemic and thus puts the patient at high risk of cerebral strokes, reno vascular hypertension, myocardial infarction and cardiovascular death. The risk factor includes smoking, hypertension, hyperlipidemia, diabetes, and family history of vascular disease, obesity and sedentary life style. Availability of modern surgical revascularization techniques as well as refined pharmacological interventions make it mandatory for the accurate diagnosis and the need for information about the location, number, length, extent and severity of the arterial involvement.

Although many imaging modalities have emerged and are being practiced like for example, catheter based angiography, digital subtraction angiography (DSA),

colour flow doppler, but no single optimal technique provided the information to its best.

The development of CFD has extended the scope of non invasive assessment of OAD. CFD provides high resolution ,precise anatomical and physiological information of peripheral arteries including the blood flow. CFD is a safe, fast,in expensive ,accurate and repeatable non invasive procedure and is being used more frequently as the first line investigation for patients with OAD of lower limb.

CFD has grown from an ancillary diagnostic aid to a critical component in non invasive diagnostic work up of OAD.

However 3 dimensional contrast enhanced MR angiography which has emerged as a newer modality for assessment of lower limb arterial diseases has yielded better results. The higher sensitivity and specificity with accuracy in diagnosing arterial lesions lead to more number of limb saving procedures like percutaneous transluminal angioplasty (PTA) and surgical revascularization. This newer technique has overcome the difficulties with other modalities like invasiveness of procedure and observer dependency .

The 3 dimensional contrast enhanced MR angiography has emerged as an recent advanced imaging modality in clearly depicting the vascular morphology, and the information needed for therapeutic intervention by the vascular surgeon in lower limb arterial diseases.

AIMS AND OBJECTIVES

To prospectively compare the diagnostic accuracy of color doppler with magnetic resonance angiography and with intraoperative findings in detecting hemodynamically significant lesions in patients with obstructive arterial disease of lower limbs

REVIEW OF LITERATURE

HISTORICAL REVIEW OF LOWER LIMB ARTERIAL DISEASE

The first era of vascular disease was dominated by vascular surgery and development of surgical techniques. The second saw the emergence of noninvasive investigations. We are now entering a third era, which concentrates, on early detection of asymptomatic disease, better understanding of its natural history in relation to risk factors.

In the third century a roman surgeon, Antyllus, described proximal and distal ligation of the artery followed by removal of aneurysm. In 1680, Mathaeus Purmann carried out ligation of the vessel and excision of the aneurysmal mass in antecubital fossa.

Anel in 1714, demonstrated ligation on the artery just proximal to the aneurysm. The ligation of carotid for aneurysm as well as aorta and internal iliac artery aneurysm was described by Sir Astley cooper in 1805[1] . John Hunter in early 18 th century described about the atherosclerotic changes in aortic and carotid bifurcation, which was demonstrated by Leriche 150 years later. Hunter, Sir Astley cooper, later Cruveilhier explained that the gangrene is due to the occlusion of the arteries by thickening and by thrombosis of the arteries.[2] Barth described the intermittent claudication in 1835, and later by Charcot in 1858.

The arterial surgery by suturing was successfully done on experimental animals by Jassinowsky in 1891 later got modified by Dorfler. The successful end to end anastomoses of carotid artery was successfully done by Jaboulay and Briau in 1896. The first successful clinical vascular surgery of resecting popliteal aneurysm and then restoring arterial continuity with an in situ venous graft using popliteal vein

was done by an European surgeon Goyanes in 1906. The use of synthetic arterial graft and arterial homograft for replacement of aorta were successfully attempted by Hufnagel in 1940.[3] In 1958 Debakey and associates for arterial graft introduced the knitted Dacron.[4]

As mentioned earlier, it was not until the middle of 19 th century that the relationship between arterial occlusion and either clinical symptoms or gangrene became clearly established. In 1916, Leriche applied the principle of sympathectomy and arteriectomy for occlusive arterial disease, which was later modified by Diez into lumbar ganglionectomy, although remained as controversial. Leriche, in 1923 described a syndrome to which his name is attached, the atherosclerotic obliteration of aorta and iliac arteries. Jacques Oudot performed a homograft surgery for proximal left iliac and distal aortic occlusion, but results were not rewarding. The procedure of percutaneous transluminal dilatation of atherosclerotic lesions was demonstrated by Dotter and Judkins in 1952.[5]

Greenstone and others described about arterial endoscopy in 1966.[6] Simpson, Kensey, and Ahn with their coworkers put fourth different methods of atherectomy.[7] The addition of intraluminal stents to maintain patency of graft as well as vessel that had been dilated was proposed by Dotter and others .[8] The procedure of using saphenous graft in infrapopliteal region with attachment to posterior tibial artery at ankle was demonstrated by Mc Caughan in 1966.[9]

HISTORY OF IMAGING MODALITIES FOR LOWER LIMB ARTERIAL DISEASE

Within a month after Roentgen's discovery of the X-ray, Haschek and Lindenthal performed the first cadaveric peripheral arteriogram by injecting Teichmans mixture into the blood vessels.

The history of arteriography began with Brooks who demonstrated the lesions of Burgers disease by intra-arterial injection of sodium iodide in 1924.[11] Reynaldo dos Santos published the basic technical approach to the arteriography of the vessels of abdomen and their branches in 1929. Seldinger in 1953 introduced major technical advance of catheter-based angiography.[12] The work of Dotter and Judkins, who used a rigid dilator passed through a large catheter-sheath under fluoroscopic guidance to dilate narrowed arteries, which led to the burgeoning field of interventional rather than purely diagnostic radiology.

The noninvasive method began with the appreciation of Doppler principle for measurement of blood flow by Satomura in 1959. McLeod devised the detection of direction of flow in the arteries by Doppler in 1967. The colour Doppler ultrasound however was operator dependent. In 1981 there was seen technical advancement with development of digital subtraction angiography by Crummy and others with vascular opacification by injecting contrast through intravenous route. The procedure had a benefit of using less contrast and minimally invasive, but the limitations being motion artifact and superimposition of vessels, which was overcome in the year 1993 with the introduction of selective intraarterial digital subtraction angiography by Ikeda.

Along with the development of these techniques there was seen introduction of vascular imaging by magnetic resonance imaging method in 1985. Prince and others brought out the technique of gadolinium enhanced three-dimensional magnetic resonance angiography in 1993, which has a greater advantage of less operator dependence, no radiation and no contrast toxicity.

In 1995 the first imaging of lower limb arteries was done with computed tomography having single row of detector. Later in 1999, with availability of multidetector computed tomography the vascular imaging got revolutionized, as it is cost effective and minimally invasive. The paper by Rubin and others in 1999 showed overall picture of the course and collaterals of an arterial segment by spiral computerized tomography although its images showed loss of some of the details.[13]

HISTORICAL REVIEW OF COLOUR FLOW DOPPLER

Ultrasound technology began to be applied in the evaluation of the cardiovascular system in the 60's. At that time, devices called Doppler flowmeters were developed. Those devices employed continuous ultrasound waves and the so-called Doppler effect to detect flow in blood vessels with a transducer.

In the 70's, the first ultrasound imaging systems were developed. Throughout the 1980's, Doppler ultrasound devices were improved, and a major breakthrough was the introduction of color flow imaging or color-coded echo-Doppler. Color-flow techniques made it much easier to image deep arteries, such as the aorta and its branches, and vessels with slow blood flow, such as the veins and arteries distal to occluded segments.

Since it became popular at the end of the 1980's, DUS has completely changed the diagnosis of several vascular disorders. DUS has partially replaced arteriography in the assessment of extracranial carotid and it has been increasingly used for the diagnosis of lower-limb arterial occlusive disease.

With the advent of DUS in the early 1980's, several studies were conducted with the objective of comparing this new method with arteriography for the evaluation of the aorto-iliac segment. In 1984,the first comparative study between CA and DUS was published which concluded that DUS seemed to be a promising method for the evaluation of the aorto-iliac segment.[14] From 1985, study done at the University of Washington, in Seattle, USA, popularized DUS as an accurate method for the initial investigation of patients with suspected lower-limb arterial occlusive disease.[15]

In 1989, the first study on the use of color-flow imaging for the detection of lower-limb arterial occlusive disease was conducted . The authors concluded that the

color imaging exam was not only more accurate, but also easier to perform than its black-and-white counterpart. Those authors for the first time suggested that DUS could potentially replace arteriography in the assessment of selected cases of lower-extremity ischemia. In 1989, a series of studies were published on Doppler ultrasound examination of the aorto-iliac segment The studies conducted were crucial for the development and popularization of DUS as a method of evaluation of the aorto-iliac segment.

In 1992, a study was done to compare arterial ultrasonographic "mapping" of lower limbs with arteriography in a series of 150 consecutive patients[16] The study concluded that Doppler ultrasound was excellent for the assessment of the aorto-iliac segment and good for the femoro-popliteal segment.

CFD has grown from an ancillary diagnostic aid to a critical component in non invasive diagnostic work up of OAD

HISTORICAL REVIEW OF MRI AND MR ANGIOGRAM

MRI is based on the principles of nuclear magnetic resonance (NMR), a spectroscopic technique used by scientists to obtain microscopic chemical and physical information about molecules. The technique was called magnetic resonance imaging rather than nuclear magnetic resonance imaging (NMRI) because of the negative connotations associated with the word nuclear in the late 1970's. MRI started out as a tomographic imaging technique, that is it produced an image of the NMR signal in a thin slice through the human body. MRI has advanced beyond a tomographic imaging technique to a volume imaging technique.

The Concept of Nuclear Magnetic Resonance (NMR) was described by Dutch Physicist C.J Gorter in 1936. Felix Bloch and Edward Purcell, both of whom were awarded the Nobel Prize in 1952, discovered the magnetic resonance phenomenon independently in 1946. In the period between 1950 and 1970, NMR was developed and used for chemical and physical molecular analysis.

In 1971 Raymond Damadian was among the first to suggest the use of NMR in medical diagnosis and he showed that the nuclear magnetic relaxation times of tissues and tumors differed, thus motivating scientists to consider magnetic resonance for the detection of disease.[17] In 1973 the x-ray-based computerized tomography (CT) was introduced by Hounsfield. This date is important to the MRI timeline because it showed hospitals were willing to spend large amounts of money for medical imaging hardware. Lauterbur published the first NMR image on small test tube samples in 1972 at Stony Brook, New York, He was able to generate the first two-dimensional NMR image of proton density and spin lattice relaxation time

In 1975 Richard Ernst proposed magnetic resonance imaging using phase and frequency encoding, and the Fourier Transform. This technique is the basis of current MRI techniques.[18] It was in 1976 and 1977, when first images of human anatomy were produced by groups at Nottingham University. In 1977, Raymond Damadian produced whole body image using field-focusing nuclear magnetic resonance

The multiplanar facility of MRI was first demonstrated in 1980 by Hawkes, who also reported the firstintracranial pathology. Edelstein and coworkers demonstrated imaging of the body using Ernst's technique in 1980. In the year 1987 Charles Dumoulin introduced magnetic resonance angiography (MRA), which allowed imaging of flowing blood without the use of contrast agents.[19] Since then there has been widespread clinical application with many sub modalities like multislice, multiecho, spectroscopy, angiography, fast scanning, surface coil etc.

In the early 1990s, a new MRA technique for aortography called Gd-enhanced three-dimensional MRA was introduced by Prince et al.[20] In 1991, Richard Ernst was rewarded for his achievements in pulsed Fourier Transform NMR and MRI with the Nobel Prize in Chemistry. In 1992 functional MRI (fMRI) was developed.[20] This technique allows the mapping of the function of the various regions of the human brain. The development of fMRI opened up a new application for EPI in mapping the regions of the brain responsible for thought and motor control

Interventional MRI was first shown by Lufkin et al in 1995and hold great promise for diagnosing and treating patients within a single visit. New parallel encoding methods used with phased array radiofrequency coils such as SMASH introduced by Sodickson et al in 1997 and SENSE introduced by Pruessmann et al in 1999 are changing the rules of imaging speed with MRI. In 2003, Paul C. Lauterbur

of the University of Illinois and Sir Peter Mansfield of the University of Nottingham were awarded the Nobel Prize in Medicine for their discoveries concerning magnetic resonance imaging

ARTERIAL ANATOMY OF LOWER LIMB

AORTIC BIFURCATION:

The aortic bifurcation normally lies at the lower portion of the fourth lumbar vertebra, where the two iliac arteries diverge, the branches being separated by an angle of 80degrees.some times the bifurcation lies at the level of second lumbar interspaces and the common iliac branches are separated by an angle of 20 to 30 degrees. In cases the bifurcation is high; the diameter of the vessels is abnormally small. The inferior venacava lies to the right lateral aspect of aorta.[21]

COMMON ILIAC ARTERIES:

Normally the aorta divides into two equal common iliac arteries, each about 10 mm in diameter and 3 to 8cms in length. There are no major branches from these arteries except their terminal divisions. They lie close together and adhere to the fragile underlying common iliac veins. Although the common iliac arteries are usually lacking in branches, the iliolumbar artery sometimes takes its origin from the distal common iliac artery instead of the hypogastric system. The common iliac artery ordinarily ends opposite the level of lumbosacral fibro cartilage.[21]

EXTERNAL ILIAC ARTERIES:

The external iliac arteries represent the continuation of the common iliac arteries beyond the point of origin of internal iliac artery. The external iliac arteries pass laterally and anteriorly near the brim of pelvis and terminate by entering the thigh at the inguinal ligament and becoming common femoral artery. The branches at its terminal part include inferior epigastric artery and deep circumflex iliac artery and

occasionally anamolus obturator artery. The deep circumflex iliac artery is often an important re-entry branch of collateral supply around a proximal aortic or iliac obstruction. Usually the external iliac artery is larger then internal iliac artery and measures 5 to 8 mm.[21]

INTERNAL ILIAC ARTERIES:

The internal iliac arteries is approximately 5mm in diameter and 3 to 4 cms in length passing into the depth of pelvis in close proximity to the internal iliac vein. This artery divides into anterior and posterior divisions. The anterior division branches are superior, middle and inferior vesicle arteries; the middle heamorroidal; the obturator; the internal pudendal; the inferior gluteal; and the uterine and vaginal arteries in the females. The posterior division branches are iliolumbar, lateral sacral, and superior gluteal arteries.[21]

COLLATERAL BRANCHES IN THE ABDOMEN AND PELVIS:

The commonest pattern of collateral flow around an obstruction of the terminal aorta and both the common iliac arteries is by collateral network in which lumbar arteries filling flank and hip muscles reenters internal iliac artery by iliolumbar and superior gluteal branches. The inferior mesenteric artery may become greatly hypertrophied in order to fill the hypogastric bed through the middle and superior heamorroidal anastomosis in the perirectal tissues. When one common iliac artery is obstructed, the collateral branches that fill the common iliac artery arise from the proximal lumbar arteries and considerable flow across the pelvis between corresponding internal iliac branches. Sometimes with extensive involvement of terminal aorta inferior mesenteric artery may feed the internal iliac bed through the

internal spermatic artery by reentry through the external spermatic and other branches of inferior epigastric artery.[21]

COMMON FEMORAL ARTERY:

The common femoral artery arises at the inguinal ligament as the continuation of the external iliac artery. The profunda femoris artery is given off 2.5 to 6 cms below the inguinal ligament as a unit or group of branches. The continuation of this artery after this branch through the femoral triangle and adductor canal is named as superficial femoral artery. The branches of common femoral artery are superficial circumflex iliac, the superficial external pudendal, the superficial epigastric, and the deep external pudendal arteries.[21]

ARTERIA PROFUNDA FEMORIS:

This artery is usually given off between 2.5 and 6cms from the inguinal ligament, and marks the end of the common femoral artery. It is a short trunk and passes posteriolaterally, promptly giving off a deep medial circumflex femoral artery in its course around the femur the artery anastomose with the branches of the obturator artery and runs down the thigh in proximity to the medial aspect of vastus lateralis muscle opposite the origin of the medial femoral circumflex artery, the deep lateral circumflex artery is given off and divides into an ascending and descending branches. These branches anastomose with the iliac circumflex artery around the femur and with the first posterior perforating branch of the main deep femoral trunk to form the cruciate anastomosis.[21]

SUPERFICIAL FEMORAL ARTERY:

The superficial femoral artery is continuation of the main line of the common femoral artery. As it passes down the thigh from the femoral triangle, it comes to lie in the adductor canal under the sartorius muscle. The artery follows a direct course down the thigh on the anterior surface of the great adductor until it passes through the adductor hiatus in the fibrous insertion of this muscle and becomes the popliteal artery. Just at or before its passage through the adductor hiatus are given off the highest genicular arteries, of which medial is the largest.[21]

POPLITEAL ARTERY:

As the superficial femoral artery continues as popliteal artery at the adductor hiatus enters into popliteal space, it deviates laterally in a deep and well protected layer of fat and comes to lie in close attachment to the more superficial popliteal vein. Rarely the popliteal artery may have anomalous course in which the lower portion of the vessel curved posteriorly around the medial head of gastrocnemius muscle and may get thrombosed.[22]

ARTERIES OF LEG:

As the popliteal artery passes superficial to popliteus muscle it gives off anterior tibial artery. This artery arises almost at right angle to the parent vessel, and then passes laterally and forward to lie in the anterior surface of interosseous membrane. At this point the artery gives off a recurrent branch, which joins the genicular network. The origin of anterior tibial artery lies 2 to 3cms below the level of tibial plateau. The artery then descends through the anterior tibial muscular compartment to

approach the surface of the skin on the dorsum of the foot, and is known as dorsalis pedis artery.[22]

The main line of popliteal artery continues as tibioperoneal trunk beneath the soleus muscle and between two heads of gastrocnemius muscle. Here it divides into smaller peroneal artery and larger posterior tibial artery, which is in substance the continuation of popliteal artery. The peroneal artery continues down the leg on the posterior tibial muscle and medial to peroneus brevis muscle.

The posterior tibial artery also lies on the posterior tibial muscle, lateral to the flexor digitorum muscle. This artery passes deep to and the lies medial to the continuation of the tibial nerve, with which it continues in the area behind the medial malleolus where it is felt as the posterior tibial pulse.

COLLATERAL BRANCHES IN THE THIGH AND THE KNEE:

Obstruction at the thigh and the knee must be considered on the basis of the pathologic process. Atherosclerosis is the commonest source of obstruction usually at the level of the adductor hiatus, with patchy areas of obstruction extending upwards. In this situation, collaterals from the descending branch of the femoral artery refill the network around the knee formed by the various genicular branches.[22]

Obstruction of the popliteal artery is of several types. Occlusion of the outflow triad is apt to be associated with extensive disease of one or more tibial arteries. There is no suitable line for re-entry, and the collaterals at their origin in the genicular branches must empty into relatively small channels in the calf.

THE LOWER LIMB ARTERIAL DISEASES

DEFINITION:

Lower limb arterial diseases (LLAD) include a wide spectrum of entities that manifest in an equally wide spectrum of presentations. LLAD is subclassified as either occlusive or aneurysmal. In occlusive diseases, the lumen is narrowed either in a chronic or acute manner. Atherosclerotic involvement of the aorta may be associated with occlusive disease in the carotid, visceral, subclavian, or iliac arteries. In aneurysmal diseases, weakening of the arterial media results in focal dilation of a blood vessel to at least twice its normal diameter. Aneurysmal disease usually affects the aorta; the infrarenal abdominal aorta is the most common site. Whereas aortic aneurysms culminate in rupture, extremity-artery aneurysms tend to thrombose.

PREVALENCE:

Despite the fact that atherosclerotic LLAD is a risk factor for premature death, it is vastly under-diagnosed. Estimates of its prevalence depend on which definition of LLAD is used. If LLAD is identified on the basis of an ankle-brachial index (ABI) of less than 0.90, its prevalence is as high as 29% among patients in primary care practices.[23]

Aortic aneurysms usually occur in men over age 50. The estimated prevalence of abdominal aortic aneurysms is 2% to 5% in men over age 60. Ruptured abdominal aortic aneurysms account for at least 15,000 deaths per year. Peripheral aneurysms occur most frequently in the popliteal arteries.

PATHOPHYSIOLOGY

The pathophysiology of arterial occlusive disease is related to the arterial blood supply versus demand of muscles or organs. In both chronic and acute occlusive disease, the degree of ischemia is related to the size and proximity of the occluded artery to the muscle or end organ, the presence of collateral circulation, the rapidity of the occlusion, and the patient's blood pressure (BP).

Chronic occlusive arterial disease is more common than acute. Chronic disease usually is caused by atherosclerosis, a systemic process that affects all vascular beds. Other causes include Buerger's disease (which affects small and medium-sized vessels), giant-cell and Takayasu's arteritis (which affect larger vessels), fibromuscular dysplasia, or chronic and repetitive occupational trauma. External compression syndromes-such as thoracic outlet syndrome, popliteal entrapment syndrome, and adductor tendon compression-also may cause chronic occlusive arterial disease.

Acute arterial occlusions may occur in both normal and diseased arteries. In most cases, a thrombus embolizes from a proximal source (eg, the heart or the wall of an abdominal aortic aneurysm) and acutely occludes a distal peripheral artery. Chronically diseased arteries and peripheral artery aneurysms may thrombose acutely leading to rapid worsening of symptoms.

Morbidity and Mortality: Because atherosclerosis is a systemic disease, LLAD patients have a high prevalence of coronary artery disease and cerebrovascular disease. Patients with symptomatic LLAD have a 5-year mortality of almost 30%, which is higher than that of breast cancer. There is a correlation with LLAD severity (as measured by the ABI) and survival. In patients with severe, symptomatic LLAD,

only 25% survive 10 years.[24] Most of the morbidity and mortality in patients with LLAD is caused by cardiovascular and cerebrovascular events.

SIGNS AND SYMPTOMS:

Intermittent Claudication: The most common manifestation of LLAD is intermittent claudication. Patients usually describe progressive ache, tightness, fatigue, or pain in a muscle group distal to the arterial obstruction. Symptoms occur predictably after the patient walks a specific distance, provided there is no change in walking speed or surface grade. Relief of symptoms occurs within 2 to 5 minutes of rest. Claudication has a gradual onset and thus might not be noticed initially. The presence of asymptomatic lower extremities occlusive disease varies, but the available data indicate that for every patient with intermittent claudication, there are probably three others with similar disease who do not complain of symptoms.[24]

Aortoiliac disease is manifested by claudication symptoms in the buttocks, thigh, and calves. Isolated aortoiliac occlusive disease associated with sexual impotence in men is referred to as Leriche's syndrome. Occlusion in the superficial femoral or popliteal arteries usually begins at the level of Hunter's canal (the adductor canal of the thigh), and typically occurs in patients older than 40 years of age. Femoropopliteal disease is manifested by claudication in the calves and occasionally in the arch of the feet. The crucial function of the profunda femoris as the bridge between the aortofemoral segment and the femoropopliteal segment becomes apparent with occlusive disease of the superficial femoral artery. The profunda femoris provides collaterals to keep the lower leg viable and free of severe ischemia. In fact, it is not uncommon that patients with isolated superficial femoral artery occlusion have only mild to moderate, stable intermittent claudication.

Among patients with intermittent claudication, 16% will experience a worsening of their claudication symptoms, 7% will require lower-extremity bypass surgery, and fewer than 4% will need primary amputation. Approximately 1.4% of patients with intermittent claudication will progress to ischemic rest pain and/or gangrene. This rate is markedly higher among smokers and diabetics.[25]

Critical Limb Ischemia: Critical limb ischemia (CLI) can present acutely (i.e. distal embolization, external compression, acute thrombosis, etc.) or, in the majority of cases, as chronic CLI. CLI is defined as the presence of ischemic rest pain requiring analgesia for more than two weeks, or ulceration, or gangrene of the lower extremity with an ankle systolic blood pressure ≤ 50 mmHg and/or toe systolic pressure ≤30mmHg.[26]

Chronic CLI in the vast majority of cases are related to advanced atherosclerotic disease. Other diseases have to be kept in mind by the clinician, especially in young patients, those with ulcers in atypical locations, or those with few or no risk factors for CLI. Chronic CLI secondary to atherosclerosis develops when arterial stenosis reaches a critical point in which the blood flow supplied to the distal extremity is insufficient to provide the basal tissue oxygen demand. When the basal tissue oxygen demand cannot be met by the peripheral vascular system, ischemic injury occurs in the tissues with the lowest blood supply and necrosis results leading to tissue destruction, the appearance of ulceration, gangrene, and rest-pain. These seem to be accentuated in diabetics, in whom it leads to a more distal and diffuse disease that might significantly limit the possibility of an effective revascularization. The presence of neuropathy in this later group increases the risk of severe toe and foot lesions due to the absence of pain during and after trauma and the lack of early recognition of wounds that require prompt attention.[27] Chronic CLI is present usually in patients

with previous history of intermittent claudication, smokers, diabetics, history of cerebrovascular or coronary artery disease, who now present with one or all the four hallmarks of CLI: rest pain, non healing ulcers, dry gangrene, and patients with suspected CLI and palpable pulses. Absence of palpable pulses in patients with CLI, the ABI is almost universally below 0.5. The presences of faint pulses that disappear after a six minute walk test are also very suggestive of severe peripheral vascular disease.

CLASSIFICATION OF LOWER LIMB ARTERIAL DISEASE

The LLAD has been classified as

1. Atherosclerotic vascular disease

2. Nonatherosclerotic vascular diseases

- Raynaud's disease
- Vasculitis
- Burger's disease
- Heritable arteriopathies
- Congenital arterial lesions
- Homocystinuria

ATHEROSCLEROTIC VASCULAR DISEASE

Atherosclerosis is an age-old systemic vascular disease commonly affecting carotid bifurcation, coronary artery, abdominal aorta, and arteries of extremities. In atherosclerosis there is seen focal accumulation of lipids, complex carbohydrates, blood, blood products, fibrous tissue and calcium deposits with variable changes in intima and media of arteries. These changes eventually lead to focal plaque formation.

In initial stages there are luminal dilatation later ending in luminal stenosis in large plaques. [28]

The common risk factor associated with atherosclerosis includes hyperlipidemia, smoking, hypertension, and diabetes mellitus.[28] The modification of risk factors has resulted in favorable changes in atherosclerosis itself and associated morbidity.

Although the atherosclerosis is a systemic disorder, but its clinical manifestation relates to segmental pattern of involvement, plaques develop in coronary, carotid arteries, aorta and arteries of lower limb. The arterial involvement in upper limb is less frequent but clinical manifestation is seen due to plaque at the origin of arch vessels. The common clinical presentation includes myocardial infarction, cerebrovascular accidents, and lower limb ischemia presenting as intermittent claudication or critical limb ischemia.

It is fairly clear that the interaction of risk factors contributes to unique and characteristic localization of lesions in lower limb arteries.[28] There are seen three patterns of localization as influenced by diabetes, smoking and hyperlipidemia.

GROUP	ARTERIES INVOLVED
A	Aortic atherosclerotic changes.
C	Combined pattern involving aorta and lower limb arteries.
L	Atherosclerosis principally involving lower limb arteries.

DM shows predominantly group L pattern, however in nonsmoker's characteristic involvement of calf vessels sparing foot arteries is seen. Smoking, and hyperlipidemia shows combined pattern of involvement particularly aortic and

superficial femoral arteries. Superficial femoral artery is the most commonly affected artery in lower limb.

DIAGNOSIS OF LLAD

HISTORY AND PHYSICAL EXAMINATION: The history and physical examination are crucial in evaluating the patient with LLAD. Information about the onset of ischemic symptoms, the duration of symptoms, the characteristics of pain, and any alleviating factors is helpful. The quality of pulses should be documented. The absence of pulses in an extremity is probably the most common physical finding. Unlike arterial bruits, which reflect turbulent blood flow due to an atherosclerotic plaque of any severity as well as vessel tortuosity, diastolic bruits reflect high velocity blood flow through a high-grade stenosis. Diastolic bruits, therefore, are a more sensitive clinical sign of significant atherosclerosis. Palpation to detect the presence of abdominal and peripheral aneurysms should be performed. Risk factors, especially smoking and diabetes, should prompt a search for LLAD.

THE ANKLE-BRACHIAL INDEX (ABI): The ABI is the ratio of (1) the higher systolic blood pressures between the dorsalis pedis and the posterior tibial artery to (2) the higher of the systolic blood pressures in the two brachial arteries. The ABI's sensitivity is 90% and its specificity is 98% for detecting angiographically defined stenosis of 50% or more. Table below shows the how ABI values relate to severity of LLAD. The ABI also helps to differentiate true claudication from pseudoclaudication. Vascular claudication does not occur without a drop in the ABI. The ABI has limited use in evaluating calcified vessels that are not compressible.

THE ANKLE-BRACHIAL INDEX (ABI)	
ABI < 0.90	Abnormal
ABI > 0.80 to < 0.90	Indicates mild, possibly asymptomatic disease
ABI 0.50 to 0.80	Indicates moderate disease
ABI < 0.50	Usually indicates severe, multilevel occlusive disease , rest pain
ABI < 0.25	tissue loss

PULSE VOLUME RECORDINGS (PVR): The principles of plethysmography are applied to evaluate changes in leg volume (ie, arterial flow) with each pulse. BP cuffs applied to the thigh, upper calf, lower calf, and midfoot help determine the level and severity of arterial disease. The resultant waveform resembles a BP waveform. An abnormal pulse volume recording reflects the presence of disease proximal to the location of the BP cuff. Calcified vessels do not limit the utility of pulse volume recordings.

DUPLEX ULTRASOUND SCANNING: A combination of two ("duplex") methods of evaluation-B-mode imaging and Doppler measurements-renders both an anatomic and a functional assessment of the patient's condition. As blood flows through a stenotic lesion, its velocity increases. With duplex ultrasound scanning, peak systolic and end-diastolic velocities can be measured and are used to estimate the severity of a focal arterial stenosis. Different velocity criteria apply to different vascular beds. Duplex ultrasonography is an excellent screening tool for abdominal aortic aneurysms

and carotid arteries. Limitations to adequate imaging include inability of ultrasound waves to pass through air. Ultrasonography is also limited due to its difficulty in ascertaining neighboring organs, and its reliance on operator experience.

ARTERIOGRAPHY: The current arteriographic gold standard is intra-arterial digital subtraction angiography. However, because this is an invasive procedure, it should be reserved for patients who are being considered for endovascular or operative revascularization. Arteriography should not be used to delineate or screen for aneurysms because the mural thrombus, which frequently forms within an aneurysm, will mask the true lumen diameter

PLAIN RADIOGRAPHS: Radiographs are of limited use in the diagnosis of LLAD, and not used for diagnostic purposes. On occasion, however, radiographs incidentally may show evidence of LLAD. Sometimes the calcified medial layer of an artery will be appreciated. Alternatively, a thin rim of calcium in the wall of an aneurysmal aorta may be detected by a chest or abdominal radiograph.

COMPUTED TOMOGRAPHIC ANGIOGRAPHY (CTA)

Imaging of the arteries in the extremities was attempted with single row detector scanners in the past.[29] A revolution in peripheral CTA began when it became possible to image with four channel multidetector computed tomographic technique (MDCT) the inflow and out flow vessels in the entire lower extremity at an adequate resolution with a single intravenous administration of contrast material in a single acquisition.[30] Unlike ultrasonography, CT angiography is relatively investigator independent and can be performed easily, even on patients with calcified native arteries. CTA is less invasive, cost effective, and exposes patient to less radiation when compared to catheter angiography. CTA also assesses aspects external to the

lumen of the vessel that DSA cannot. MDCT angiography can characterize fully the arterial lesions detected, including their number lengths, diameter, and degree of calcification, assisting in pretreatment planning of balloon. The limitations being inability to use in patients with compromised renal function and interpretation may be suboptimal owing to obscuration of vascular flow channels by calcification.

MAGNETIC RESONANCE IMAGING AND ANGIOGRAPHY

Over the past several years, magnetic resonance imaging (MRI) and angiography (MRA) have become standard method of evaluation for several vascular disorders. The most common indication for MRA is evaluation of renovascular disease and peripheral vascular disease.

MRI can delineate the aorta and it's surrounding anatomic relationships, and also provides good images of the carotid, renal, and lower-extremity arteries. Moreover MRA and its three-dimensional reconstruction are superior to that of CT as it is more accurate. MRA has been demonstrated to be effective in the preoperative evaluation of patients with peripheral vascular disease, including imaging of the inflow vessels, distal runoff and stenosis. MRA has been shown to be superior to DSA in the evaluation of distal vessels. MRA is beneficial particularly in patients with renal failure in whom intravenous contrast agents are not desirable and it is minimally invasive. MRA cannot be used in patients who have implanted ferromagnetic equipment. Other limitations include cost and claustrophobia during scanning.

OTHER INVESTIGATIONS

1. Hemogram: heamoglobin estimation is done to assess the nutritional status.

2. Total Leukocyte Count, And ESR: are done in the evaluation of vasculitis as a cause of vascular disease.

3. Antinuclear Antibody screening done in systemic lupus erythematosus.

4. Renal function tests like Blood Urea and Serum Creatinine done to exclude renal failure.

5. Blood Glucose estimation done to exclude diabetes.

6. Hyperlipidemia is excluded by the estimation of Serum Cholesterol, LDL, HDL, and Triglycerides.

THERAPY AND OUTCOMES

The therapeutic aims of occlusive LLAD are three-fold:

1. To improve the functional status of patients with intermittent claudication, this will lead to improvements in quality of life and exercise capacity.

2. To preserve the limb and obviate the need for extremity revascularization with its associated morbidity and mortality.

3. To prevent coronary and cerebrovascular events, which prove to be fatal in 75% of LLAD patients.

Exercise Programs and Pharmacologic Therapies: Patients who participate in 3 to 6 months of supervised walking programs can increase their pain-free walking time.

Pharmacologic agents [pentoxifylline and cilostazol] are used in an attempt to increase walking distance.

RISK-FACTOR MODIFICATION:

Smoking and Diabetes Mellitus: The two most important risk factors associated with LLAD are smoking and diabetes mellitus. One study of intermittent claudication reported that 16% of smokers progressed to ischemic rest pain, compared with 0% of those who had quit smoking.[31] Among diabetic LLAD patients; gangrene develops in 31%, compared with only 5% of nondiabetic LLAD patients. Rest pain occurs in 40% and 18%, respectively.[92] Finally, patients with LLAD and diabetes are reported to have 5-year mortality rates of up to 50%.

Cholesterol: Dyslipidemias are common in patients with LLAD. Several trials have demonstrated significant reductions in death and myocardial infarctions in patients treated with HMG-CoA reductase inhibitors.

Hypertension: High BP not only increases the risk of claudication in patients with LLAD, it increases the risks of cardiovascular morbidity and mortality as well. Ideally, systolic BP should be kept lower than 130 mm Hg and diastolic BP less than 85 mm Hg. Keep in mind, however, that lowering BP too much can also lower limb perfusion pressure and worsen claudication symptoms.

Antiplatelet Therapy: Antiplatelet treatment is the cornerstone of therapy to prevent ischemic events in patients with LLAD. Aspirin has been shown to lower the risk of ischemic cardiovascular events. Aspirin has also been shown to prevent limb loss by preventing occlusions in native arteries and in lower-extremity bypass grafts.

Thienopyridine derivatives such as ticlopidine and clopidogrel inhibit platelet aggregation induced by adenosine diphosphate and superior to aspirin in reducing cardiovascular and cerebrovascular ischemic events in patients with LLAD.

Revascularization: Among patients with chronic arterial occlusive disease, revascularization is indicated for those who have lifestyle-limiting intermittent claudication, ischemic rest pain, or tissue loss. "Lifestyle-limiting" is a very subjective criterion, but it probably should include an inability to participate in a cardiac rehabilitation program because of claudication. Endovascular revascularization has achieved some popularity because it is associated with lower morbidity and less rehabilitation time than surgical revascularization. Generally speaking, endovascular revascularization [percutaneous transluminal angioplasty (PTA) with or without stenting] is favored for shorter lesions, while surgery is preferred for longer lesions as well as for lesions that fail endovascular revascularization. A general comparison between endovascular and surgical revascularization are outlined below:

In aortoiliac disease, PTA with stenting has been associated with a 24-month patency rate as high as 84% and a mortality rate as low as 0.2%. Surgery for aortoiliac disease yields 5-year patency rates of 80% to 90% and a mortality rate of 4.4%.[33]

The 5-year patency rate with PTA in femoropopliteal disease ranges from 40% to 60% (depending upon the length of diseased segment), and its mortality rate is lower than that of surgery.[34] Surgery has a 2.6% mortality rate and a 5-year patency rate of 70% for above-the-knee femoropopliteal autogenous vein bypass procedures and 40% for below-the-knee procedures. The latter figure drops to 20% when prosthetic graft material is used.[35]

In patients with disabling claudication due to femoropopliteal disease, a comparison study of surgery and angioplasty showed that PTA was the preferred initial treatment.[36] Infrapopliteal PTA has been used effectively for limb salvage, although anatomic selection plays an important role in outcomes.

PTA for a focal lesion in a tibial vessel with restorable run-off and a complete pedal arch yields a reasonable patency rate (80% at 2 yr).[37] The 4-year patency rates for infrapopliteal bypass are approximately 50% with autogenous vein grafts and only 12% with prosthetic grafts.[38]

Amputation: For patients who are not candidates for revascularization, amputation is an important treatment option. The level of amputation and the potential for effective rehabilitation are the two main factors to take into account. More distal amputation has a better rehabilitation potential, but also have a higher risk of incomplete healing with a sub-optimal treatment, resulting in further amputations. Therefore, before the level of amputation is chosen it is important to consider the following factors besides the overall cardiopulmonary condition of the patient: Non-invasive or invasive assessment of the arterial perfusion in the affected limb to guarantee effective healing, the presence or absence of infection, glucose control in diabetics, adequate nutrition, and attention to any mechanical feature that might compromise wound healing after the amputation.

BASIC PHYSICS

BASIC PHYSICS OF COLOUR FLOW DOPPLER

Ultrasonography uses a probe containing one or more acoustic transducers to send pulses of sound into a material. Whenever a sound wave encounters a material with a different density (acoustical impedance), part of the sound wave is reflected back to the probe and is detected as an echo.

The time it takes for the echo to travel back to the probe is measured and used to calculate the depth of the tissue interface causing the echo. The greater the difference between acoustic impedances, the larger the echo is

The frequencies used for medical imaging are generally in the range of 1 to 18 MHz. Higher frequencies have a correspondingly smaller wavelength, and can be used to make sonograms with smaller details. However, the attenuation of the sound wave is increased at higher frequencies, so in order to have better penetration of deeper tissues, a lower frequency (3-5 MHz) is used..

To generate a 2D-image, the ultrasonic beam is swept. A transducer may be swept mechanically by rotating or swinging. Or a 1D phased array transducer may be use to sweep the beam electronically. The received data is processed and used to construct the image. The image is then a 2D representation of the slice into the body.

3D images can be generated by acquiring a series of adjacent 2D images. Commonly a specialised probe that mechanically scans a conventional 2D-image transducer is used. However, since the mechanical scanning is slow, it is difficult to make 3D images of moving tissues.

Doppler ultrasonography is used to study blood flow and muscle motion. The different detected speeds are represented in color for ease of interpretation, for example leaky heart valves: the leak shows up as a flash of unique color. Colors may alternatively be used to represent the amplitudes of the received echoes.

MODES OF SONOGRAPHY

Four different modes of ultrasound are used in medical imaging . These are:

- A-mode: A-mode is the simplest type of ultrasound. A single transducer scans a line through the body with the echoes plotted on screen as a function of depth. Therapeutic ultrasound aimed at a specific tumor or calculus is also A-mode, to allow for pinpoint accurate focus of the destructive wave energy.
- B-mode: In B-mode ultrasound, a linear array of transducers simultaneously scans a plane through the body that can be viewed as a two-dimensional image on screen.
- M-mode: M stands for motion. In m-mode a rapid sequence of B-mode scans whose images follow each other in sequence on screen enables doctors to see and measure range of motion, as the organ boundaries that produce reflections move relative to the probe.
- Doppler mode: This mode makes use of the Doppler effect.

Sonography can be enhanced with Doppler measurements, which employ the Doppler effect to assess whether structures (usually blood) are moving towards or away from the probe, and its relative velocity. By calculating the frequency shift of a

particular sample volume, for example a jet of blood flow over a heart valve, its speed and direction can be determined and visualised.

This is particularly useful in cardiovascular studies (sonography of the vasculature system and heart) and essential in many areas such as determining reverse blood flow in the liver vasculature in portal hypertension.

The Doppler information is displayed graphically using spectral Doppler, or as an image using color Doppler (directional Doppler) or power Doppler (non directional Doppler). This Doppler shift falls in the audible range and is often presented audibly using stereo speakers: this produces a very distinctive, although synthetic, pulsing sound.

TECHNIQUE OF COLOUR FLOW DOPPLER

Ultrasound images are obtained by holding a probe on the skin surface. An ultrasonic scanner usually has a range of probes with different characteristics, and for lower-limb vascular scanning a linear array probe is normally used.

This produces a rectangular image which is displayed with the skin surface at the top, the vertical axis showing depth into the body and the horizontal axis showing position along the probe.

When imaging blood vessels, the probe can either be placed along the vessel to produce a longitudinal scan or across the vessel to produce a transverse scan .

To produce the images, the probe emits short pulses of ultra-sound, and these travel into the body from the probe. Within the soft tissues or at boundaries between them, a small proportion of the ultrasound is scattered or reflected and arrives back at the probe as an echo .

The speed of ultrasound in the body is constant (1540 m/s), so the depth of any scatterer or reflector can be found from the time delay from emitting the pulse to receiving the echo. The main pulse continues deeper into the body to be scattered or reflected from deeper structures.

When the echoes from one pulse have died down, the next pulse is emitted from a slightly different position along the probe . In this way, it is possible to build up an image of a plane in the body, with depth into the body as the vertical axis and position along the probe as the horizontal axis.

The probe determines the frequency of the ultrasound within the pulses. Frequencies between 3 and 7 MHz are generally used for peripheral vascular imaging. Higher frequencies give better resolution and more detailed images, but the higher frequency sound loses energy more quickly as it travels through the body so the depth of penetration is less. The operator usually uses as high a frequency as possible. Ultrasound of these frequencies does not travel through air, so a layer of water-based coupling medium is used between probe and skin.

BASIC PHYSICS OF MRI AND MR ANGIOGRAM

Magnetic resonance describes the phenomenon whereby the nuclei of certain atoms, when placed in magnetic field, absorb and emit energy of a specific frequency. The spectrum of absorbed or emitted energy depends upon the nucleus under observation and its chemical environment.

The nuclei for MRI are those which have an odd number of protons or neutrons and therefore posses a net charge and have angular momentum, because of combination of charge and angular momentum, these nuclei behave as magnetic dipoles. Almost all images produced till date have been of nuclear magnetism of the hydrogen nucleus (or proton), which is a particularly favourable nucleus from the MRI standpoint, and is present in virtually all biological material.

Other naturally occurring magnetic nuclei which are of interest include phosphorus (^{31}P), sodium (^{23}Na), Carbon (^{13}C), and potassium (^{39}K). In addition, exogenous noble gases such as helium (^{3}He) and Xenon (^{129}Xe) can be made sufficiently sensitive by polarization outside the magnet using laser techniques to allow imaging of airways and in case of xenon, blood perfusion.

The proton can be recharged as a small, freely suspended bar magnet spinning rapidly about its magnetic axis. When a group of protons are placed in a uniform magnetic field, their magnetic field, their magnetic moments experience a couple tending to turn them parallel to the direction of the field.

In a strong magnetic field, more of these nuclear magnetic dipoles align with applied static magnetic field than against it. This produces net magnetization in the direction of field. The direction of the strong magnetic field conventionally defines

the Z axis, which is generally along the longitudinal axis of the patient in a typical MRI imaging machine. In an interventional open magnet the field is often in the vertical direction. In dedicated extremity and neonatal MR field is in the horizontal plane across the magnet.

The strong magnetic field, which must be homogenous over a volume large enough to contain the human body in an MRI imaging machine, is provided by a resistive, permanent or superconducting magnet. Magnetic field strengths are used for clinical imaging currently range from 0.02 Tesla (T) to 8 T.

INSTRUMENTATION

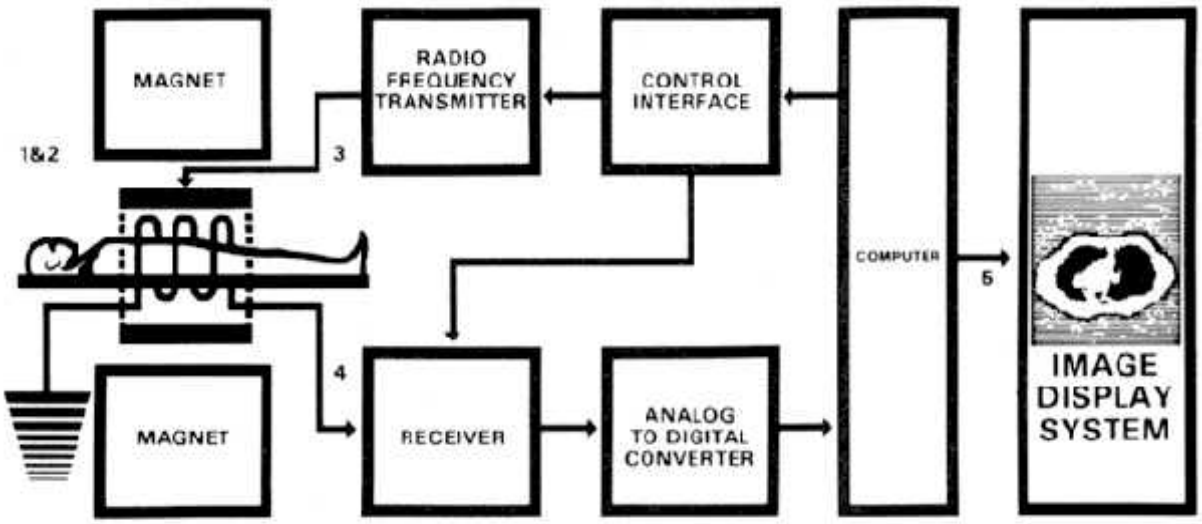
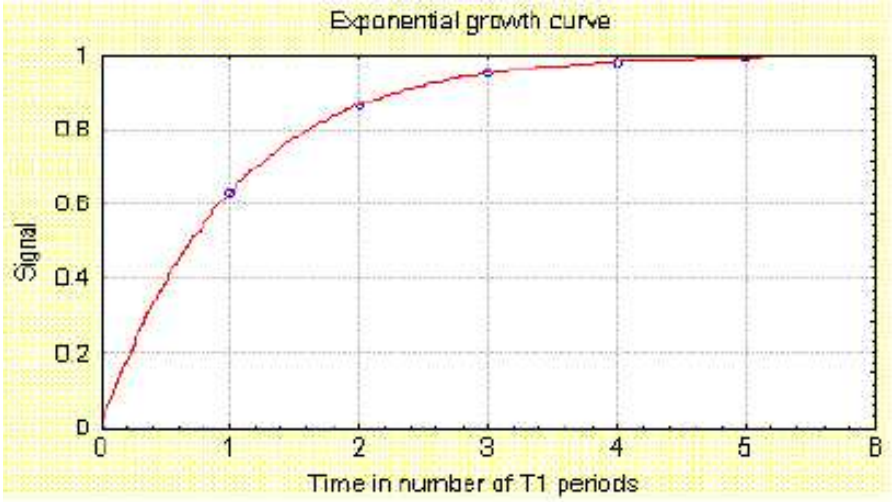


Fig. 1. Block diagram of a typical NMR imaging system. (Partain CL, James AE, Rollo FD, Price RR: Nuclear Magnetic Resonance (NMR) Imaging. Philadelphia, WB Saunders, 1983)

MRI AND MR ANGIOGRAM SEQUENCES

T1: The return of excited nuclei from the high energy state to the low energy or ground state is associated with loss of energy to the surrounding nuclei. Nuclear magnetic resonance was originally used to examine solids in the form of lattices, hence the name "spin-lattice" relaxation. Macroscopically, T1 relaxation is

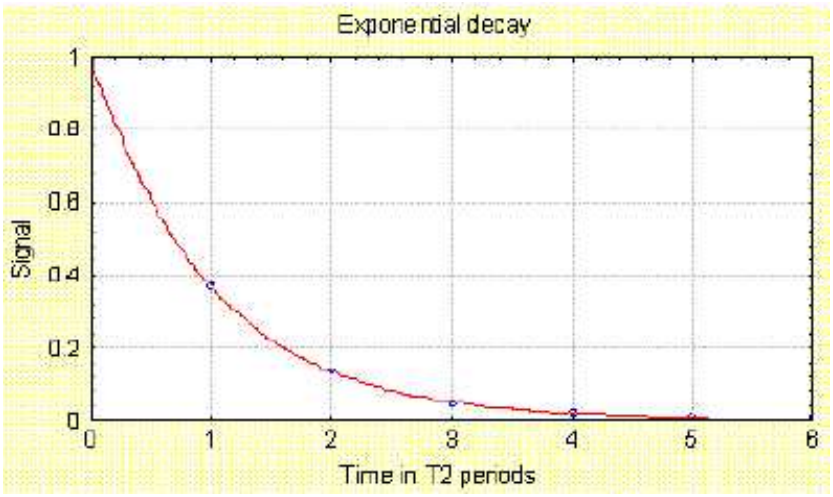
characterized by the longitudinal return of the net magnetization to its ground state of maximum length in the direction of the main magnetic field. The rate of return is an exponential process as is shown in the following figure



The T1 relaxation time is the time for the magnetization to return to 63% of its original length. After two T1 times, the magnetization is at 86% of its original length. Three T1 times gives 95%. Spins are considered completely relaxed after 3-5 T1 times. T1 relaxation is dependent on the main magnetic field strength. Higher magnetic fields are associated with longer T1 times.[39]

T2: Microscopically, T2 relaxation or spin-spin relaxation occurs when spins in the high and low energy state exchange energy but do not loose energy to the surrounding lattice. This results macroscopically in loss of the transverse magnetization.

T2 relaxation occurs exponentially like T1 relaxation with 63% of the transverse magnetization gone after one T2 period as shown in the graph.



T2*: T2* relaxation is the loss of signal seen with dephasing of individual magnetizations. It is characterized macroscopically by loss of transverse magnetization at a rate greater than T2 and is caused by magnetic field inhomogeneity

In liquids or systems containing mobile protons, T2/T1 is approximately unity, whereas in solids T2/T1 is very small. A local change in magnetic field homogeneity, e.g. due to local iron or deoxy-hemoglobin content, causes a reduction in T2 which is called T2*. In addition, flowing material within the image plane may alter contrast. T1 and T2 variations between tissues are usually very much greater than variations in proton density and images with high dependence on T1 or T2 therefore have greater contrast.

In pure water, the T2 and T1 times are approximately the same, 2-3 seconds. In biological materials, the T2 time is considerably shorter than the T1 time. For CSF, T1=1.9 seconds and T2=0.25 seconds. For brain white matter, T1=0.5 seconds and T2=0.07 seconds (70 msec).

TECHNIQUE FOR MR ANGIOGRAM

There are three general methods currently available for MR angiography

1) **Time-of-flight MRA (TOF)** : based on the principle of flow-related enhancement and highlights differences in magnetization between nuclei in flowing blood and those in stationary tissue.

2) **3D phase contrast MRA** : based on the principle of using velocity-induced phase shifts to depict flowing blood. In contrast with stationary tissue, spins moving through a magnetic field will experience a phase shift that is proportional to the velocity of flow, amplitude of the bipolar gradients, and time interval between the gradient lobes.

3) **Gd-enhanced 3D MRA (bolus-chase MRA):** Arteriography of patients with LLAD has been particularly challenging because the length of the vascular anatomy that must be illustrated (from at least the aortic bifurcation to the level of the ankle or distal trifurcation vessels) is extensive. This is required because lesions are typically multiple and tandem lesions are common (70%). Surgical planning requires comprehensive evaluation of the entire arterial territory.

Using individual fields of view of roughly 40 to 50 cm, peripheral MRA typically requires the imaging of three or more overlapping locations or stations. Gd-enhanced three-dimensional MRA is much faster than two-dimensional TOF MRA and has been found to afford improved diagnostic performance for imaging the peripheral vessels.

The most recent development of Gd-enhanced three-dimensional MRA has been the development of a technique called bolus-chase MRA. The basic concept is to synchronize imaging with the arterial transit of a single contrast bolus. In MR

imaging, this can be achieved by aligning table translation with the arterial phase of an intravenously administered Gd-chelate contrast bolus .

Typically, a 40-mL or 0.2-mmol/kg dose of Gd-chelate contrast media is administered at a slow rate (0.3 to 0.8 mL/second). The rate of contrast infusion should be adjusted so that the length of the contrast bolus duration matches roughly the time required to acquire the critical k-space data for the three overlapping stations. For example, if imaging requires 100 seconds (30 seconds per station with 5 seconds between stations), a 40-mL dose injected at 0.4 mL/second results in a 100-second bolus duration. Recently, a biphasic injection rate has also been shown to be effective.

METHODOLOGY

Study design

A cross sectional study.

Source of Data

30 patients of any age group diagnosed as having OAD of lower limb at KLESH,Belgaum based on comprehensive history and physical examination,subjected to CFD and MR angiography and later taken up for surgery.

Sample size

30 patients of lower limb arterial diseases.

Inclusion criteria

30 patients of any age group diagnosed as having OAD of lower limb at KLESH,Belgaum based on comprehensive history and physical examination,subjected to CFD and MR angiography and later taken up for surgery will be included in the study after taking their consent.

Exclusion criteria

1.Patients not fit or not opting for surgery .

2.Patients having blood dyscrasias .

3.Pregnant patients

4.Patients with history of allergy

5.Pts with artificial cardiac implants(metallic implants)

Statistical analysis:

30 cases of OAD are investigated with CFD and MR Angiography.

The lesions will be divided into :

1. Regionwise into aortoiliac and femoropopliteal.
2. Severity wise into :
    - Grade 0 (normal)
    - Grade 1 (stenosis)
    - Grade 2 (total obstruction)

- Lesions with Grade 2 & 3 stenosis will be considered as hemodynamically significant

3.Hemodynamically (HSL) significant lesions of CFD and MR Angiography and intra-operative findings will be recorded in the same subject and results will be compared as follows.

		INTRA OPERATIVE		
	HSL	PRESENT	ABSENT	TOTAL
CFD	PRESENT	A	B	
OR	ABSENT	C	D	
MRA	TOTAL			

Aortoiliac Region / femoropopliteal region

sensitivity = a/ a+c x 100 = _____%

specificity = d/ b+d x 100 = _____%

Results are compared by calculating sensitivity and specificity.

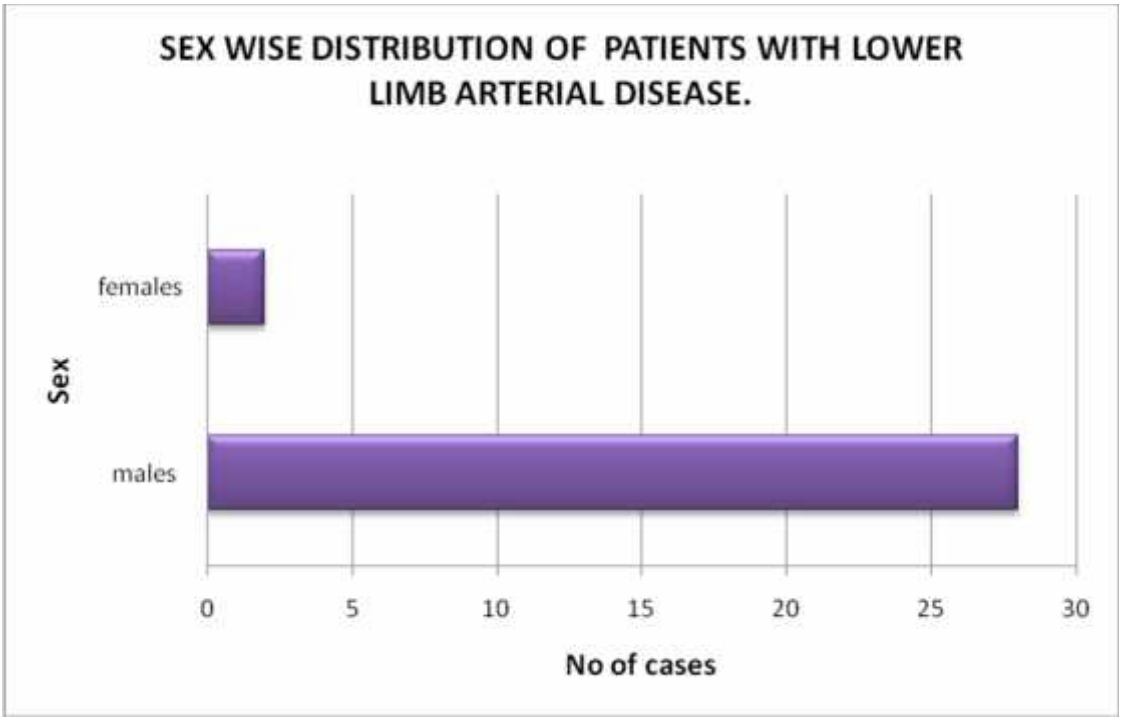
Statistical analysis done by using Chi-square test

P value of < 0.05 is considered statistically significant

RESULTS

TABLE NO. 01: SEX WISE DISTRIBUTION OF PATIENTS WITH LOWER LIMB ARTERIAL DISEASE.

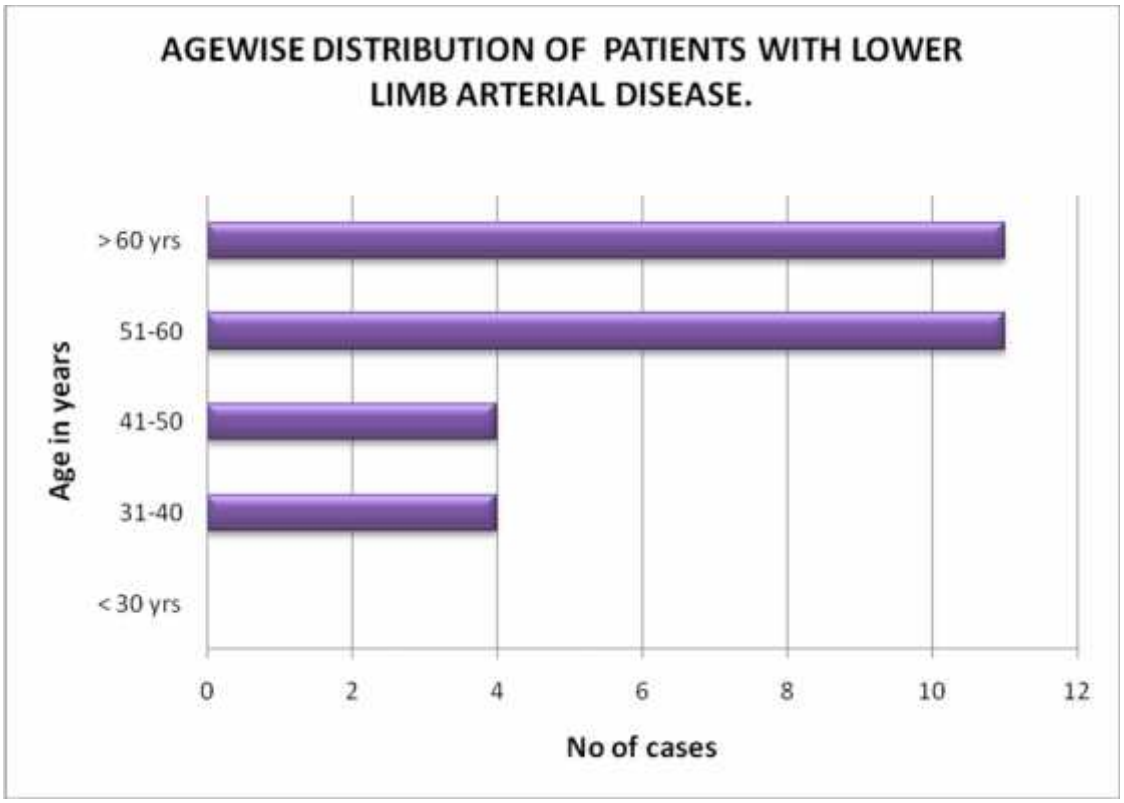
SEX	NO OF CASES	PERCETAGE%
MALES	28	93.3
FEMALES	2	6.7
TOTAL	**30**	**100**



In the present study there is male preponderance, male: female ratio being 14:1.

TABLE NO. 02: AGEWISE DISTRIBUTION OF PATIENTS WITH LOWER LIMB ARTERIAL DISEASE.

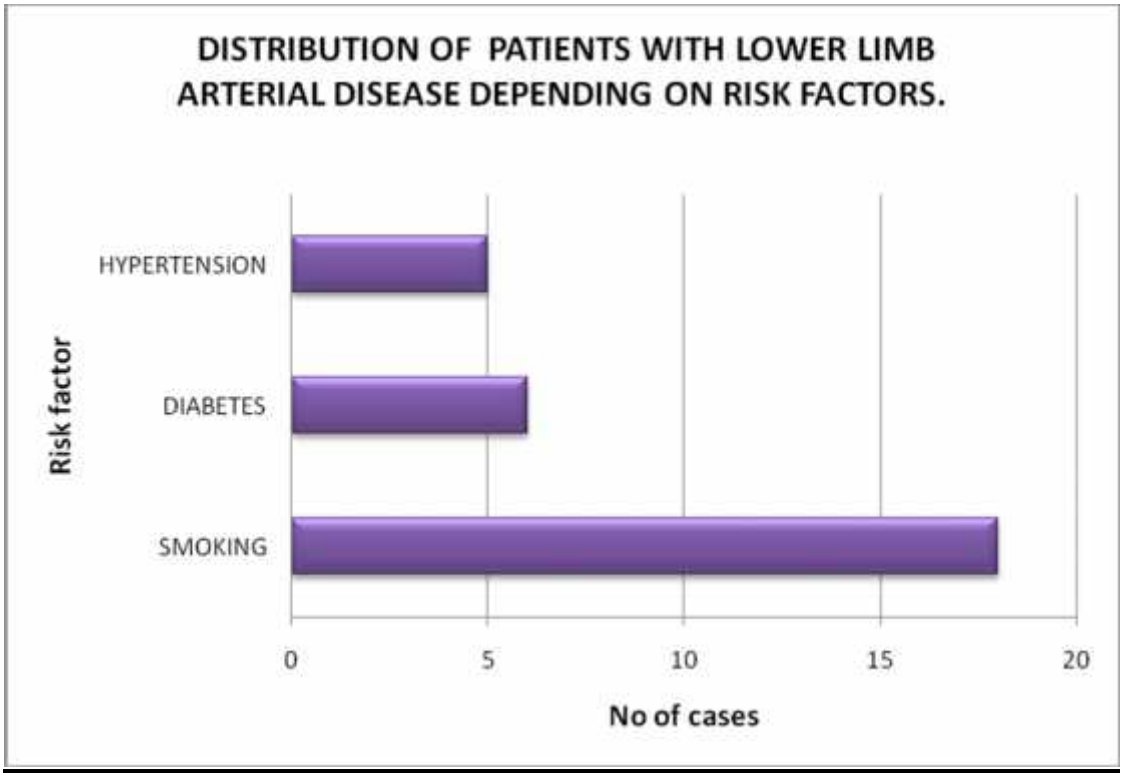
AGE	NO OF CASES	PERCENTAGE
< 30 YRS	**0**	**0**
31-40 YRS	**4**	**13.3%**
41-50 YRS	**4**	**13.3%**
51-60 YRS	**11**	**36.6%**
>60 YRS	**11**	**36.6%**



In the present study the peak occurrence of lower limb arterial disease is seen equally in the age group of 51-60 & > 60 years (36.6% each).

<u>TABLE NO.03</u>: DISTRIBUTION OF PATIENTS WITH LOWER LIMB ARTERIAL DISEASE DEPENDING ON THE RISK FACTOR.

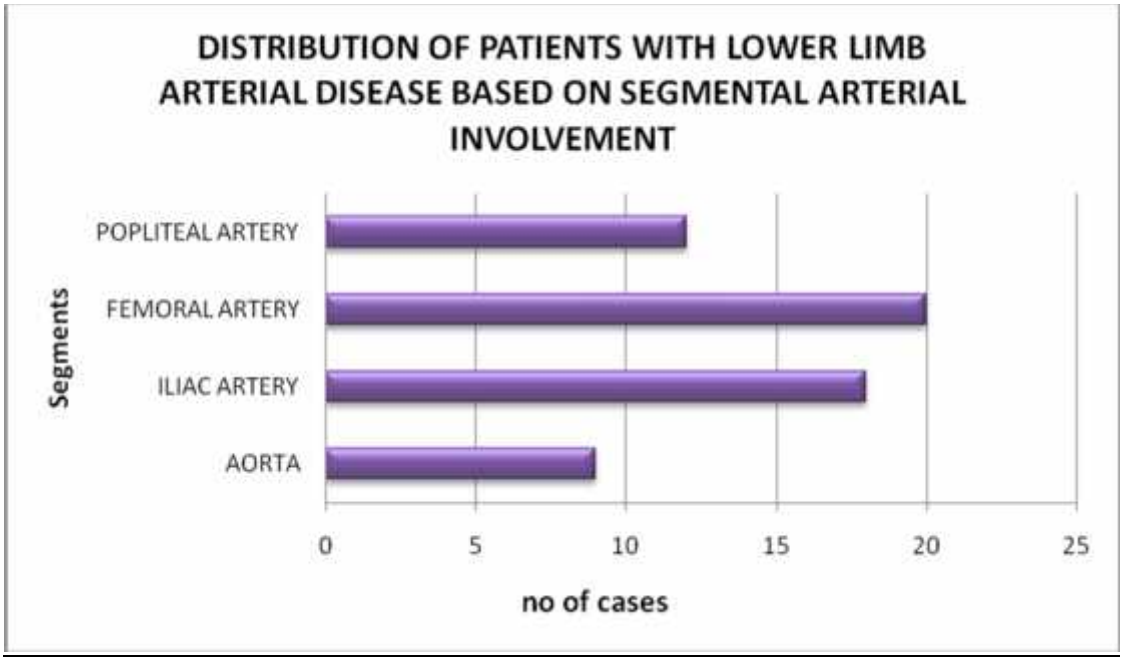
RISK FACTOR	NO OF CASES (N=30)	PERCENTAGE (%)
SMOKING	18	60
DIABETES MELLITUS	06	20
HYPERTENSION	05	16.67



In the present study, smoking is the commonest risk factor associated with lower limb arterial disease, seen in 60% patients and second commonest is diabetes mellitus in 20% patients.

<u>TABLE NO.04</u> : DISTRIBUTION OF PATIENTS WITH LOWER LIMB ARTERIAL DISEASE BASED ON SEGMENTAL ARTERIAL INVOLVEMENT

ARTERIAL SEGMENT	NO OF CASES	PERCENTAGE (%)
AORTA	09	30
ILIAC ARTERY	18	60
FEMORAL ARTERY	20	66.7
POPLITEAL ARTERY	12	40



In the present study, femoral arterial involvement is the commonest observation, seen in 20 patients (66.7%), followed by iliac artery in 18 patients (60%).

TABLE NO 05: COLOR DOPPLER OBSERVATION IN DETECTING ARTERIAL DISEASE IN AORTOILIAC SEGMENT IN COMPARISON WITH INTRAOPERATIVE FINDINGS.

COLOR DOPLLER FINDINGS	INTRAOPERATIVE FINDINGS			
	DISEASE	POSITIVE	NEGATIVE	TOTAL
	POSITIVE	26	00	26
	NEGATIVE	11	53	64
	TOTAL	37	53	90

SENSITIVITY – **70.27%**

SPECIFICITY – **100%**

(P value < 0.0001)

TABLE NO 06: MR ANGIOGRAPHY OBSERVATION IN DETECTING ARTERIAL DISEASE IN AORTOILIAC SEGMENT IN COMPARISON WITH INTRAOPERATIVE FINDINGS.

MR ANGIOGRAPHY FINDINGS	INTRAOPERATIVE FINDINGS			
	DISEASE	POSITIVE	NEGATIVE	TOTAL
	POSITIVE	35	00	35
	NEGATIVE	02	53	55
	TOTAL	37	53	90

SENSITIVITY - **94.59%**

SPECIFICITY – **100%**

(P value < 0.0001)

TABLE NO 07: COLOR DOPPLER OBSERVATION IN DETECTING ARTERIAL DISEASE IN AORTOILIAC SEGMENT IN COMPARISON WITH MR ANGIOGRAPHY FINDINGS.

COLOR DOPLLER FINDINGS	MR ANGIOGRAPHIC FINDINGS			
	DISEASE	POSITIVE	NEGATIVE	TOTAL
	POSITIVE	26	00	26
	NEGATIVE	09	55	64
	TOTAL	35	55	90

SENSITIVITY – **74.28%**

SPECIFICITY – **100%**

(P value <0.0001)

TABLE NO 08: COLOR DOPPLER OBSERVATION IN DETECTING ARTERIAL DISEASE IN FEMOROPOPLITEAL SEGMENT IN COMPARISON WITH INTRAOPERATIVE FINDINGS.

COLOR DOPLLER FINDINGS	INTRAOPERATIVE FINDINGS			
	DISEASE	POSITIVE	NEGATIVE	TOTAL
	POSITIVE	28	00	28
	NEGATIVE	12	80	92
	TOTAL	40	80	120

SENSITIVITY – **70%**

SPECIFICITY – **100%**

(P value < 0.0001)

TABLE NO 09: MR ANGIO OBSERVATION IN DETECTING ARTERIAL DISEASE IN FEMOROPOPLITEAL SEGMENT IN COMPARISON WITH INTRAOPERATIVE FINDINGS.

MR ANGIOGRAPHY FINDINGS	INTRAOPERATIVE FINDINGS			
	DISEASE	POSITIVE	NEGATIVE	TOTAL
	POSITIVE	36	00	36
	NEGATIVE	04	80	84
	TOTAL	40	80	120

SENSITIVITY – **90%**

SPECIFICITY – **100%**

(P value < 0.0001)

TABLE NO 10: COLOR DOPPLER OBSERVATION IN DETECTING ARTERIAL DISEASE IN FEMOROPOPLITEAL SEGMENT IN COMPARISON WITH MR ANGIO FINDINGS.

COLOR DOPLLER FINDINGS	MR ANGIOGRAPHIC FINDINGS			
	DISEASE	POSITIVE	NEGATIVE	TOTAL
	POSITIVE	28	00	28
	NEGATIVE	08	84	92
	TOTAL	36	84	120

SENSITIVITY- **77.77%**

SPECIFICITY – **100%**

(P value < 0.0001)

DISCUSSION

Lower limb arterial disease (LLAD) is a prevalent disorder with substantial morbidity. The risk factors associated with LLAD have increased the prevalence of mortality due to renal and cardiovascular involvement. A variety of invasive and noninvasive imaging techniques are available for evaluation of LLAD .

Lower limb arterial disease is believed to be more common in males than females. In a series of 520 cases Juergens et al. found male to female ratio of 11:1.[39] In epidemiological study by Jelnes et al. have consistently reported gender prevalence ratio of less than 2:1.[40] while one explanation for the discrepancy in reported male to female ratio may be an increasing disease frequency among women, perhaps due to an increasing rates of smokers among women., other plausible explanation is a referral bias in the studies in which men with symptomatic LLAD were more likely to obtain medical attention than women. Male predominance is also seen in present study where male to female ratio is 14:1. (Table No 01)

The incidence of LLAD increases with age. With extensive search no single study clearly explains the true incidence of LLAD. The study by Vogt et al. have shown five times increase in prevalence of LLAD in men over 50 years.[41] In present study around 73% of pts were above the age of 50 years. (Table No 02)

There are multiple risk factors involved in LLAD. The common risk factors include smoking, diabetes, hypertension, and hyperlipidemia other than age and sex. The study by Hughson and colleagues in 1978 reported the prevalence of smoking in 90%, diabetes in 11%, hypertension in 33%, and hyperlipidemia in 17%.[42] The study by Cronenwett and colleagues in 1984 reported the prevalence of smoking to be

96%.[103] The study by kennel had shown that the diagnosis of LLAD is made up to a decade earlier in smokers than nonsmokers and LLAD is associated with smoking in 80% of cases.[44] In the present study 60% of LLAD are smokers & 20% are diabetics (Table No 03)

In LLAD the arteries commonly involved are superficial femoral arteries. Stefan Reum and others in their study observed that 27% of aortoiliac, 23% of femoropopliteal, and 40% of leg arteries are diseased in lower limb arterial disease

The present study revealed that the femoral artery was most commonly involved (66.7%) followed by iliac (60%) (Table No 04).

The color Doppler ultrasound observations done by Leng in his study revealed sensitivity of 70% and specificity of 96% in assessment of aortoiliac disease by duplex ultrasound in comparison with angiography.[45] The analysis in this study for aortoiliac segment revealed a sensitivity of 70%, specificity of 100% in comparison with intraoperative findings & a sensitivity of 74%, specificity of 100% in comparison with MR angiography (Table No 05 & 07).

For femoropopliteal segment the sensitivity was 70%, specificity was 100% in comparison with intraoperative findings & sensitivity was 77%, specificity was 100% in comparison with MR angiography (Table No 08 & 10).

MR angiography is a well established modality in assessment of peripheral vascular disease . The analysis in this study revealed a sensitivity of 95%, specificity of 100% for aortoiliac segment & a sensitivity of 90%, specificity of 100% for femoropopliteal segment in comparison with intraoperative findings (Table No 05 & 07).

CONCLUSION

1. Lower limb arterial disease was more prevalent in male population.
2. Lower limb arterial disease was more prevalent over the age of 50 years.
3. The most frequent risk factor associated with lower limb arterial disease was smoking followed by diabetes mellitus, hypertension, and hyperlipidemia.
4. The most common clinical presentation was intermittent claudication .
5. Commonest involved arteries in was common femoral artery followed by iliac artery.
6. The color doppler sonography was less sensitive but a highly specific modality in assessment of both aortoiliac & femoropopliteal segments in comparison with contrast enhanced MR angiography . Therefore doppler sonography can be used as a initial investigation . (P value < 0.0001)
7. MR angiography is the "GOLD STANDARD" investigation for diagnosis and preoperative evaluation of pts with lower limb arterial disease .

   (P value < 0.0001)

SUMMARY

From the present study it was noted that, colour doppler sonography is one of the most comprehensive, noninvasive ,cheap, safe and repeatable modality for the diagnosis of lower limb arterial disease and its extent.

MR angiography is the "GOLD STANDARD" investigation for diagnosis and preoperative evaluation of pts with lower limb arterial disease.

It can also be used as an effective prognostic modality. The early and timely diagnosis of extent of involvement of lower limb arteries and information regarding distal runoff arteries is extremely helpful in deciding the vascular intervention like PTA or surgical revascularization in saving the limb from amputation. Pastprocedure assessment of graft patency and progression of the disease is quite well demonstrated on MR angiography.

In summary , three dimensional contrast enhanced magnetic resonance angiography is the most comprehensive, non invasive, safe, in-vivo diagnostic modality for delineation of vascular anatomy and diagnosis of lower limb arterial disease. It assesses the extent of involvement, collateral circulation, distal runoff and predicts the prognosis .However colour doppler sonography can be used as an initial investigation in pts with lower limb arterial disease.

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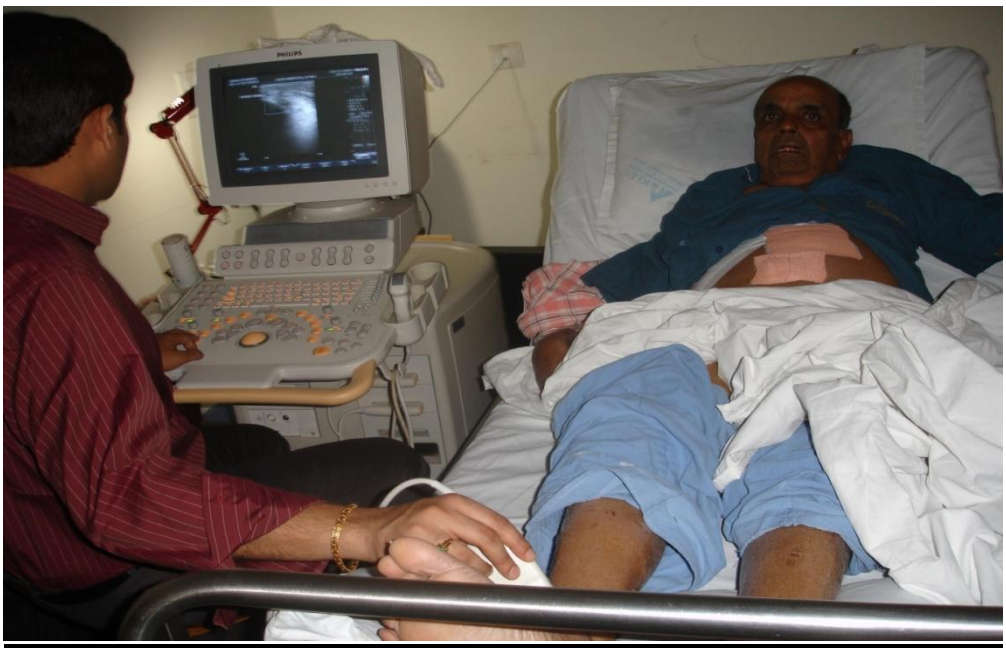
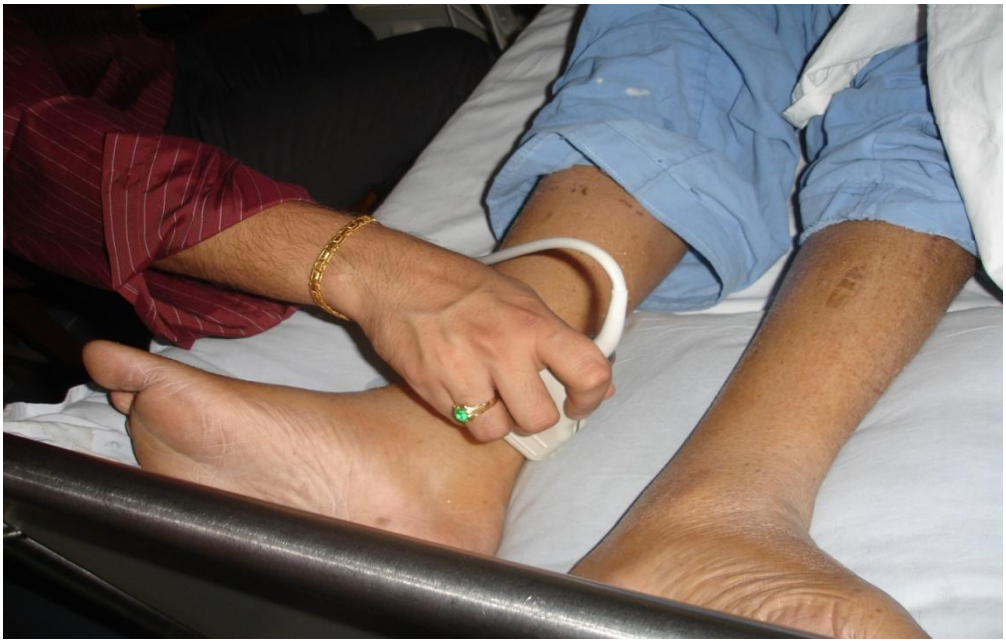
PHOTOGRAPHS



Colour Doppler being done on a patient



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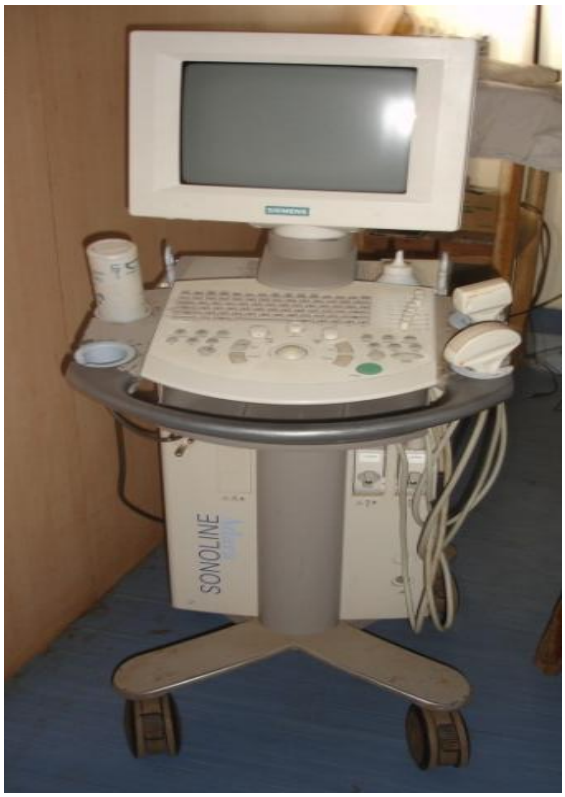
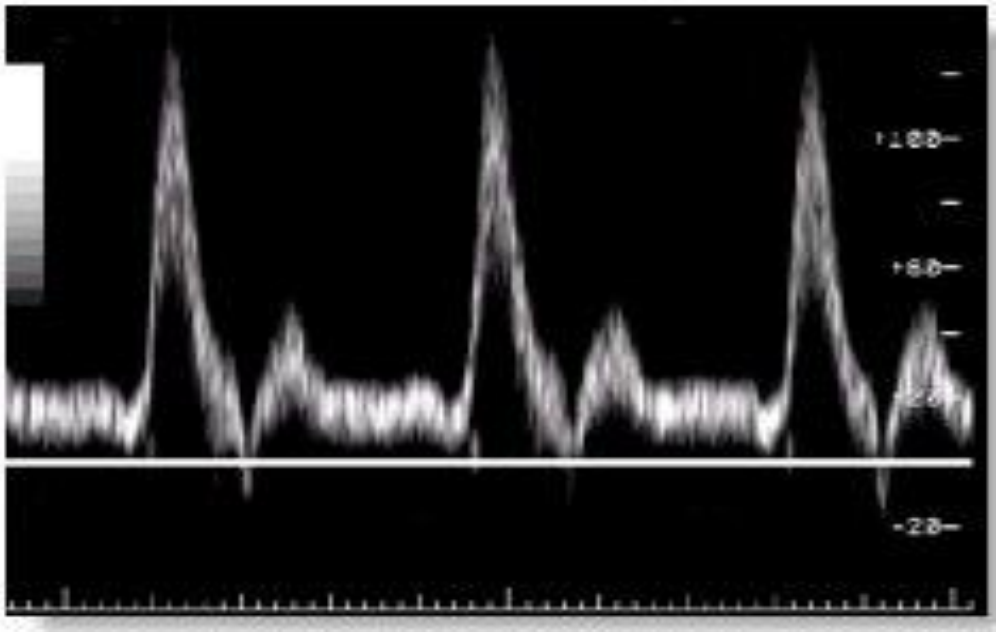
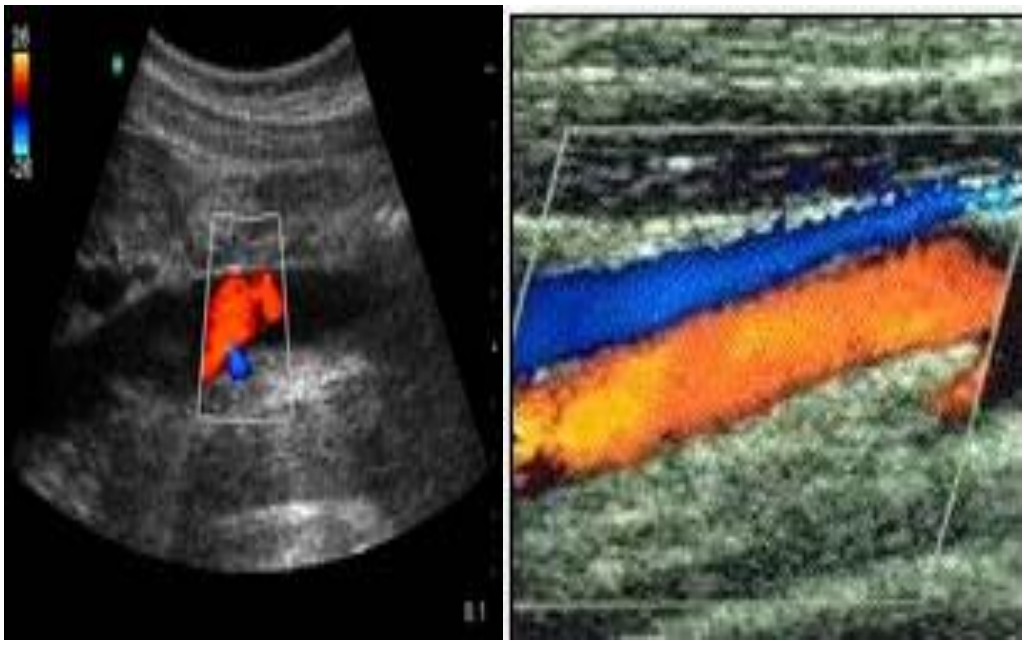


The Colour Doppler machine

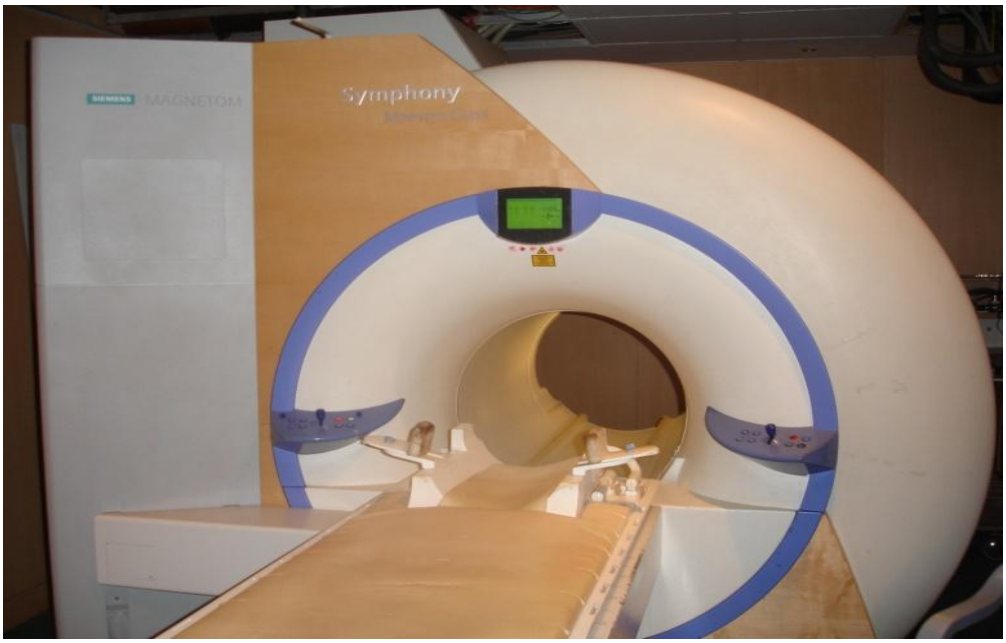
The Colour Doppler machine with different types of probes



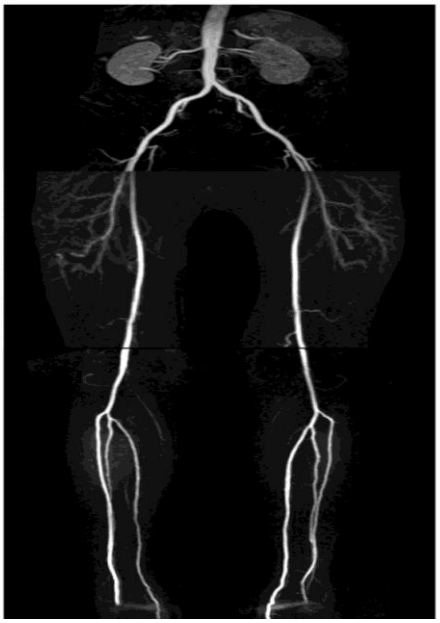
Spectral Doppler measurement of blood flow in the common femoral artery



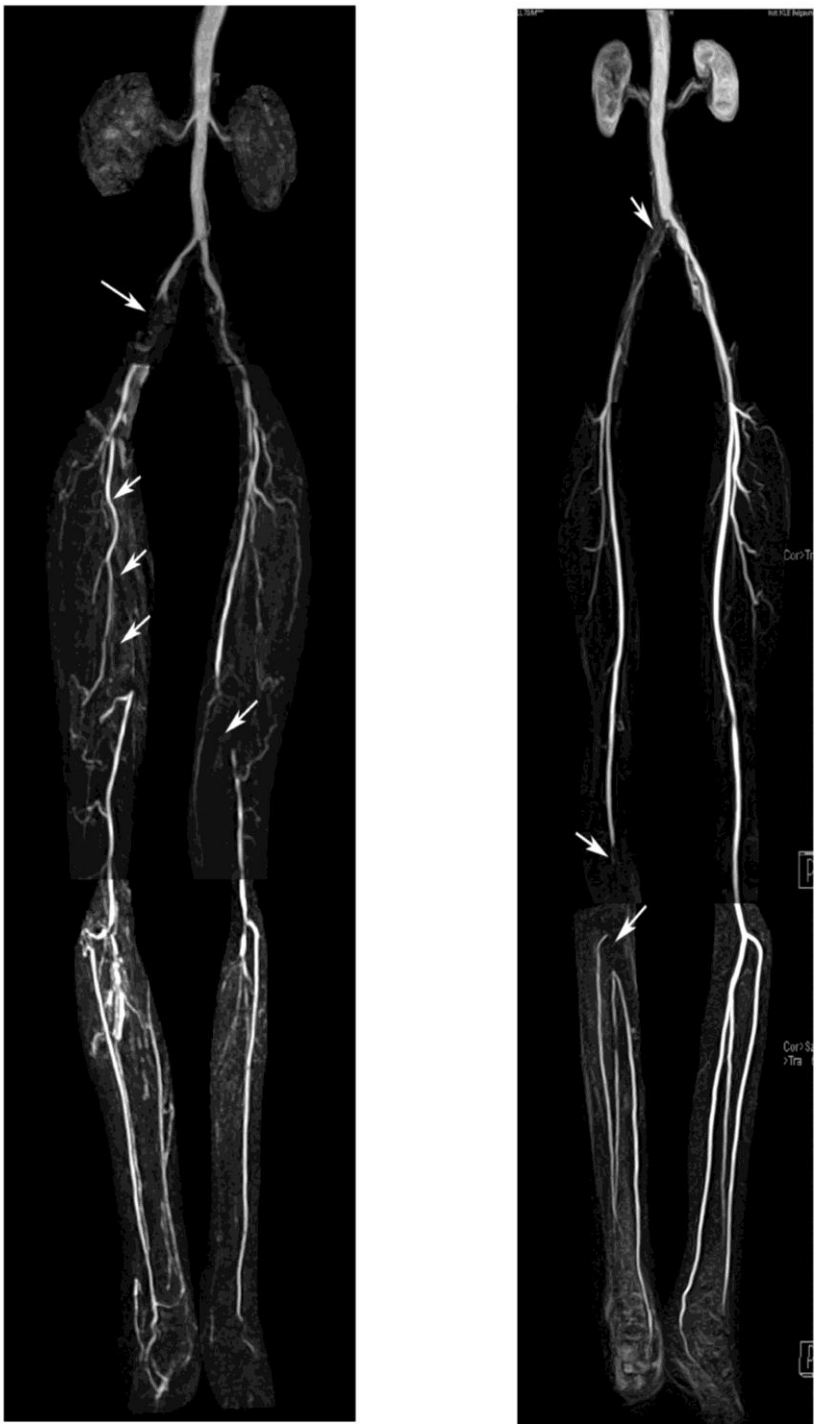
Colour flow images showing arterial and venous blood flow



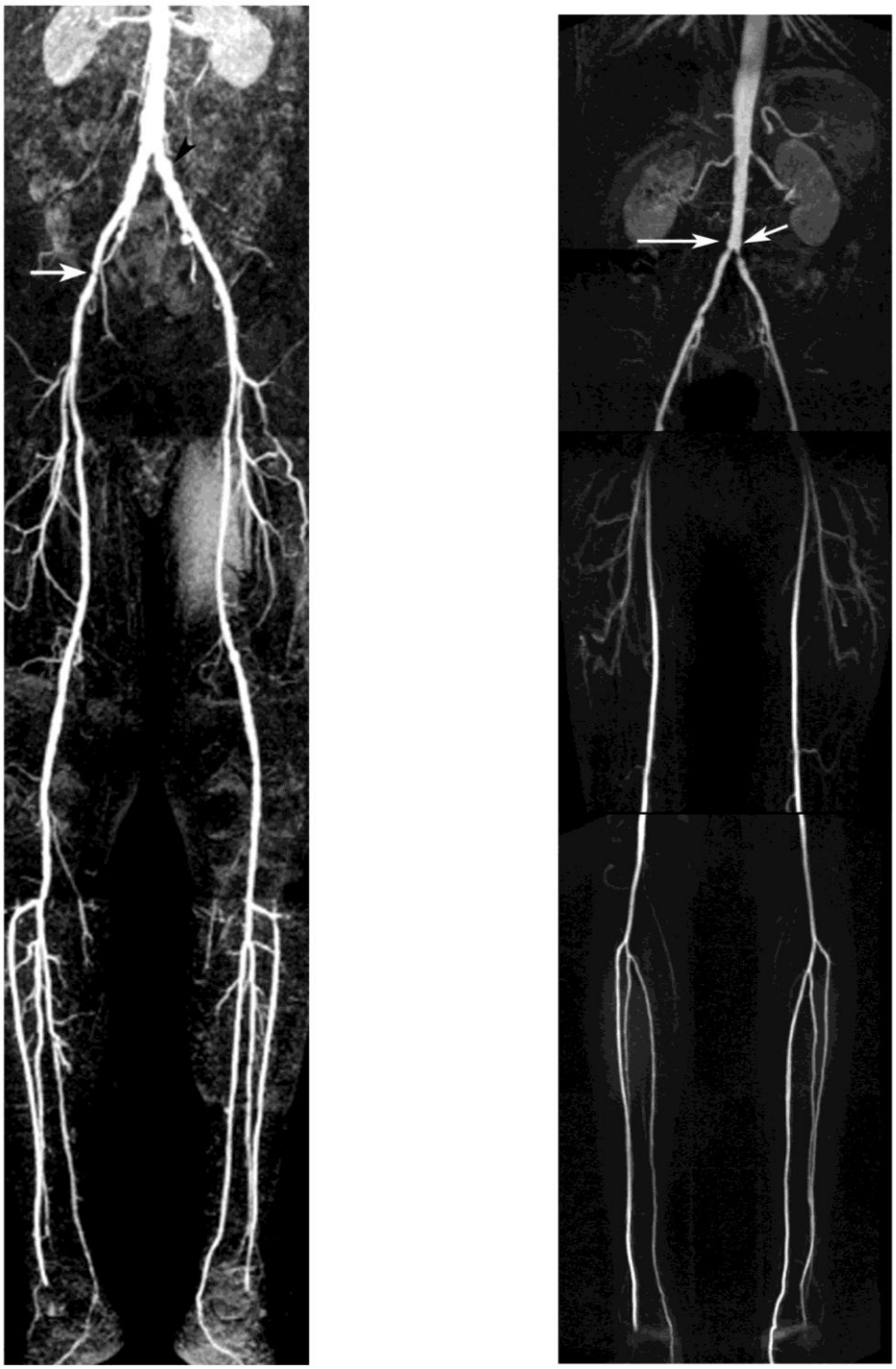
The 1.5 Tesla magnetic resonance angiography machine



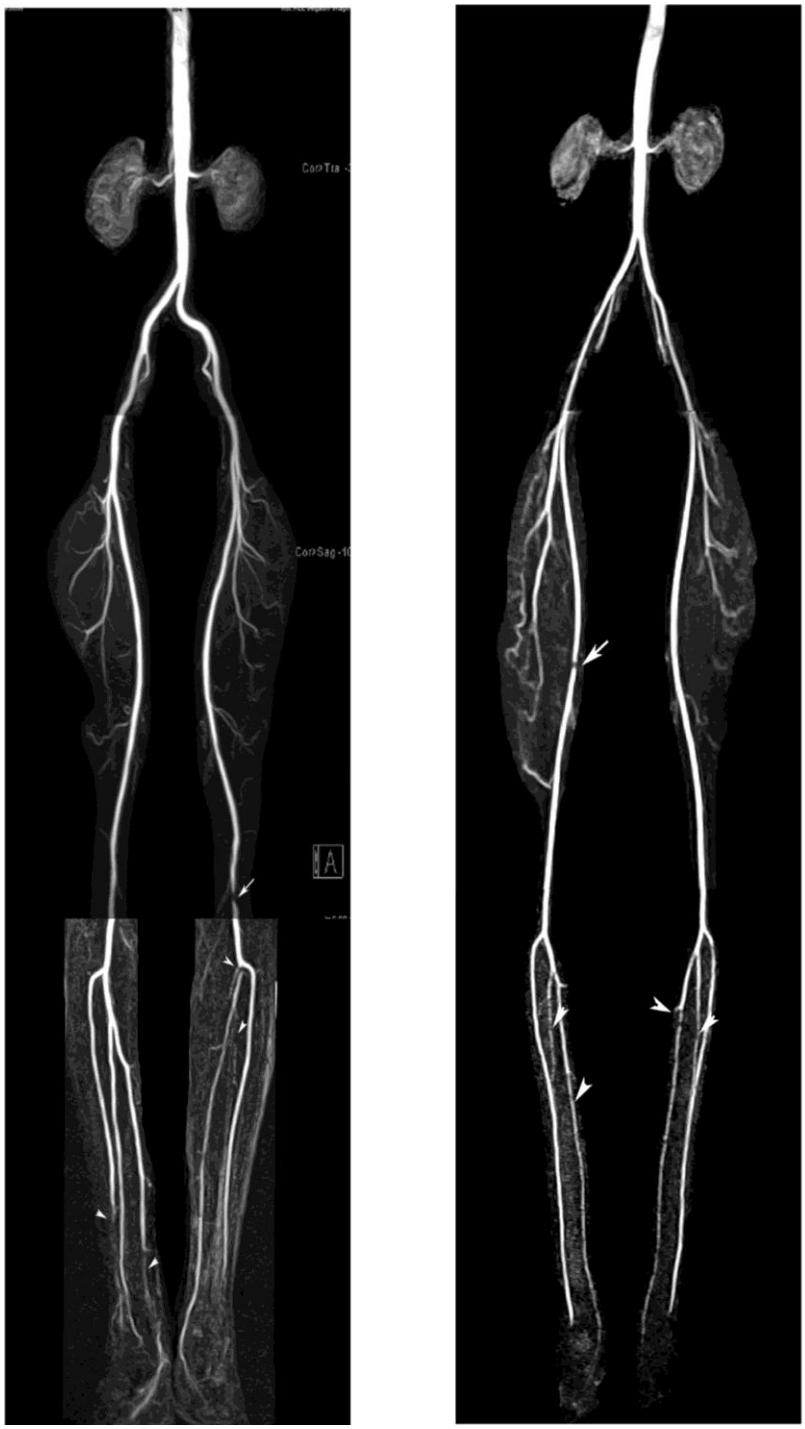
Normal 3D gadolinium enhanced MR angiogram of lower limbs



Diffuse atherosclerotic arterial involvement of lower limbs on a MR angiogram



Atherosclerotic iliac artery involvement on MR angiogram



Popliteal and small arterial involvement on MR angiogram

PROFORMA

Name:	Age:	Sex:
Unit:	I.P.No:	Referring Physician:
Address:	D.O.A.:	D.O.D.:

Occupation:

Presenting Complaints:

Intermittent claudication

Rest Pain

Gangrene

Tissue Loss

History of Past Illness:

Diabetes:

Hypertension:

Personal History:

Life Style:

Allergy:

Diet:

Smoking:

Tobacco chewing:

General Physical Examination:

Built:	Clubbing:	
Nourishment:	Jaundice:	
Pallor:	Lymphadenopathy:	
Cyanosis:	Pulse:	BP:

Clinical Diagnosis:

Investigations Done:

Blood and Biochemistry:

1. TC, DC, Hb, ESR
2. Blood Sugar
3. Urea
4. Creatinine
5. Lipid profile
6. Others

Colour doppler study :

M.R. Angiography study :

1) Aortic region

HSL	CFD	MR ANGIO	INTRA – OP
PRESENT			
ABSENT			

2) Iliac region

Right Side

HSL	CFD	MR ANGIO	INTRA – OP
PRESENT			
ABSENT			

Left Side

HSL	CFD	MR ANGIO	INTRA – OP
PRESENT			
ABSENT			

3) Femoral Region

Right Side

HSL	CFD	MR ANGIO	INTRA – OP
PRESENT			
ABSENT			

Left Side

HSL	CFD	MR ANGIO	INTRA – OP
PRESENT			
ABSENT			

4) Popliteal region

Right Side

HSL	CFD	MR ANGIO	INTRA – OP
PRESENT			
ABSENT			

Left Side

HSL	CFD	MR ANGIO	INTRA – OP
PRESENT			
ABSENT			

CONSENT FORM

Title : "ONE YEAR STUDY OF COMPARISON OF DIAGNOSTIC ACCURACIES OF COLOUR FLOW DOPPLER WITH CONTRAST ENHANCED MAGNETIC RESONANCE ANGIOGRAPHY (M.R ANGIOGRAPHY) AND WITH INTRAOPERATIVE FINDINGS IN 30 PATIENTS WITH OBSTRUCTIVE ARTERIAL DISEASE OF LOWER LIMBS PRESENTING AT KLE HOSPITAL, BELGAUM".

Purpose of study:

The purpose of this study is to know arterial involvement in terms of location, number, length and severity of the disease in lower limb arterial diseases by CFD and 3 dimensional contrast enhanced magnetic resonance angiography. There will be approximately 30 patients with lower limb arterial disease participating in the study during the period of 1 year. This study will be under the supervision of **Dr. A. C. Pangi,** Associate Professor, Department of General Surgery, of the J. N. Medical College of Belgaum.

Procedure and Treatment:

You will qualify for the study only if you have symptoms of lower limb arterial diseases like intermittent claudication, rest pain and gangrene and agreed to provide additional background and medical information.

The procedure includes the CFD and magnetic resonance imaging after injecting the gadolinium DTPA contrast intravenous. The contrast enhanced images of lower limb vascular tree is obtained and will be studied. The procedure will be done under the supervision of **Dr. A. C. Pangi,** Associate Professor, Department of General Surgery of the J. N. Medical College of Belgaum.

Risks:

There are certain risks and discomforts that you may experience as a result of participating in this study. These may include temporary minor side effects like nausea, headache, dizziness, injection site reaction, parasthesia, urticaria which generally resolve without treatment

Benefits:

By this study the detailed information of morphologic abnormalities of the lower limb arteries in arterial disease is obtained which will help you in best possible treatment in relieving the symptoms of lower limb arterial disease further preventing from limb loss.

Financial incentive for participation:

You will not receive any payment for participating in this study.

Alternatives:

If you decide not to participate in the study you will receive usual standard care as given in the hospital

Results of this study may be published for scientific purposes or presented to scientific groups; however you will not be identified.

Institutional Policy

The J. N. Medical College will provide, within the limitations of the laws of the State of Karnataka, facilities and medical attention to subject who suffer injuries as a result of participating in its projects. In the event you believe that you have suffered any physical injury as

result of your participation in this study you may contact Principal Investigator **Dr. Santosh B. Chikaraddi, Mobile No. 9886232107**

Voluntary Participation:

Your participation in this study is voluntary. Your decision whether or not to participate will not affect the care or your current or future relations with the doctor and the hospital. You are free to discontinue the participation in this study at any time and for any reason. In case you need any further information regarding your rights as a study participant you may please contact Dr. V. D. Patil, Principal, J. N. Medical College, Belgaum and Chairman of the J. N. Medical College Ethics Committee on Human Subjects Research, Telephone No. 0831-2471350.

Statement of consent

I volunteer and consent to participate in this study. I have read the consent or it has been read to me. The study has been fully explained to me and I may ask questions at any time.

_____ _____

Signature or left hand thumb impression (Volunteer Subject) Date

_____ _____

Signature (Witness) Date

_____ _____

Signature of investigator / designee obtaining informed consent Date

MASTER CHART

Serial number	Name of patient	Age (yrs)	Diagnosis	Inpatient number	Date of entry
1.	Rama.Sawant	65	Right ileopopliteal block	212743	5/01/07
2.	Ningappa.Sajjanar	55	Right ileofemoral block	213948	20/01/07
3.	Swayam.P.Inamdar	51	Left femoral block	217626	13/02/07
4.	Kusta.N.Gaude	45	Right iliac block	217926	16/02/07
5.	Babli.Gaonkar	34	Aortic with bilateral iliac block	217807	20/02/07
6.	Nagappa.S.Guggeri	42	Right femoropopliteal & Left femoral block	218907	25/02/07
7.	Abdul.R.Doulatdar	62	Aortic with bilateral ileofemoral block	221611	28/03/07
8.	Rajendra.kadolli	62	Left femoral block	226185	18/04/07
9.	Bhimappa.Mane	55	Aortic with bilateral iliac block	225288	26/04/07
10.	Fakirappa.Patil	72	Aortic with bilateral ileofemoral block	229617	22/05/07
11.	Basappa.A.A	72	Aortic with bilateral iliac & left femoral block	227188	12/06/07
12.	Annappa.Hiremath	60	Aortic with bilateral iliac block	229066	4/07/07
13.	Virupaxi.Avate	55	Left popliteal block	236187	11/07/07
14.	Shankargouda.Hadli	63	Left femoral block	245668	20/08/07
15.	Rajashekar.Hatyal	65	Right femoropopliteal block	245428	24/08/07

MASTER CHART

Serial number	Name of patient	Age (yrs)	Diagnosis	Inpatient number	Date of entry
16.	Basavaraj.C.Ulagaddi	32	Left popliteal injury	245525	30/09/07
17.	Dundappa.Shindolli	66	Bilateral ileofemoral block	248880	18/10/07
18.	Kallangouda.Patil	38	Left common iliac block	248703	22/10/07
19.	Basappa.Kumbar	54	Aortic with bilateral femoral block	251119	16/11/07
20.	Basavesh.Shiri	65	Right popliteal block	251931	26/11/07
21.	Basanagouda.Desai	60	Bilateral common iliac block	252438	7/12/07
22.	Mutappa.Sakannavar	35	Left femoral block	255778	22/12/07
23.	Shivappa.S.Jirali	82	Left femoral block	255902	10/01/08
24.	Subhash.Kulkarni	64	Right femoral block	257896	10/01/08
25.	Azad.Kalandar	46	Right common iliac block	258765	20/01/08
26.	Razaksab.Kaladgi	54	Left femoral block	260064	6/02/08
27.	Shahji.Patil	55	Aortic with right ileofemoral block	260965	18/02/08
28.	Satyappa.Kamate	60	Right femoral block	263812	7/03/08
29.	Basavanappa.Abbai	49	Left femoral block	264660	22/03/08
30.	Basappa.D.Belkod	60	Right common iliac block	266463	26/03/08