Masters   Science

2011-03-01

Is there a Benefit to Screening for Abdominal Aortic Aneurysm in the Irish Male Population between the ages of 55 to 75 years; an Ideal Opportunity Group for Evaluating Cardiovascular Risk Factors?

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Is there a benefit to screening for abdominal aortic aneurysm in the Irish male population between the ages of 55 to 75 years; an ideal opportunity group for evaluating cardiovascular risk factors?

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DECLARATION

I hereby certify that the material which is submitted in this thesis towards award of the **Masters (M.A.) in Work-based Learning** is entirely my own work and has not been submitted for any academic assessment other than part-fulfilment of the award named above.

Signature of candidate:………………………………………….
Date: ………………………………

ACKNOWLEDGEMENTS

I wish to thanks my supervisors Dr. Ann O Shaughnessy, Education Specialist and Accredited Vascular Technologist and Dr. Patrick Goodman Department of Physics, Dublin Institute of Technology.

I would   like to thank the staff of the Vascular Department in Connolly Hospital, Blanchardstown, Dublin who have assisted in making this work possible.

I also wish to thank Blackrock Clinic for all their support while I was completing this dissertation.

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Abstract

Introduction: Abdominal Aortic Aneurysm (AAA) screening programmes have been carried out worldwide on males between the ages of 65-75 years. The results of such programmes show AAA screening to be beneficial and cost effective. In the Multicentre Aneurysm Screening Study conducted in the United Kingdom, the incidence of AAA was 4.9%. Early diagnoses of AAA's have reduced AAA related deaths by 42%.

This study investigated the incidence of AAA in Irish males between the ages of 55-75 years and incorporated an assessment of cardiovascular risk factors. A younger group of males were screened to see if there was any benefit in screening for AAA and to determine the incidence of cardiovascular risk factors in this younger population.

Method: From April 2006 to December 2007, males ages between 55-75 years living in the catchment area of the hospital, were invited to participate in the screening programme. A ultrasound scan of their aortas was preformed and a finger prick blood test was carried out to assess their cardiovascular risk factor status.

Results: Nine hundred and four participants were screened. Of these, 17 (1.9%) participants had an undiagnosed AAA, of which 4.2% were aged between 65-75years and 0.6% aged between 55-64 years. The incidence for hypertension, 33% had been previously diagnosed with hypertension, with 165 of these uncontrolled. In the participants with no history of HTN, 31% had an elevated blood pressure reading. The study found, 26% had a previous history of hypercholesterolemia, with 70% of these remaining uncontrolled. Of those with no previous history of hypercholesterolemia, 33% had an elevated reading. The glucose results revealed 3% of the total participants had a raised glucose level with had no previous history of DM. Of those who were being treated for diabetes, 49% showed poor sugar control. Only 63% (573) of all participants agreed to have their body mass index measured. Of these, 16% were found to be morbidly obese and 64% were overweight.

Conclusion: The incidence of AAA in males between 65-75 years is similar to other worldwide studies, therefore screening would be beneficial in Ireland. However, screening males of 55-65 years was not proven to be beneficial. Cardiovascular risk factors, such as hypertension, hypercholesterolemia and diabetes are very prevalent in Ireland. In this study

the prevalence of cardiovascular risk factors were high. Of those who have been diagnosed with a cardiovascular risk factor, many remain uncontrolled despite treatment. There was also a larger number of the screened population undiagnosed for their risk factors. Therefore screening for cardiovascular risk factors is a necessity and it can easily be incorporated in to other screening programmes.

1.   Introduction of abdominal aortic aneurysms (AAA)

In the following thesis, I aim to show the benefit for AAA screening of Irish males. The results of this screening study for AAA will be analysed and compared with other international studies. We screened men in the 65-75 years of age group when AAA's commonly occur and we also screened men aged 55-64 years to see if there was any benefit in screening a younger population. In addition to the AAA screening, these males were also screened for cardiovascular disease such as hypertension, hypercholesterolemia and diabetes all of which have a high incidence in present day Ireland. These figures will also be analysed and compared.

And the incidence of risk factors and age of the participants will be discussed.

Chapter 2 the anatomy of the aorta, its location and branches and the structure of the arterial wall will be discussed.

Chapter 3 contains the literature review. The review will discuss what is an aneurysm and types of aneurysms that occur. The epidemiology of AAA's and risk factors which contribute to AAA formation and growth will also be examined. There will be a detailed view of AAA screening programmes, their results and the financial burden posed by ruptured AAA's. Finally there will be a review on the types of treatments available for AAA.

Chapter 4 the methods for diagnosing AAA are reviewed and compared. As ultrasound is the method used for AAA screening, in this study this will be dealt with in detail. An overview of the physics of ultrasound will be given.

Chapter 5 will look at the participants demographics. The result of the screening programme will be analysed. A comparison of the participants with AAA's and those without AAA's and their risk factors will be carried out.

Chapter 6 is the discussion and the results obtained in this study will be looked at in detail and compared to findings from other studies.

Chapter 7 is the conclusion and an overall review of the study and its results.

2.   The Aorta:

2.1 Anatomy and physiology of the Abdominal Aorta

The aorta is the largest artery in the body and is the main trunk of a series of vessels, which convey the oxygenated blood from the heart to the tissues of the body for their nutrition. It commences at the upper part of the left ventricle, where it is about 3cm in diameter. It ascends for a short distance then arches backwards and to the left of the heart. It then descends within the thorax on the left of the vertebral column and inferior vena cava and passes into the abdominal cavity through the hiatus in the diaphragm where it becomes the abdominal aorta. At this point it measures approx 1.75cm in diameter. It runs longitudinally superior to the spine, under the left lobe of the liver just left of the mid-line and ends opposite the lower border of the fourth lumber vertebra, by dividing into the right and left common iliac arteries. (Figure 2.1)
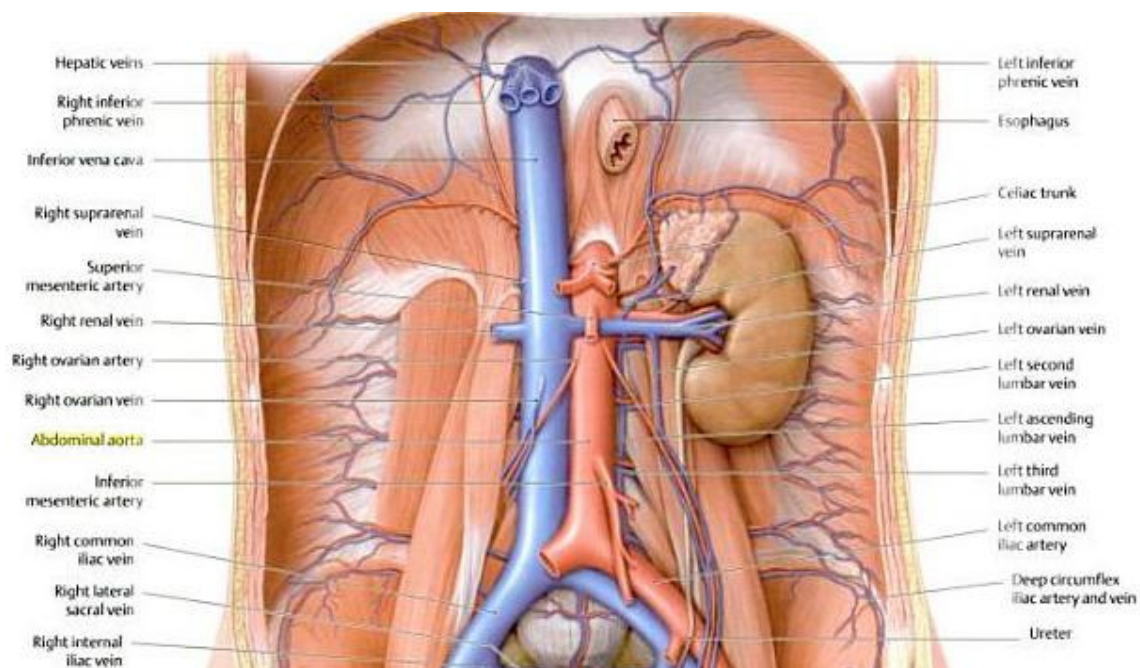
Figure 2.1 Anatomy of the abdominal aorta, its location and the arterial branches arise from it[1]

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[1] anatomytopics.wordpress.com

The abdominal aorta gives off visceral and parietal branches which feed the surrounding organs ie, liver kidneys, spine, pelvis etc. The first visceral branch of the abdominal aorta is the celiac artery which arises anteriorly off the abdominal aorta. It bifurcates approximately 1-3cm from its origin. Its left branch gives off the left gastric artery and splenic artery and the right branch is the common hepatic artery. The Superior Mesenteric Artery (SMA) arises just distal to the celiac artery, from the anterior surface of the abdominal aorta. After approx 1cm from its origin the SMA diverts inferiorly. It then branches and feeds the jejunum, ileum, cecum, ascending colon and segments of the pancreas and duodenum. Just below the origin of the SMA, the renal arteries arise laterally off the abdominal aorta. The right renal artery is usually slightly superior to the left renal artery. The renal arteries feed the right and left kidneys respectively. Approx 3 cm below the SMA and inferior to the renal arteries, the Inferior Mesenteric Artery (IMA) arises from the anterior surface of the abdominal aorta. This feed the descending and sigmoid colon as well as the rectum. (Zweiebel, 2005; Martini, 2009; Tortora, 2002)

The aorta bifurcates at the fourth lumber vertebra into the left and right common iliac arteries. The right common iliac is longer than the left as it travel more obliquely across the abdomen to the right lower extremity. The common iliac arteries divide into the internal and external iliac arteries. The internal iliac artery feeds the pelvic region and the external iliac artery becomes the common femoral artery which feeds the lower extremity. (Figure 2.2)
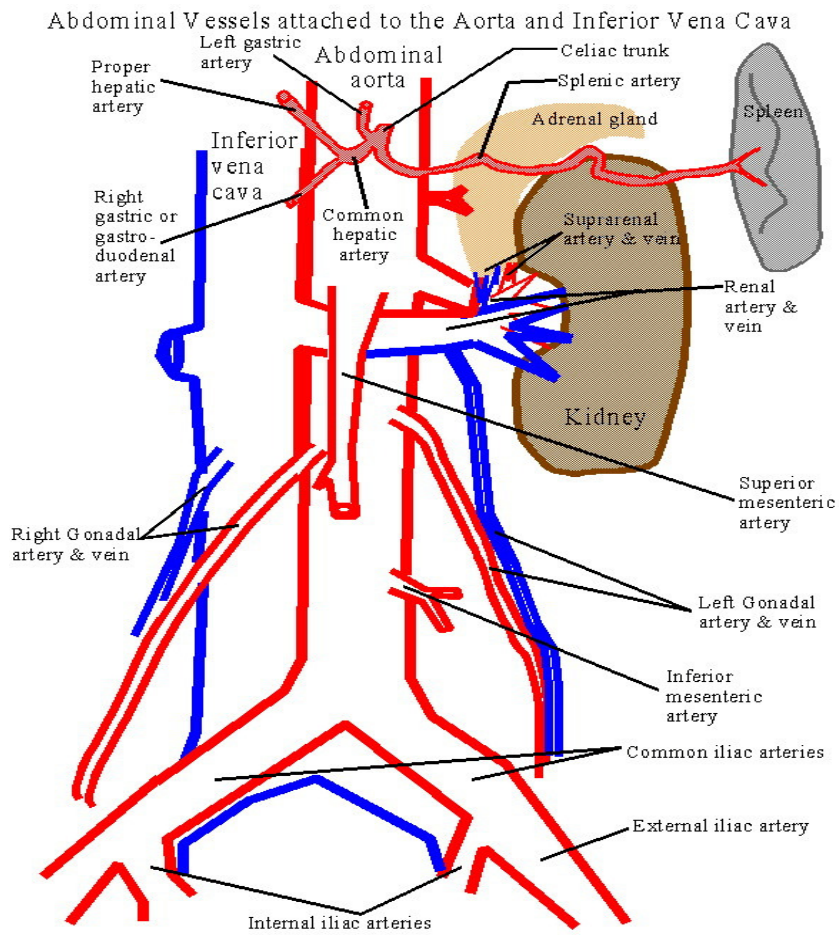
Figure 2.2 A closer view of the abdominal aorta and its branches including the iliacs[2]

The aorta is responsible for the supplying the oxygenated blood that is expelled from the left ventricle of the heart around the body. Its wall structure which is discussed below, allows the aorta to expand when the blood enters from the heart by the stretching of the elastic fibers. The blood is then pushed down and out if the aorta around the body, as the elastic fibers recoil.

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[2] webanatomy.net/anatomy

2.2 Structure of the arterial wall

The wall of the aorta is made up of three different layers, a) the intima (inner layer) which consists of endothelial cells, b) the media (thick, middle layer) which consists mainly of elastic fibers and c) the adventitia (thin, outer layer) made of collagen. The wall has a high density of elastic fibers, making it very resilient and able to withstand the pressure changes during the cardiac cycle. As the heart contracts it expels a large amount (74 millilitres) of blood into the aorta. In response to the hearts contraction the pressure in the aorta rises, the aorta's elastic fibres expand and accommodate the large amount of blood expelled by the heart. During ventricular diastole, the pressure drops in the aorta, the elastic fibres recoil and the aorta is returned to its normal size. (Grabowski, 2002) (Figure 2.3)

Intima:
endothelial cell layer
and
basement membrane
(collagens IV and XVIII,
laminin, nidogen)

Media:
smooth muscle cells,
elastic connective matrix
(collagens I and III,
vitronectin, laminin,
elastin fibrils)

Adventitia:
fibroblasts, nerve cells,
collagens and elastin fibrils

Schematic view of an arterial wall in cross-section

Expert Reviews in Molecular Medicine © 2002 Cambridge University Press
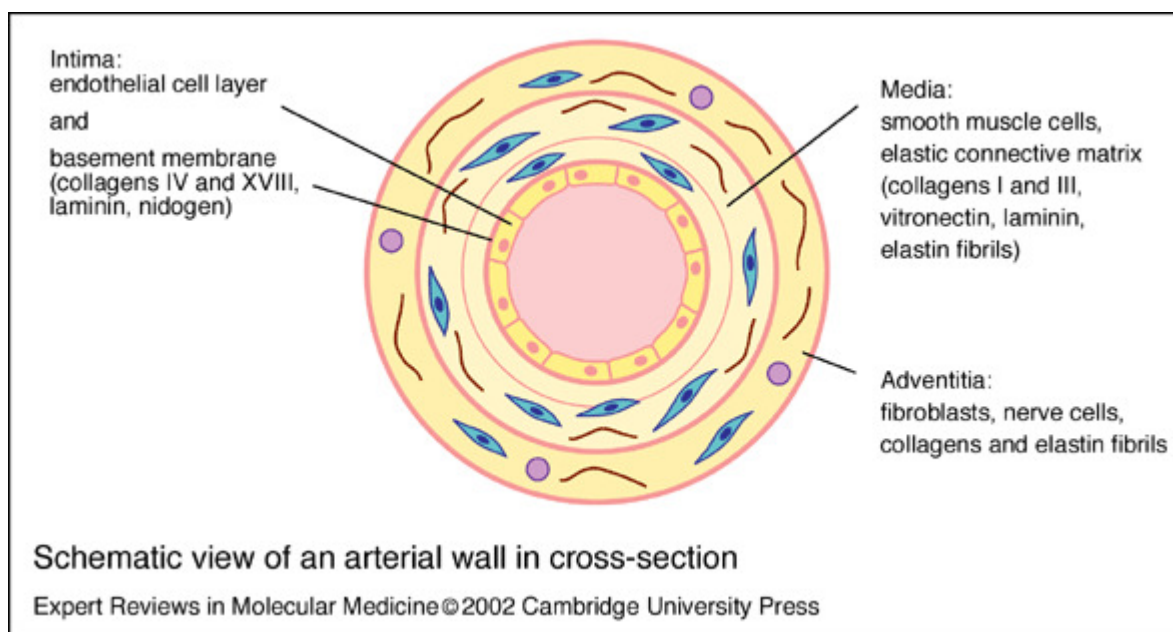
Figure 2.3 An illustration of the arterial wall and its three layers in a cross section view[3]

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[3] journals.cambridge.org

2.3 Aneurysms:

An aneurysm is defined as a localized dilation of an artery by approx 50% as compared with the expected normal diameter of the vessel. It usually is the result of the breakdown of elastin and collagen in the media and adventitia of the arterial wall, with loss of smooth muscle and thinning of the medial layer (Lopez-Candales, 1997).

There are two types of aneurysm, true or false.

2.3.1 A true aneurysm

A true aneurysm involves the dilation of all three layers of the arterial wall: the intima, the media and the adventitia. (Figure 3.1)

There are two forms of true aneurysm, these are:

➤ Fusiform aneurysm
➤ Saccular aneurysm

2.3.1.1 Fusiform aneurysm:

As the name implies, the aneurysm is spindle shaped. The weakness is often along an extended section of the aorta and involves the entire circumference of the artery. The weakened portion appears as a generally symmetrical bulge, the length of which can vary. (Figure 3.1)

2.3.1.2 Saccular aneurysm:

This is a pouch or sac like outgrowth from one side of the artery, occurring particularly at bifurcation points. Thrombotic debris is often present in the lumen of the aneurismal sac. It is usually caused by trauma or as a result of a penetrating ulcer. (Figure 3.1)

2.3.2 False aneurysm (pseudoaneuysm)

Unlike a true aneurysm, this type of aneurysm does not involve the vessel wall. It consists of a collection of blood, held around the vessel by connective tissue. (Figure 3.1)

False aneurysms may arise following traumatic damage to the wall. False aneurysm results in a slowly expanding blood-filled cavity. The cavity may rupture or thrombose. (Figure 2.4) (Kumer , 2009; Zweiebel, 2005; Fox, 2004; Martini, 2009)
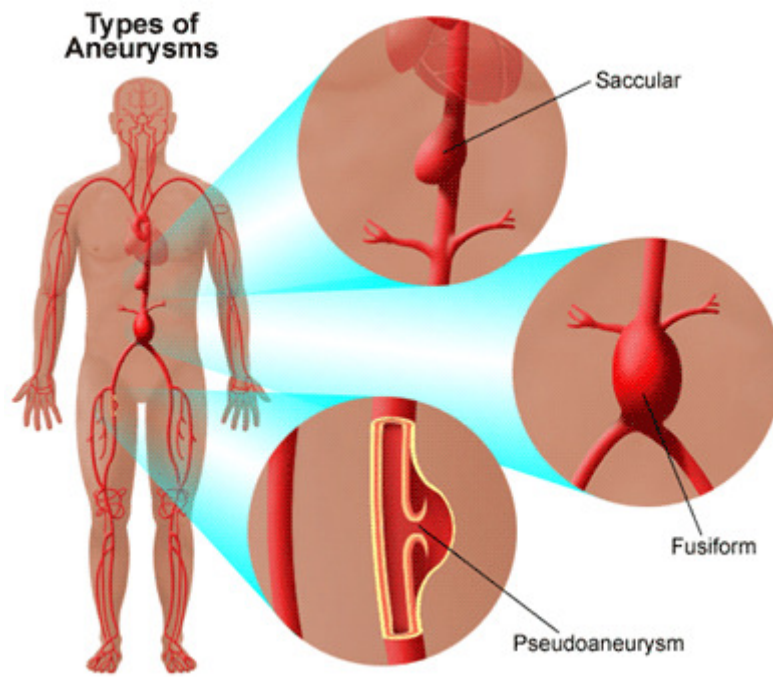
Figure 2.4 Aneurysm types, an illustration of true and false aneurysms[4]

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[4] columbia-stmarys.org

2.4 Epidemiology of Abdominal Aortic Aneurysms:

AAA is an incidental medical condition with a high mortality. The pathogenesis of AAA's are not well understood and appear complex and multifactorial. Weakening of the aortic wall forming a balloon type sac nearly twice its normal diameter can enlarge and eventually rupture (Kumer, 2009). Enlargement of a AAA is due to remodelling of the parietal extracellular matrix, particularly to collagen and elastin metabolism (Ailawadi , 2003)
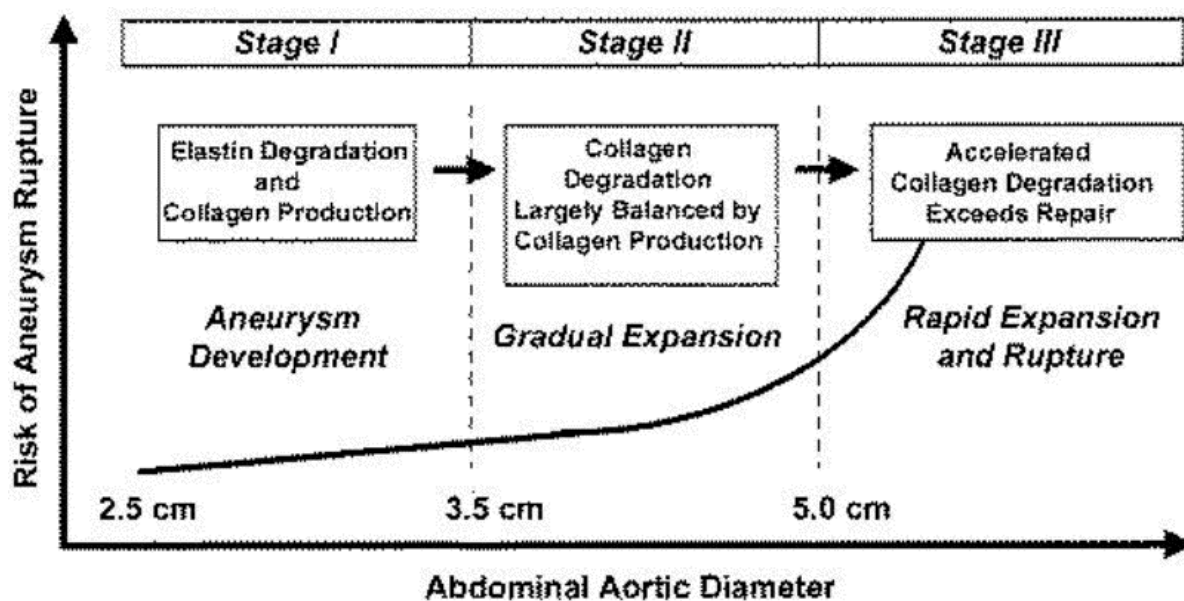
Figure 2.5 Stages of aneurysmal degeneration[5].

The schematic diagram (Figure 2.5) depicts the evolution of an aortic aneurysm. The early stages of aneurysmal degeneration are characterized by destructive changes in the connective tissue of the aortic wall by a reduction in collagen production and degradation of elastin, which promotes dilatation. In time, aneurysm growth occurs through a gradual variation between connective tissue (collagen) repair and degradation and the risk of rupture begins to rise. Large AAA's are characterized by more extensive connective tissue (collagen) degradation, a more rapid rate of expansion and an accelerating risk of rupture (Thompson, 1999).

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[5] Thompson RW, Baxter BT, 1999

The incidence of AAA in men aged between 65 -75 years is 3.9% and 0.7% in women (Derubertis 2007; Cho , 2009). AAA usually presents in women who are at an older stage of life compared to men (Dillavou, 2006; Brown, 2003)and the growth rate of female AAA's is faster than males (Solberg 2005; Dillavou, 2006).

The incidence of AAA in Caucasians is much greater than in African and Asian communities (Spark , 2001; Hobbs , 2003; Salem, 2009; LaMorte, 1995). One such study compared all races and found the incidence of AAA to be extremely low in Asians and Hispanic, very low in Native Americans and African Americans and extremely high in Caucasians (Kent, 2010).

 The pathogenesis of AAA is unclear. However it is thought that an increase in certain matrix metalloproteinases (MMP's) is involved. MMP are proteins which are involved in the breakdown of extracellular matrix in normal physiological processes. A localized increase in MMP-8 and -9 levels is a potential pathway for collagen breakdown and has been implicated in expansion and rupture of AAA (Kajimoto, 2009; Wilson, 2006). Transcription factors such as nuclear factor kappaB (NF κb) which regulate transcription of MMP's and E-twentysix (ETS) with regulates expression of MMP's are also elevated in patients with AAA (69).

Studies have shown that the size and growth rates of an aneurysm are significant risks of rupture and are associated with high mortality rates (Multicentre Aneurysm Screening Study Lancet, 2002; Ogata 2005; Forsdahl, 2009; UK Small Aneurysm Trial, 1999; Heller, 2000; Lederle, 2002; Kniemeyer, 2000; Wanhainen, 2005; Zarins, 2006).

A growth of 1cm or more in 12 months is significant (Ballard, 2000; UK Small Aneurysm Trial, 2002). The growth rate of aneurysms increases as they expand. The growth rate of an aneurysm at 5cm is 70% faster than an AAA of 4cm (Brady, 2004).

Rupture of an AAA is a tear in the aortic wall, which occurs due to the weakening of the aneurismal wall. The rupture of an AAA is a traumatic and possibly fatal event. The aorta is the largest artery in the body origination at the heart and supplying the rest of the body with blood. The pressure within the aorta is very high and this leads to excessive and rapid bleeding into the retroperitoneal space on rupture, which in turn leads to shock and possible death (Beard, 2010). The size of an aneurysm at risk of rupture is 6cm in males and 5cm in females (UK Small Aneurysm Trial, 1999; Dillavou, 2006). The risk of rupture is 3 to 4 times higher in females than in males (UK Small Aneurysm Trial, 2002; Dillavou, 2006; UK Small Aneurysm Trial, 1999).

Iliac artery and popliteal artery aneurysms can also be identified with the presence of an AAA. Iliac aneurysm occurance is usually associated with AAA's. An iliac aneurysm is diagnosed at a diameter of greater than 1.2cm. They are usually quite large, 4cm and greater

but at 3cm their risk of rupture is significant. Popliteal artery aneurysms are the most common peripheral aneuryms. Approximately 35-40% of popliteal aneurysms occur with the presence of an AAA. The normal diameter of a popliteal artery is 0.5cm. When a popliteal aneurysm reaches 2cm, elective surgery is considered (Beard, 2010).

Due to the popliteal artery's continued stretching with the movement of the leg, the presence of thrombus in the aneurysm poses as a high risk for emboli. 'Acute blue toe syndrome' is a side effect of proximal aneurysms which include the abdomen, iliac, femoral and popliteal. This is due to emboli from a proximal aneurysm travelling down the limb and occluding the arterial vessels of the toe, which can result in limb damage. (Beard, 2010; Kremkau, 2001).

2.5 Treatment of AAA's

AAA's are generally asymptomatic and are usually diagnosed as incidental findings during physical examinations for other conditions. The treatment of AAA varies depending on the size of the AAA and the risk factors of the individual patient.

2.5.1 Medical Therapy

At present there are no pharmacological treatments available to prevent AAA formation, growth and rupture. However, treating cardiovascular risk factors has been shown to prevent AAA's or reduce the progression of an already existing AAA (Beard, 2010).

When treating the risk factors there are conflicting arguments whether statins are beneficial in slowing the growth of AAA's. Statins are generally used to lower cholesterol by inhibiting the enzyme involved in the synthesis of cholesterol in the liver. Studies have reported the use of statins to reduce the inflammatory response of macrophages, T lymphocytes and MMP and thus reducing AAA progression (Schouten, 2006; Luan, 2003; Kajimoto, 2009). Other studies show that lipid lowering drug treatments can delay growth in small AAA's (Schlosser, 2008). While others report that the use of statins, do not help in reducing AAA growth or changes in AAA wall composition (Fergusion 2010; Forsdahl 2009, Hurks,2010).

2.5.2 Surgery

Surgery is the only treatment for AAA's, however no benefit has been shown for elective AAA repair procedures on AAA's of less than 5cm. (UK Small Aneurysm Trial, 2004; Lederle 2002; Brown 2008). In AAA's over 5.5cm elective surgery is usually the preferred method of choice (Choke, 2009).

With the risk of rupture increased at 5.5cm, elective repair surgery has been recommended for males with an aneurysm of 5cm or greater (Brown, 2003; Ballard, 2000; Zarins, 2006). This procedure prevents the incidence of aneurysm rupture and prolongs life (Rigberg, 2006). The mortality of elective repair of screened AAA's is 3%, somewhat lower than the repair of incidental aneurysm repair of 9% (Earnshaw, 2004). Due to more elective surgery being performed the incidence of emergent ruptured aneurysm surgery has fallen (Greenhalgh, 2004) as well as the mortality associated with emergency surgery which is 65-85% of patients (Multicentre Aneurysm Screening Study Lancet, 2002, UK Small Aneurysm Trial , 1999;

Heller, 2000; Lederle, 2002; Kniemeyer, 2000; Ogata, 2005; Wanhainen, 2005). Open repair and endovascular AAA repair (EVAR) procedures in the treatment of AAA are expensive. However the cost of emergency repair is double that of elective surgery (Kent, 2004).

2.5.2.1 Procedure for open AAA repair

AAA repair involves proximal and distal anastomoses, so a transperitoneal, longitudinal incision is usually the method used. An incision is made in the posterior parietal peritoneum to reveal the aneurysm. The common iliac arteries are exposed in preparation for clamping. Once the iliacs and the proximal aorta are clamped the aneurysm sac is opened. The lumen of the AAA usually contains thrombus, which has to be removed. Once the sac is clear of thrombus a synthetic Dacron graft is sutured into place. (Dacron grafts are manufactured coated with protein (collagen/albumin) to reduce blood loss and antibiotics to prevent graft infection). In the majority of cases a simple tube graft can be inserted but if the iliac arteries are involved then a bifurcation graft maybe used. The limbs of the graft can be anastomosed to the iliac or femoral arteries. Once haemostasis is secured the aneurismal sac is closed over. (www.emedicine.medscape.com)

Open repair even though it is invasive, has been shown to be a successful and effective procedure with good graft durability. (Figure 2.6)
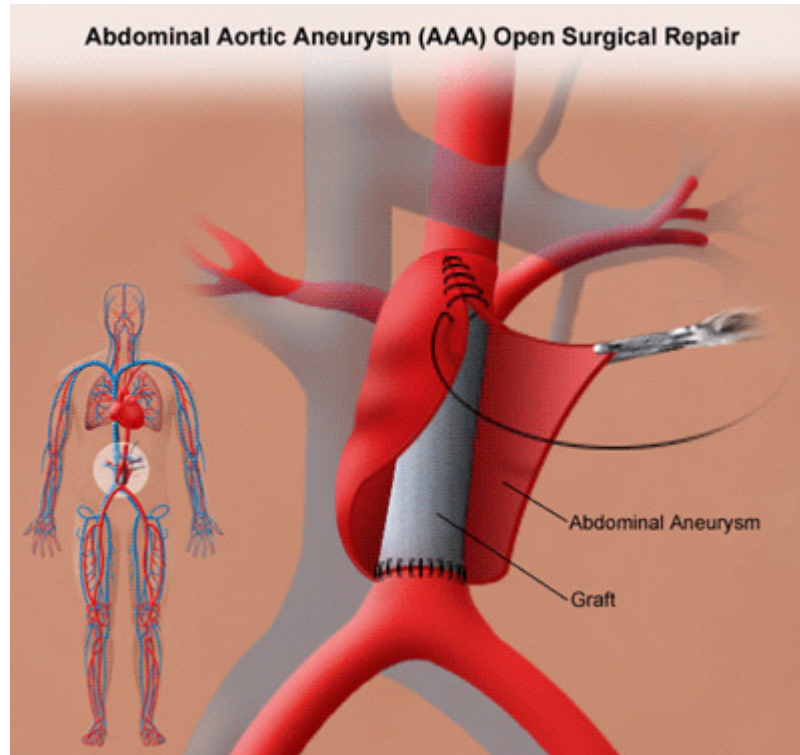
Figure 2.6 Diagram of an open AAA Repair[6]

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[6] yalemedical group.org

2.5.2.2 Procedure for Endovacular aneurysm repair (EVAR):

This is a minimally invasive technique. In general, it requires the proximal neck of the AAA to be relatively straight and between 15 and 30mm in length. Also the iliac arteries need to be 7mm in size for delivery of the device into the aorta.

Small groin incisions are made to expose the femoral arteries and a self-expanding stent-graft (special fabric supported by a rigid structure) is inserted via guide wires and catheters into the aortic aneurysm. Usually a modular stent is used, it consists of two pieces one being the main trunk of the graft with an ipsilateral limb and the other being the contralateral limb. Both iliac arteries are used in the passage of such a stent. Confirmation of stent positioning above and below the aneurysm is made by angiography before deployment of the stent and hooks are used to attach the stent to the proximal and distal areas of fixation. The stent-graft is anchored to a normal part of the patient's aorta, preventing it from moving. Deployment of the graft can be by a self expanding mechanism or balloon expansion, using angiography. Once the main trunk and ipsilateral limb are deployed and the contralateral gate in the main trunk is open, the contralateral limb is introduced by another guidewire. Deployment of the contralateral limb is by retrograde cannulation of the contralateral limb gate of the main trunk. The stent-graft is flexible and conforms to the patient's anatomy, allowing blood to flow through it into the iliac arteries and seals off the aneurysm. Angiography is also used to ensure the aneurysm is excluded and that correct landing points have been achieved to prevent endoleak. The aneurysm sac will shrink over time and be excluded from arterial pressure (Beard, 2010; www.medterms.com; Katzen, 2005). (Figures 2.7 and 2.8)

Figure 2.7 Example of the stent-grafts used in EVAR[7]

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[7] Scientific-analysis.com/medical -technology
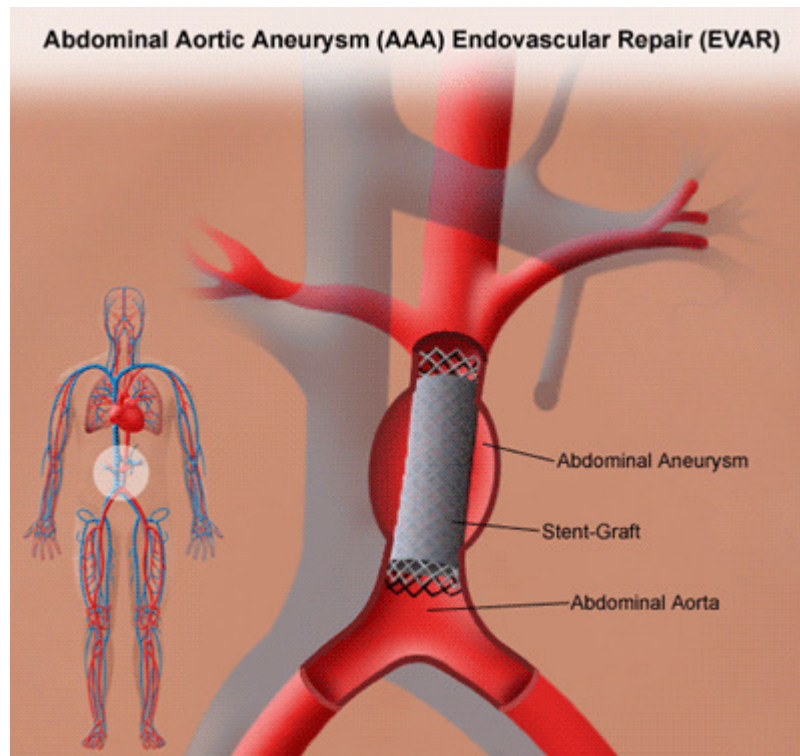
Figure 2.8 Diagram of an Endovascular Aneurysm Repair (EVAR)[8]

The EVAR procedure is more preferable than open repair, even though both the open repair and EVAR in the 2 to 4 years follow up reports are comparable (Peterson, 2007; Faizer 2007).

The mortality rate for EVAR is 5% compared to 8.3% for open repair (Moore, 2007; Peterson, 2007) and its post 5 year freedom from rupture is 93% and AAA related death is 92% (Zarins, 2006). Procedure times, blood loss, length of stay in intensive care and hospital stay are reduced for EVAR compared to open repair (Moore, 2007; Peterson, 2007). The EVAR procedure is more beneficial for unstable, elderly patients as it can be conducted under local anaesthesia (Acosta, 2006; Dillovua, 2006; Moore, 2007; Harris, 2005). However EVAR is a relatively new procedure, a long term outcome has not been proven. There have been cases where conversion to an open repair was performed on post EVAR patients (Peterson, 2007).

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[8] yalemedical group.org

Not every patient is suitable for EVAR due to the size and course of their AAA and peripheral arteries, therefore careful selection is important before such a procedure.

Females have an increased mortality rate than men and do not survive rupture or surgical treatment very well (Semmens, 2000; Solberg 2005; Acosta, 2006, UK Small Aneurysm Trial;, 1999; Dillavou 2006; Katz, 1997; Harthun, 2008). Females have a 40% increased risk of dying during or after surgical repair (Katz ,1997). Surgery is much more traumatic on females than on males, this is due to longer hospital stays caused by their older age and presence of other co morbid conditions (Dillavou, 2006). In females, open repair is the method of choice as Endovascular Aneurysm Repair (EVAR) can be more complicated due to short proximal aneurysm necks and small iliac arteries (Acosta, 2006; Katzen, 2005).

As AAA's are asymptomatic in nature, screening is the best method of detecting and preventing AAA reaching the point of rupture. Due to the high mortality rate associated with ruptured AAA, screening is an effective, cost saving exercise.

3. Literature Review on Abdominal Aortic Aneurysms

3.1 Introduction of Abdominal Aortic Aneurysms:

An abdominal aortic aneurysm (AAA) is defined as a localised dilation of the aorta, usually below the renal arteries (infra-renal) which measures 3cm or greater in diameter or a diameter of 1.5 in comparsion to the proximal aorta (Fleming, 2005). AAA is a common and potentially life threatening condition which predominately affects men of 65 years and older (Katz 1997, Âlund , 2008).

A normal proximal abdominal aorta has a diameter of 1.75cm in men and 1.3cm in women (G.J Tortora, 2002; Goldberg , 1993). Studies have suggested that a non-aneurysmal infra-renal diameter measuring >2.6cm may indicate the possible risk of a AAA formation, particularly dyslipidaemia (Forsdahl, 2009; Devaraj 2008).

AAA's are asymptomatic and are rarely detected until rupture. The incidence of asymptomatic AAA's appear to be 0.8% at age 50 and increase to 6% at age 65 in males (Vardulaki, 2000). Rupture is defined as extravasion of blood or hematoma outside the AAA. (Acosata Hardiman Index, 2006). One third of untreated AAA's will rupture. Ruptured AAA's (rAAA) are responsible for 1.3% of all deaths among males between the ages of 65–85 years. (Sakalihasan, 2005; UK Small Aneurysm Study, 1999).

Ruptured AAA's require emergency surgery and have an associated mortality rate of 65–85% half of which occur prior to surgery. It is more preferable to perform elective surgery on AAA's before they rupture. The mortality rate for elective AAA repair is 0%-9%, a rate significantly lower than emergency repair surgery. (Multicentre, Aneurysm Screening Study Lancet 2002; UK Small Aneurysm Trial, 1999; Heller, 2000; Lederle, 2002; Kniemeyer, 2000; Ogata, 2005; Wanhainen, 2005).

AAA's are mainly asymptomatic; therefore screening is required for diagnosis. Once diagnosed, the aneurysm size and growth can be kept under surveillance to assess the risk of rupture. An AAA of 5.5 - 6cm is considered a risk of rupture. Once it is considered a risk, elective surgery is recommended. Previous studies have shown that screening for AAA's is cost effective and can reduce the mortality rate. (Multicentre, Aneurysm Screening Study Lancet, 2002 & BJM 2002; Norman 2006; UK Small Aneurysm Trail, 1999 & 2002; Forsdahl, 2009).

3.2 Risk Factors for AAA development:

Abdominal Aortic aneurysm is a complex vascular condition with no one specific cause for its development. Risk factors for AAA formation include male sex, age, smoking, family history as well as atherosclerosis. (Cole, 2001; Vardulaki, 2000).

3.2.1 Gender:

Male sex is the most predominent risk factor. AAA's occur up to 5 times more in men than in women (Vardulaki, 2000). With the incidence of AAA in women thought to be 0.7% compared to that of men, which is 3.9% (Cho, 2009; Derubertis, 2007). However, the growth rate of AAA's is significantly higher in females than in males (Solberg, 2005; Dillavou, 2006).Women have smaller anatomies compared to men therefore the risk of rupture in females is at a smaller AAA size compared to males (Harthun, 2008; Katz, 1997; Forsdahl, 2009; Brown,2003, UK Small Aneurys Trial, 1999).

AAA's in males are reported at 65 years and older, where as AAA's in women occur in a later age group (75-80 years) (Harthun, 2008). When women are diagnosed with AAA they usually have other co morbid conditions, making treatment of their AAA complicated. The risk of AAA in females compared to males appears to be similar to their risk for cardiovascular disease. Females are protected from such disease in their middle ages due to the high level of oestrogen in their system pre-menopause. A lab based study documented a decrease in AAA formation in male rats when they were treated with oestrogen, thus like other cardiovascular diseases, oestrogen may protect females from AAA formation until later in life (Cho, 2009)

Astrand *et al* reported that stress on the male abdominal aortic wall increases with age and its response to compensatory thickening is insufficient, unlike that of the female abdominal aorta (Astrand, 2005).

3.2.2 Age:

The incidence of AAA increases with age from 0.8% in males at the age of 50 years to 6% of those aged 65 years (Vardulaki, 2000). The risk of AAA formation and rupture increases with age, with the incidence peaking at 65-70 years in males (Vardulaki, 2000; Lederle, 2009; Alcorn 1996; Âlund, Mani, Wanhainen, 2008), where as in women it is at 70-80years (Derubertis 2007; Dillavou 2006). AAA usually presents in women who are at an older stage of life compared to men (Dillavou 2006; Brown 2003)

3.2.3 Smoking:

Smoking appears to be one of the strongest independent risk factors for AAA formation and growth. (Lee, 1997; Ogata, 2005; Wanhainen, 2005; J.F. Blanchard, 2000). Current smoking and duration of smoking are the most prevalent (Wanhainen, 2005; Ogata 2005; Wilmink, 1999; Bergoeing, 2007).

Life- time male smokers are 2.5 times more likely to present with an AAA than non smoking males (UK Small Aneurysm Trial, 2002). Patients who have been previous smokers have reduced risk of death compared to current smokers (UK Small Aneurysm Trial, 2002). Previous smoking still poses a risk, but at a lower incidence of 1.5 times that of non smokers (Vardulaki, 2000). A study by Lee *et al* of current and recent ex-smokers the likelihood of AAA was 3 times greater than ex-smokers of 5 years and more, than those who never smoked (Lee, 1997). Smoking has also been proven to be the biggest risk predictor for AAA in females (DeRubertis, 2007). Studies have shown that smoking increases growth rates of AAA's by 15-20% and therefore increasing the risk of rupture (UK Small Aneurysm Trial, 1999; Lee 1997; Brady 2004).

The link between smoking and its strong association with AAA formation and growth appears unknown, however some studies suggest serum cotinine, a nicotine metabolite increases growth rate of AAA's (Wilmink, 1999). It is also thought that some components of smoking may inhibit the active site of α 1 –antitrypsin, leading to the degradation of elastin in the aortic wall by proteolytic enzymes. (Lee, 1997; Wilmink, 1999).

The association of smoking and AAA formation and progression is much more pronounced than the association of smoking with coronary artery disease (CAD) (Lederle, 2003). Long term smokers have a higher possibility of death from AAA's than CAD. This suggests that AAA formation is not independantly caused by the atheriosclerotic process. (Lederle, 2003; Lee, 1997; Wilmink, 1999).

3.2.4 Atherosclerosis:

Atherosclerosis is associated with damage to the endothelial lining and lipid deposits in the tunica media. Increased lipid levels in the blood initiates the formation of atherosclerosis. Atherosclerosis formation occurs with breakdown of the endothelial wall, promoting aggregation of platelets and also attracting phagocytes. Cholesterol and triglycerides collect at the injury site of the inner layer of the arterial wall. Macrophages arrive at the site due to the inflammatory process. Contact with platelets, lipids and other components of blood stimulate smooth muscle cells and collagen fibres in the arterial wall to proliferate abnormally. This occurs due to low levels of apolipoprotein- E (ApoE), which transports lipid in the blood and are quickly absorbed by body tissues or by high levels of low density lipoprotein which is slowly absorbed by the body. In response to this there is a build up of lipids and formation of atherosclerosis which causes a narrowing in the arterial wall and disturbance to the blood flow. (Martini, 2009; Tortora, 2002) (Figure 3.3)

The inflammatory process of atherosclerosis is linked with the AAA formation, enlargement and rupture cycle. (Sandford,2007, Daugherty 2002, Kaschina, 2009). One study implicates the inflammatory response as a potential cause of aneurysm rupture (Choke, 2009). Matrix metallopeptidase 9 (MMP9) is an enzyme when secreted presents a pathway for collagen degradation, AAA expansion and rupture. (Wilson, 2006) However, this does not prove that atherosclerosis and an inflammatory response is a direct cause of AAA. A recent study examined the diabetic association of AAA and reports atherosclerosis as an associated feature and not a causative factor (Shantikumer, 2010). (Ref Figure 3.1)

FIGURE 2

Inflammation in the atherosclerotic process

1

Lipoprotein
T cell
Cholesterol entering vessel wall
Monocyte
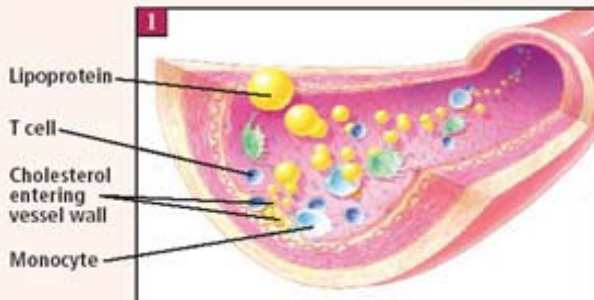
Lipoproteins transport cholesterol to vessel walls, where the innermost endothelium (intima) undergoes molecular changes that cause monocytes, T cells, and monocyte-derived macrophages to aggregate and permeate the endothelial layer.

2

Macrophage
T cell
Monocyte
Foam cell
Platelets
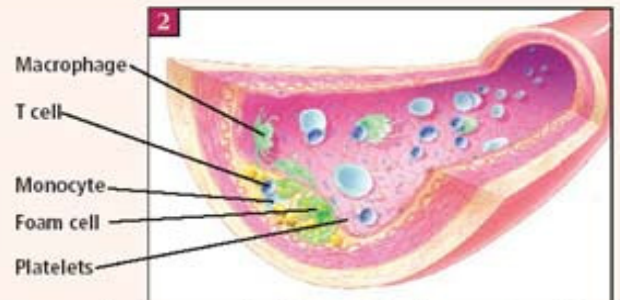
As macrophages consume the cholesterol, they become enlarged foam cells, which are prone to rupture. These foam cells, along with the monocytes and T lymphocytes form fatty streaks between the intima and elastica interna.

3

Fibrous cap
Smooth muscle cell
Necrosis
Platelets
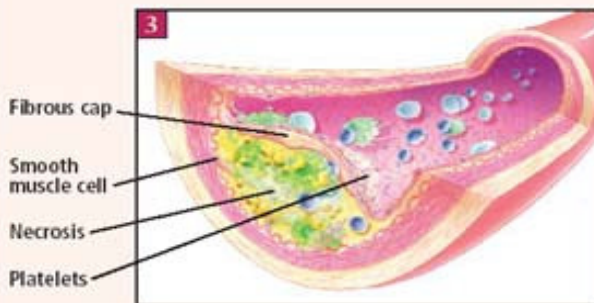
Platelets aggregate and adhere to the endothelium, while the lesion grows to include smooth muscle cells and debris. The lesion may become necrotic, and a fibrous cap often forms.

4

Activated macrophage
Plaque rupture
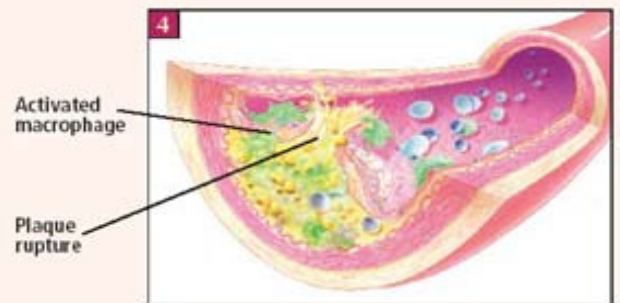
As macrophages continue to aggregate and become active, the fibrous cap thins and the plaque may rupture, leading to thrombosis.

Source: Ross R.[21]

Figure 3.1 The inflammatory process involved in the formation of atherosclerosis[9]

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[9] medscape.org

3.2.5 Hypertension and its association with AAA:

Hypertension (HTN) has been shown to pose a risk of AAA formation (Lee, 1997). There are conflicting studies which argue that HTN is risk of rupture rather than formation and growth of an AAA. While other studies have reported that there is no relationship between HTN and formation of AAA or increased expansion rates of existing AAA's (Vardulaki, 2000; Wanhainen, 2005; Brady, 2004).

HTN has been shown to be associated with AAA rupture due to its haemodynamic stress effect and its involvement in the up regulation of transcription factors (Shiraya, 2006; Astrand, 2005). The haemodynamic burden on the aortic wall depends on the mean blood pressure. An elevated burden is constantly putting pressure on the ever weakening aneurismal section causing the AAA to enlarge (UK Trial, 1999). In large and ruptured AAA's the wall stress at maximal systolic blood pressure is considerably higher than in small AAA's (Truijers, 2007; UK Small AneurysmTrial 1999; Choke, 2009; Astrand, 2005) which shows the association between HTN and rupture. (See Appendix 4 for different ranges of blood pressure)

3.2.6 The role of high cholesterol in AAA formation:

Elevated LDL cholesterol, total cholesterol and triglycerides have been recorded in patients with AAA (Wanhainen, 2005; Lee 1997). Studies have shown that cholesterol alone does not cause aortic enlargement (Kobayashi, 2004; Lindholt, 2001; Ferguson, 2010). Significant association of plasma LDL and small aortic aneurysms has been shown (Hobbs, 2003). One study has shown that small LDL size is an independent risk factor for AAA (Rizzo, 2009). However, Golledge *et al* claims there is no association between LDL and AAA, but there is consistent association between low HDL and small AAA (Golledge, 2010). HDL has anti inflammatory and antioxidant properties and a low HDL level reduces its preventive properties and therefore may lead to inflammation of the abdominal aorta (Golledge, 2010). (See Appendix 5 for normal value of cholesterol)

3.2.7 Relationship of Diabetes Mellitus and AAA:

Most studies have shown the inverse effect of Diabetes Mellitus (DM) on AAA formation and growth. (DeRubertis, 2007; Vega de Cengina, 2006; Brady 2004; Shantikumar, 2010). One study has shown the association of the circulating marker of the glycation pathway, carboxymethyllysine (CML) and discovered levels of CML to be lower in patients with diabetes and AAA compared to patients with AAA and no diabetes (Norman, 2009). Another study suggests that hyperglycemia inhibits metalloprotinases (MMP) production, and therefore inhibiting MMP activity which is essential in AAA progression (Miyama, 2010). This is one explanation of the negative relationship of DM and AAA formation. (Figure 3.2)
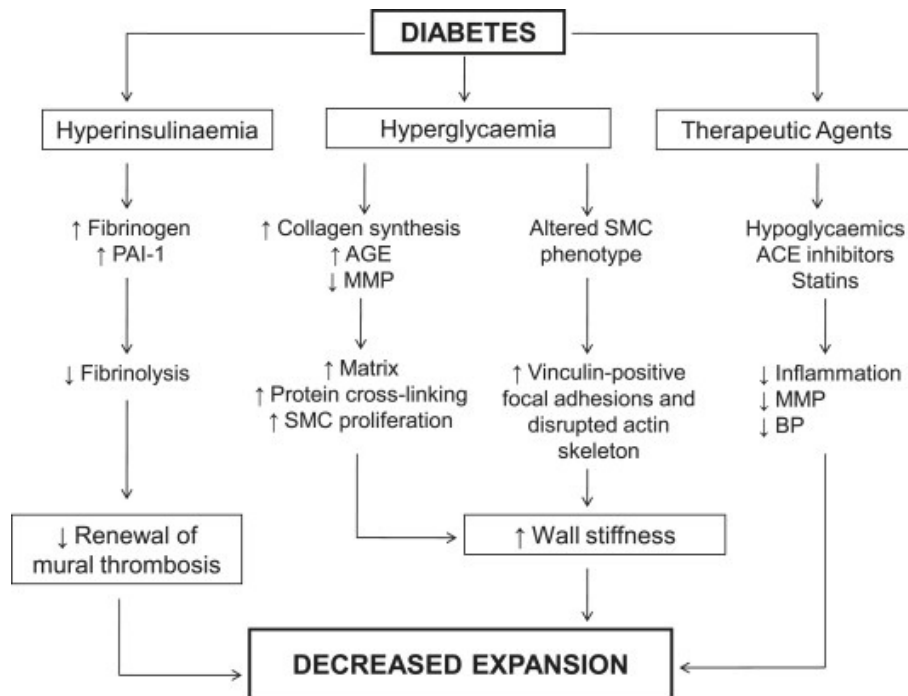
Figure 3.2 Effect of diabetes on AAA

The above diagram (Figure 3.4) shows the inverse effect of diabetes in AAA expansion. In hyperinsulinaemiam, decreased fibrinolysis leads to decreased mural thrombus formation which accumulates in an AAA. The less mural thrombus present, prevents the AAA from expanding further.

Hyperglycaemia causes that arterial wall to stiffen due to an increase in matrix, protein cross-linking and vainculin positive focal adhesions. Due to this increased wall stiffness the aneurysm is unable to expand further.

The therapeutic agents given to diabetes sufferers, decrease inflammation, MMP levels and blood pressure. All of which are heavily involved in the formation and expansion of an AAA.

3.3 Screening for AAA:

Screening is used to detect and diagnose specific population groups for disease before they become symptomatic. Its advantage is that a disease caught in its early stages can be treated effectively and prevent it from becoming a risk of mortality. The disadvantages of screening programmes are the cost of the programme and the stress and anxiety caused to the patient once diagnosed.

There are specific guidelines for the feasibility of screening. For a screening programme to be effective, the disease involved in the screening programme has to cause a burden on the health system due to the serious consequences when well developed. There must be a well established method of treatment if the disease is found in its early stages. This early treatment needs to be more beneficial than treatment of the disease in its later stages. It is also essential that diagnostic and treatment facilities for such a screening programme exists.

Many studies have been undertaken and have shown the need for screening for AAA in men between the ages of 65-74 years. The Multicentre Aneurysm Screening Study (MASS) carried out in the United Kingdom was one of the first large screening programmes for AAA. It looked at many aspects of screening for AAA, such as incidence, the effect on mortality and cost effectiveness of an AAA screening programme. It showed the incidence of AAA in males between the ages of 65-74years to be 4.9%. The detection of AAA reduced the risk of death in a four year period from 3.3% to 1.9% per 1000.

The high mortality of a ruptured AAA (rAAA) is a major burden on all health systems. A large number of screening studies have shown a 50% or more reduction in AAA related deaths in screened patients (UK Small Aneurysm Trial, 2002; Norman, 2004; Lindholt , 2010; Thompson, 2010; Takagi H, Goto, 2010). Mani's study reported that patients with AAA's detected at a screening programme had a higher survival rate and more opportunity for elective surgery, than patients who were selectively scanned in a vascular laboratory (Mani, 2009).

Some studies have investigated the likelihood of AAA development years after screening. Acosta *et al*, Vardulaki *et al* and Thompson *et al* all claimed that a single scan would be enough for men of 65 years of age with a normal aortic diameter, as the development of an AAA is highly unlikely in ten years post a normal scan. However, Thompson did find a very

small number of patients had a rAAA 8 years post a normal abdominal aortic scan. But this number was so small that it did not justify the need for rescreening (Acsota, 2006; Vardulaki, 2002; Thompson, 2010).

Screening has shown that it can reduce the mortality of a rAAA and the high cost of treatment for this potentially fatal disease (Greenhalgh, 2006). A screening programme can accurately diagnose a AAA and reduce the incidence of rAAA and emergency surgery by up to 75%, while increasing elective repair and reducing AAA specific mortality by 50-67% (Heller, 2002; Lindholt, 2006; Lindholt, 2008; Lindholt, 2010; Thompson, 2010; Takagi, 2010). Due to the early diagnosis of AAA during screening, elective repair is more cost effective, is shorter and has fewer complications than emergency repair (Lindholt, 2006; Multicentre Aneurysm Screening Study 2002; Wanhainen, 2005).

The cost effectiveness of any screening programme is always a point consideration. As mentioned above a screening programme for AAA is cost effective as it reduces the high cost of emergency repair for ruptured AAA's. There have also been studies into the cost effectiveness in relation to life years gained (LYG) and quality adjusted life years (QALY). Four studies have a reported a survival advantage to AAA screening. The addition of life years gained has increased due to such screening. Overall the incremental cost for LYG and QALY is lower than the recommended, set values considered to be cost effective for this type of screening programme (Lindholt , 2008; Schmidt, 2010; Thompson, 2010).

Some argue that one of the disadvantages of AAA screening is the decrease in psychological morbidity in patients diagnosed with AAA, as it may cause a permanent source of anxiety (Wanhain, 2005). The majority of studies who investigated the mental effects of AAA screening showed no ill effects (Multicentre Aneurysm Screening Study 2002; Fleming, 2005; Brannstorm, 2009; Khaira, 1998). The results of the questionnaire showed that men diagnosed with AAA as well as those with normal aortic sizes, had better health or stayed the same post screening (Spenser, 2004).

Women are currently not considered for screening for AAA as the prevalence of AAA in women is at an older age (approximately ten years older than men) (Dillavou ,2006; Brown 2003; Scott, 2002). There are still arguments on whether females should also be screened for AAA. Due to women's small and more complex anatomies it is thought that the risk of

rupture in females is at a smaller AAA size compared to males (Harthun, 2008; Katz, 1997; Forsdahl, 2009; UK Small Aneurysm Trial, 1999; Brown, 2003). Mean diameter at rupture of females is 5cm compared to a mean diameter of rupture in males of 6cm (UK Small Aneurysm Trial, 1999; Dillavou, 2006). Surgery should be considered in females with AAA's of a diameter between 4.5-5cm (Scott, 2002). One study recommends females of ≥65 with confirmed arterial stenosis to be screened as such a condition could be a predictor of AAA (Âlund, 2008). Another study has recommended screening for women over 65 years of age, who smoke and have other cardiovascular disease (DeRubertis, 2007). Many studies recommend different guidelines to be set and used in screening females for AAA' s (Brown, 2003; UK Small Aneurysm Trial, 1999). Due to the fact that there is a low incidence of rupture in females below 75 years of age, screening is not considered to be cost effective (Scott, 2002).

The United States Preventive Services Task Force (USPSTF) has recommended the screening of all men between the ages of 65-75 years who have ever smoked for AAA disease, due to its possible fatality and cost of emergency treatment. (Fleming, 2005).

Studies in Europe have proven a similar incidence of AAA and increased cost in its treatment as in the U.S. especially the MASS study in the United Kingdom. Due to these reports it is now accepted that screening is beneficial in saving lives and reducing the expensive costs of emergency health care due to ruptured AAA's.

4.   Methods of Diagnosis of AAA:

Most AAA's are asymptomatic and are usually detected accidentally during physical examination. Large AAA's may be detected clinically by careful palpation or feeling of the abdomen, which may reveal an abnormally wide pulsation of the abdominal aorta. In overweight people, aneurysms can be very difficult to detect on physical examination.

Aneurysms on the verge of rupture and that are rapidly enlarging, are often tender. Listening with a stethoscope may also reveal a bruit or abnormal sound from turbulence of blood within the aneurysm. Symptoms only occur near to or at point of rupture. These include lower abdominal, back or testicular pain, nausea and vomiting, feeling of coldness in the legs, profuse sweating and hypotension post rupture. (Kumer, 2009; Warrell, 2010).

An abdominal aortic aneurysm needs diagnostic imaging to be diagnosed and accurately measured. The first method of choice is ultrasound as it is non-invasive. Ultrasound has been shown to be a reliable and a cost effective method in the diagnosis of AAA.

4.1 Physics of Ultrasound

4.1.1 Sound Waves:

Sound waves consist of mechanical vibrations of particles within a medium. The vibration of one particle transmits a vibration to the next particle and so the wave moves through the medium. The transmission of a sound wave occurs at a fixed speed which is determined by the density and elasticity of the medium. Velocity of ultrasound depends on the medium it penetrates. (See appendix number 1 for velocity of ultrasound in different mediums) The rate at which the particle vibrates is called the frequency.

Sound waves have a longitudinal, sinusoidal waveform which varies from high pressure (compression) to low pressure (rarefraction). The waveform has characteristic properties such as wavelength (λ), frequency (F) and period (T).

The wavelength (λ) is the distance between identical points in a cycle.

The frequency (f) is the number of cycles occurring in one second. Units are Hertz (Hz)

The period (T) is the length of time it takes for one cycle to occur. Unit are microseconds (µs). (Figure 4.1)

Ultrasound is a cyclic sound wave of a frequency greater than human hearing (20 kHz).

4.1.2 Frequency

The frequency of a sound wave is the speed of which the particle vibrates. This is measured in hertz and is the number of cycles per second (Kremkau, 2001).

The frequency range of Ultrasound is above 20kHz. Diagnostic ultrasound has a frequency greater than 1MHz. Frequency is very important, higher frequencies give better resolution (clearer, crisper image) but there is greater attenuation.
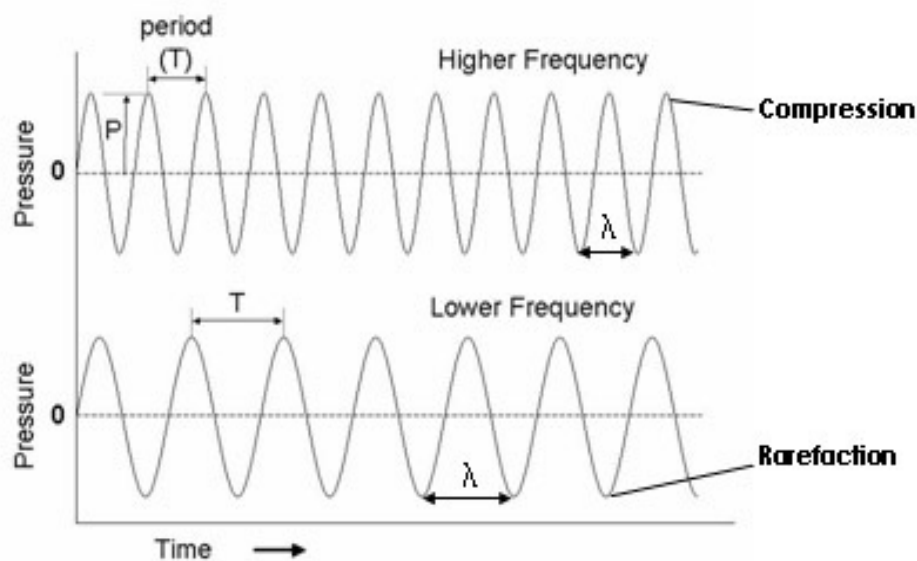
Figure 4.1 A sound waveform[10]

4.1.3. Attenuation

Attenuation is the reduction of the intensity of an ultrasound beam as it passes through a medium. It is a major limitation in ultrasound scanning. It is very important to use an appropriate frequency for the anatomical region being scanned. Higher frequencies are best as they give a more resolved image. However due to the high attenuation associated with high frequencies, depth of penetration is reduced. As frequency increases, attenuation increases and the depth of penetration decreases.

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[10] usra.ca

Ultrasound is altered by the type of tissue it penetrates. At boundaries between different tissues with different acoustic impedances, the ultrasound beam will be reflected, scattered, refracted or absorbed depending on the tissue. (See appendix number 3 of acoustic impedances of body tissues)

Attenuation mechanisms are:
1. Absorption
2. Scattering
3. Reflection
4. Beam divergence
5. Refraction

Absorption and scattering are the two main causes for attenuation. Eighty percent of the attenuation of the sound wave in soft tissue is caused by absorption resulting in the energy of the ultrasound wave being converted into heat. Attenuation is measured in decibels per centimetre of tissue and is expressed by the attenuation coefficient of the specific tissue. The higher the attenuation coefficient for the specified tissue, the more attenuated the ultrasound wave is. Bone has a very high attenuation coefficient and therefore severely limits beam transmission. (See appendix number 2 for attenuation coefficients of specific tissues). The degree of attenuation also depends on the frequency of the ultrasound wave and the distance travelled by that wave. The higher the frequency of a wave, the greater the attenuation therefore the depth of tissue penetration is limited. The lower frequency of a wave, the lower the tissue attenuation and the greater the depth of penetration.
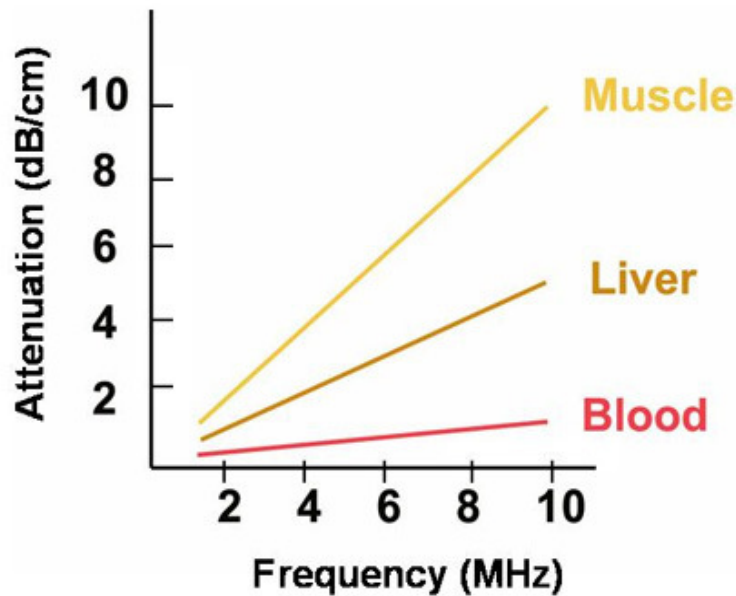
Figure 4.2 A graph showing the impact of ultrasound frequency on attenuation[11]

To compensate for attenuation and low signal amplitude, gain is used. This boosts the attenuated echo signal. If the overall gain is increased there is uniform amplification of the returning echo which will increase the brightness of the overall image and produce noise which can distort the image. Time gain compensation (TGC) is preferred as it can be adjusted for the weaker signals returning from deeper structures boosting their amplitude to that equal amplitudes are displayed on the entire image.

4.1.4 Reflection and Scattering:

Reflection is determined largely by the angle of incidence. If the angle of incidence is 90 degrees to the medium the reflected echo will be perpendicular to the transmitted beam. If the angle of incidence is < 90 degrees to the medium the resultant wave will be deflected away from the transducer at an angle equal to the angle of incidence but in the opposite direction (angle of reflection). When this occurs, the returning echo signal is weakened.

Ultrasound is reflected at smooth surfaces between two media for example the diaphragm or walls of a major vessel. For reflection to occur, the wavelength of the ultrasound wave must be smaller than the reflective structure. At interfaces that are not perfectly smooth the ultrasound wave is scattered. Scattering occurs when the wavelength of the ultrasound wave is greater than the size of the reflective structure (e.g., red blood cells). The echo's received

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[11] usra.ca

from scattering are usually weaker than reflected echo's. Not all of the ultrasound beam is reflected or scattered some of the beam will generally be transmitted into the next medium.

Specular Reflection

Diffuse Reflection (Scattering)

One Direction

Multiple Directions Low Amplitude
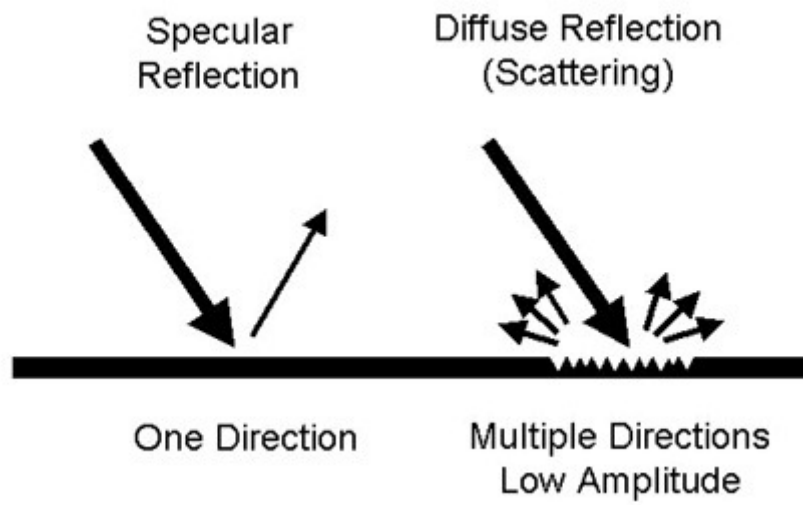
Figure 4.3 Reflection of Ultrasound[12]

[12] usra.ca

4.1.5 Refraction:

Refraction is the change in the direction of a sound beam as it crosses from one medium to the next. It depends on the velocity of ultrasound in both media, which is determined by the impedence of the media. If the sound beam crosses from a medium with lower ultrasound velocity into a medium of higher ultrasound velocity the angle of transmission will be greater than the angle of incidence and visa versa. This is based on Snell's Law, which states that the ratio of the sines of the angles of incidence and of refraction is a constant that depends on the media. Tissues like bone and fat cause extensive refraction and image distortion.
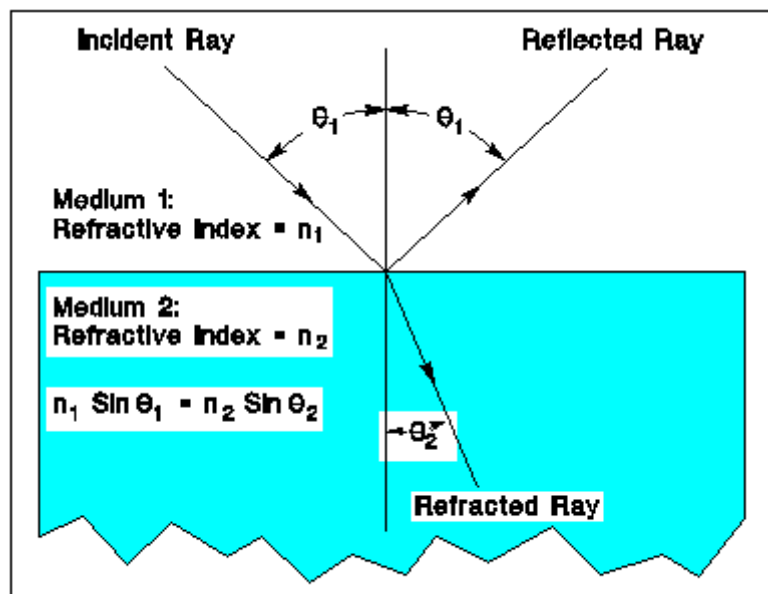
<u>Snells Law</u>

Figure 4.4 Snells Law[13]

$$n_1 \, Sin \, \theta_1 = n_2 \, Sin \, \theta_2$$

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[13] tiaonline.org

4.1.6 Ultrasound Transducer

The transducer is both the source and the receiver of ultrasound waves this is due to the rectangular piezoelectric elements which make up the transducer. The piezoelectric effect is the conversion electrical energy into ultrasound (mechanical) energy and then conversion the ultrasound energy back into electrical energy. When the piezoelectric crystals are excited they vibrate and send out waves, the combination of these waves makes up the ultrasound beam. They also detect the returning echo's covert them back into electrical energy which can then be processed to produce the ultrasound image.
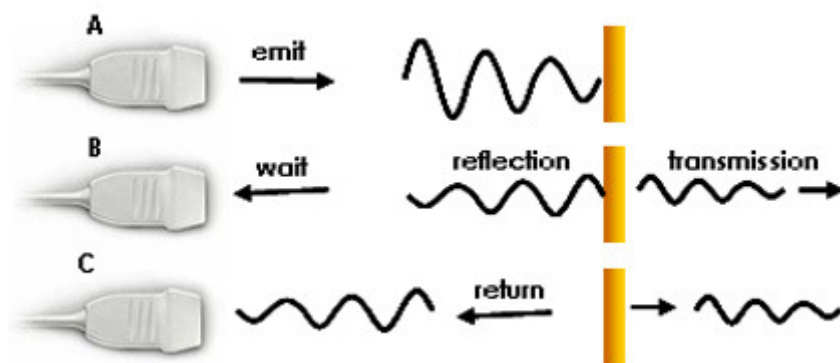
Figure 4.5 Diagram of the operation of an ultrasound transducer[14]

There are many types of transducers such as linear, curvilinear, phased and vector arrays.

In this study the curvilinear transducer is only transducer relevant, so this is the only probe that will to be dealt with in this review.

The curvilinear probe has a curved surface. It is made up of approximately 200 rectangular piezoelectric elements. Voltage is applied to the elements in groups of about 5-20 elements. The first group will send out its pulse, it will then wait to receive its returning echo before the next group of elements is excited. This means the beam will sweep from one side of the transducer to the other side to form the image. Several beam sweeps per sec are needed to provide a real time image.(Figure 4.5)

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[14] usra.ca

Because of the curved construction, the pulses travel out in different directions. This provides a real-time sector type image. Curvilinear transducers usually have a frequency ranging from 3.5MHz to 5MHz. Therefore they are the transducer of choice when scanning deep regions (greater than 5cm and more below the skin) like the abdomen and provide highly resolved images at such depths. (Figure 4.6)
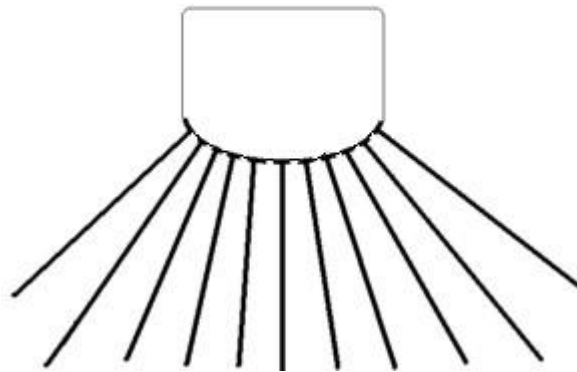
Figure 4.6 Direction of ultrasound beams in a curvilinear transducer[15]

[15] om-sy.com/curvilinear

4.1.7 B-mode imaging

B-mode is a two dimensional (brightness modulated) grey-scale image. It is comprised of a number of grey dots. The brightness of each dot is a representation of the amplitude of the signal received. In grey scale imaging, solid structures (bone) appear white and fluid (blood) appears black, with white having the strongest intensity and black having the lowest intensity. Short ultrasound pulses are sent into the body at a fixed rate call pulse repetition frequency (PRF). The transducer will then wait for the echoes from that pulse to be reflected back before it transmits the next ultrasound wave. Echoes are reflected back from areas where there is an acoustic impedence between tissues. These reflected echoes will be amplified and processed for display on the monitor. The vertical position of each bright dot is determined by the time delay from pulse transmission to return of the echo, and the horizontal position by the location of the receiving transducer element. The varying shades of grey give information on the variation of the textures of the organs interrogated. Each echo position gives depth and brightness information.

Depth of each echo is determined by the range equation.

$$d = \frac{cT}{2}$$

d = distance to reflector where echo was produced (mm)

c = speed of sound (1540m/sec)

T = time travelled by pulse from the transducer to the reflector and back to the transducer again (sec)

A number of beam lines are used to construct a B-mode image, this is usually approximately 100 to 200 pulses.
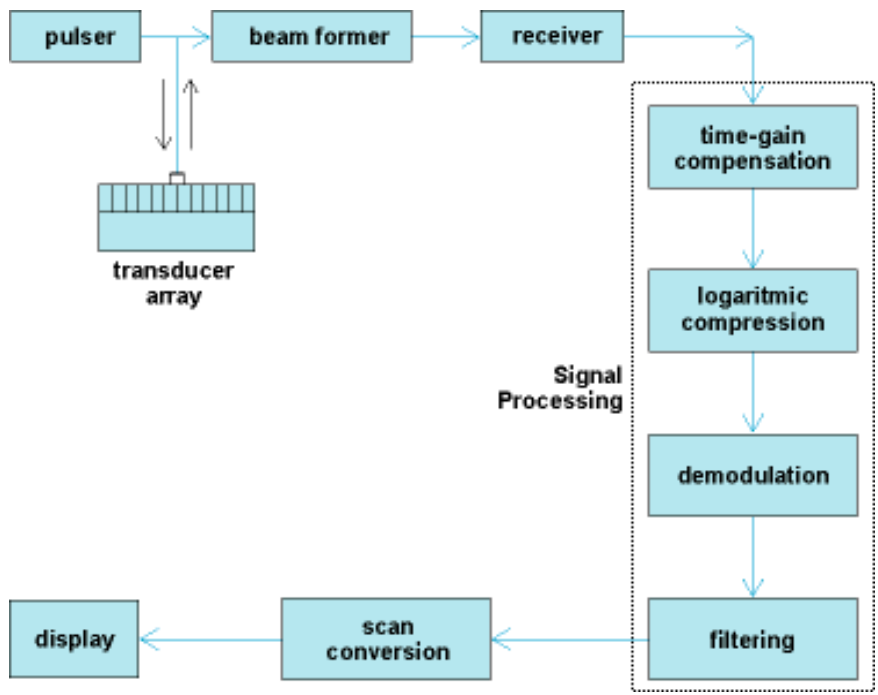
Figure 4.7 Block diagram of a B-mode scanner[16]

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16 accessscience.com

4.1.8 Artifacts associated with B mode:

1. Reverberation.

This occurs due to a strong reflector ie vessel wall or needle stick, which causes multiple artificial reflectors below the reflector. Each subsequent reflection is weaker than the prior reflection

2. Mirror imaging

This is a form of reverberation where a structure at one side of a strong reflector is also present on the other side too. It leads to false positioning of structures. It can be caused by the diaphragm.

3. Shadowing.

This is due to a strong reflector or absorber in the scanned field. The attenuation at this point cannot be compensated by time gain control (TGC). A shadow occurs beyond the structure obscuring imaging of the field below the reflector. It occurs in areas of bone and calcified plaque.

When screening for AAA's B-mode is usually the only ultrasound mode used. Pulse Doppler would only be used to verify an artery and colour Doppler would not be used due to flash artefact. However in the majority of vascular scans pulse wave Doppler and colour Doppler are both used. In this thesis we will have brief look at both these modes.

4.1.9 Doppler mode:

Ultrasound Doppler equipment is used to evaluate blood flow by using sound waves to image and measure the velocity of blood flow, which in turn gives functional information about a blood vessel. This functional information is based on a slight change in frequency of the ultrasound beam after it reflects off a moving object e.g blood cells, corpuscles.

It is based on the Doppler principle. The transducer emits a beam with a frequency (f_o) and receives an echo of a different frequency (f_r). The frequency difference is due to echoes being picked up by moving scatterers such as red blood cells.

The Doppler shift frequency (f_d) is the difference between the transmitted and reflected frequencies.

$$fd = fr - fo = 2fo\frac{V cos\theta}{c}$$

f_d = Doppler shift

f_r = reflected frequency

f_o = transmitted frequency

V = flow velocity

 θ = Doppler angle

c = speed of sound (1540m/sec)

There are two types of Doppler, continuous wave and pulse wave Doppler.

In continuous wave Doppler the transducer is continuously transmitting and receiving ultrasound pulses. This form of Doppler gives no directional information and therefore angle independent.

Pulsed Doppler sends ultrasound pulses repetitively to a target at a particular range. A localised sample volume, which is controlled by the operator, is placed within the target at a fixed depth. The sample volume is repeatedly interrogated by transmitted pulses from the transducer. The detected Doppler signal is produced by the reflected echo pulses received. Each sample of the Doppler shift is filtered and added to other samples to produce a waveform. This waveform is plotted as a function of time (horizontal axis) and frequency shift (vertical axis) to provide a two-dimensional spectral display (Zweiebel, 2005; Hykes,

1992; Kremkau , 2001). Pulsed wave Doppler gives directional information and is angle dependent.

Doppler angle (θ) is extremely important and depends on Cosine. Accurate Doppler shifts of flow are angle dependant. The error is greater at larger angles then in smaller angles due to the Cosine. If θ is 0 than Cosine θ is 1 and this would only occur if the blood is flowing directly at the transducer. At large angles Doppler shifts decease as well as the systems sensitivity. At angles less than 30° the sound no longer enters the blood but bounces off the vessel wall.

Flow speed calculations are not reliable at angles of greater than 60°. For an accurate measurement of flow the Doppler angle must be correct for the angle of the blood flowing. There will always be errors at angles of less than 60°. However they are small and acceptable. For blood flow calculation it is recommended that the operator only use angles between 40° and 60°, with the angle line in a parallel position to the blood flow.
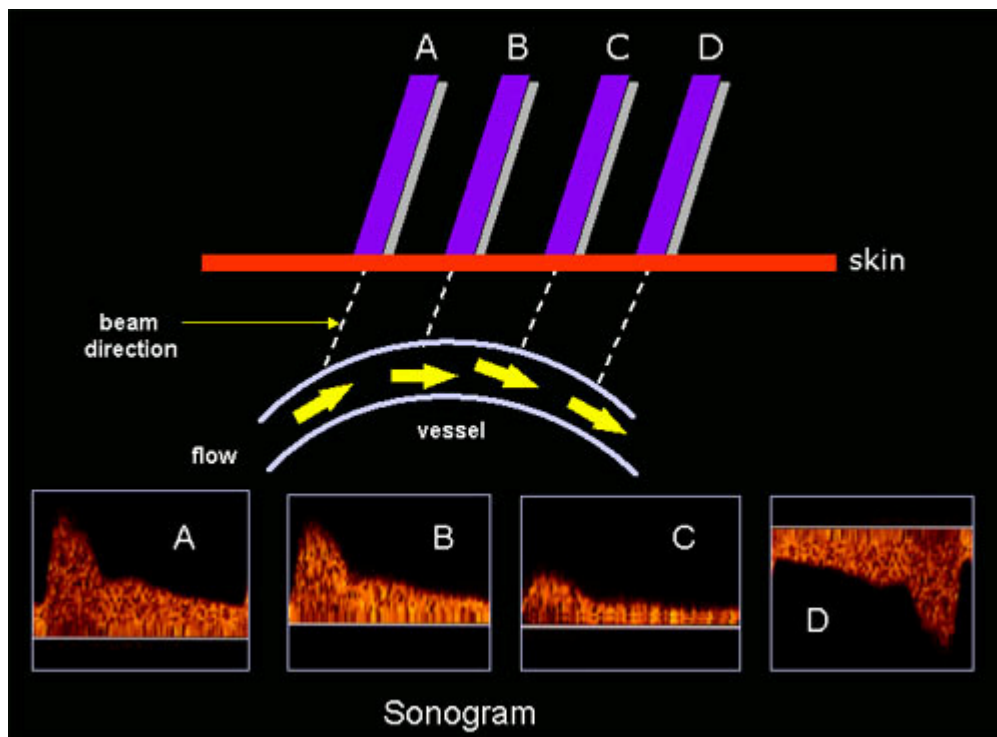
Figure 4.8 Effect of the Doppler angle in the sonogram. (A) higher-frequency Doppler signal is obtained if the beam is aligned more to the direction of flow. In the diagram, beam (A) is more ali)gned than (B) and produces higher-frequency Doppler signals. The beam/flow angle at (C) is almost 90° and there is a very poor Doppler signal. The flow at (D) is away from the beam and there is a negative signal.[17]

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[17] centrus.com

4.1.10 Colour Doppler mode

Colour Doppler imaging extends the use of the pulse-echo imaging principle to include Doppler-shifted echoes that indicate blood flow or tissue movement. Colour flow image data are superimposed on B-mode data from stationary structures to obtain a composite image. Colour coding is due to the mean Doppler shift along a scan line. Eight to ten pulses are used per scan line which will in turn increase frames rate. Approx 4-32 frames per sec are generated in a colour flow image. This increase in frame rate will decrease the resolution of the image.

The mean Doppler shift per scan line is designated a hue or shade. This gives direction and flow velocity information. Red and blue are the opposing directional colours with green indicating turbulent flow. A light hue indicates high velocity flow and a dark hue indicates low velocity flow.

Due to colour Doppler being based on a mean Doppler shift and with an unknown angle of interrogation colour Doppler is not accurate enough to use as a single diagnostic tool. It must be incorporated with pulse wave Doppler. (Zweiebel, 2005; Hykes, 1992; Kremkau, 2001)
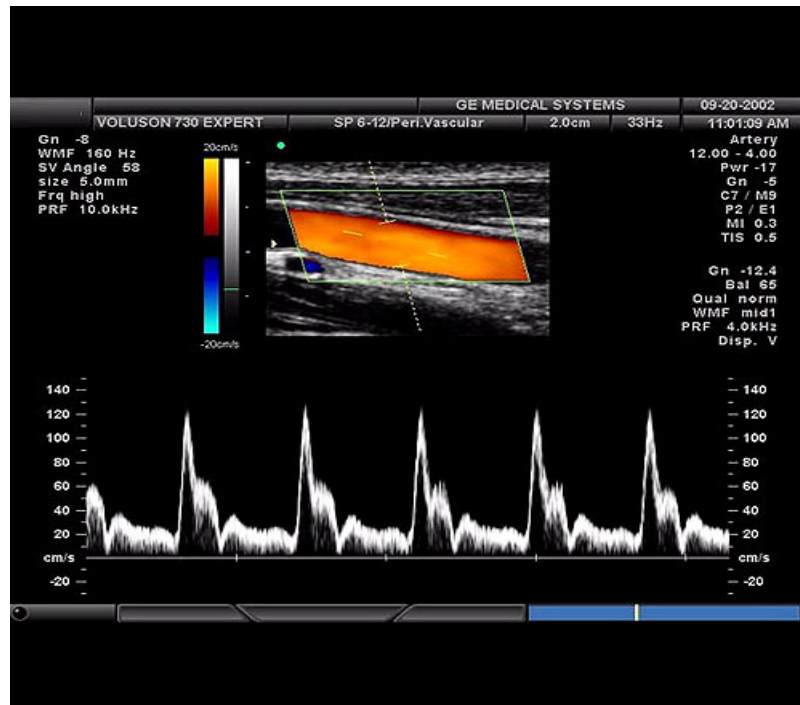
Figure 4.9 Pulse-wave and Colour Doppler image[18]

4.1.11 Image Optimisation for vascular ultrasound imaging

To ensure the best image is obtained, controls on the ultrasound machine can be changed to suit the area of interest depending on depth and location of the organ.

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[18] diagnostica.com

4.2. Limitations of Ultrasound

Major limitations with ultrasound is that it cannot travel through bone, air or gas. In AAA scanning is the presence of bowel gas and obesity can obscure the imaging. Patients who are obese are more difficult to image as the sound wave attenuates as it passes deeper into the body, therefore leading to suboptimal imaging and inaccurate measurements being obtained. Intestinal gases also prevent visualization of deeper structures. Calcification of the artery can also obscure the image as the beam may not be able to penetrate the artery, therefore not giving a clear view of the arterial wall. Tortuousity can also impede the imaging, making it difficult to follow the course artery. The scan is also operator dependant, inter observer error can lead to inaccurate measurements of AAA and therefore maybe misleading in AAA growth on follow up scans. Performing an inter observer error test is vital to assess the error of measurement between fellow technologists in a scan centre. Detailed knowledge of image optimization (the max amount of depth and width required to view the aorta etc) is also necessary to attain a clear image and accurate measurements. Therefore it is important that a full train vascular technologist performs the scanning in a screening setting. It is vital the machine settings are correct for the scan being performed. To ensure the best possible image is obtained.

4.3 Ultrasound for AAA diagnosis

In a clinical setting Ultrasound is said to be the most practical, non-invasive and inexpensive modality in screening for and surveillance of AAA , with a sensitivity of 98.9% and specificity of 99.9% (Sprouse, 2004; Lindholt 1998; Lederle, 2000; Fleming, 2005; Multicentre Aneurysm Screening, 2002). Ultrasound can reliably image the aorta in 99% of patients (Lindholt, 1999), however it is highly operator dependent (Mirza, 2010).

Real-time ultrasound provides the examiner with a two-dimensional greys-scale image of the abdominal organs and vasculature. It is possible to image anormalies of arterial location and arterial course as well as pathologically dilated segments. Information can be gathered about the extent of aneurysms from cross-sectional measurements in different planes and these values can also be used in relevant follow-up examinations.

Significant portions of the abdominal aorta are not visualised on emergency due to non fasting patients and the presence of bowel gas etc. This rate is higher than reported for fasting patients receiving elective ultrasound for evaluations of their aortas.

Ultrasound is not very accurate in determining the presence of a leak from an aneurysm. A RAAA can be indicated by the presence of free fluid in potential abdominal spaces. However, contrast enhanced CT is required for confirmation.

Duplex and colour flow Doppler ultrasound examinations of the abdominal cavity are highly dependent on the clear display of the tissues and vascular structure provided by B-mode ultrasound. B-mode is often used on its own in abdominal ultrasound to detect arteriosclerotic wall plaques and aneurysms of the abdominal aorta and pelvic arteries.

The more echogenic structures within the vascular lumen can be recognised due to their strong ultrasound reflection when compared to blood. This makes sonographic imaging of morphological wall changes of varying pathology possible as they occur in various types of aneurysm, including walls deposits (plaques) and also parietal thrombi.

Doppler mode and colour flow are not necessary tools in AAA diagnosis but can be helpful in identifying the iliac arteries. (Figure 4.10)
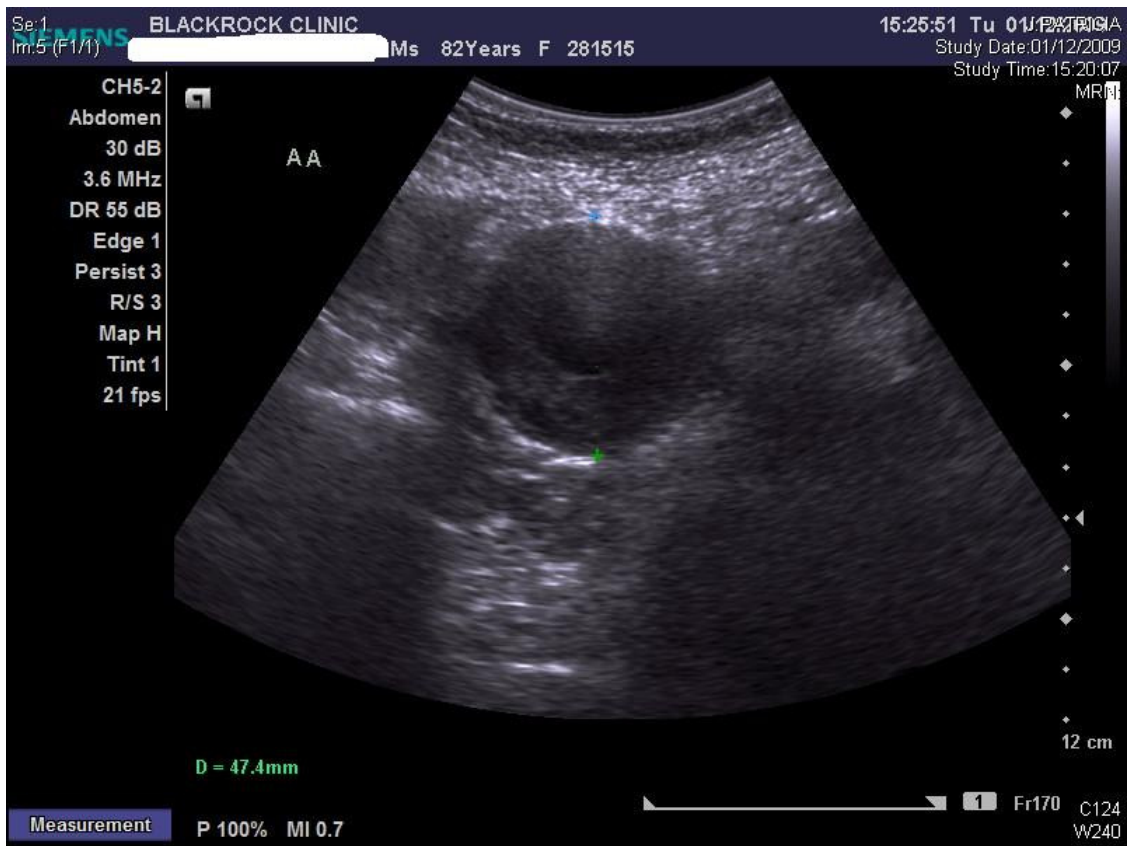
Figure 4.10 Transverse B-mode image of an AAA, with an anterior posterior measurement.
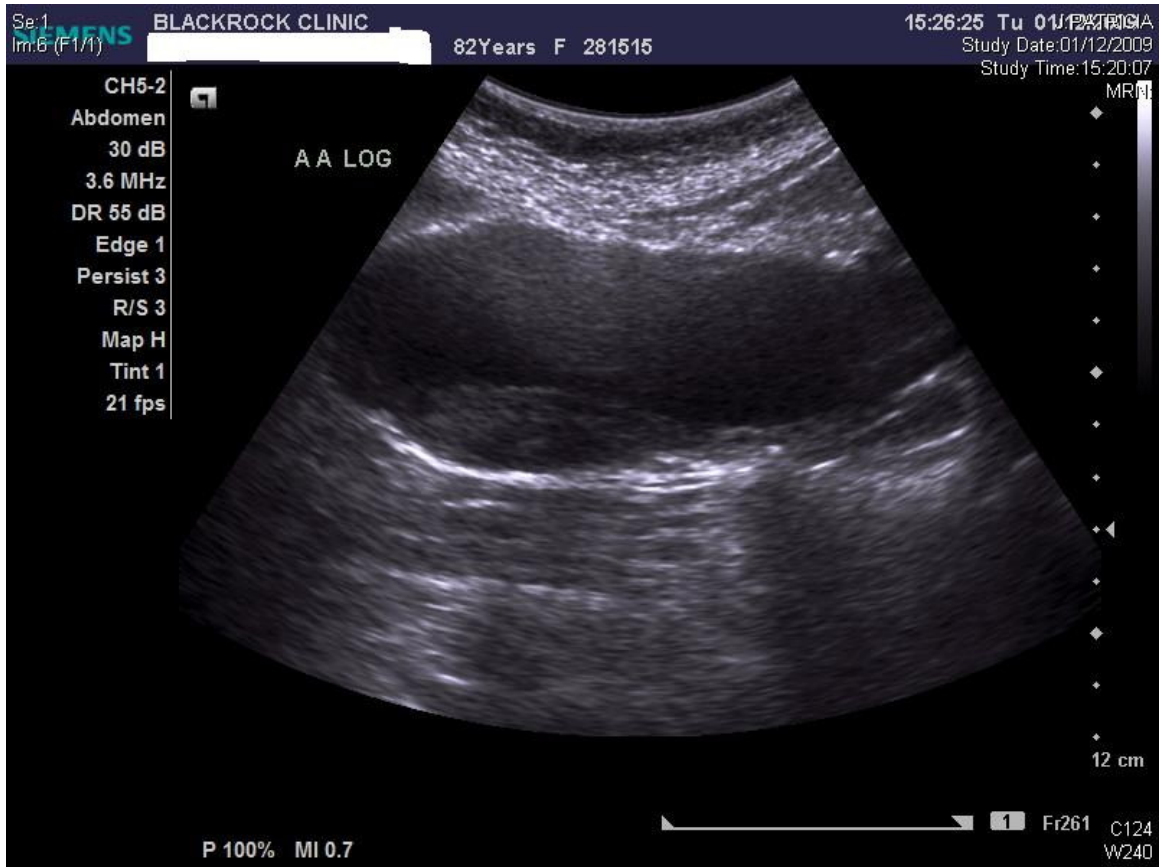
Figure 4.11 Longitudinal B-mode image of an AAA

4.4 Computed Tomography (CT)

Computed Tomography is based on the principle of attenuation. It is composed of a large ring containing x-ray sources and arrays of detectors which rotate around the patient. Multiple x-ray fan-beam sources sends out ionizing radiation into the patient's body. Attenuation occurs and the array detectors then process the beams post attenuation. The level of attenuation depends on the density of the medium (e.g. muscle is more dense than blood). The arrays mathematically construct the image by numbering the attenuations detected. The larger the number, the more dense the medium and the lighter the shading on the image.

This method happens in 4 steps:

Step 1: The tube and detectors are rotated at a constant speed.

Step 2: The x-ray tube is energised and data collected for 360 degrees.

Step 3: The tube and detectors slow down and come to a stop.

Step 4: The table and patient are indexed to the next scanning position. (Figure 4.111 and 4.12)

CT gives a digital, transverse (transaxial) image. It is composed of slices of cross-section views. Computed tomography scanning creates superb images of the brain, bone, lung and soft tissue and it doesn't allow information from irrelevant locations to enter the acquired data.

Contrast-enhanced CT is widely used in the preprocedural imaging of AAA's. The 3-D images obtained from the CT are also used in the planning of endovascular procedures. It involves the use of CT and the injection of a high speed contrast media. This procedure is used in the assessment of the arterial tree, as the contrast agent highlights a narrowing in an artery. In AAA imaging it shows the dilation of the aorta, it allows the accurate measurement of the diameter of the aneurismal section and the length of the vessel involved.

The advantage of contrast-enhanced CT imaging is the accurate assessment of the blood vessels, giving detail to the location and length of the affected vessel. However there are many disadvantages to CT contrast imaging:

1. It is highly invasive.

2. The patient may be allergic to the iodine contrast agent.

3. During CT imaging the patient is exposed to high doses of ionizing radiation.

DATA ACQUISITION SYSTEM
continuous acquisition of CT data
up to 140 levels in 15 seconds

ELECTRON GUN
permits 640 mA of x-ray power
for fast, low-noise studies

TARGET-RING
comprised of multiple targets for optimal
single-slice or multi-slice scanning modes

PRECISE, HIGH-SPEED
COUCH MOTION
makes continuous volume
scanning possible

ELECTRON BEAM
allows millisecond
scanning

SELF-CONTAINED
INTERNAL COOLING SYSTEM
eliminates interscan delay, permits
higher throughput, longer volume studies

Figure 4.12 Components of a CT machine[19]

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[19] rst.gsfc.nasa.gov
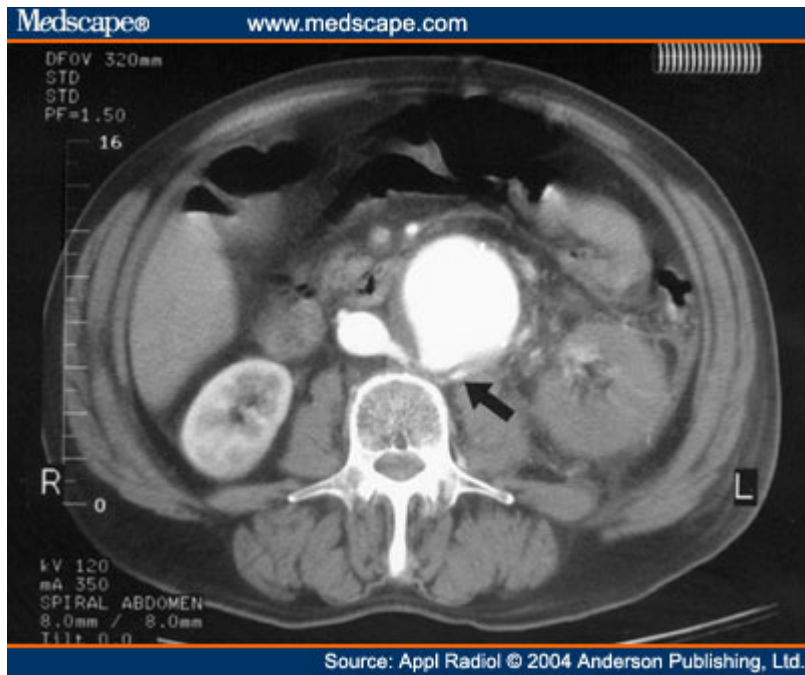
Figure 4.13 CT image of an AAA [20]
The arrow is pointing at the AAA.

[20] medscape.com

4.5 Ultrasound verse CT

Ultrasound is the method of choice in screening and AAA surveillance as it avoids high doses of radiation and minimises costs compared to computed tomography (CT). (Sandford 2006; Pages 2001; Collins 2007; Sprouse,2004).

CT has been a widely used tool in the diagnosis and detection of AAA. However it is an expensive, time consuming method with high doses of radiation being given to the patient. Ultrasound is a quick, inexpensive and non invasive method which is more suitable in diagnosis and screening for AAA (Multicentre Aneurysm Screening Study, 2002; Sprouse, 2003). CT is gold standard preoperatively as it accurately measures the diameter of the proximal neck of aorta, diameter and length of the aneurysm, diameter of the aorta just before the bifurcation, length from the aneurysm to the bifurcation and diameters and length of the iliacs and femoral arteries. The use of CT provides accurate configuration of stent grafts for the individual's anatomy. (Kim, 2010)

Ultrasound has also been shown to be the method of choice for measuring maximum AAA diameter. Ultrasound and CT do not always take the measurement on the same axis (Sprouse, 2003). CT takes the max cross-sectional area at any point, ultrasound takes the largest diameter in anteroposterior or transverse aspects (Sprouse, 2004).CT takes an oblique cut of the aneurysm to measure the max diameter, if the AAA in angulated more than 25 °, the diameter measured by the CT will be over estimated. (Sprouse, 2003 & 2004). Ultrasound is less effected by a tortuous vessel as the probe can be tilted to get a more accurate cross sectional area. (Sprouse, 2003 & 2004).

5.   Method:

5.1 Programme Set Up

An AAA and cardiovascular screening programme was set up in the Vascular Diagnostic Unit in Connolly Hospital over a two year period.

The General Practitioners (GP's) in the catchment area of the hospital were asked to identify patients on their databases who fit the criteria of this study. (Please see inclusion criteria below). Once the vascular lab received the patient lists from the GP's the lab and I coordinated the appointment schedule. I was assigned the project manager for this pilot screening study. All participants were invited to attend the vascular unit for AAA and cardiovascular risk factor screening. Participants were advised to fast for a minimum of twelve hours pre-examination, to enable a fasting lipid and triglyceride profile to be obtained by finger prick blood test and also to reduce bowel gas thereby improving ultrasound imaging of the aorta.

At the end of every screening session I collected the data obtained and correlated the database to achieve the final results.

5.2 Ethics

 Ethical approval for the proposed screening programme was granted and informed consent was obtained from all patients in the study.

5.3 Population Criteria

5.3.1 Inclusion criteria

The inclusion criteria were male sex in the age group 55-75 years.

5.3.2 Exclusion criteria

The exclusion criteria include participants with terminal medical conditions or previous history of AAA. Females are also excluded from the study.

5.4 Screening Examinations

The assessment consists of two parts: clinical risk assessment with a fasting lipid profile, and a duplex ultrasound of the aorta.

5.4.1 Clinical risk assessment with a fasting lipid profile

A full cardiovascular history was obtained by a clinical nurse specialist. The participant's height and weight was measured to determine their body mass index (BMI). BMI equals a person's weight in pounds divided by their height in inches squared, multiplied by 703.

Normal BMI was defined as between 18 and 25 overweight was >25 and morbidly obese was >30 (WHO, 2000). Their blood pressure reading was recorded. Normal blood pressure values were defined as less that 140mmHg systolic and 90mHg diastolic. Finger prick tests were also performed for total cholesterol, triglyceride and glucose estimation using Cholestech LDX$^®$ System (Cholestech, California). Normal cholesterol valves, including high density lipoprotein (HDL) and low density lipoprotein (LDL), as well as triglyceride values were defined per standard guidelines.

A fasting serum total cholesterol of 5.0mm/mol or greater was classed as hypercholesterolaemia. An abnormal glucose was defined as a fasting serum glucose of 7.0mm/mol or greater (WHO, 2006). All abnormal finger prick test were confirmed using standard blood samples.

The nurse specialist advised on the risks of developing symptomatic athero-thrombosis with the participants. Advice was also give on lifestyle changes which would help them prevent or control their risk factors.

5.4.2 Duplex ultrasound of the aorta

A duplex ultrasound was performed according to the protocols of the Society for Vascular Technology of Great Britain and Ireland (Ref) by a team of accredited vascular technologists, including myself.

A General Electric Logic 9 ultrasound machine with a curvilinear 3.5 MHz transducer was used. (Figure 5.1 and 5.2)

Figure 5.1 GE Logiq 9 Ultrasound Machine[21]

Figure 5.2 Curvilinear Transducer[22]

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[21] all-medical.co.uk

[22] all-medical.co.uk

The machine was pre set for abdominal scanning. Calibration is done automatically by the machine once it is powered on. The machine was serviced regularly and tested using a phantom by the technical staff from GE.

5.4.2.1 B-mode control settings in Abdominal scanning

Overall gain is usually be adjusted throughout the scan. It is increased for deep vessels such as the aorta. An appropriate gain is when the lumen of the vessel appears black and the walls white.

Time gain compensation (TGC) toggle knobs should be gently sloping which compensates more for the greater attenuation at deeper structures. The slope is usually seen beside the B-mode image.

Focus control sets the focal zone which is the arrow beside the B-mode image. This arrow should always be at or just below the level of interest. This provides the best image resolution at this point.

5.5 Protocol for screening for abdominal aortic aneurysm screening

Participant should be fasting for at least 10-12 hours prior to screening.

The participant was placed in a supine position with knees slightly bent and arms relaxed at their sides, to ensure the abdominal muscles are relaxed.

Normal respiration was usually sufficient, but in cases where bowel gas obscures the image the patient was asked to take a deep breath in and as they breathe out the technologist puts pressure on the probe to try dispersing the gas and improve the image.

A 3MHz curvilinear probe was used for maximum depth.

A clear water-based gel was applied to the abdomen to help the transducer make secure contact with the body and eliminate air pockets between the transducer and the skin.

The transducer was placed in a transverse plane, just left of the participants mid line above the umbilicus.

The abdominal aorta was located.

In the transverse plane, the abdominal aorta displays a large, pulsatile, round, anechoic lumen surrounded by bright, echogenic, muscular walls. It is positioned anterior to the spine, just left of the midline. The renal arteries can be seen to branch from the lateral walls of the aorta.

In the longitudinal plane, the abdominal aorta appears as a large, echo free, tubular structure running superiorly to inferiorly through the retroperitoneum of the abdominal cavity. The celiac and superior mesenteric arteries arise from the anterior wall of the aorta.

The inferior vena cava was seen on the left of the image. It appears as a less pulsatile, generally triangular structure.

The transducer was moved distally until the aortic bifurcation into the right and left common iliac arteries was seen.

The transducer was then slowly moved proximally, along the length of the abdominal aorta as far the coeliac axis and superior mesenteric artery (SMA) origin. The size and calibre of the vessel were examined.

The widest point of the aorta was located by slowly sweeping the transducer proximally and distally.

Only a slight pressure application was applied with the transducer to prevent compression of the aorta and in accurate measurements being obtained also in concern of a precipitating aorta rupture.

The aorta may be tortuous not only in an anterior posterior plane, but also in mediolateral plane, causing a significant deviation from the normal course.

Once the largest diameter of the aorta was identified, the image playback function was used to freeze the image in systole. The aorta was imaged along its length and the largest diameter located. The measurement was taken in systole measuring leading edge to leading edge both in transverse and longitudinal section. The renal arteries are located and diameter of the infa-renal and supra-renal segments are measured.

The anterior posterior diameter of the aorta was measured using calipers.

Making sure when measuring the outer wall to outer wall diameter and that the correct focal zone was set at the correct level.

Keeping the transducer in a transverse plane and the aorta was measured at the level of the renal arteries.

Remaining in transverse mode, the transducer was moved distally and the aorta was measured at the most distal point, just above the level of the bifurcation into the common iliac arteries.

The transducer was rotated into a longitudinal plane and the length of the aneurysm was estimated. The aneurysm may be longer than the capacity of the image display and this can lead to error in measurement.

Remaining in a longitudinal plane, the infra-aneurysmal section of aorta was estimated, between the distal extent of the aneurysm and the iliac bifurcation.

Once an aneurysm was detected, it was measured in transverse along its length when frozen in systole to achieve the largest diameter. It was also measured in longitudinal to assess the length of the aneurysm.

When an aneurysm was detected the machine was unfrozen and we looked for any signs of thrombus within the aneurysm.

The appearance of any thrombus for fissures or dissection was examined.

The aneurysm was examined for signs of inflammation. Inflammatory aneurysms may be identified by the presence of a low echogenic region surrounding the immediate area outside the bright echogenic artery wall.

The iliac arteries were then imaged for aneurysmal disease by tilting the probe to the left and right of the participant.

If an AAA was detected the participants iliac, femoral and popliteal arteries were also assessed for the presence of an aneurysm.

5.6 Follow-up Criteria

Follow up was defined as per international guidelines (Fleming, 2005) (see table below). The normal abdominal aortic measurement is defined as less than 3cms. A normal iliac artery measurement is defined as l cm.

	Follow-up
less than 3cm	Discharged
3-4cm	12 months follow-up scan
4-4.5cm	6 months follow-up scan
4.5-5.4	3 months follow-up scan and surgical consult
5.5cm and greater	Elective surgery

Table 5.1 Follow up criteria chart

Any participant identified with an AAA of 3cm or greater had a consult with a vascular surgeon on the day of diagnosis. The results of the risk profile and recommendations for treatment are referred back to the family practitioner for follow-up.

6.   Data

6.1 Participant demographics

A total of 1414 male participants between the ages of 55-75 were invited to participate in the screening programme. A total of 904 (64%) participants accepted the invitation. Of these, 568 (63%) were aged between 55 and 64 years and 336 (37%) were aged between 65 and 75 years. The mean age was 62 years and the standard deviation was 5.37.
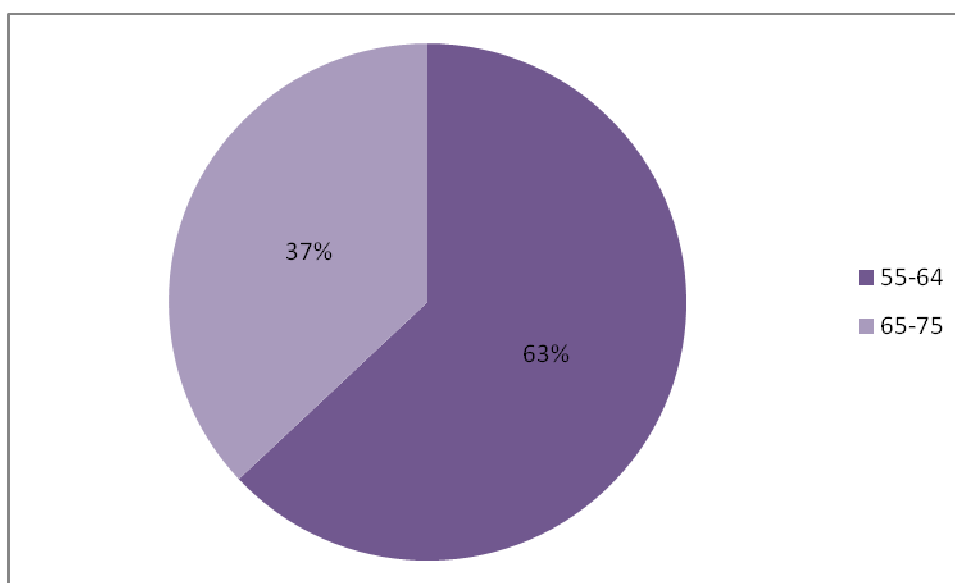
Figure 6.1 Age range of the participants

6.2 Risk Factor Assessment:

6.2.1 Previous Medical history:

When questioned by the nurse it emerged that 137 participants had been treated for ischemic heart disease (IHD) by means of a stent or coronary artery bypass, 21 participants had a history of a transient ischemic attack (TIA) or cardiovascular attack (CVA) and 9 participants had diagnosed peripherial vascular disease. Aspirin had been prescribed to 222 of the participants for its antiplatelet effect and warfarin had been prescribed to 32 of the participants for its anticoagulant effect.

6.2.2 Body mass index

Five hundred and seventy three participants agreed to have their body mass index measured, 16% (93/573) were morbidly obese (BMI > 30) and 64% (367/573) were overweight. Overall 80% of the participants whose BMI was calculated were overweight.

6.2.3 Smoking

A total of 11% (104/904) of participants were smokers. There were 6% (58/904) ex-smokers and 82% had never smoked.

6.2.4 Hypertension

Six participants did not have their blood pressure recorded due to an ill fitting cuff.
Of the 898 who had their blood pressure checked, 33% (294/898) of participants had a previous history of HTN and 68% of these still had an isolated elevated blood pressure, despite having been previously been prescribed an anti-hypertensive. Of participants with no previous history of hypertension, 31% (278/898) had a single elevated blood pressure measure during the screening process. ($\rho < 0.00001$)

6.2.5 Hypercholesterolemia

Of the 904 participants tested for hypercholesterolemia, 26% (234/904) had a previous history of elevated cholesterol, with 165 (70%) of these being inadequately controlled. In participants with no previous history, 33% (302/904) of these were newly diagnosed with hypercholesterolemia, of these 71% of the newly diagnosed where between the ages of 55-64 years of age.
From our results 33% (303/904) of the screened population had an HDL level of less than 1mmol/l and 41% (374/904) had a LDL level of greater than 3mmol/l. ($\rho < 0.01$)

6.2.6 Diabetes Mellitus (DM)

The results in screening for DM were, 6% (55/904) of participants had an elevated fasting blood glucose level of greater than 7 mm/mol, 49% (27/55) of these had a previous history of DM and had a poor sugar control. Of the participants with no previous history, 3% (28/904) undetected elevated glucose levels in excess of 7mmol/l. ($\rho < 0.02$)
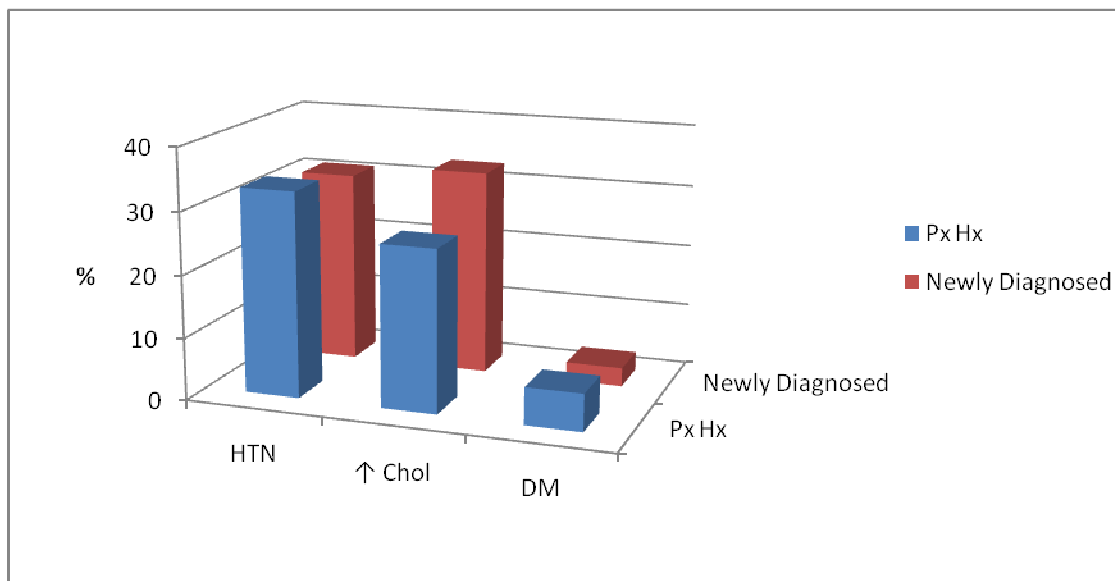
Table 6.2 Risk Factor Assessment

From the above graph the participants with a previous history of HTN, hypercholesterolaemia and DM are compared to the participants who never had a history for these risk factors but on the day of screening their levels were above the normal average. (Table 6.2)
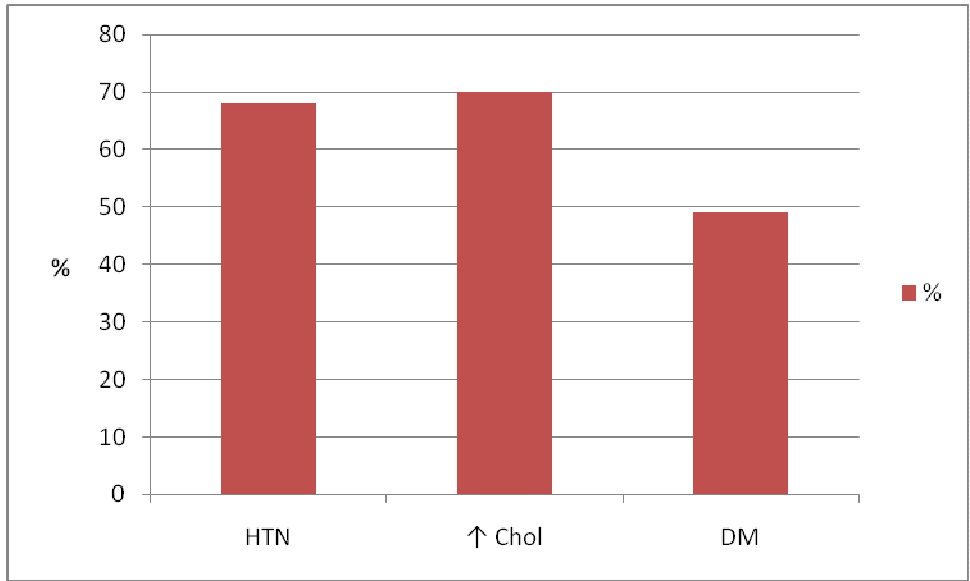
Table 6.3 Uncontrolled Treatment of Risk Factors

The above table shows the number of participants who were treated for a previously diagnosed risk factor, but on the day of the screening they had elevated levels for their treated risk factor.

6.3 Abdominal aortic Aneurysms

All participants underwent an ultrasound of their aorta. Two aortas were not successfully imaged due to morbid obesity and these patients declined further attempts of imaging.

Of all of the scanned patients the incidence of AAA was found to be 1.9% (17). An incidence of 0.6% of the men aged between 55-64years had an AAA and 4.2% of the men aged 65-75 years had an AAA(p <0.01).

The aneurysm sizes ranged from 3.0cm to 5.8cm. Three AAA's were detected in the 55-64 years age, the size of each were 3.8, 3.4 and 3.09cm. Fourteen AAA's were detected in the males between 65-75 years. Six of these patients had a measurement of between 3.0-3.9cm, five had an AAA measurement of 4.0-4.9cm, 2 had an AAA measurement of 5.1 and 5.3cms and one patient had a measurement of 5.8cm.
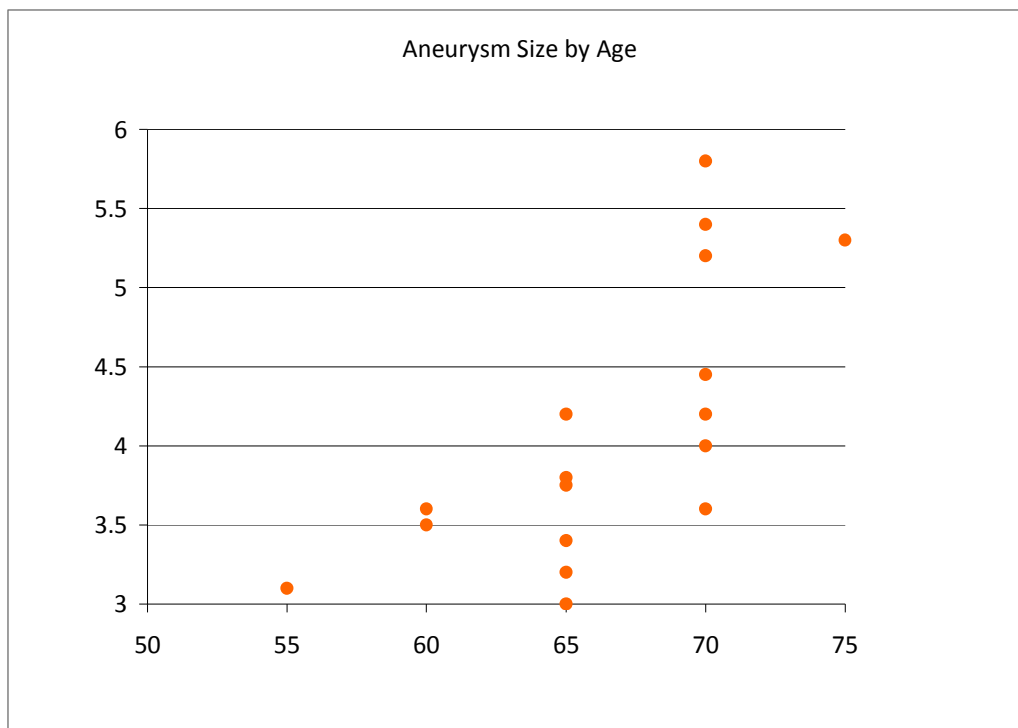
Table 6.4 Aneurysm Size

Of the 17 participants who were diagnosed with a AAA, two of these had an iliac aneurysm. Both patients with the iliac aneurysms were aged over 65. No femoral aneurysm was detected.

For the purpose of analysis the participants were then separated in to two groups, Group A had a normal abdominal aortic measurement (887 patients). Group B had an AAA of 3cm or greater diagnosed (17 patients).

The risk factors of both groups were compared

Group A: participants with a normal abdominal aortic measurement (n = 887)

- 54% had an elevated blood pressure reading
- 38% had elevated total cholesterol
- 32% had a HDL reading of less than 1.0mm/mol
- 6% had an elevated glucose level
- 12% smoked and 6% were ex smokers
- 16%% were morbidly obese

Group B: participants with an abdominal aortic aneurysm (n = 17)

- 58% had an elevated blood pressure reading
- 17% had elevated total cholesterol
- 65% had a HDL reading of less than 1.0mm/mol
- 5% had an elevated glucose level
- None claimed to smoke, however there were two ex smokers in the 17 diagnosed
- 42% were morbidly obese
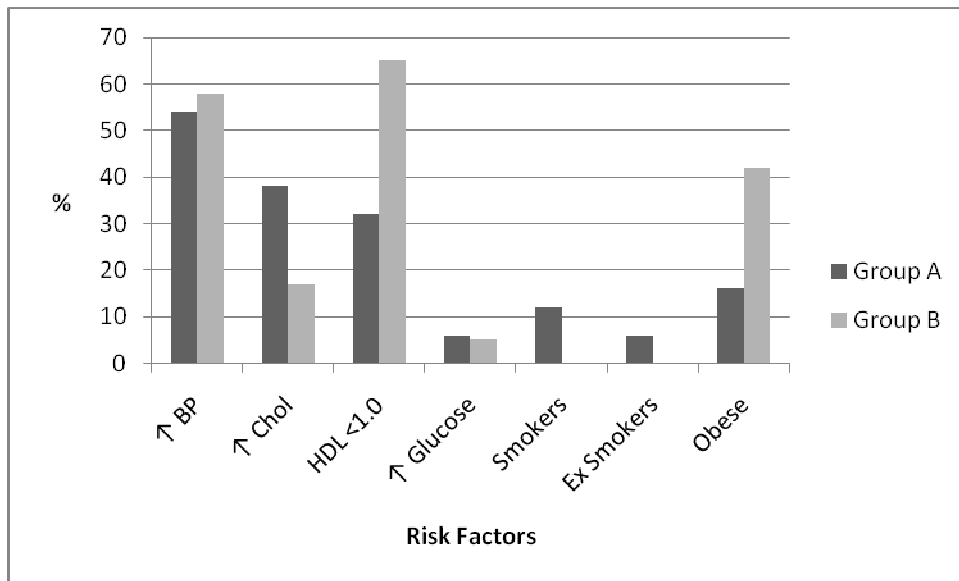
Table 6.5 Risk Factor comparison

All the participants with a diagnosis of an AAA were followed up according to the criteria given in Figure 25. The participant with an AAA measuring 5.8 was seen by a vascular surgeon, sent for a CT and elective surgery was performed. The operation was successful and the patient is good health.

7   Discussion:

Many abdominal aortic aneurysm screening programmes have proven to be successful in the diagnosis of asymptomatic AAA's and have helped to reduce the related mortality of AAA (Multicentre Aneurysm Screening Study, 2002; Adam, 1997; Powell, 2003; Lederle, 2000; Kent, 2010). AAA screening has shown to reduce all cause mortality by 5 per 1000 (Takagi, 2010). Diagnosis leads to adjustments in cardiovascular risk factors which can in turn lower other cardiovascular deaths (Mastracci, 2007).

This AAA screening study was one of the first of its kind to be held in Ireland. Males between the ages of 55-75 years were screened for AAA unlike most other programmes which only included males between the ages of 65-75 years of age (Multicentre Aneurysm Screening Study, 1999; Lindholt, 2005; Thompson, 2010, Montreil, 2008). The risk factors in these younger men were also examined. Screening males of younger than 65 years has not been thought to be beneficial as males younger than 65 years would need to be rescanned in ten years (Crow, 2001; Ashton, 2002). The study showed the incidence of AAA in Irish males between 65-75 years to be 4.2% comparable with other worldwide AAA screening studies (Multicentre Aneurysm Screening Study, 1999; Lindholt, 1996; Jamrozik, 2000). The incidence of AAA in the males between 55-64 years was found to be significantly lower (0.6%) which also concur with other studies who have found the incidence of AAA is most prevalent between 65 and 75 years (Kent, 2010) ($\rho > 0.01$). This would suggest that screening males between the ages of 65-75 in Ireland is justified but the screening of men between 55-65years was not justified ($\rho < 0.01$).

The cost effectiveness of such programmes has also been shown by a considerable number of programmes from around the globe. This included cost incurred by the health system and cost of life years gained and quality adjust life years (Multicentre Aneurysm Screening Study, 1999; Schmidt, 2010; Thompson, 2010; Ehlers, 2009; Montreil, 2008). AAA screening has reduced the frequency of emergency surgeries by up to 75%. The cost of elective surgery has proved to be less than emergent procedures. And the cost of life-years gain has also reduced since the introduction of AAA screening in the late 90's (Multicentre Aneurysm Screening Study, 1999; Lindholt, 2006). The real cost effectiveness of AAA screening was beyond the scope of this study. With the necessary service, machines and expertise in place, additional

From this screening programme, 17 AAA were diagnosed. Compared to other screening studies our finding of 4.2% of our screened population aged between 65 and 75years concurred well. These findings suggest that screening for AAA's in Irish males of 65 and over would be worthwhile and beneficial to our health system. The incidence of AAA detected by the screening programme in males aged 55-65 years of age was found to be 0.6% ($\rho > 0.01$) which compares to other findings who do not believe screening these younger men to be beneficial or cost effective (Crow, 2001; Aston, 2002). All of the patients diagnosed with AAA from this study were followed-up as per international guidelines (Fleming, 2005). However, on the day of screening, all the AAA patients had a consult with the department's vascular surgeon. This reassured the patients and reduced any anxiety caused by their new diagnosis.

A screening programme for AAA will never prevent all AAA ruptures as the initial screening attendance rate will never be 100% and not all patients with diagnosed AAA will co operate fully with the follow-up procedures given to them.

Due to the age of this programmes population it was decided to take the opportunity to screen for cardiovascular risk factors. Cardiovascular disease (CVD) causes a major burden on health care systems worldwide and is the main cause of death under 75 years of age. CVD accounts for 36% of all deaths in Ireland, 48% of all deaths across Europe and 42% of all deaths in the United States of America (USA). It is estimated that cardiovascular disease costs the European Union (EU) 192 billion euro yearly (www.croi.ie; www.heartstats.org; www.apps.who.int; www.healingwithnutrition.com).

There is a high incidence of cardiovascular disease in Ireland. It is believed that 80% of heart disease can be prevented if the risk factors for CVD are diagnosed early and adequately treated. This study screened for the main risk factors which included BMI, smoking, HTN, cholesterol and DM.

Obesity has always being a major risk factor in CVD. However in recent years the levels of obesity are increasing worldwide as children are heading into pre adulthood already over weight. This is due to an increased calorie intake and a decrease in physical activity. In 2007, a study of the Irish population showed 31% had a BMI of $>30kg/m^2$ and 80% had a BMI of $>25kg/m^{2.}$ In 2003 statistics from the United Kingdom showed 23.6% had a BMI of $>30kg/m^2$ and 66% had a BMI of $>25kg/m^2$. In the same year the USA statistics reported 42.3% had a BMI of $>30kg/m^2$ and 79% had BMI of $> 25kg/m^2$ (www.apps.who.int). From this study 331 men refused to have their BMI calculated for reasons assumed due to it being a psychologically sensitive matter. For the other 573 who did agree, 16% had a BMI of $> 30kg/m^2$ and 64% had a BMI of $>25kg/m^2$. Comparing the elevated BMI results from this study 80% of the participants were overweight, which compare well to other Irish and worldwide studies. In AAA, an increased waist circumference is associated with a large number of AAA's above 4cm (Golledge, 2007). Obesity is a major determining factor on the mortality and morbidity post surgery and reduces the success of treatment. It causes an increase in wound complications and operating times. In the study, the relationship between BMI and AAA is not clearly defined due to the small number of AAA patients diagnosed, even though 42% of the 17 new diagnosed patients were overweight. However there is no doubt that increased BMI is becoming a major burden on health systems as both the younger and older generations are now suffering from obesity where only a few decades ago it was only a problem arising in adults. Ireland has one of the highest rates in childhood obesity in the world. The "Growing Up in Ireland" study in 2009 found 1 in 4 nine year olds being overweight or obese, another survey suggests the level of obesity in young Irish people between 16 and 24 years of age has tripled in between 1990-2000.

Smoking is a major, independent risk factor for CVD. It appears that smoking is more strongly related to AAA development and growth than in CAD (Lederle, 2003). The association between smoking an AAA development and progression is relatively unclear. There have been studies which suggest that the components of smoking effect the arterial wall and therefore correlate with AAA formation and growth.(Lee,1997; Wilmink, 1999) However, this is not a clear and confirmed conclusion and further studies need to be carried out to support this research. From a European Commission health survey published in 2009 (www.ec.europa.eu), approximately one third of the European population smoke and from the WHO database of males (www.who.int/en) between 2002 and 2005, 27.5% in the US were smokers, 28% of the UK population smoked and 24.2% of Irish smoked. In this study

only 11% were current smokers. Compared to the smoking statistics this figure seems significantly low. It is likely that the incidence was possibly higher but unreported by the patient population. This may reflect the negative social aspects of smoking in Ireland in the aftermath of the smoking ban, which was introduced in 2004.

Hypertension has been shown as a risk in the formation of AAA's. It is a significant risk for rupture on large AAA's as it puts added haemodynamic stress on the ever weakening arterial wall (Lee, 1997; Wainhainen, 2005; Truijers, 2007; Choke, 2009). When rupture occurs there is increased blood loss into the abdominal activity a due to HTN and this significantly increases the risk of morbidity.

In 2009 it was estimated that 44% of Europeans suffer from hypertension (www.centrus.com). It is thought that over half the Irish population aged 50 or greater are affected by HTN with only a third being treated for their elevated blood pressure (Awareness Initiative Highlights Ireland's Biggest Killer. *Prolog May 2008*). In this study, 33% had a previous history with 68% of those on treatment, but with an elevated blood pressure reading at the time of screening, 31% had never been diagnosed with hypertension but were found to have an elevated blood pressure reading during screening. From our results the single blood pressure reading taken at the time of screening gave 64% with elevated blood pressure, this is 14% greater than the estimated 50% of the Irish population suffering from HTN. However these values maybe falsely elevated, so these patients were referred back to the GP for further investigation and monitoring.

When screening for hypertension, one must consider the number of factors that may give a false elevated measurement. The two main reasons are cuff size and 'white coat syndrome'.
Often in a screening situation a full range of cuff sizes are not available. The measurement of blood pressure needs to be accurate, so the size of the cuff and its correct placement is vital. Six patients did not have their blood pressure recorded in this study due an ill fitting cuff. The cuff available was of normal adult size but was not big enough to be placed around some patient's arms so their blood pressure could not be measured accurately. If a normal adult sized cuff is used in an obese person it artificially overestimates the blood pressure reading significantly.
Elevated blood pressure can also be due to "white coat syndrome". This is usually at a subconscious level where the patient feels relaxed going to the doctor, however their 'fight or

flight' response is activated once they arrive and their blood pressure is abnormally elevated. Often blood pressure readings at home can be normal but appear elevated at the doctor's clinic setting. Ambulatory blood pressure monitoring can be used to differentiate between true hypertension and "white coat syndrome". The patient is required to wear the monitor for over a 24 hours period. A blood pressure measurement will be taken half hourly during the day and hourly at night. This gives an overall view of the patient's blood pressure in their normal everyday life.

It has been documented that Ireland has the lowest rates for HTN testing in a GP setting in Europe. From this study 68% of participants diagnosed and treated for HTN still had elevated blood pressure readings. This is a major problem which needs to be dealt with. It could be due to poor GP follow up, with the patient on too low a dose or on a type of medication that is not strong enough to control their HTN. However it could also be due to poor medication compliance by the patient. It is hoped that the GP will follow up these patients and ensure they are on adequate treatment and their HTN is controlled.

Cholesterol appears to be a contributing factor to AAA formation and growth as well as being a well known cardiovascular risk. It is associated with 56% of all coronary heart diseases. It is generally due to heredity factors or poor diet. Approximately 20% of the adult population in America suffer from hypercholesterolemia (National Cholesterol Education Program. Second Report of the Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults, 1994). A comparison study between Irish and European cardiovascular risk factors showed Ireland to be favourable with only 27% having a total cholesterol of greater than the target level of 4.5mm/mol (Cooney, 2009). The recommendations for cholesterol screening are checks every five years for men of 35 years and over (www.uptodate.com). It is preferable to have the patients fasting but nonfasting results can also be indicative of hypercholesterolemia (National Cholesterol Education Program. Second Report of the Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults, 1994; US Preventive Services Task Force. Guide to Clinical Preventive Services, 1996; Craig, 2000).

In this study, 26% of the patients had been diagnosed and treated for hypercholesterolemia of these 70% still had an elevated total cholesterol reading. Of the screened population 33% were newly diagnosed with hypercholesterolemia. From these results, the percentage of participants who had previously being diagnosed with hyperlipidaemia are comparable with

the 27% recorded in another study. However, 33% had never been diagnosed with hyperlipidaemia but had an elevated level of >5mm/mol. Therefore in this result up to 60% of our screened population had a fasting lipid profile of >5mm/mol, which is much larger than the other Irish studies recording.

Diabetes Mellitus is characterised by a partial or complete lack of insulin production by the body. There are two types of DM. Type 1 is a complete lack of insulin production and the only treatment is a regular injection of insulin. Type 2 is a partial lack of insulin in the body which is managed by oral medication, diet and exercise programmes. It poses as a major risk factor for cardiovascular disease with a 2 to 4 fold increased risk of CVD in patients with Type 2 DM. However, it appears to have an inverse effect on AAA formation and growth (DeRubertis, 2007; Vega de Cengina, 2006; Shantikumar, 2010). DM diagnosis is increasing at an alarming rate due to the increased levels of obesity and lack of exercise in the current times. This is a significant problem as there are many side effects linked to DM, the main organs affected are the kidneys, eyes, feet and heart. It is estimated that 7.8% Europeans and 4% of the Irish population suffer from DM, with approximately 50% unaware of their condition. In this study 6% of the patients had a previous diagnosis of DM, with 49% of these still having a blood reading of >7mm/mol. In those patients who had no history of DM, 3% of those presented with an elevated blood sugar level. The levels of DM in this study compared well with the European result but is slightly higher than the Irish record. Diagnosis and proper control of such a disease is vital to contain this chronic and life rendering effects on the population and keep the financial burden of such a disease low on the health care system. For those already diagnosed DM patients it is important that they are educated on their disease and the effects of a bad lifestyle. This may help with the control of such a disease and reduce its side effects.

This study differs from screening programmes due to its inclusion of a younger age group. In the males between 55 and 64 years who had AAA and also being diagnosed with cardiovascular risk factors, questions could arise on the possibility of such an early pick up of both AAA and the risk factors could also reduce the level of AAA surgery and mortality. A long term study is planned to investigate if early pick and treatment of risk factors can halt the growth of their AAA in five and ten year periods. However, this is beyond the scope of the present study.

During this study the patients received lifestyle advice from a clinical nurse specialist. Life style is major risk for all cardiovascular disease. In patients diagnosed with risk factors for cardiovascular disease it is important to stress that their medication alone does not control their condition. Exercise is a very good and simple method of controlling HTN, cholesterol, obesity and DM. A recent European survey showed that only 18% of the Irish population reported moderate physical activity, with 41% sitting for an average of 4-8 hours daily (Euorbarometer Survey on Physical Activity, 2005). Having a healthy lifestyle is also a major factor in control of such diseases and can also help the patient to feel better and more vibrant. Many people are not well educated on the importance of a healthy lifestyle. It is very important that this advice is given as it can make the patients feel more positive and more proactive in their own treatment.

Another limitation was we did not note if any of these participants had medical cards as it was a free screening programme. In view of our alarming high uncontrolled condition results and overall elevated results which compare badly to the national statistics, it maybe due to low social economic community of the GP's, lack of knowledge on a healthy lifestyle or lack of finance which deterred the participants from having regular visits to their GP to monitor their risk factors.

In view of the smoking results as a whole the low level of smokers is unbelievable. If the study was continued it might be an idea to include an exhaled carbon monoxide exam for a true recording of the smokers and non smokers in the group.

This study has proven that AAA screening is beneficial and cost effect in men aged 65-75 years in Ireland. In the younger group AAA screening did not prove to be beneficial. The AAA's picked up were of very small sizes and these would be picked up at the screening of this group at 65 years. The screened population also benefitted from the cardiovascular risk factor analysis. It proved the real need for a national cardiovascular screening programme for both the younger and older groups.

Such combined screening studies acting as a "one stop shop" where screening for AAA, cardiovascular risk factors and a consult are cost effective and worthwhile. Screening for multiple factors as a research programme is possible. However, screening for these multiple

factors in a clinical setting is not viable or effective as every disease has a precise criteria and patient demographics would differ too much.

8   Conclusion:

From this study the incidence of AAA in Irish males between the ages of 65-75 years is similar to the incidences recorded worldwide. Therefore, screening for AAA is beneficial and programmes need to be established to reduce AAA related deaths and would impact the cost incurred on emergency medical treatment for AAA's. However, screening males of 55-64 years of age for AAA has not been proven to worthwhile or economically viable.

The incidence of cardiovascular risk factors in Irish males is considerably high. Unfortunately, some males who had already been diagnosed and treated for their risk factor were not adequately followed up, and their risk factor remaining uncontrolled. This leaves these men susceptible to cardiovascular disease despite treatment.

Many Irish men between the ages of 55-75 years appear to have undiagnosed risk factors for CVD. This can lead to early disease and possibly a high cardiovascular morbidity and mortality rate at an early age. This proves the necessity of screening for cardiovascular risk factors at 55 years or younger. It is imperative that once diagnosed and treated, the patient is regularly monitored to assess their cardiovascular risk. It is essential to educate the patient on treatment compliance and give advice on the lifestyle changes required. This gives the patient empowerment in the control of their cardiovascular risk.

Screening for cardiovascular risk factors is not complicated and can easily be incorporated into other screening programmes. This would take advantage of the high attendance that maybe achieved in screening for other individual medical conditions.

9   Appendix

Medium	Ultrasound Speed (m/sec)
Air	300
Lung	500
Fat	1,450
Brain	1,520
Muscle	1,580
Liver	1,550
Kidney	1,560
Brain	1,560
Soft Tissue	1,540
Bone	4,000

1. Velocity of Ultrasound in tissue

Body Tissue	Attenuation Coefficient (dB/cm at 1MHz)
Water	0.002
Blood	0.18
Fat	0.63
Liver	0.5-0.94
Kidney	1.0
Muscle	1.3-3.3
Bone	5.0

2. Attenuation coefficients of body tissues

Body Tissue	Acoustic Impedance (10^6 Rayls)
Air	0.0004
Lung	0.18
Fat	1.34
Liver	1.65
Blood	1.65
Kidney	1.63
Muscle	1.71
Bone	7.8

3. Acoustic impedances of body tissue

Top number (systolic) in mm Hg		Bottom number (diastolic) in mm Hg	Your category*	What to do**
Below 120	and	Below 80	Normal blood pressure	Maintain or adopt a healthy lifestyle.
120-139	or	80-89	Prehypertension	Maintain or adopt a healthy lifestyle.
140-159	or	90-99	Stage 1 hypertension	Maintain or adopt a healthy lifestyle. If blood pressure goal isn't reached in about six months, talk to your

				doctor about taking one or more medications.
160 or more	or	100 or more	Stage 2 hypertension	Maintain or adopt a healthy lifestyle. Talk to your doctor about taking more than one medication.

4. Blood pressure chart, what the readings mean

Total cholesterol

U.S. and some other countries	Canada and most of Europe	
Below 200 mg/dL	Below 5.2 mmol/L	Desirable
200-239 mg/dL	5.2-6.2 mmol/L	Borderline high
240 mg/dL and above	Above 6.2 mmol/L	High

LDL cholesterol

U.S. and some other countries	Canada and most of Europe	
Below 70 mg/dL	Below 1.8 mmol/L	Ideal for people at very high risk of heart disease
Below 100 mg/dL	Below 2.6 mmol/L	Ideal for people at risk of heart disease
100-129 mg/dL	2.6-3.3 mmol/L	Near ideal
130-159 mg/dL	3.4-4.1 mmol/L	Borderline high
160-189 mg/dL	4.1-4.9 mmol/L	High
190 mg/dL and above	Above 4.9 mmol/L	Very high

HDL cholesterol

U.S. and some other countries	Canada and most of Europe	
Below 40 mg/dL (men)	Below 1 mmol/L (men)	Poor

Below 50 mg/dL (women)	Below 1.3 mmol/L (women)	
50-59 mg/dL	1.3-1.5 mmol/L	Better
60 mg/dL and above	Above 1.5 mmol/L	Best

Triglycerides		
U.S. and some other countries	Canada and most of Europe	
Below 150 mg/dL	Below 1.7 mmol/L	Desirable
150-199 mg/dL	1.7-2.2 mmol/L	Borderline high
200-499 mg/dL	2.3-5.6 mmol/L	High
500 mg/dL and above	Above 5.6 mmol/L	Very high

5. Normal values for cholesterol and triglyercides (138)

10   Figures

Figure 2.1 Anatomy of the abdominal aorta, its location and the arterial branches arise from it

Figure 2.2 A closer view of the abdominal aorta and its branches including the iliacs

Figure 2.3 An illustration of the arterial wall and its three layers in a cross section view

Figure 2.4 Aneurysm types, an illustration of true and false aneurysms

Figure 2.5 Stages of aneurysmal degeneration

Figure 2.6 Diagram of an open AAA Repair

Figure 2.7 Example of the stent-grafts used in EVAR

Figure 2.8 Diagram of an Endovascular Aneurysm Repair (EVAR)

Figure 3.1 The inflammatory process involved in the formation of atherosclerosis

Figure 4.1 A sound waveform

Figure 4.2 A graph showing the impact of ultrasound frequency on attenuation

Figure 4.3 Reflection of Ultrasound

Figure 4.4 Snells Law

Figure 4.5 Diagram of the operation of an ultrasound transducer

Figure 4.6 Direction of ultrasound beams in a curvilinear transducer

Figure 4.7 Block diagram of a B-mode scanner

11   Abbreviations

AAA   Abdominal Aortic Aneurysm

HTN   Hypertension

DM   Diabetes Mellitus

SMA   Superior Mesenteric Artery

IMA   Inferior Mesenteric Artery

MMP Matrix Metalloproteinases

NF κb Nuclear Factor KappaB

ETS   E-twentysix

CAD   Coronary Artery Disease

ApoE Apolipoprotein- E

LDL   Low Density Lipoprotein

HDL   High Density Lipoprotein

CML   Carboxymethyllysine

EVAR Endovascular AAA Repair

MASS Multicentre Aneurysm Screening Study

rAAA   Ruptured AAA

LYG   Life Years Gained

QALY Quality Adjusted Life Years

USPSTF United States Preventive Services Task Force

TGC   Time gain compensation

MHz   Mega Hertz

PRF   Pulse Repetition Frequency

CT   Computed Tomography

BMI   Body Mass Index

WHO   World Health Organisation

GE   General Electric

IHD   Ischemic Heart Disease

TIA   Transient Ischemic Attack

CVA   Cardiovascular Attack

GP   General Practitioner

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13   Publications

Making the Case for Cardiovascular Screening in Irish Males: Detection of Abdominal Aortic Aneurysms, and Assessment of Cardiovascular Risk Factors

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Abstract

Introduction

AAA screening programmes have proven to be beneficial and cost effective worldwide for males greater than 65 years of age, with 4.9% males of 65–75 years of age having an un-diagnosed AAA at screening, resulting in a 42% reduction in the risk of rupture in an English population. This study assessed the incidence of AAA and risk factors for atherosclerosis in Irish males of 55–75 years.

Methods

From April 2006 to December 2007, males between the ages of 55 and 75 years, living within the catchment area of Blanchardstown Hospital were invited for AAA screening using duplex ultrasound and cardiovascular risk factor screening.

Results

1.9% (17/904) of the study population had previously un-diagnosed aneurysms detected, with sizes ranging from 3.0 cm to 5.8 cm (0.6% in 55–65 years old (yo) and 4.2% in 65–75 yo, $p < 0.01$). 33%

(302/904) of patients had hyperlipidaemia, while 16% of those with a previous diagnosis of hyperlipidaemia, were inadequately controlled on the test date. 31% of patients had a single elevated blood pressure reading, meriting further investigation for possible hypertension. 3% (28/904) of all patients had a raised glucose levels which had not previously been identified and of those who had a previous history of DM, 46% had abnormal glucose levels. 16% of patients (93/573) were morbidly obese (BMI > 30) and 64% (292/573) were overweight.

Conclusion

The incidence of AAAs in 65–75-year-old men is similar to international figures. This study confirms that screening for hyperlipidaemia, hypercholesterolaemia, obesity and hypertension may be worthwhile in all males over 55 years, while AAA screening should be reserved for 65–75-year-old Irish males.

Keywords: Abdominal Aortic Aneurysm ; Screening; Cardiovascular risk factors; Obesity; Hyperlipidaemia; Hypercholesterolaemia

Article   Outline
Introduction
Materials   and   Methods
Results
Abdominal   aortic   aneurysm
Risk   factors
Smoking
Hypertension   (Table   1)
Hypercholesterolaemia   (Table   2)
Diabetes   mellitus   (DM)   (Table   3)
Body   mass   index   (Table   4)
Discussion
References

Introduction

Cardiovascular disease accounted for 43% of all deaths in Ireland in 1997.[1] The incidence of abdominal aortic aneurysms (AAAs) has increased in the last two decades, due in part to an ageing population, with increasing number of smokers and also improved detection.[2] Ruptured AAAs cause 1.3% of all deaths among males between the ages of 65–85 years.[2] One third of untreated AAAs will rupture, with an associated mortality rate of 65–85%, (half of these deaths occurring prior to arriving

to surgery)[3, 4 and 5]. However, elective repair of these aneurysms has a reported mean 30-day mortality of 2–6%.[6 and 7]

AAA screening by ultrasound fulfils all WHO criteria for screening and is non-invasive using duplex ultrasound, with a sensitivity of 98.9% and a specificity of 99.9%.[8, 9, 10, 11 and 12] AAA screening programmes have proven to be beneficial and cost-effective worldwide for males greater than 65 years of age,[13] with 4.9% males of 65 years of age and over having an un-diagnosed AAA at screening, resulting in a 42% reduction in the risk of rupture[14] in an English population. In Gloucestershire a population screening programme performed ultrasound scanning for all men at age 65. If the aorta was less than 26 mm in diameter they were reassured and discharged, as aneurysm disease can be ruled out for 95% of these patients.[15, 16, 17, 18, 19 and 20]

Risk factors for AAA formation include male sex, smoking, atherosclerosis as well as age[21] therefore AAA screening provides an opportunity to identify patients with atherosclerotic risk factors. This would allow intervention to reduce both AAA expansion rates, and also to reduce other cardiovascular risk factors to improve future outcome.

This study assessed the incidence of screening detected AAAs in a population of Irish males from 55 to 75 years of age, with a view to identifying the ideal age group for screening. Furthermore patients were stratified for cardiovascular risk factors, to see if they might potentially benefit from medical/behavioural management.

Materials and Methods

A cardiovascular risk factor study was initiated by the vascular department in Connolly Hospital, Blanchardstown in Dublin from April 2006 to December 2008. Males between the ages of 55–75 years, living within the catchment area of the hospital, who were identified from the registers of General Practitioners, were studied. Exclusion criteria included patients with terminal medical conditions or a previous history of AAA.

These patients were invited to attend the vascular unit for AAA and cardiovascular risk factor screening. Patients fasted for a minimum of eight hours to enable a fasting lipid and triglyceride profile to be obtained and also to reduce bowel gas thereby improving ultrasound imaging of the aorta. Ethical approval was granted by the hospital's ethical committee and informed consent was obtained from every patient in the study.

The screening programme consisted of three parts:

• Duplex ultrasound of aorta

• Clinical risk factor assessment

• Fasting lipid profile

Duplex ultrasound of the aorta was performed in a standard way by a team of accredited vascular technologists with the patients in a supine position using a curvilinear 3.5 MHz transducer ultrasound probe (General Electric Logic 9). The protocol was taken from the Society for Vascular Technology of Great Britain and Ireland.[22] If the aortic diameter was less then 26 mm, the patients were discharged, as aneurysm disease can be ruled out in 95% of these patients.[23] Follow-up was defined as per international guidelines.

A clinical nurse specialist met with each patient. Their blood pressure, height, weight and body mass index (BMI) were recorded. Normal blood pressure values were defined as less than 140 mmHg systolic and 90 mmHg diastolic. Finger prick tests were performed for total cholesterol, triglyceride and glucose estimation using the Cholestech LDX® System (Cholestech, California). Normal BMI was defined as between 18 and 25.[24] Normal cholesterol values, including high density lipoprotein (HDL) and low density lipoprotein (LDL), as well as triglyceride values were defined per standard guidelines.

A fasting serum total cholesterol of 5.0 mm/mol or greater was classed as hypercholesterolaemia. An abnormal glucose was defined as a fasting serum glucose of 7.0 mm/mol or greater.[25] All abnormal finger prick tests were confirmed using standard blood samples. The nurse specialist discussed the patient's lifestyle and advised them on changes which would help them prevent or control their risk factors.

The results of the risk profile and the recommendations for treatment were referred back to the family practitioner for follow-up. Patients with AAAs were followed up in the Vascular Diagnostic Unit of Connolly Hospital.

Statistical comparison between the two groups was by Chi-squared test with $p < 0.05$ considered significant.

Results

Using the general practitioners' register, 1414 patients were invited to attend and a total of 904 patients accepted the invitation (64%). Of these, 568 (63%) were aged between 55 and 64 years (Group A) and 336 (37%) were aged between 65 and 75 years (Group B). The two groups were analysed together and then compared to assess their relative risks.

Abdominal aortic aneurysm

All patients underwent ultrasound of the aorta with 17 (1.9%) having previously un-diagnosed aneurysms with sizes ranging from 3.0 cm to 5.8 cm. The incidence of AAA was found to be 0.6% in group A and 4.2% in group B ($p < 0.01$).

Two aortas were not successfully imaged due to morbid obesity and these patients declined further attempts at imaging.

Risk factors

Smoking

A total of 11% (104/904) of patients were smokers. There were 6% (58/904) ex-smokers and 82% had never smoked. Smoking cessation advice was offered to all smokers.

Hypertension (Table 1)

Six patients did not have their blood pressures (BP) recorded as the cuff diameter available was too small to measure the level accurately. 33% (294/904) of patients who had a previous history of hypertension and 68% of these had an isolated elevated blood pressure, despite having previously been prescribed an anti-hypertensive. 31% (278/898) of patients with no previous history had a single elevated blood pressure measurement, suggestive of hypertension.

Table 1.

Single raised blood pressure reading in Group A (55–64 yo) and Group B (65–75 yo)

	55–64	65–75	Total	*P*
Single elevated blood pressure	269	217	486	$p < 0.00001$
Known hypertension poorly controlled	105	98	200	
No previous history	164	119	278	

Hypercholesterolaemia (Table 2)

26% (234/904) of patients had a previous history of hypercholesterolaemia, with 16% of these being inadequately controlled. 33% (302/904) of patients were newly diagnosed with hypercholesterolaemia.

Table 2.

Cholesterol and lipoprotein levels in Group A (55–64 yo) and Group B (65–75 yo)

	55–64	65–75	Total	*P*
Elevated cholesterol	234	105	339	$p < 0.01$
Hx hypercholesterolaemia poorly controlled	19	18	37	
Un-diagnosed hypercholesterolaemia	215	87	302	
HDL < 1	221	82	303	
LDL > 3	279	95	374	

As high density lipoprotein (HDL) and low density lipoprotein (LDL) values are independent risk factors for AAA and atherosclerosis development for these values were also analysed.[6, 13, 26, 27 and 28]

From our results 33% (303/904) of the screened population had HDL level of less than 1 mmol/l and 41% (374/904) had LDL level of greater than 3 mmol/l.

Diabetes mellitus (DM) (Table 3)

6% (55/904) of patients had an elevated fasting blood glucose level; 49% (27/55) of these had a previous history of diabetes mellitus and had poor blood sugar control. 3% (28/904) of patients had previously undetected elevated glucose levels in excess of 7 mmol/l and were referred to their GP for further investigation and follow-up (Table 3).

Table 3.

Diabetes mellitus – poorly controlled and single elevated fasting blood glucose in Group A (55–64 yo) and Group B (65–75 yo)

	55–64	65–75	Total	*P*
Elevated blood glucose	26	29	55	$p < 0.02$
Hx diabetes mellitus poorly controlled	8	19	27	
No history	18	10	28	

Body mass index (Table 4)

Of the patients who agreed to have their body mass index measured, 16% (93/573) were morbidly obese (BMI > 30) and 64% (367/573) were overweight. Overweight patients received lifestyle advice from the nurse specialist and a risk profile was sent to their GP.

Table 4.

Body mass index in Group A (55–64 yo) and Group B (65–75 yo) including those who declined measurement

BMI	55–64	65–75	Total
BMI > 30	70	23	93
30< = BMI > = 25	270	97	367
<25 BMI	76	37	113
Declined	152	179	331

Discussion

Abdominal aortic aneurysm screening has been shown to be cost effective in England in men greater than 65 years of age, significantly reducing the risk of rupture.[29] However in the population of 75 years and older an invitation to screening has not been shown to reduce all-cause mortality, since AAA-related mortality accounts for a small number of deaths in older men.[30, 31 and 32] What is less clear, however is the cost-effectiveness of screening for AAA in men between 55 and 65 years of age.[6, 13 and 33]

This study assessed the effectiveness of studying a population of Irish males for AAA. This study had an attendance rate of 64% comparable to other Irish studies,[1] and slightly less than other published screening studies.[34], [35] and [36] In men between 65 and 75 years, 4.2% had AAAs detected, which is comparable to incidences found in this age group in England and the United States.[10], [11], [27] and [28] This would suggest that AAA screening in this age group in Ireland is justified. The incidence of screening detected AAAs in 55–64-year-old men in Ireland was 0.6%, which suggests that duplex screening is not justified or cost-effective in this group ($p < 0.01$).

Ireland has a high incidence of cardiovascular disease as previously reported and supported by these results. The results of this study suggest that screening for cardiovascular risk factors is justified in Irish males over 55 years. The number of people that never smoked at 82% was quite surprising and suggests significant under reporting by the invitees, reflecting the negative social aspects of smoking currently in Ireland in the aftermath of the smoking ban.

The incidence of hyperlipidaemia was notable in this study population. In patients between 55 and 65 years old, 49% had an abnormally elevated lipid profile. These patients were educated with dietary advice, recommendations for possible statin therapy if indicated, and urgent referral back to their family doctor for further investigation and management. In patients aged 55–64 years old, 41% had a raised cholesterol level, compared with 31% of 65–74 years old ($p < 0.01$). As this is a significant difference, it is suggested that cholesterol and triglyceride screening is worthwhile in all males between 55 and 75 years of age.

Blood sugar levels were elevated in 6% (55/904) of patients 46% of them with known DM suggesting poor control and 3% of patients with no history of DM. All patients were referred for further investigation and management to their family practitioners.

80% of the study population was found to be overweight with 16% morbidly obese. These results are higher than those previously published in this country and indicate that obesity is becoming a significant health problem.[1]

54% of all males had a single elevated blood pressure, which is suggestive of hypertension. 68% of those with previously documented hypertension had a raised blood pressure measurement, which could indicate poor control. Those with elevated blood pressure readings were referred to their family practitioner for further blood pressure measurements in order to determine the presence of hypertension.

The results of this study would indicate that undiagnosed and under-treated hypertension, diabetes mellitus and hypercholesterolaemia are common in Irish males over 50 years of age. Control of hypercholesterolaemia has been shown to have a 24–35% reduction in coronary events as well as 30% reduction in cerebrovascular events.[37 and 38] Lifestyle modifications would have a significant impact on reducing these patients' risk of a cardiovascular event.[39 and 40] This study shows the benefits of AAA screening in Irish males of 65–75 years; however, screening in males less than 65 years cannot be justified. In the younger group, screening for cardiovascular risk factors is beneficial both to determine the rate of un-diagnosed cardiovascular disease and to monitor and control these risk factors.

A number of conclusions can be drawn from this study, which is the first report of AAA screening in Irish males. The incidence of AAAs in 65–75-year-old men is similar to that in Britain and USA. This suggests that the recent recommendation of the introduction of a national screening programme in Britain should be imitated in Ireland.[41] The lower incidence of AAAs in Irish males under 65 does not justify screening in this age group.

The high incidence of cardiovascular risk factors in all males over 55 years is hardly surprising given the recognised prevalence of atherosclerotic disease in Ireland. This study confirms that screening for hyperlipidaemia, hypercholesterolaemia, obesity and hypertension in this age group may be worthwhile.

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