THE INFLUENCE OF DIFFERENT DIAGNOSTIC IMAGING AND INTERVENTIONAL REPAIR TECHNIQUES ON MORTALITY RATE IN AORTIC ANEURYSM PATIENTS

By

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DEDICATION

This work is dedicated to my lovely parents, Asma Alamoudi and Othman Alamoudi, my mam demonstrated what it meant to be strong and independent man. She inspired me to pursue a career in healthcare and was beaming with pride upon my acceptance into the Doctoral program. My dad I am grateful for your continuous support and what you taught me has helped me achieve this milestone, for which I am forever thankful.

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ABSTRACT

Among the several factors related to high mortality, imaging methods and intervention procedures could be important. American College of Radiologists (ACR) prescribed some appropriateness guidelines for diagnostic imaging. Not complying with them fully or partially may also be a mortality factor. The present study was undertaken to investigate these aspects.

NIS data for the period of 2008-2012 using ICD-9 codes were obtained for 6 types of aneurysms- intact and ruptured Abdominal Aortic Aneurysm (AAA), Thoracic Aneurysm and Thoracio-Abdominal Aneurysm; four imaging methods: Computerized Tomography (CT), Magnetic Resonance Imaging (MRI), Ultrasound (US) and Digital Subtraction Angiography (DSA) as diagnostic imaging methods; EVAR or OAR as the intervention procedures; patient characteristic factors of age, gender, race, comorbidities and insurance type; and hospital context factors of size, location and teaching status, region and admission type. The dependent variables were total, died in hospital and did not die frequencies patients. Data on 38263 patients were obtained from this search from more than 4,300 participating hospitals. The data were analyzed using SPSS22 software using descriptive statistics, ANOVA, logistic multiple regression test, Chi square test, McNemar test and Gamma test.

AAA was most frequent (73.4%) followed by TA (20.6%). All ruptured aneurysms together constituted only about 3.4%. Very few cases of ruptured aneurysms affected precise evaluation of high mortality due to rupture. About 63% aneurysms were repaired

using OAR and only 23% cases were treated by EVAR. Increasing popularity of EVAR was not reflected in this data. Among the imaging methods, DSA was used in about 86% cases and US was used in 13% cases.

Always DSA was highest followed by US, CT and MRI in the decreasing order. Higher numbers of younger age group patients (65-79) were imaged using DSA and US. More numbers of older patients were imaged using CT and MRI (70-84). Whites, blacks and Hispanics were the highest three percentages among the races. About 70% of all aneurysm patients were males. Most patients were covered by Medicare or Medicaid or private insurance. Only 2% patients met their expenses on their own. Among comorbidities, hypertension, diabetes, heart failure and anaemia were more common.

All objectives were achieved. Effect of imaging methods and its interaction with interventional procedures in reducing in-hospital mortality rates were demonstrated. Compliance with ACR appropriateness helps to reduce mortality rates. Age groups and comorbidities of patient characteristics influenced mortality rate more effectively. Linear logistic equations for odds for dying against imaging methods, its interaction with intervention procedures, ACR compliance level, patient age and comorbidities and some hospital contexts were developed. Limitations of this research and future scope of research have also been discussed.

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LIST OF ABBREVIATIONS

TA	Thoracic Aortic Aneurysm
rTA	Ruptured Thoracic Aortic Aneurysm
TAA	Thoracico-Abdominal Aortic Aneurysm
rTAA	Ruptured Thoracic-Abdominal Aortic Aneurysm
AAA	Abdominal Aortic Aneurysm
rAAA	Ruptured Abdominal Aortic Aneurysm
EVAR	Endovascular Aortic Repair
OAR	Open Aortic Repair
CT	Computed Tomography Imaging
CTA	Computed Tomography Angiography
MRI	Magnetic Resonance Imaging
MRA	Magnetic Resonance Angiography
US	Ultrasound Imaging
DSA	Digital Subtraction Angiography Imaging

CHAPTER I: INTRODUCTION

1.1 Background of the Problem

US National Institute of Health defines aneurysm [1] as "balloon-like bulge in an artery". Number of people affected with aortic aneurysm in different states of USA from 2008 and 2012 are presented in **Figure 1.**

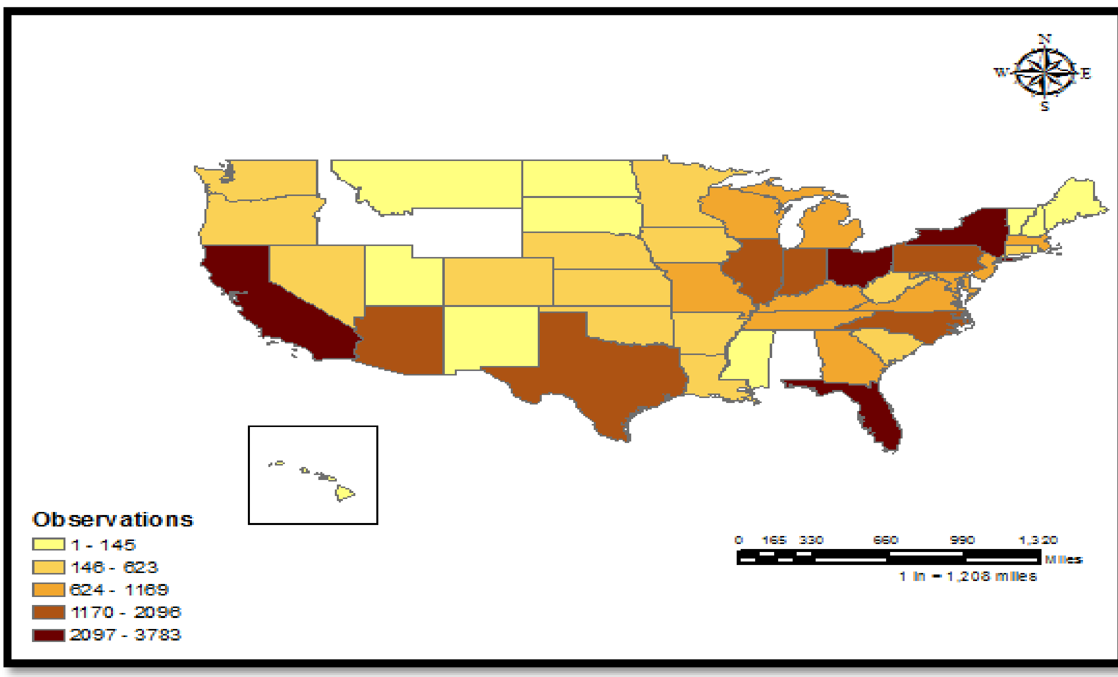

Figure 1: Number of People Affected by Aortic Aneurysm in Different States of USA

Least incidence of the disease is found in the Midwestern and Western states. High incidence can be found in the North-eastern, South-eastern and South-western states. However, the map is based on absolute numbers without considering population in each state. Therefore, these conclusions have limited validity.

Another map draw from NIS result between 2008 and 2012, based on prevalence per 100,000 population neutralizes the population bias. This map is given in **Figure 2.**

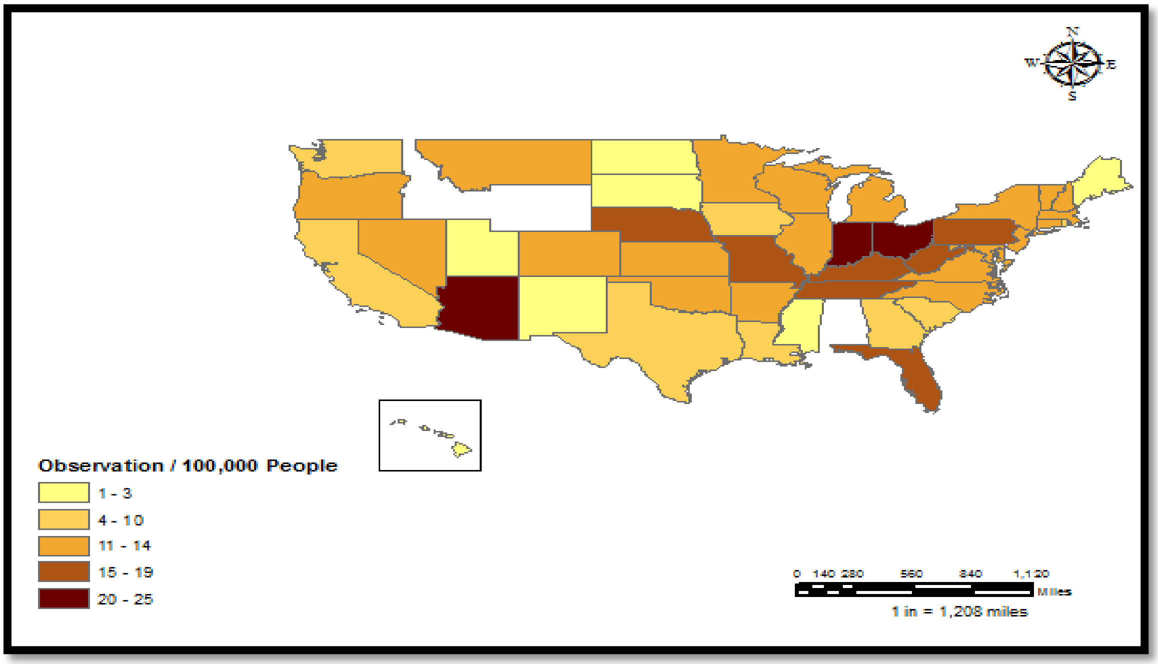

Figure 2: Aortic Aneurysm Incidence per 100,000 Population in Different States of USA

A comparison of this map shows that the intensity of aortic aneurysm prevalence is low in Midwestern states and high prevalence is limited to three states Ohio state, Indiana state, and Arizona state. However, medium incidence level of about 5-15 per 100,000 is fairly widespread among other states.

Aneurysm can be fatal when it ruptures or dissects. Out of all deaths due to different types of aneurysms, abdominal aortic aneurysm (AAA) has the highest mortality percentage of 35.2. The next top five are: rCAA (19.1%), thoracic aortic aneurysm (TA) with10.7%, cerebral artery aneurysm (CAA) with 10%, lower extremity (femoral and popliteal) artery aneurysm (LEAA) with 8.3% and iliac artery aneurysm (IAA) with 5.8%. These six types together account for about 89% of all aneurysm deaths.

A publication by Brain Aneurysm Foundation of USA states that one in 50 (about 6 million) people suffer unruptured intracranial aneurysm. About 30000 people have ruptured brain aneurysm. Ruptured brain aneurysm is fatal in about 40% cases. Most of the survivors live with some permanent disability. The victims of world-wide 500000 deaths due to brain aneurysm are below 50 years of age. About 15% subarachnoid hemorrhage (SAH) patients die before reaching hospital [2].

There are some studies show that such mortalities vary with patient characteristics as well as the specific hospital contexts. Patient characteristics, such as gender, age, comorbidities of some aortic aneurysm types have been studied. Hospital contexts include, type, location, educational qualifications and experience of health care professionals, patient volume. However, not many studies have been reported on influence of using various type of imaging modalities and its capability to lead and guide to aneurysm repair procedures to decrease the mortality rate of aortic aneurysm patients. Also, one important aspect hospital contexts is its adherence with ACR guideline especially on medical imaging methods and patients safety aspects. Lack of protocols and costs have been cited as important reasons for not practicing the most desirable or appropriate imaging methods in the case of aneurysm [3]. Obviously this affects the extent of compliance with ACR. However, not many studies have been reported on influence of extent of compliance medical imaging guidelines of ACR on the in-hospital mortality of aortic aneurysm patients.

However, six inter-related dimensions of health care quality have been recognized. This is illustrated in **Figure 3.**

Figure 3: Six Dimensions of Health Care Quality [4].

Health care should be presented to the patient in the most suitable setting within a reasonable distance and time. For many cases, ambulatory surgery can be used for saving time and costs down and reserve hospital sources for in-patient surgeries of serious cases. Patients coming from distant places can go home same evening without having to stay at the hospital even overnight. Thus distance factor is also taken care of, and an illustration of this is provided by the US data pertaining to outpatient and in-patient surgeries performed on body systems in 2012 (**Figure 4**).

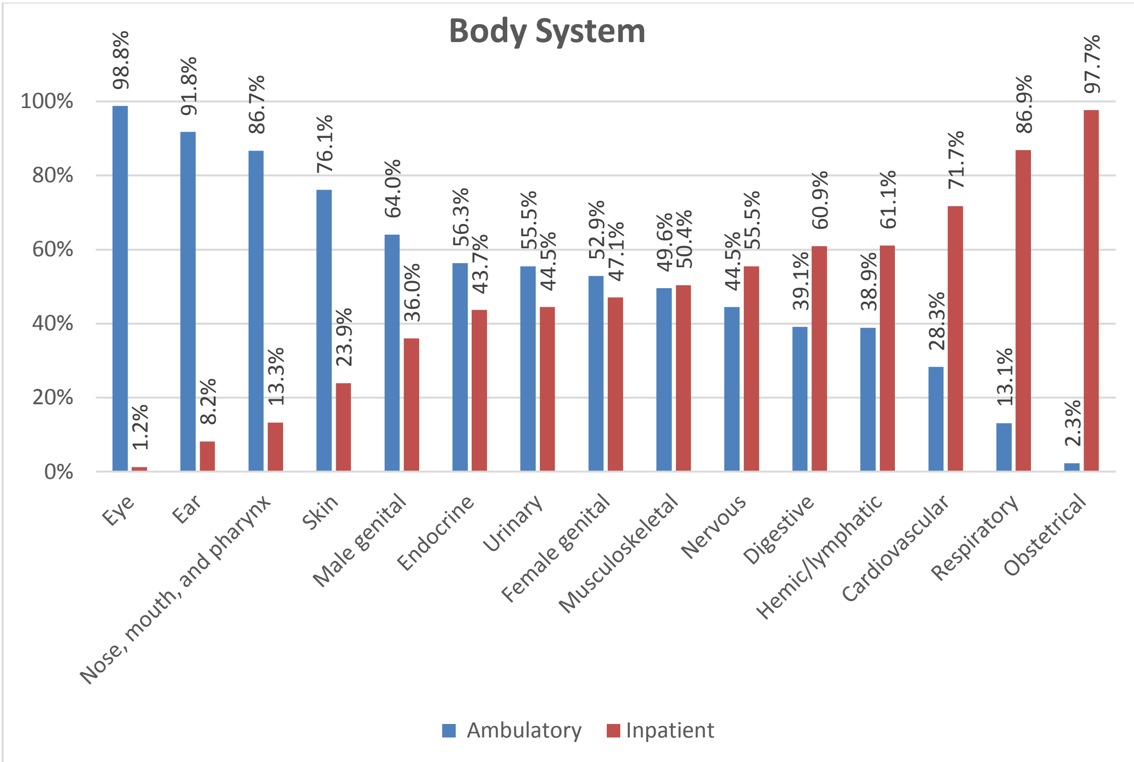

Figure 4: Inpatient Versus Outpatient Surgeries in USA Hospitals During 2012 [5].

Thus cost, distance and time are prime factors and these are related to affordability also. Data presented in **Table 1** relate to mean cost, length of stay and in-hospital mortality in the case of circulatory diseases in 2004 [6]. The trends reflect efficiency and effectiveness of health care in US hospitals. There is no way to judge whether the costs are reasonable as standard costs are not available. Length of stay did not exceed seven days in majority of cases. Coronary diseases contributed to only a small fraction of less than 3% of all hospital stays. In the case of a few diagnoses, admissions were mostly through emergency department. It is not clear why almost all patients were over 60 years of age. Overall, efficiency was good, but effectiveness may need improvement.

Table 1: Efficiency and Effectiveness of USA Hospitals in Terms of Cost and Length of Stay in The Case of Coronary Diseases in 2004 [6].

Principal diagnosis	Total number of stays	Percent of all hospital stays	Mean length of stay	Mean cost	Percent died in the hospital	Mean age
Coronary atherosclerosis	1,192,400	3.1%	3.4	$13,200	0.6%	65
Congestive heart failure	1,104,400	2.9%	5.5	$9,400	4.0%	73
Nonspecific chest pain	845,700	2.2%	1.9	$4,100	0.1%	58
Acute myocardial infarction (heart attack)	695,100	1.8%	5.4	$16,200	7.2%	68
Cardiac dysrhythmias	693,700	1.8%	3.5	$8,700	1.2%	70
Acute cerebrovascular disease (stroke)	546,000	1.4%	6.3	$11,100	10.7%	71
Hypertension with complications	226,100	0.6%	5.3	$9,900	2.4%	63
Transient cerebral ischemia	187,900	0.5%	3.0	$5,000	0.2%	71
Peripheral and visceral atherosclerosis	174,300	0.5%	5.7	$12,800	4.8%	69
Phlebitis, thrombophlebitis and thromboembolism	155,900	0.4%	5.2	$6,400	1.1%	63
Occlusion or stenosis of precerebral arteries	142,100	0.4%	2.6	$7,700	0.4%	71
Pulmonary heart disease	135,100	0.3%	6.4	$9,900	4.7%	63
Heart valve disorders	89,500	0.2%	8.8	$31,300	4.0%	68
Aortic, peripheral, and visceral artery aneurysms	83,600	0.2%	7.5	$24,700	9.2%	70
Peri-, endo-, and myocarditis, cardiomyopathy	78,900	0.2%	7.1	$15,400	4.5%	56
Essential hypertension	73,600	0.2%	2.8	$4,400	0.1%	61
Conduction disorders	68,800	0.2%	3.3	$13,900	1.5%	72
Cardiac and circulatory congenital anomalies	46,500	0.1%	8.2	$29,600	2.6%	20
Aortic and peripheral arterial embolism or thrombosis	37,100	0.1%	6.9	$15,700	5.1%	67
Late effects of cerebrovascular disease	19,700	0.1%	9.8	$8,300	4.7%	71
Cardiac arrest and ventricular fibrillation	16,200	0.0%	4.9	$16,700	51.6%	65
Varicose veins of lower extremity	5,900	0.0%	5.9	$6,700	*	64

Some hospital contexts like location, facilities, qualifications and experience of heath care professionals, service efficiencies, patient volume and admission type determine the extent of accessibility and making health care services of particular hospital affordable to patients. Number for stays for different clinical procedures increased in absolute numbers, but decreased in terms of per 10000 population from 1997 to 2011 for most cases listed in **Table 2**. This is also demonstrative of efficiency improvement, not necessarily effectiveness.

Table 2: Change in Number of Stays for Clinical Procedures in USA Hospitals from 1997 to 2011 [7].

All-listed Clinical Classifications Software (CCS) procedures	Number of stays with the procedure per 10,000 population	
	1997	**2011**
All stays (with and without procedures)	1,272	1,239
All stays with any procedure	780	780
Stays with a procedure, %		
Blood transfusion*	40	94
Prophylactic vaccinations and inoculations	21	60
Respiratory intubation and mechanical ventilation	34	52
Repair of current obstetric laceration	42	42
Cesarean section	29	41
Diagnostic cardiac catheterization, coronary arteriography	54	40
Upper gastrointestinal endoscopy, biopsy	41	39
Circumcision	43	36
Artificial rupture of membranes to assist delivery	27	30
Hemodialysis	17	29
Diagnostic ultrasound of heart (echocardiogram)	23	28
Fetal monitoring	37	25
Arthroplasty knee	12	23
Enteral and parenteral nutrition	10	19
Percutaneous transluminal coronary angioplasty (PTCA)	21	18
Colonoscopy and biopsy	19	17
Laminectomy, excision intervertebral disc	16	17
Spinal fusion	7	16
Incision of pleura, thoracentesis, chest drainage	13	15
Hip replacement, total and partial	11	15

Gender, age, educational level, socio-economic status, race (cultural background) of patients determine affordability of patients in availing the accessible services. Thus, there are two sets of factors- patient classifications and hospital contexts, interacting the outcome of offer-availing combinations. In this study includes some of these factors are studied, but with respect to in-hospital mortality of aneurysm patients. When accessibility-affordability factors are not aligned properly, the outcome could be negative. This aspect will be demonstrated by the findings of this study.

User acceptability is of prime importance in any product or service offer. However, in the case of heath care, the treatment procedure prescribed by the doctor may not be as per the expectations or preferences of patients. It is based on the disease condition of particular patient. What the patient “needs” for cure of the disease is determined by the doctor and the patient is incompetent in this regard. Hospital contexts determine the extent to which acceptability is served. The findings of this study highlights the importance of hospital-directed user acceptability.

Scientific knowledge is the basis of diagnostic and treatment procedures. It determines the diagnostic methods to be used for accurate assessment of the disease so that effective treatment procedure can be determined. In US hospitals, although there is increasing preference for using drug eluting stents over non-drug eluting stents in cardiac surgeries, there is overall decrease in stent grafting itself during 2007 to 2009 reflecting on reduced use of both types of surgeries [8]. The data on this is presented in **Figure 5.**

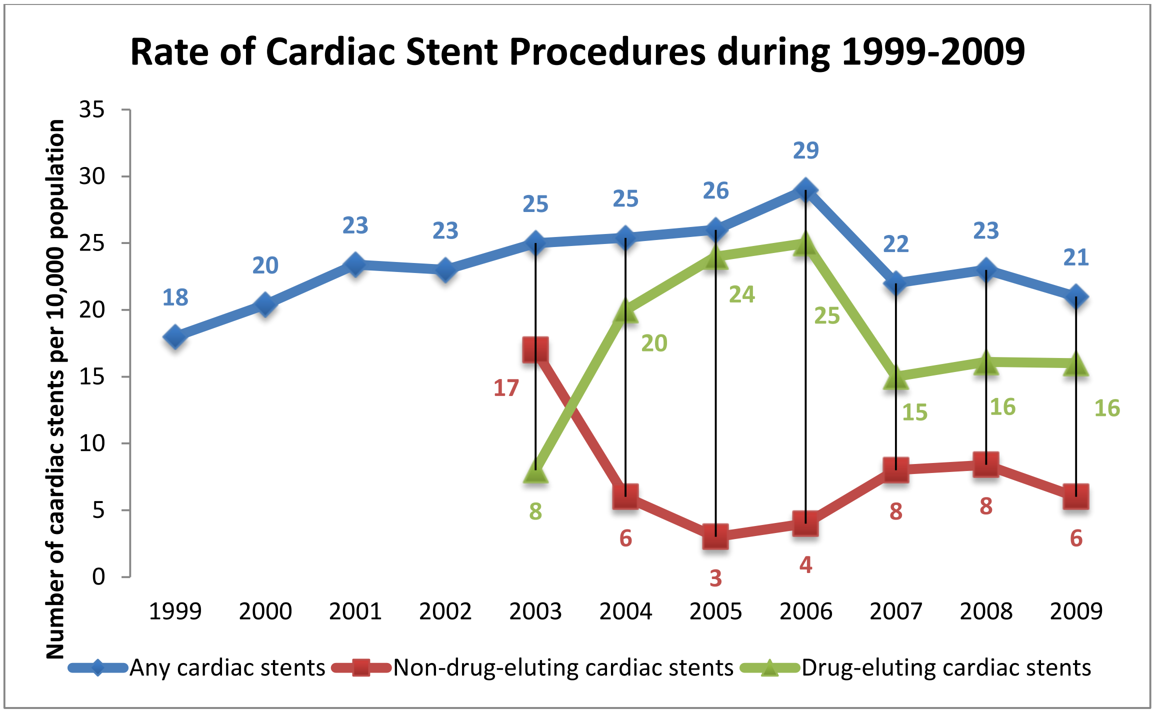

Figure 5: Rate of Cardiac Stent Procedures during 1999-2009 [8].

Imaging is a scientific method used for diagnosis of aneurysm. If appropriate imaging methods are not used, the treatment outcome may be negative. The guidelines of ACR is relevant in this respect. Hospitals are rated according to their compliance with ACR and its influence on in-hospital mortality is evaluated. The relationship between in-patient hospital mortality and aneurysm and the relationship between compliance with ACR and in-hospital mortality of aneurysm patients point to the importance of evidence-based diagnosis and treatment procedure. Thus, effectiveness of diagnosis using imaging techniques and its outcome in terms of mortality for hospitalized patients form the most important components of the findings.

Service efficiencies are related to effective service delivery, which was discussed above. This, in turn, will influence its acceptability. High in-hospital mortality under poor hospital contexts (low compliance with ACR) leads to poor acceptability due to perception of poor efficiency and effectiveness. This is an integral aspect brought out by this study.

Relevance to patient needs and scientifically proven, evidence-based practices are reiterated with respect to appropriateness. Imaging method used and treatment procedure prescribed should be appropriate to the patient classifications. ACR guidelines have an important role here. The points related to appropriateness have been discussed already above.

Patient safety is an important aspect of both diagnosis and treatment. Radiation exposure in terms of type, dose and duration and conditions under which imaging is done are of critical importance and ACR has critical points on these aspects. This applies to treatment also. So, ACR compliance level and other hospital contexts determine the extent to which patient safety is cared for. This is an aspect derivable from the findings of this work. Thus, some of the six dimensions of heath care quality are evaluated in this work.

This study is aimed at the essential need for filling the gap in the understanding of causes related to high in-hospital mortality rates of aneurysm patients. The results of this study leads to some methods to reduce in-hospital mortality rates for various combinations of patient classifications and hospital contexts.

1.2 Statement of the Problem

Most studies with NIS dataset have examined the relationship between surgical aneurysm repair (EVAR and OAR) and mortality rate of aortic aneurysm patients without considering the impact of medical imaging to reduce the mortality rate across various regions of the United States hospitals. However, extent of compliance of hospitals on medical imaging procedure laid down in the ACR guidelines can influence in-hospital mortality rates of aneurysm patients depending on factors related to patients and hospital contexts. This effect could be due to lack of compliance on most appropriate imaging method (increasing risk exposure) and/or patient safety parameters of medical imaging methods used by the hospitals. These aspects have not received adequate attention.

Thus, there is an urgent need to study the extent of compliance of hospitals with ACR guideline, the extent of risks due to non-compliance with appropriate imaging method and patient safety parameters and the reported mortality related to different types of aortic aneurysms.

1.3 Research Purpose, Specific Aims and Hypotheses

1. RESEARCH PURPOSE

Based on the above, the exact research purpose can be defined as to explore; firstly, whether or not there is an impact of using different type of medical imaging procedures to reduce the mortality rate among aortic aneurysm patients who underwent for interventional aneurysm repair. Secondly, whether the extent of compliance of hospital on medical imaging techniques of ACR guideline influence the outcome of patients undergoing aneurysm repair. The roles of various patients' factors and hospital contexts related to such observed mortality variations are also studied.

2. OBJECTIVES AND HYPOTHESES

1- To study the relation between imaging modalities and in hospital mortality among aortic aneurysm patients through US hospitals.

Hypothesis: types of medical imaging used with aortic aneurysm patients has effect on in hospital mortality.

Null Hypothesis: H0 = H1

Alternative Hypothesis: H0 ≠ H1

2- To compare in hospital mortality of EVAR with OAR when different imaging techniques are used in both cases.

Hypothesis: There is difference in-hospital mortality with either EVAR or OAR or combined repair procedures with any diagnostic imaging modalities.

Null Hypothesis: H0 = H1

Alternative Hypothesis: H0 ≠ H1

3- To evaluate the effect of using ACR recommended imaging methods and extent of compliance on in-hospital mortality.

Hypothesis**:** There is statistically significant relationship between appropriateness of imaging criteria and in-hospital mortality.

Hypothesis**:** Extent of compliance with national aortic aneurysm guideline can influence in hospital mortality, thus higher the compliance level, lower the mortality in US hospitals.

Null Hypothesis: H0 = H1

Alternative Hypothesis: H0 ≠ H1

4- To determine among various patient characteristics, and hospital contexts, those factors which can be used for prediction and thereby reduction of in-hospital mortality in US to desire levels.

***Hypothesis*:** Combinations of some patient characteristics, and/or hospital contexts can significantly reduce in-hospital mortality.

Null Hypothesis: H0 = H1

Alternative Hypothesis: H0 ≠ H1

5- To determine among significant predictor factors, which type of diagnostic imaging performed is associated with in-hospital mortality.

Hypothesis: Diagnostic imaging modalities are significantly impact to decrease the risk of in-hospital mortality.

Null Hypothesis: H0 = H1

Alternative Hypothesis: H0 ≠ H1

1.4 Significance of Study

This study is essential and important for a variety of reasons. Firstly, it fills the long-felt gap of relating medical imaging management with in-hospital mortality of aortic aneurysm patients. Although in-hospital mortality has been studied on other factors related to hospitals and patients, imaging methods were not included in any of them. This is perhaps first time that clear relationship between aneurysm and in-hospital deaths and aneurysm as its reason are elucidated.

There are some distinct guidelines of American College of Radiology (ACR) on imaging methods appropriate to some types and conditions of aneurysm, such as Abdominal Aortic Aneurysm (AAA) for pre and post interventional procedures. Compliance levels of different hospitals with these guidelines will vary depending upon their contexts. If in-patient mortality could be correlated with level of compliance with ACR guidelines (as influenced by their contexts), in-hospital mortality could be reduced by increasing the level of compliance. Thus, a method for reducing in-hospital mortality becomes available.

Some patient-related characteristics are known to influence in-hospital mortality rates. The factors could serve as predictors of mortality. Controlling the factors which increase in-hospital mortality becomes another method to reduce mortality rates.

CHAPTER II: LITERATURE REVIEW

2.1 Aneurysm Overview

Aneurysm was the primary cause of more than 10597 deaths and a contributing cause of over 17215 deaths in USA in 2009 [9]. Some essential details on aneurysm, its diagnosis, factors of influence and prevention and treatment are described in 2014 by Nordqvist C.[10]. The author gives a more detailed description of aneurysm. The disease occurs when an artery or cardiac chamber swells. This results in the damage of artery or weakness of its walls. The swelling balloons out at its weakest point resulting from increasing blood pressure. This means, there should be a threshold pressure above which only ballooning out happens. Although small swellings may be confined to a small area of the artery, large ones can extend along the whole length of the affected area. The balloon may become too large and it may rupture when pressure build up continues. Furthermore, a threshold point is indicated for the rupture. The rupture naturally leads to hemorrhage and other complications and even sudden death. Although aneurysm can occur in any part of the body, it is more common in the arteries, particularly in the aorta.

2.2 Symptoms

Although some symptoms are common for all types of aneurysms, there can be variations in some respects. These variations are primarily due to disruption of physiological functions of the affected organ.

In the case of abdominal aortic aneurysm, the symptoms are presence of throbbing mass in the abdomen, deep pain in the back or side of abdomen and gnawing pain steady felt for hours or days. If it ruptures, sudden severe pain in the lower abdomen and back, nausea and vomiting, constipation, urination problems, sweaty skin, light-headed feeling, rapid heart rate when standing up can be the symptoms.

In the case of thoracic aortic aneurysms, symptoms may include: pain in neck, back, chest or jaw, hoarseness with without coughing and trouble in breathing as it becomes short and swallowing difficulties. If dissected or ruptured, the symptoms may be sudden, sharp and severe pain starting from upper back and moving towards abdomen. Pain in the chest and arms and going into a shock are also possible [11].

Symptoms of cerebral aneurysms are: sudden severe headaches, nausea, vomiting, sight problems, seizures or fits, consciousness loss, confusion, drooping eyelid, stiff neck and sensitivity to light. If it ruptures, bleeding in the brain, haemorrhage and stroke occur. Intracranial haematoma can also occur.

Apart from these three main types of aortic aneurysms, there are non-aortic arterial aneurysms called peripheral aneurysms. Aneurysms affecting popliteal, femoral, visceral and carotid arteries and arteries of arms are less common [12]. Symptoms occur as warning signs of more serious stages. These are: a possible feeling of lump in the affected part, pain on legs or arms on cramping with exercise (claudication), pain on legs or arms during rest, painful ulcers or sores in the fingers and toes. Numbness or radiating pain on legs or arms caused by nerve compression and gangrene due to severe blockage in the limbs mostly requiring amputation.

2.3 Aneurysm Classifications and Types

True aneurysms can be atherosclerotic, syphilitic, congenital or ventricular following trans-mural myocardial infarctions and can occur in any of the three walls of the artery.

False aneurysm (pseudo-aneurysm) is also possible. There is complete leaking of the out of an artery or vein and confined to the tissue surrounding the vessel. Eventually, this blood-filled cavity may clot to seal the leak or it may rupture out of the surrounding tissue. Trauma can be caused by punctures in the artery created by knife, bullet and so forth. Pseudo-aneurysms can be caused by percutaneous surgical procedures like coronary angiography or arterial grafting or an injection into the artery.

Aneurysms are classified according to their morphology or by location. Morphologically, saccular aneurysms are spherical, 5-20 cm diameter, partially or fully filled by thrombus and involves only a portion of the vessel wall. Fusiform types are spindle-shaped, with varying diameter up to 20 cm and with varying length, involving large portions of ascending and transverse aortic arch, abdominal aorta or iliac arteries.

Aneurysms, by location could be arterial or venous, the former being more common. Aneurysms related to heart can be coronary artery aneurysms, ventricular aneurysms, aneurysms of sinus Valsalva. Aneurysms following cardiac surgery also occur. Related to aorta, abdominal aortic aneurysm and thoracic aortic aneurysm can occur. Results of some studies show that about 25% of aneurysms occur in the thoracic area [11].

Related to brain, cerebral, berry or Charcot-Bouchard aneurysms can occur. Cerebral aneurysm (intracranial or brain aneurysm) is more common at the base of the brain and more commonly in the anterior cerebral artery, especially in the internal carotid artery.

Aneurysms can occur in the legs, especially in popliteal arteries. In kidney, renal artery or intra-parenchymal aneurysms can occur. However, renal and leg aneurysms are rare. A comprehensive list of various types of aneurysms is given in **Table 3.**

Table 3: Comprehensive List of Aneurysm Types

AFFECTED REGION	ANEURYSM NOMENCLATURE
Aortic aneurysm	• Thoracic aortic aneurysm • Ruptured thoracic aortic aneurysm • Thoracico-abdominal Aortic Aneurysm • Ruptured Thoracico-abdominal Aortic Aneurysm • Abdominal Aortic Aneurysm • Ruptured Abdominal Aortic Aneurysm
Cranial & Neck Aneurysm Artery	• Cerebral Artery Aneurysm • Ruptured Cerebral Artery aneurysm • Ruptured Syphilitic Cerebral Aneurysm • Congenital Cerebral Artery Aneurysm • Carotid Artery Aneurysm • Subclavian Artery Aneurysm
Intra-Thoracic Aneurysm Arteries	• Heart Aneurysm • Coronary Artery Aneurysm • Pulmonary Artery Aneurysm • Mediastinal and Spinal artery Aneurysm
Intra-Abdominal & Pelvic Aneurysm Arteries	• Renal Artery Aneurysm • Splenic Artery Aneurysm • Visceral Artery Aneurysm • Iliac Artery Aneurysm
Upper Extremity Arteries	• Brachial Artery Aneurysm • Radial Artery Aneurysm
Lower Extremity Arteries	• Femoral Artery • Popliteal Artery

Detailed discussions on intra-cranial aneurysms of various types are available in Forsting et al.[13]. They list saccular, dissecting, fusiform, infectious, traumatic, inflammatory, neoplastic and radiation-induced and those due to arteriovenous malformations as the types.

Isselbacher et al.[14], discussed the current status of knowledge on thoracic and abdominal aortic aneurysms. The author advocated for vigilance on patients at risk. Current screening and imaging methods enable this to a great extent. Genetic screening may become available in future. Increasingly, EVAR technique may replace OAR in future.

2.4 Aortic Aneurysm

2.4.1 Thoracic Aortic Aneurysm (TA) and Thoracico-abdominal Aortic Aneurysm (TAA)

In a comprehensive review, Ramnath et al. [15], discussed pathophysiology, risk factors, classifications, epidemiology, clinical presentation, diagnosis, management options and outcomes of aortic conditions with special reference to acute and chronic aortic and thoracic aortic aneurysms. Most importantly, the classification and staging systems of thoracic aortic aneurysm, circadian variations each hour and seasonal variations of acute aortic dissection and has been dealt with. Observing the rarity of reports on infected upper extremity aneurysms, Leon et al. [16] reviewed the work done on these diseases during 1950-2007. The most frequently reported occurrence was in the brachial artery. This disease was associated with drug abuse, catheterization procedures or endocarditis. Infections were mostly due to gram positive bacteria. Even with limited follow ups during early years, outcomes were good with timely surgical interventions. The rarity and less serious nature of this type of aneurysm might have also been factors of low risk. Knowles et al. [17] concluded from their study that upper extremity approach is safe and feasible in the case of patients undergoing fenestrated endovascular aneurysm repair (FEVAR). Open exposure in the upper extremity is relatively safer than percutaneous access during FEVAR. There is no increase in stroke risk although multiple visceral vessel stenting is involved. However, chances of infection is higher in such cases, which the authors do not seem to have looked into.

Conventional open surgery for TAA produced good outcomes with acceptable one month mortality rate of 5%, although it increased to 6% in the case of those who had entire thoracico- abdominal aorta replaced [18].

The one month and one year mortality rates were evaluated for TAA repair risks by Rigberg et al.[19]. Overall elective mortality was 19% for one month and 31% for one year. The mortality rates for age were 18% for 50-59 years and 40% for 80-89 years old. For ruptured instances, one month mortality was 48.4% and one year mortality was 61.5% and these also increased with age. One year mortality had much higher risk with age than one month mortality. These findings are in line with general population trends.

Verhoeven et al.[20] , described the experiences of branched stent grafting in 30 TAA patients. Technical success was 93% consisting of 28 out of 30 patients. Out of 97 targeted vessels, two were lost. Rupture of renal artery occurred in one patient when the bridging stent graft was being inserted. In another patient, a coeliac artery was lost as it could not be catheterized. The mortality at one month was 6.7%. The survival rates at half year and full year were 89.3% and 76% respectively. The authors concluded that endovascular procedure was promising in the case of TA. Anatomical problems need to be considered. These are tortuous vessels, access problems and quality of targeted side branches.

Kolvenbach et al.[21], described a sandwich technique of surgery combining the use of standard off-the shelf ViaBahn chimney grafts and standard thoracic and abdominal aortic stent grafts on five TA patients. One type 1 endoleak was observed and rectified in two months. During the follow-up, one target vessel of right renal artery was lost. Overall, this technique offered promise in urgent treatment.

Results of 337 operations in a single hospital done by a single surgeon on TA patients during 1987-2001 were reviewed by Cambria et al. [22]. Specifically, the temporal effect of epidural cooling (EC) on spinal cord ischemic complications (SCI) was assessed. Clamp/sew technique with adjuncts was used in 93% cases. Since July 1003, EC to prevent SCI was done on 194 patients. An operative mortality of 8.3% was observed in the case of factors like non-elective operation, intraoperative hypertension, total transfusion requirement and post-operative complications of renal failure, paraplegia and pulmonary insufficiency. Independent correlation was observed for renal failure and transfusion requirement with mortality. EC reduced the risk of SCI in patients with Type I-III TA 10.6% against 19.8%. Survival rates at two and five years were 81.2% and 67.2% respectively. SCI risk was reduced due to EC after TA repair. Reducing patients who are non-elective operations will improve results. Overall, spending resources for TA repair is shown to be worthwhile.

In one finding Louridas et al. [23], the ratio of diameter of aneurysm to the diameter of normal aorta adjacent to it was found to predict high risk group of infra-renal thoracic aneurysm patients. The mean ratio increased from 2.0 for normal to 2.7 for aneurysm without rupture and 3.4 for aneurysm with rupture.

2.4.2 Abdominal Aortic Aneurysm (AAA)

Shah et al.[24] , estimated 20-40 AAA cases per 100000 persons annually in USA. About 45000 AAA operations are performed every year. Elective surgical mortality for unruptured AAA varies from 2 to 7%. However, if ruptured before surgery, the mortality rises to 50-70%. Mortality risk increases with increasing size of aneurysm.

Presence of elastase within aortic media produced aneurysm in the in vivo experiments on rats done by Anidjar et al.[25]. Many authors have shown that loss of elastic tissue due to increased elastolytic activity of elastase can lead to aneurysm in human beings. Thus, initial stage of aortic aneurysm consists of dissolution of elastic wall of aortic blood vessels. The results obtained by the authors upheld this hypothesis. The authors also pointed out from other works that calcium deposits can fragment elastin network leading to arterial dilation. In a related finding, Holmes et al. [26] observed medial neovascularization associated with partial disruption of elastin and chronic inflammation. However, they associated early development of aneurysm with angiogenic or inflammatory processes extending from atherosclerotic plaque into aortic media. If it does, dissolution of walls may arise as a consequence of this. Thus there is one more intermediate process here. The authors proposed the possibility of using medial neovascularization as a morphological marker of AAA. According to Nordon et al.[27], rupture of AAA is related to physiological reactions leading to mortality of up to 80%, accounting for 2% of all deaths. Pathological conditions are: inflammation, smooth muscle cell apoptosis and degradation of wall matrix. Genetic studies have not established causative gene mutations. The data given by the authors on AAA prevalence in different countries show a tendency of sample size dependence on AAA detection percentage. Thus the probabilities of getting lower percentage with very large sample size and higher percentage with smaller sample size are high. Annual incidence rate is 0.4 to 0.67% in Western Europe while it is lower by a factor of 10 in Asia. Nonetheless, the incidence of rupture in Sweden increased from a mean 5.6 during 1971-1986 to a mean 10.6 during 2000-2004 per 100000 person-years, although elective AAA surgery doubled. Increase in chances of rupture due to lengthening life span may be one reason for this. The authors cited the work of Greenhalgh et al. (2010) comparing open and endovascular repair outcomes for aneurysm and those for any disease. Although within groups, the two methods did not differ, number of survivors declined during eight years of follow up when any disease is considered, whereas it was same over all the eight years [28]. The authors have not discussed this variation. It is difficult to explain why survivors declined in the case of any surgery and remained the same for aneurysm cases.

However, increasingly studies are showing involvement of a few enzymes in various stages of aneurysm development. As enzyme activity can be traced to genetics, studies on those lines may establish definite genetic connections for prevention of the disease. Involvement of some genes like MMP9, IL6 and AT1R was suggested by Thompson et al. [29].

2.4.3 Small Abdominal Aortic Aneurysm (AAA)

Identification of factors which can be used as growth predictors of small AAA facilitates assessment of the likelihood of small aneurysms growing into larger ones which can rupture later. As a part of SMART study in Netherlands, [30] followed up the growth of AAA diameter of patients whose initial diameter was in 30-55 mm range. Effects of demographic characteristics of patients, cardiovascular risk factors and initial diameter on the growth of AAA were evaluated. Lipid lowering drug treatment and initial diameter had independent relationship with lower AAA growth rate. Rupture risk of small aneurysms were low. Hence only watchful waiting is recommended.

Lederle et al.[31], undertook a study on behalf of Aneurysm Detection and Management-Veterans Affairs Cooperative Study Group to evaluate whether elective surgery of small aneurysms improve survival. Even when operative mortality was low, there was no improvement in survival due to elective repair of AAA with sizes smaller than 5.5 cm.

According to Powell et al.[32], there is no evidence that treatment of hyperlipidemia and hypertension will slow the growth aneurysm. Early elective surgery also does not improve survival and hence surveillance is adequate. When the aneurysm reaches 5.5 cm (two years) and exceeds surgery by suitable method can be done.

2.4.4 Infra-renal AAA

Long term stability of aortic neck is important for proximal endovascular graft fixation and maintenance of haemostatic seal. Infrarenal aortic diameter is important, however, suprarenal fixation of fenestrated and branched stent grafts can improve long term integrity of aortic attachment site. For this, natural history of suprarenal and infrarenal aortic segment should be known. Falkensammer, et al. investigated these aspects in open AAA repair cases of 1998-2002 in Austria. However, the number of cases with mean increases more than clinically relevant 3 mm per year were very few [33].

Annambhotla, et al. in 2014, discussed EVAR procedures for infrarenal aneurysm. Use of two different aortic stent graft devices were discussed step by step. Advances in branched and fenestrated graft technologies will expand treatment options available especially in cases like complex juxtarenal, suprarenal and iliac aneurysms [34]. In the same book, some of the techniques essential for success of EVAR for ruptured AAA were discussed in 2014 by Malinowski, et al [35].

No gender differences were seen, Dubois, et al., 2013, in short term outcomes after endovascular repair of infra-renal aneurysm using Endurant stent grafts. Based on an international data, women were older and had smaller aneurysms with shorter, narrower and less angular infra-renal aortic neck. Neck anatomy, technical success of the repair procedure, endoleak (special reference to type I) incidence, endograft occlusion, absence of adverse events, and survival rate after one month and after one year were similar for both genders in spite of the anatomical differences [36].

2.4.5 TA/TAA AND AAA Occurrence

Bonilla et al. [37] described a case in which multiple endovascular stent graft implantations were done. The female patient 30, suffered Takayasu arthritis (TA) and developed progressive thoracic and abdominal aortic aneurysms. As imminent rupture of TA was observed, an emergency endovascular stent graft was implanted. A year later, the AAA size increased and required another endovascular stent graft implantation. Both procedures produced good outcomes. The success of this case demonstrated the effectivity and security of multiple endovascular stent graft implantations in multiple aortic aneurysms.

Schlösser et al. [38] reviewed works done so far to evaluate whether higher mortality or morbidity are associated with repair of TAA and TAA following previous AAA surgery. The probability of developing TA in AAA patients was 2.2% and it was 2.5% for TAAA development. The mean interval between AAA repair and detection or surgery of TAA was 8 years with wide variability. No difference in one month mortality rates was observed for open surgery for TAA following AAA surgery or not. Morbidity risks were high for both TAA and TAA post-operative risk of neurological deficit after AAA repair and the risk of renal failure in the case of TAA repair. Many prognosis factors were identified. These findings demonstrated the need for maximum protection for spinal cord and renal function in such patients. An earlier paper on the same topic by Lombardi et al. [39] also reported similar results.

2.5 Aneurysm Diameter

To answer the question: whether the diameter of treated AAA changes in course of time, Hadjibashi et al.[40], measured diameter of AAA after repair. The mean diameter decreased from 6.49 cm in 2000 to 5.83 in 2009. This decrease was correlate with time in years. The general reduction in expansion rates of AAA across USA and progressive decrease in aneurysm rupture rates may be associated with this.

Role of various imaging methods in aneurysm sizes, abnormalities and other characteristic features were explained by Schmidt WA.[41]. The author has dealt with Ultrasound and high resolution MRI, CT, MRA, CTA, Positron Emission Tomography (PET) and conventional angiography. The importance of early diagnosis of impending rupture of AAA and differentiating impending and complete rupture helps clinical intervention decision making. Vu et al [42] showed that findings of intramural imaging can help diagnosis of impending AAA rupture and the rupture occurs at the end of continuous growth and weakening of walls. Although the signs obtained by imaging might not always be specific to impending or complete rupture, certain special features are exclusive to impending or complete rupture. These have been delineated by the authors.

2.6 Prevalence and Epidemiology

Cowan et al. [43] described the epidemiology of aortic aneurysm, practically Abdominal Aortic Aneurysm (AAA). It primarily affects the elderly males, especially those who smoke, have hypertension or a positive family history of the disease. Ageing population and increased screening of high-risk population have brought out the hitherto undetected cases also. As per US national records, overall rates of treated ruptured and unruptured AAA remained stable over 1993-2003. In-hospital mortality following unruptured AAA repair declined from 5.3% in 1993 to 4.7% in 2003 in the case OAR and from 2.1% to 1.0% for the same years. Thus, mortality rates of endovascular repair itself was lower and it decreased faster than OAR during the period. In the case of ruptured AAA, the mortality rates for open surgery were 46.5 % and 40.7% in 1993 and in 2003 respectively. The corresponding figures for endovascular repair were 40% and 35.3% respectively. As the result, the numbers of patients undergoing elective repair were relatively stable, although less invasive method was available. The increasing shift from open to elective endovascular method is justified at least from short term advantage of reduced mortality. Similar observations were made by Dua et al. [44] for subsequent US data from 2000 to 2010.

2.7 Risk Factors and Prediction

In a review and meta-analysis, Cornuz et al. [45] identified age, smoking and history of peripheral or coronary artery disease as risk factors of asymptomatic AAA. The prevalence of AAA among men was 4.1 to 14.2% and among women it was 0.35 to 6.2%. Odds ratios were used for identifying risk factors.

Long term survival against rupture risk of AAA should be used for deciding which patients need surgical intervention. Mastracci et al.[46], developed a predictive model in which age, aneurysm diameter, chronic obstructive pulmonary disease, history of peripheral artery disease, home oxygen requirement, congestive heart failure, and use of salicylates were used as independent predictors.

Scoring systems for prediction of mortality may not be accurate in the case of EVAR repair. [47] Developed a practical risk score to predict in-hospital mortality after open repair of ruptured AAAs and compared it with Glaxo aneurysm score, Vancouver score, Hardman Index and Edinburg ruptured aneurysm score. Although other systems predicted mortality after AAA repair, they did not identify patients with highest risk. This was made possible by the VSBNE RAAA risk score developed by the authors.

Prophylactic AAA repair should overcome operative risk. Death within one year of AAA repair may indicate ineffective treatment. Therefore a prediction model to predict this mortality will facilitate clinical decision making. Beck et al.[48], developed a model which had low impact on one-year survival, even when congestive heart failure and large AAA were present. There was a combined effect of age, chronic obstructive pulmonary disease, renal insufficiency and the need for suprarenal clamping for one-year mortality after open AAA repair. These predictors can be used for deciding on elective AAA repair.

Giles et al.[49], developed a differential predictive model for perioperative mortality after AAA repair. Comorbidities, gender and age were used as predictors for both open and EVAR procedures.

2.8 GLASGOW Aneurysm Risk Scoring System

Glasgow Aneurysm Score (GAS) estimates the mortality risk of patients admitted to hospitals with rAAA. The formula for calculation is given by-

GAS= (Age in years) + (17 for shock) + (7 for myocardial disease) + (10 for cardiovascular disease) + (14 for renal disease). The suggested cut-off is a GAS score of 85- Samy et al.[50].

The main drawback is that mere presence of the cardiovascular or renal disease puts a person of 70 years at the risk level. There is no provision to assign different scores for different severities of accompanying complications.

A study in 2008 by Baas et al. [51] compared GAS predictability for EVAR and OR outcomes. They obtained cut-off values of 75.5 for OAR sand 8.5 for EVAR. Thus, risk was lower with EVAR. Two years after either surgery, the cut-off values decreased to 74.5 for OAR and 77.5 for EVAR. Thus, over time, the risk of either procedure equalizes. Although GAS was useful to identify low risk patients, it was not useful to identify high risk patients.

The predictive value of GAS in elective open AAA patients was tested by Hirzalla et al. [52]. GAS was sensitive both for post-operative mortality and for major morbidity. The best cut-off GAS score was 77 as all diseased patients and 63.3% of those who had major complications had GAS values above 77. In-hospital mortality was predictable by supra-renal clamping during surgery. Predictive value of three GAS parameters: age, cardiac and renal diseases was validated. However, the low predictive value of GAS reduces its utility for clinical decision making in the case of high risk patients. Patients with GAS score of 79 or above were considered high risk and hence unsuitable for operation.

According to Pattterson et al. [53], GAS did not discriminate between survivors and dead patients in their cohort study on OR done in AAA patients. This may be because patients risk factors for poor outcomes with EVAR are selected for OAR. Poor predictability of GAS and its non-utility for clinical decisions was also reported by Tambyraja et al. [54] and in 2009 by Gatt et al.[55].

On the other hand, findings of Biancari et al. [56] and Leo et al. [57] showed usefulness of GAS for decisions of treatment in all AAA patients. The 30-day mortality rate was 1.1% for patients who had less than 74.4 GAS value, 2.1% for patients with GAS between 74.4 and 83.6 and was 5.3% for patients with GAS score of above 83.6. Usefulness of GAS as a predictor of in-hospital mortality after elective OAR for AAA was also observed in 2014 by Ozen et al. [58]. GAS was significantly lower at 76.05 for patients who survived operation than those who did not (92). The cut-off value was 77.5 and all patients with lower values survived operation. Another study in 2012 by Kurc et al. [59], also observed significant correlation of GAS with in-hospital mortality. However, the authors caution that high score may not necessarily mean high mortality rate. Hence, GAS should not be used as the sole criterion to determine surgery procedure.

In a recent paper by Mani et al. [60] in 2015, used GAS for cross-country comparisons and noted high variability in risk profiles of AAA patients in different countries, lowest in Finland and highest in UK. Antonopoulos et al. [61] in 2014, suggested modifications to GAS to apply it for EVAR.

2.9 Patient Classifications

Although Cohen's convention of effect size applies well to medicine, there was no dramatic change in most therapeutic interventions based on size. Therefore, rapidly increasing biomedical knowledge has little effect on rapidly improving therapeutic efficiency. Applying this finding of Caspi O. [62], there cannot be any change in size conventions even if there is rapid progress in diagnosis or treatment methods for aneurysm. As size and risk of rupture are related, this factor is indirectly related with mortality rates as well.

Katz et al.[63], identified age, gender and smoking as the most important predictors of AAA. Alcohol and post-menopausal oestrogen use were inversely associated. Predictors may act through different pathways in their relationships with AAA. Screening programs targeting current and previous smokers and people of 65 and above could yield best results. Addition of hernias in the screening program enhances its predictive value. Association of AAA with some other diseases was also observed, but they could have been consequential rather than serving any predictive utility. On the other hand, race, socio-economic status, exercise, coffee consumption, use of aspirin, family history, obesity, diabetes, gallstones, pregnancy and height were associated in bivariate analysis; but were not associated in multivariate analysis as their effects were accounted by other variables.

In another study on the same topic using case-control method, Blanchard JF. [64], obtained relationship of increased age and male gender with AAA. Smoking (former and current) was also strongly associated especially for women. Other factors strongly associated with AAA were: diastolic blood pressure, positive family history and diabetes. The findings contradicted the theory that AAA was caused by atherosclerosis.

Lederle et al.[65], identified age, smoking, family history of AAA and atherosclerosis as the main factors associated with AAA. Female gender, diabetes and black race were negatively associated. Skow et al.[66], used a case study of 72 year old male smoker diagnosed with AAA to discuss the prevalence, diagnosis, screening guidelines and treatment options for AAA.

According to Pettersson et al.[67], patients, who had undergone surgical procedures for AAA were unable to come to terms with a life-threatening condition. They had a sense of living on borrowed time and being granted a new lease of life. In the case of open repair, there was an ordeal to endure. In the case of endovascular repair, there was a sense of gratitude, security and insecurity. Discovery of aneurysm itself gave a sense of being blessed and saved. These observations can be used for nursing care strategies. The difference in perception of open and endovascular repair shows superiority of the latter in terms of rendering a better psychological outlook to the patient. This is an addition to many dimensions of advantage for the procedure over the open surgery. The reason for the authors calling diagnosis and surgery as drama is not clear.

2.9.1 Age

The post-operative mortality rate is higher than perioperative rate since mortality risk continues through 31 to 365 days. Mortality increased significantly with age for both intact and ruptured AAA repair as Rigberg et al. [68] found from their Californian study. Improved short term outcome has prompted US hospitals to increasingly adopt EVAR for asymptomatic AAA especially in patients over 85. Long term outcome need to be evaluated through further study. This was pointed out by [69].

2.9.2 Gender

Risk factors associated with aortic aneurysm and dissections as influenced by gender were examined by Golabbakhsh H.[70] . Higher risk of dissection was observed in the case of males with non-congenital heart disease and alcohol. Non-congenital heart disease and bicuspid aortic valve showed higher risk in the case of females.

In UK as a part of MASS (randomised mass screening study), [71] noted that the reduced mortality benefits of screening men 65-74 for AAA were maintained for 10 years of this study. Cost effectiveness became more favourable with longer time. To obtain maximum benefit of screening, maximisation of initial screening attendance, adherence to clinical follow ups, ensuring no delay in surgery and ensuring low operative mortality after elective surgery are advised. Rescreening of those declared as normal in the initial screening was not justified.

Prevalence, risk factors and screening implications of AAA in women were assessed in a US study [72]. Out of 17540 persons screened, 10012 were women of mean age 69.6 and 7528 were men of 70. AAA prevalence rates were 0.7% and 3.9% for women and men respectively. In spite of this low incidence among women, specific risk factors associated with high prevalence in women were identified. These included: age more than 65, smoking and heart diseases.

Care of AAA affected women can be improved if screening techniques to detect before rupture and at younger age, especially for timely repair are available. Decreasing mortality in OAR and developing endovascular devices suitable for anatomical features of women will be required. Gender differences in pathophysiology needs to be studied [73].

From a study of US national database for 1995-2006, Egorova et al. [74], noted that women had higher operative mortality rates than men. In ruptured AAA, long term outcome was worse for women both with OAR and EVAR. The benefit of EVAR was sustained longer time than men. In another US work [75] on gender differences and 40-day outcomes of EVAR repair, ACS NSQIP data were used. The 30-day mortality and morbidity were higher for women than men undergoing EVAR. Increased risk of women was due to emergency presentations, in more debilitated conditions and requiring iliac or brachial exposure. Women were at higher risk regarding many complications and increased length of stay.

According to Stackelberg et al. [76], based on analysis of Swedish data from 1998 to 2011, women were more sensitive to current smoking than men. After cessation of smoking, excess risk declined more rapidly in women. The risk was reduced to half in 11 years for women and 23 years for men. Thus association between smoking status and AAA risk was different for women from that of men.

McPhee et al.[77], used NIS data of 2001-2004 and observed higher mortality among women undergoing AAA repair. They observed higher percentage of women presenting with ruptured aneurysm and had in-hospital mortality rates for both intact and ruptured AAA. Gender differences were also observed in long term persistence of gender differences in outcomes after AAA repair.

In another US study, Mehta et al.[78], significantly higher mortality and more hazardous for women than men who undergo elective EVAR. Colon ischemia, native artery rupture and type 1 endoleaks were more common among women. Thus elective EVAR benefits men more than women.

2.9.3 Race

In spite of reduced mortality and complications of AAA, its operative complications and perioperative mortality is still high, especially in the case of ruptured AAA. While pointing out this, Lemaire et al. [79] also found ethnicity and insurance influencing EVAR surgical outcomes. Whites had less perioperative mortality and post-operative complications than

Blacks and Hispanics. Self-payers had more adverse outcomes than insurance covered patients.

2.10 Hospital Contexts and Mortality

Association between procedure volume and mortality rates in US hospitals was studied by Allareddy V. [80]. He used NIS data of 2000 to 2004. AAA elective repair was one of the nine surgical procedures reviewed. High volume hospitals were associated with low in-hospital mortality rates. Lower complications, better patient mix, selective referrals and perfection by practice were identified as causative factors, but unable to explain significant percentage of the relationship. In the case of AAA repair, the in-hospital mortality rates were 2.63% and 3.47% for high and low volume hospitals respectively. As the author categorized the hospitals only into high and low volumes, establishing correlations was difficult. Better would have been to correlate absolute volume numbers with their absolute mortality numbers of all hospitals without such categorization. Generally complications were higher in low volume hospitals. Apparently some patient classifications are also involved.

In the studies by Leonhirth et al.[81], implementation of clinical decision support systems (CDS) was positively related with risk-adjusted mortality rate for AAA repair and Percutaneous Coronary Intervention (PCI). Thus hospital context factors may be related with in-hospital mortality rates. This finding contradicts that of [82].

Quality of patient care in hospitals on weekends were compared with weekdays in a study by Bell CM.[83]. Mortality, procedural waiting time, staffing levels and potential predictors were included. Hospital mortality rates were significantly higher for weekend admissions of ruptured AAA, acute epiglottitis and pulmonary embolism. It is interesting that other two are also frequently associated with AAA. Of the top 100 causes of death, 23 were related to weekend diagnosis against lower mortality with no weekend diagnosis. Mean wait times for seven top urgent procedures from admission to completion of procedure were longer for weekend admissions. Staffing levels (both clinical and non-clinical) were lower on weekend than weekdays. The author concluded that more consistent weekend staffing could solve most of the problems.

Through evaluation of one month mortality, failure to rescue, prolonged and mean length of hospital stays and using regression models of detailed risk assessment, [84] observed that nurse organization reduced the effect of volume on mortality and failure to rescue in AAA repair. Significant interactions of nurse staffing with surgical volume, mortality and failure to rescue were also observed. Hospitals with patient: nurse ratio of 4:1 had increased effect of high volume compared to the ratio 8:1. These findings suggested significant role for nursing organization in the volume-mortality rate relationships.

2.10.1 Hospital Contexts and Patient Classifications

In his thesis, Dueck AD.[85], studied the effects of patient, surgeon and hospital factors on survival after repair of ruptured AAA. Patient classifications considered were age, gender, comorbidity and income quintile. Process factors included emergency room efficiency, technical skill of the operating team and quality of post-operative care. Hospital factors were: volume of elective and ruptured AAA, type of hospital, location and size. Patient characteristic's like age and comorbidity were less important and average surgeon volume and their expertise in AAA repair procedure decreased mortality rate. However mortality rate remained the same over the study period partly because average patient age increased during the time. Men had higher survival rate than women and were more prone to ruptured AAA. The process and hospital factors together can constitute hospital context. Surgeon factors included annual case volume of elective and ruptured AAAs handled by the surgeon and his/her super-specialty training. Time of treatment in relation to presentation becomes the delay factor. However, this factor has not been adequately studied. Hospital contexts can be modified by policy decisions and management, but not patient classifications. Here the ACR guidelines become relevant.

2.10.2 Geographical and Hospital Volume

Analysis of US data for cerebral aneurysm 1994-1997 showed [86] that patients treated at hospitals which used endovascular coil embolization had lower relative risks for every 10% of endovascular treated cases. This was observed for both ruptured and intact aneurysms. Patient volumes of hospitals were not associated with in-hospital deaths.

Based on data analysis on elective aortic route and aortic valve ascending procedures performed during 2004-2007 in 741 US hospitals, Hughes et al. [87], noted similar preoperative patient risk profiles in all hospitals irrespective of patient volume. There was a higher mortality risk in hospitals where less than 30-40 such procedures were handled.

Goshima et al.[88], criticized the use of surrogate markers like case volume or subspecialist involvement in determining centers of excellence for aneurysm treatment. The authors claimed, based on analysis of data of 1994-2005, that University of Arizona Health Sciences Centre was able to achieve the standards prescribed for centers of excellence in spite of being a low volume center. Thus without meeting Leapfrog Group’s proposed criteria, the institution is equivalent to a center of excellence.

Based on their experience of high success in screening for AAA in remote rural areas of UK, Duncan et al. [89] proposed that it is possible to achieve high uptake, acceptable clinical results and costs comparable to big urban centers do with screening for AAA in those areas.

2.11 Interventional Aneurysm Repair Procedures

As the treatment of vascular diseases has been shifting towards less invasive procedures, especially in the case of renal and mesenteric vessels and lower extremities, more catheter-based approaches are required for peripheral vascular diseases. This observation was made by Anderson, et al., 2004 based on the data from 1980-2000 of US hospitals [90].

McDonald, et al. observed that care coordination is one of the key strategies for improvement of health care quality [91]. Based on investigation results, the authors concluded that care coordination involves multiple levels of service delivery and systems. Their effectiveness depends on what extent the interventions solve the care coordination problem in the organization. Much research is needed to elaborate this concept further. The first step of quality improvement may be in the diagnosis of aneurysm. Rand, et al. in 2013 described quality improvement guidelines for imaging detection and procedures for endoleaks which occur after endovascular aneurysm repair [92]. The authors noted that only Type II endoleak occurs more frequently. Endoleaks can be managed easily using endovascular methods in most cases where it occur. This paper does not give any specific quality improvement method. The authors may be assuming that prescribed procedures will ensure quality automatically.

2.11.1 Endovascular Aortic Repair (EVAR)

Statins were used in the case of about 58% of patients not treated surgically. Sizes of AAA were 4.6 cm at baseline and 4.5 cm at 23 months of follow-up for these patients. For patients not treated with statins, the sizes were 4.5 cm at baseline and 5.3 cm at 24 months follow up. At 45 months, 5% of statin-treated patients died while 16% for those not treated with statins died at 44 months [93].

Outcomes of ruptured AAA in UK and USA were compared by Karthikesalingam et al. in 2014 [94]. In-hospital mortality rate was lower (53.05%) in USA than in England (65.9%). Intervention rates were higher in USA. EVAR was more common in USA than in England. Post-intervention mortality was similar in both countries. The differences were persistent irrespective of gender or age. In both countries, mortality was lower with increase in use of EVAR, increased case volume for ruptured AAA, high hospital bed capacity, teaching status and admissions on weekdays.

Giles et al. in 2009 studied the US data during 1993-1998 as the pre-EVAR and 2001-2005 as the post-EVAR periods [95]. Mortality rates of both intact and ruptured AAA declined significantly. There was an increase in intact AAA repair after introduction of EVAR and decreased diagnosis and repair volume of ruptured AAA.

2.11.2 Endovascular Aortic Repair (EVAR) and Open Aortic Repair (OAR) Comparison

According to Pomposelli JA. [82], short term reduction in AAA mortality rate was established for endovascular repair compared to open surgery for older patients in well-equipped hospitals with well-trained staff. Long term data is lacking. In the case of off-pump

Coronary Artery Bypass Grafting (CABG), reduced risks due to stroke, arterial fibrillation and infections were observed. However, these effects need to be moderated by limitations of randomized controlled trials (RCT), time required for learning, tendency to use fewer grafts and likely need for reintervention. Hospital variations were not explained at all by patient classifications and only slightly by hospital characteristics. This means, hospital contexts may not be completely definable by hospital factors even if hospitals follow ACR guidelines.

In another dissertation comparing open surgery and endovascular coiling of ruptured AAA, [96] observed that the latter method increased over time during 1995-2004. Increased hazard of mortality or subarachnoid hemorrhage (SAH) readmission was observed in the case of endovascular coiling with associated increase in diagnostic and repeat therapeutic procedures. The author recommends further studies rather than justifying open surgery based on his findings. It is notable that the mean age in both cases was around 54 years, considerably younger than encountered for AAA rupture cases. The rate of decline in survival rate was gradual in both cases and was parallel suggesting there is no special mortality problem differentiating the two methods. However, mortality during the first month was only 13.2% in the case of open surgery, but was 15.5% for coil method. Other secondary outcomes were also higher for coil method

In Sweden, intact EVAR increased and ruptured AAA repair decreased especially since 2005 with improved outcomes, according to Mani et al.[97], data of three intervals of 1994-1999, 2000-2005 and 2006-2010 were used.

Mureebe et al.[98], noted that although the number of patients diagnosed with ruptured AAA declined there was no reduction in repairs of AAA in US hospitals during 1995-2006. There was significant improvement in perioperative mortality due to endovascular repair and only a small improvement in the case of open surgery procedure.

According to Chadi et al. [99], over the ten years of 2000-2010, there was significant shift towards endovascular procedure in infra-renal AAA repair in Canada. Higher risk and older patients are more likely to be treated with endovascular method due to its better survival chance.

Hertzer et al.[100], reported good success with open infrarenal AAA repair and suggested wide usage of endovascular method only after its long term effect is assessed. Many parameters were measured in this detailed study. Rayt, et al. obtained lower mortality rate for EVAR than for OAR in the case of patients with ruptured AAA in their meta-analysis of reports published during 1950-2007 [101]. High level of publication bias was attributed as one reason for this. It is surprising that they could use results of only 31 studies from such a vast data covering a long period.

From Serbia, Šarac et al., in 2014 suggested emergency endovascular repair in local anesthesia as an alternate option for open surgery in the case of patients with ruptured AAA and with comorbidities. The authors contended better survival and with low perioperative and post-operative morbidity or mortality with this technique. However, the conclusion is based on a single patient involving only one post-operative monitoring after three months [102].

According to Galovich et al., for ruptured AAA, endovascular repair should be the first option considering its advantages, although it requires continuous post-operative monitoring [103]. Although based on case reports of two patients, no post-operative problem occurred over two years. Lower mortality over first month and better survival rate after five years based on review of data on 283 such patients during 2002-2011 made Mehta et al., in 2013 support endovascular repair of ruptured infrarenal AAA [104]. Using the NIS data of 2001-2004, 28123 admissions of ruptured AAA, nationwide trends of time and demography were evaluated by Lesperance, et al., in 2008 [105]. There was stepwise decline in admissions over the period. Use of EVAR increased from 6% in 2001 to 11% in 2004. Mortality decreased significantly from 43% to 29% over the period, whereas mortality with open repair was unchanged around 40%. Mortality was higher at non-teaching hospitals (55%) than at teaching hospitals (21%). According to another report by Dillavou, et al., in 2006, EVAR increased to 41% of all elective repairs during 2000-2003 [106]. Overall elective mortality also declined from 5% to 3.7%, while it was unchanged for open surgery. EVAR was usually done on older patients. EVAR was used in 10.6% cases of ruptured AAA with decreased mortality (31.8%) compared to open procedure (50.8%). Consequent on these trends, reimbursements to hospitals have also declined. Factors determining long term survival of patients treated with elective open or EVAR repair were identified by De Martino, et al., 2013 from the data on AAA in New England hospitals during 2003-2011 [107]. Factors affecting long term (five year) survival for either of the elective procedure were: age over 80 years, multiple risk factors, unstable angina, oxygen-dependent chronic obstructive pulmonary disease and estimated glomerular filtration rate less than 30 ml per minute per 1.73 m2. However, if risk of rupture was very high, elective procedure becomes emergency procedure and thus is not influenced by these factors. In the case of mycotic aortic aneurysm, EVAR procedure with careful antibiotic treatment to prevent infection and care of other risk factors help to reduce surgical morbidity and mortality. If aneurysm rupture or fever is present, definite surgical intervention is required. These conclusions were obtained by Kan et al. after review of published work [108].

In the DREAM project on AAA, a multicenter randomized control trial was done by Prinssen et al. [109] to compare open and endovascular repair outcomes of 174 open surgery and 171 EVAR patients with diagnosed AAA requiring repair. Mean operative mortality rate was 4.6% (range for 95% confidence 2 to 8.9%) for open and it was 1.2% (range for 95% confidence 0.1 to 4.2%) giving a risk ratio of 3.9. The combined rates for operative mortality and complications together were 9.8% (range for 95% confidence 5.8 to 15.2%) for open and 4.7% (range for 95% confidence 2 to 9%) for endovascular giving a risk ratio of 2.1. Notably, the lowest mortality rate of open method (2%) is still higher than the mean of (4.7%) for EVAR. It is possible for EVAR to be close to zero mortality as its lowest value was only 0.1%. The highest mortality of 4.2% for EVAR was lower than the mean (4.6%) of open. Thus, on short term, EVAR has decisive advantage over open.

Comparison results of OAR with EVAR in the case of inflammatory AAA (IAAA) obtained from meta-analysis of reviewed works were reported by Paravastu et al. [110]. The 30-day mortality (range for 95% confidence level) were: 6% (6-13%) for OAR, 2% (0-7%) for EVAR. Peri-aortic inflammation regressed in 73% of OAR compared to 65% in EVAR. Inflammation progressed in 1% for OAR and 4% for EVAR. The progress of hydronephrosis was also higher (21%) for EVAR compared to 9% in OAR. But new development of hydronephrosis was only 2% in EVAR compared to 6% in OAR. One year all-cause mortality was 2% for EVAR and 14% for OAR. Although it is difficult to establish superiority of either procedure, the authors favored OAR for IAAA when there is hydronephrosis with low risk.

Comparison of OAR and EVAR in the case of ruptured AAA among US Medicare population was done by Edwards et al. [111]. Data of 2001-2008 were used. Perioperative mortality rates were 33.8% for EVAR and 47.7% for OAR and this difference continued for more than four years. At 36 months, EVAR patients had higher (10.9%) AAA-related endovascular re-intervention rate than OAR (1.5%). OAR had higher laparotomy-related complications than EVAR. Use of EVAR increased from 6% in 2001 to 31% in 2008. Overall 30-day mortality declined from 55.8% to 50.9% during the same period. Thus EVAR is more promising for ruptured AAA treatment. Based on similar results, Qin et al. [112] also concluded that EVAR is more advantageous in terms of lower perioperative mortality and hospital stay.

In an AHRQ report [113], data on unruptured EVAR and OAR till 2006 were compared by reviewing various types of publications on such comparisons. The strongest predictor for AAA rupture was initial or attained diameter. Annual risk of rupture was less than 1% for less than 5.5 cm diameter. Risk of rupture increased by 10% every year for those who were medically ill and unfit for OAR. All-cause mortality could not be reduced by early or immediate OAR intervention compared to monitored and delayed intervention. Age, gender, base AAA diameter or creatinine concentration did not have any effect. Early decline in all-cause mortality with EVAR did not continue after two years. Post-operative complications and need for re-interventions were higher in the case of EVAR. There were initial small differences in life quality, which disappeared soon. Sometimes no intervention was as good as EVAR with respect to all-cause mortality. In some non-randomized trials, AAA and OAR compare well. Positive outcome for higher patient volume was indicated by some results, but were not conclusive to help policy decisions. Cost of immediate OSR was more with no reduction in long term mortality compared to surveillance and delayed OAR. Long term costs of EVAR were higher due to follow-up costs. In conclusion, the relative merit of either method is size and patient-condition dependent. For less than 5.5 cm size, active surveillance with delayed OAR seems better. For sizes more than 5.5 cm, EVAR has only short-term advantages with better peri-operative outcomes. Survival of patients who are medically unfit for OAR was not improved by EVAR. More post-operative-complications, need for re-interventions, need for monitoring and higher costs compared to OAR and to no intervention makes EVAR less attractive. On the other hand, Schermerhorn et al. [114], studied on US Medicare beneficiaries who underwent repair between 2001 and 2004 till 2005 for various comparison parameters. They concluded that although more reinterventions are needed for EVAR, they are balanced by increased laparotomy-related reinterventions and hospitalisations required for OAR. The survival advantage of EVAR was more long term for older patients.

A report reviewed an extensive randomized trial at 37 UK hospitals surgery done during 1999-2004 and monitored till 2009 [115]. The findings re-stressed on increased rates of graft-related complications which required reinterventions and higher costs of EVAR.

For AAA cases unsuitable for standard EVAR procedure can be considered for fenestrated EVAR (FEVAR). Based on a UK study of 107 such patients, [116] concluded that FEVAR reduced mortality and morbidity significantly compared to OAR with reduced total hospital stay and intensive care requirements for this type of patients.

The need for reinterventions and no long term advantage of higher survival rate were highlighted as the problems of EVAR compared to OAR by Jetty et al. [117]. In this Ontario study, all patients who underwent elective surgery for AAA during 2002-2007 were included. Those who underwent EVAR were older and had more comorbidities, spent less time in hospitals including special care and underwent more imaging studies.

According to Martino et al., mortality rates of EVAR and OAR were similar after 1.6 and 1.9 years at around 15.5% [118]. About 25% of these deaths occurred before or within 30 days of discharge and the remaining 75% occurred after hospital discharge after 30 days. Cardiac and pulmonary diseases were most common causes of late deaths. Thus late deaths from aneurysm rupture after either procedure was not very frequent and are not associated with ether procedure. Effectiveness of EVAR was comparable to that of OAR in prevention of deaths due to aneurysm.

Foster et al., 2010 reviewed the evidence on 30 day survival of patients with elective EVAR for acute ruptured AAA. Although validity problems existed, the available evidence showed the suitability of EVAR as a primary treatment for ruptured AAA with reduced mortality compared to OAR [119].

Causes and implications of early (30 day) readmissions after elective AAA repair by EVAR or OAR were evaluated by Greenblatt, et al., in 2012 using CMS Chronic Conditions data for 2005-2006 [120]. The 30-day readmission rates were equal for both EVAR an OAR. Wound complication was the most common problem in both cases. Among other causes, bowel obstruction was most common in the case of OAR and graft complication for EVAR. Comorbidities did not have very high effect. One year mortality was significantly lower

(4.5%) for not readmitted than that 23.4%) for not readmitted. After adjusting comorbidities, post-operative events predict readmission. Thus, proactive prevention, detection and management can minimize readmissions. In another study on readmissions after open repair, Casey et al. in 2013 used US data of 2003-2008 and concluded that readmissions were higher for EVAR than OAR. Readmissions were related to magnitude of open surgery in the case of OAR and devices issues in the case of EVAR and cardiac and infection problems in either case [121].

2.11.3 Long Term Survival

Long term survival after open and endovascular repair of intact AAA among Medicare beneficiaries was evaluated by [122]. US Medicare data on patients who underwent intact AAA repair during 2003-2007 were analyzed. Among older patients, use of OAR was associate with higher risk of all-cause and AAA related mortalities. Length of hospital stay was longer and incidence of incisional hernia repair were higher for OAR than EVAR. On the other hand, incidence of 1 year readmission, repeat AAA repair and lower extremity amputation were similar for both OAR and EVAR.

2.12 Medical Imaging Modalities

In the book of Upchurch et al. [123], chapter 3 deals with imaging procedures for aortic aneurysm and diagnosis of aneurysms are also covered in some other chapters. Recent advances have made CTA and MRA as the most useful diagnostic tool for aortic aneurysm. These developments have helped to reduce the procedural risks of trans-arterial catheterization. Cross-sectional images provide information on the affected blood vessel and length of its affected part, total aortic diameter and diameter of the artery, true vascular diameter which includes patent lumen, the extent of formation of mural thrombus, the distance of diseased wall from critical aortic branches and extravascular pathology. This imaging method is used as a single procedure for diagnosis, procedure planning and post-operative monitoring. It has helped to reduce the rate of morbidity and mortality. Catheter based angiography is used as an adjunct to treatment procedures. Integrated with contemporary cross-sectional imaging, this method includes uses of carbon dioxide angiography and intravascular ultrasound methods. Multiple imaging is done in which one pre-contrast imaging series and at least one contrast-enhanced imaging are included. Although contrast injection protocols include a number of parameters, the critical challenge is the optimal delivery of appropriate quantity of contrast to the volume of interest is a critical challenge. These protocols need to be carefully determined for each specific situation. CTA has definite edge over MRA in many respects. Renal impairment prevent use of iodine contrast agents. Renal protective strategies are used for its mitigation, with doubtful benefit at times.

The book edited by McGloughlin TM. [124] contains contributed chapters on epidemiology, aetiology and pathophysiology of aneurysms, imaging aneurysms, biomechanics, pathobiology of aortic aneurysms, computer-aided diagnosis of AAAs, mechanical properties of AAA tissue, fluid–structure interaction in healthy, diseased and endovascularly-treated AAAs, biomechanical aspects of AAA in relation to its risk of rupture, experimental analysis of endovascular treatment of AAA and predictors of long term outcomes, clinical assessment and treatment of TAs and intracranial aneurysms, modelling cerebral aneurysm evolution. Biomechanics section has fluid structure interaction (FSI) studies and computational analysis of displacement forces acting on endografts used for treatment of aortic aneurysms and biomechanical considerations of animal models of aortic aneurysm. Thus, although the book title focuses on biomechanics, the treatment of the subject is fairly exhaustive.

In the book, Vascular and Interventional radiology [125] has chapters in which aneurysms are also discussed. Mainly diagnostic angiography, diagnosis of vascular and non-vascular diseases and interventions, arteries, veins, aorta and fluid flows and interventions of various types are discussed.

A general textbook on imaging techniques by Haidekker MA. [126], first outlines the history of imaging technology and then discusses various imaging methods starting from X-ray and progresses through CT, nuclear imaging, MRI, ultrasound and finally trends on medical imaging. Variations of these methods are included in the topics.

According to Kamal et al., in 2008, duplex ultrasonography and CT were comparable in accuracy of aneurysm diameter post-endoluminal repair. The agreement on detection of endoleaks was moderate between the two methods. CT was more reliable for detection of endoleaks related to aneurysm growth. Contrast enhancement did not improve the accuracy of duplex ultrasonography in detecting endoleaks [127].

O'Connell applied novel electron and confocal microscopy to produce 3D images of aortic medial-, micro- and nano-structures from normal and AAA affected rat abdominal aortas [128]. Elastin dose disturbed smooth muscle cells leading to apoptosis and collagen remodeling leading to weaker collagen matrices. Repeated repair and remodeling cycles resulted in weakening of macroscopic vessel. Accumulation of localized failures resulted in ultimate rupture of aneurysm although strong and stiff collagen is present in them.

In a review on imaging techniques for detection and management of endoleaks occurring after EVAR, Stavropoulos, et al. stressed on the need for lifelong post-surgery surveillance to ensure proper stent graft functioning and to detect complications [129]. Endoleak is the main complication. CTA is the most commonly used device for its detection. MRA and ultrasound (US) are also suitable. After detection, diagnostic DSA is required for its classification. Continuous outcome-based imaging methods will enhance effectiveness of treatment procedure.

Bergqvist et al., in 2008 pointed out that most of the WHO criteria for screening for AAA are being followed in the case of males [130]. Nonetheless, more knowledge is required for applying them to females. Size is the main factor for treatment decisions. Thus many aneurysms are repaired which may not rupture at all.

US Medicare AAA screening benefit was being utilized only by less than 1% of those eligible. As screening will increase life expectancy of smokers with familial history for both males and females, average gain of 131 life years per 1000 screened persons is lost due to low utilization [131].

According to Rudarakanchana et al., in 2013, findings of 20th century favored screening of 65 year old males for AAA. However, in 21st century, prevalence of aneurysms in 65 year old males has declined by more than half [132]. This could be due to lower prevalence of smoking and better cardiovascular risk prevention. Surveillance rate frequency of one in three years for aneurysms of up to 4.5 cm diameter and annual surveillance for larger aneurysms on males older than 65 may be sufficient. This reduces surveillance visits by half.

Giving credit to contributions of Dr.Michael Ellis Debakey, particularly the development of Dacron grafts, Brunner, et al. described the current trends in diagnosis and treatment of AAA, especially ruptured AAA [133]. Innovative surgery techniques like synthetic grafts survival of such patients has become a strong possibility if timely disease management is practiced.

Litmanovich et al. reviewed the role of CT and MRI in diagnosing, surgical planning and follow-up of aortic aneurysms. Definition, natural history, causes and imaging principles of TA, AAA, TAA and acute aortic diseases were also covered. The maximum normal aortic diameters are given as 4 cm for ascending, 3 cm for descending thoracic and 2 cm for abdominal aorta [134]. For aneurysms, the sizes will be 5, 4 and 3 cm or larger respectively. While CT and MRI provide good images, imaging results with multi-detector CT depend upon specific protocols for best results. Utilization of maximum detector array and bolus timing software for optimization of contrast delivery timing, acquisition of thin sections and ensuring that a minimum volume of 100 ml non-ionic contrast material of correct dilution (350 mg Iodine per ml) was injected at rapid rate of infusion (4-5 ml/s) targeting to achieve opacification of aorta greater than 350 HU are some of them. Axial images are to be sued for initial detection and evaluation. Post-processing of data can yield further useful results. The main image processing methods are: multiplanar reformation (MPR), maximum intensity projection (MIP), curved planar reformation and 3D volume rendering. MPR of curved planar reformation is best as MIP and 3D have limitations. Contrast-enhanced MRA is more useful than MRI. MR images should be interpreted using measurements from source images in which vessel wall is visible. Better image quality can be obtained with cine imaging techniques like steady-state free precession imaging (SSFP) and fast imaging employing steady state acquisition (FIESTA). Contrast enhancement as ratio of T2 to T1 eliminates saturation effects. Oblique sagittal MRI displays entire length of aorta. Different protocols and imaging methods are suitable for different types of aneurysms.

Macedo et al., in 2004, reported on results of using various imaging devices to diagnose infected aortic aneurysm. These included CT, anteriograms, nuclear medicine, MRI. The devices were used to evaluate size, shape and location, branch involvement, calcification of aortic wall, gas, uptake of radiotracer, periaortic and other aspects. Angiography and MRI scans identified saccular aneurysms. Those with lobulated contour were also identified by angiography. Different imaging methods highlighted different aspects of infected aneurysms. Angiography, MDCT and MRI were the choice methods of the authors [135].

In a study comparing CT and Colour Duplex Ultrasound (CDU) for detection of endoleak after EVAR, Schmieder et al. in 2009 observed that CDU detected endoleaks needing intervention in 89% cases; but CT detected only 58% of such cases. The ability to correctly identify the endoleak type was 74% for CDU and 42% for CT. CDU had values of sensitivity 90%, specificity 81%, negative predictive value of 99% and positive predictive value of 16%. The corresponding values for CT were: 58%, 87%, 98% and 15% respectively. Thus, CDU had higher sensitivity but lower specificity than CT. CDU identified endoleak type better. Hence, CDU was superior to CT with respect to endoleak intervention [136]. In a similar comparison, Manning, et al. obtained positive predictive value of 45%, negative predictive value of 94%, specificity of 67% and sensitivity of 86% for CDU compared to CTA. Based on higher sensitivity and radiation hazards and cost, the authors preferred CDU over CTA [137]. Moreover, a third report on similar comparison, Beeman, et al. found both CDU and CT equivalent in detecting an endoleak accurately or falsely, in missing an endoleak detection and in determining aneurysm sac diameter. Use of CDU alone for surveillance saved cost by 29%. The authors supported exclusive use of CDU based on these findings [138].

According to Jadhav et al., MRA is better suited to blood flow evaluation and anatomical features of lumen. When combined with MRI, it can be used for high resolution visualization of parenchyma. With CTA, it is possible to rapidly assess large vessel patency and most vascular abnormalities. Further enhancement of sensitivity is possible using MDCT and dual energy CT. However, DSA is still the gold standard for characterization of vascular pathology when there is uncertainty regarding diagnosis for intervention decisions [139].

Usefulness of a sac angiography technique and the feasibility of N-butyl cyanoacrylate (NBCA) embolization were tested in the case of an emergency EVAR for ruptured AAA sac in hemodynamically unstable patients [140]. After performing stent grafting, angiography within the aneurysm sac (sac angiography) with manual injection of 10 ml contrast material was done using a catheter. This was done to identify the presence and site of active bleeding. Where bleeding was detected, NBCA embolization using coaxial catheter system was performed. Accumulation of NBCA as expected was shown in the follow-up CT images as was expected. Thus, sac angiography can detect endoleak bleeding of type II and IV and the imaging and embolizing techniques used here demonstrated successful outcomes.

The possibility of automated detection of aneurysm was explored by Stewart, in 1999 using differential geometry expressed by normal (cylindrical) and aneurysm (spherical) vascular tissues. Qualitative results suggested that the method can be used for identifying aneurysms prior to radiologist review of MRA studies [141]. In a similar work, Sharda in 2011 developed a method of constructing approximate 3D geometry of aneurysms from biplane angiograms using curve morphing technique. The method was validated using a large sample of cerebral aneurysm patients. The method was able to capture the shape characteristics of aneurysm better than the radiologist in approximating aneurysm as an ellipsoid formed from the three anatomical dimensions [142]. The usefulness of these findings is doubtful. Whatever pre-diagnosis is made, the final decision rests on review by radiologist.

2.12.1 Computed Tomography (CT)

Prosthetic graft placement is a common clinical practise for treatment of AAA and aorto-iliac occlusive disease. The most serious complication is infection of the graft and aorto-enteric fistula. Bruggink et al.[143], compared the diagnostic accuracy of fluoro-2-deoxy-D-glucose positron emission tomography (FDG-PET) with CT scanning to make fused FDG-PET-CT more remarkable in the diagnosis. Single FDG-PET recorded best results with sensitivity 93%, specificity 70%, positive predictive value 82% and negative predictive value 88%. Corresponding values were 56%, 57%, 60% and 58% for CT. Fused CT-FDG-PET also produced high values for the four variables. However, the best inter-observer agreement was obtained for FDG-PET was. Thus, for detection of vascular prosthetic graft infection, FDG-PET gave better diagnostic accuracy than CT. However, according to the results obtained by Fukuchi et al. [144], the sensitivity of PET was higher than CT (91 vs 64%), its specificity was lower than CT (64 vs 86%). When focal uptake was taken as the criterion for FDG, the specificity and positive predictive values improved to 95%. Use of characteristic uptake pattern of FDG as the criterion makes PET superior to CT for diagnosis of aortic graft infection. The findings of de Meijer et al. [145] also favoured use of FDG-PET and FDG-PET/CT as two non-invasive diagnostic options to detect vascular prosthetic graft infections. Basu, et al., also endorsed the combined use of PET/CT for detection of vascular graft infection and fistula was also endorsed [146].

Rozenblit et al.[147], found helical CT more sensitive than angiography to evaluate efficacy of endovascular grafts. Technical success is indicate by decreased or stable size of aneurysmal sac without perigraft channels in late follow-ups. Persistent or recurrent perigraft channels can cause later enlargement of aneurysm and therefore failure of graft procedure.

For detection of cerebral artery aneurysm, 74-row multisection computed tomography MSCT) was more effective than 3D DSA in the meta-analysis done by[148]. In the context of coronary artery disease, [149] discussed the basic principles and technical aspects of PET in comparison with Single Photon Emission Computed Tomography (SPECT) (a variant of PET) and the hybrid fused PET-CT. Radiation safety is an issue with PET.

2.12.2 Computed Tomography Angiography (CTA)

Selective catheter angiography is still a method for diagnosis of aortic aneurysm. The risk of permanent neurological complications undergoing DSA is low. The method is invasive and time consuming.

CTA is a quick, reliable, simple and non-invasive diagnostic tool for aneurysms and can effectively replace conventional angiography [150]. Therefore, according to Prestigiacomo, et al. 3-D CTA can be used as an initial screening tool in place of DSA. Sensitivity and predictive values of 100% were obtained by them. Sensitivity of 2D and 3D CTA to detect very small aneurysms was 98-100% compared to 95% for DSA [151]. CTA accuracy was also 99-100%. Based on these findings, Villablanca, et al. recommended use of CTA with commercial detectors to detect very small aneurysms [152]. Even without pre-operative angiography, pre-operative 3D CTA (instead of DSA angiography) can provide good anatomical information for microsurgical interventions of aneurysms, as was concluded by González-Darder, et al. [153]. According to Forsting in 2005, concluded that CTA can effectively replace DSA and even MRA for diagnosis aneurysm [154]. Hoh, et al. demonstrated the possibility of using only CTA instead of DSA for diagnosis and pre-treatment planning in patients with ruptured and unruptured aneurysms in Massachusetts General Hospital [155]. In the findings of Karamessini, et al., CTA had sensitivity, specificity, positive predictive, negative predictive and accuracy values of 88.7%, 100%, 100%, 80.7% and 92.3%. The corresponding values for DSA were: 87.8%, 98%, 97.7%, 89.1% and 92.9% respectively [156]. On the basis of these findings, the authors concluded that CTA and DSA were equally good for detection of aneurysms of 3 mm or more. With 100% detection accuracy, CTA is also useful to detect AcoA and MCA bifurcation aneurysms. According to Matsumoto et al., 3D CTA can effectively replace conventional catheter angiography in the diagnosis and surgery of most ruptured aneurysms [157]. Furthermore, a recent systematic review study in 2015 by Alamoudi et al. also support use of CTA as an effective substitute for other imaging methods, at least to some extent, in treatment and diagnosis of AAA [158]. In measuring volume of aneurysms, CTA, MRA and rotational DSA produced statistically non-significant differences and hence can be considered equally as per the report of Piotin et al. [159].

On the other hand, in a comparative study, Biasi et al. found CTA inadequate to detect small aneurysms occasionally and therefore recommended DSA/3D Rotational angiography [160]. Stavropoulos et al. also considered CTA inferior in detecting small aneurysms and use of DSA should be continued. Difficulty of detecting small aneurysms using CTA has been reported by many other workers as well [129].

According to latest study in 2015, Chung et al, multi-slice 3D CTA offers better image resolution and hence more useful than single slice CTA to detect aortic aneurysms for post EVAR [161]. In another finding, Van Gelder [162] supported further investigation of small aneurysms detected by CTA if there is no pre-test probability of ruptured aneurysm. Very low probability of clinically significant aneurysms can be detected by CTA when screening is done for unruptured aneurysms.

Some technological improvements include Sailer et al. in 2014 on using fluoroscopy image fusion guidance for CTA in endovascular interventions to reduce iodine contrast dose and procedure duration [163], Deak et al., 2014 on automated systems for detection of aortic aneurysms in CTA images [164], and Wada et al., 2014 on combining 3D CTA with 2D CT imaging guidance for clipping surgery [165].

There is risk due to the need for iodine contrast agent and radiation exposure. This limits its large scale use especially as a screening tool. However, it can be used effectively in the pre-therapeutic phase. It is especially useful in the case of large and giant aneurysms. In certain cases of hematoma, CTA can rule out underlying aneurysm. Patients on whom

MRA cannot be performed, CTA can be useful. As CTA is independent of flow rate, diagnosis possible even with low cardiac output. Here MRA may have saturation effects. Aneurysm wall classifications and assessing completeness of aneurism clipping can be done with CTA. However, CTA cannot be used in patients for angiographic follow up of patients treated with endovascular methods. Time of flight (TOF) MRA can be used here, especially for aneurysms less than 10 mm size. Contrast-enhance MRA may need to be used for examination of large and giant aneurysms as an additional method.

2.12.3 Magnetic Resonance Imaging (MRI)

In MRI radiofrequencies and magnetic fields are used for imaging. MRI depends on the weighted sequences of the integrated spectrum of tissue appearances on its T1 (longitudinal recovery) and T2 (transverse recovery). When this is used for non-invasive vascular imaging, it is called MRA. Many modifications of basic technology are applied for various applications. Association of Gadolinium-based contrast agents with certain nephrogenic systemic fibrosis disorders is suspected in patients with impaired renal function. Therefore caution is required in its use and non-contrast techniques may be the only option. Although this article describes various imaging methods used in aortic aneurysm, risk factors and limitations are not discussed adequately. Many points discussed here are similar to those in [166] detailed above.

Usefulness of gadolinium (Gd) based contrast-enhanced 3D image acquisition in MR scans for detection and diagnosis of vascular diseases was explained by Zhang et al. [167]. Optimization of contrast enhanced MRA depends on the interaction of factors such as contrast injection timing, Fourier mapping of data, the multi-tube parameters of resolution, coverage of anatomy and sensitivity to motion artefacts. The bolus peak timing should coincide with acquisition of central k-space data. This determines the image contrast. Reconstruction of multiple 3D acquisitions in rapid progression can be done by oversampling central k-space. Resolution can be increased scan time can be shortened by parallel imaging. This also achieves compression of central k-space into shorter time which help to minimize artefacts of motion and timing. As there is no ionizing radiation, MRA can be repeated and it can be combined with additional sequences of more important scans to enable full characterization of anatomy, physiology and flow. Use of stepping table technology and thigh compression permits whole body scans using a single contrast injection. With advancement of technology, contrast enhanced MRA becomes better and simpler. This can enhance the efficiencies of diagnosis and management of vascular diseases.

As PET/CT has emerged as good hybrid imaging tool, the scope for using PET/MRI as a better imaging tool was evaluated by [168]. Hybrid PET/MR is already in clinical use. However, PET/MRI combines the positive aspects of the two tools better. The features of MRI such as good soft tissue contrast, dynamic contrast-enhanced imaging and diffusion-weighted imaging combine well with quantitative physiological information given by PET. Therefore, PET/MRI has distinct advantages over PET/CT combinations. Research in this aspect being in the initial stages, the authors are less specific about the competitive edge PET/MRI offers over PET/CT combination. Whatever advantage, it should be clearly due to MRI over CT as PET is common to both combinations. The advantages of combining PET and MRI in the same imaging session was also demonstrated *in vivo* in a myocardial infection of mouse heart by [169]. The authors used MRI to assess heart function, hindered profusion with late gandolinium-enhanced imaging, muscular functions with displacement encoding by stimulated dense MRI. PET with 18F-fluorodeoxygloucose was complemented to assess the metabolism. Support for preferred use of PET/MRI is also provided by Schwenzer et al. [170].

2.12.4 Magnetic Resonance Angiography (MRA)

MRA is a fast, accurate and non-invasive procedure for evaluation of intracranial aneurysms. It avoids the risks of conventional angiography. With good spatial resolution and sufficient field of view, it covers all relevant intra-dural arteries. It can be used within a reasonable acquisition time. Method of image processing and interpretation determines its accuracy. With maximum intensity projection alone, per patient aneurysm identification sensitivity was 75%. With axial source and spin echo images, sensitivity increased to 95%. Aneurysms of larger than 6 mm produce sensitivity higher than 95%. But it is reduced to as low as56% when the size is smaller than 5 mm. Some reports suggest that TOF-MRA can be used for smaller size of up to 3 mm, but not below this size in any case. This needs to be considered when using for screening programmes and follow up after coiling. DSA may be superior in some cases and MRA can only be complementary. Utility of MRA for diagnostic and predictability is lower compared to that of DSA in some applications. The skills of the reader may determine the quality of diagnosis. Overall, MRA is considered useful by majority of practitioners as a follow up tool with known aneurysms or post-endovascular treatment. It is also useful for screening programs on high risk patients of strong family history of SAH or multiple aneurysms or other risk factors.

2.12.5 Ultrasound Scan (US)

Hafez et al.[171], noticed an AAA prevalence of 4.4% initially. Another 2.8% (120 persons) developed AAA in subsequent scanning 26 persons were detected AAA incidentally.

During the follow-up period on these 166 persons, 14% died of AAA-related causes, another 14% had successful surgery. The findings showed that AAA can develop in normal persons further to initial scans. Those with sizes of 2.5 to 2.9 cm face high risk and their surveillance can reduce mortality risk.

Under current guidelines, about half the population are outside the scope of AAA screening. Kent et al.[172], undertook a cohort study on over 3 million persons who were screened during 2003-2008. Smoking, obesity, white or Native Americans, male gender, age, positive family history and cardiovascular diseases were risk factors. Using a predictive model, the authors estimated 1.1 million AAA cases of persons over 65 years in USA of which 569000 were women. The algorithm include people who were at risk, but not included in the current screening program.

Lezzi et al.[173], found contrast-enhanced ultrasound superior to unenhanced colour duplex ultrasound and the standard CTA in endoleak detection of AAA post-EVAR follow-up. Using of recommended dose of 2.4 ml contrast medium was important. Similar finding was obtained by Napoli et al. [174] in the case of endoleaks missed by CTA. Delayed slow echo enhancement was detected for more than 150 seconds after contrast injection. BVI 9600 did not have sufficient accuracy to detect AAA in screening programs as reported by [175]. The aim of the authors was to reduce the cost of screening by reducing the need for training the operator of screening equipment and BVI 9600 was considered suitable for this purpose.

In UK, for AAA initial screening with ultrasound and using CT for aneurysm which reaches the size requiring intervention achieved good results. For peripheral aneurysms like femoral and popliteal aneurysms, ultrasound alone was sufficient [176].

Lederle FA.[177], in a review, summarized the status of current knowledge about various aspects of AAA screening based on four randomized trials involving more than 125000 men. In a recent review, Guirguis-Blake, et al., in 2014, supported one time invitation screening using ultrasound of men aged above 65 years for AAA based on the benefits highlighted by evidence [178].

Noting that development of surgical techniques depend on development of imaging techniques, Scarcello et al.[179], defined the role of ultrasound as diagnosis, AAA location, per operative management with IVUS mode and post-operative follow-up.

2.12.6 Digital Subtraction Angiography (DSA)

High resolution makes conventional angiography the most desirable diagnostic tool for aortic aneurysm. It is done at the earliest opportunity of patient presentation after bleeding. Rehaemorrhage risk being high within the first 24 hours, an early angiogram is necessary for therapeutic decisions. Aortic angiography can locate lesions, reveal the size and shape of aneurysm, detect presence of multiple aneurysms, examine vascular anatomy and its collaterals and evaluate presence of vasospasm and its intensity.

Comparisons of CTA and DSA done by many workers have been discussed above. Other works related to DSA are reviewed here. More often, DSA is used as a confirmatory or extended test of other imaging methods. For example, although 3D CTA compared very well with DSA, in the experiment, DSA was used for confirmation of the results obtained with 3D CTA in the work of Thurnher et al [180]. The 3D rotational reconstructed DSA images can improve the assessment of aneurysms [181]. Although CTA can add value to DSA, it can never replace it [182]. In one finding Van Rooij et al., 3D Rotational Angiography (3DRA) was found superior to DSA and hence suggested it as the new gold standard [183]. However, according to Zhang, et al. contrast-enhanced dual energy CTA had better diagnostic image quality at lower radiation dose than 3D DSA. Based on their research [184], Defillo et al. concluded that indocyanin green video-angiography (ICGV) had distinct advantages over intraoperative catheter DSA with respect to rapid feedback and visualizing of local perforators [185]. DSA had better visualization of residual aneurysm and parent artery stenosis which did not limit flow. Based on these findings, they recommended combined use of the two imaging tools. On the other hand, due to missing of small neck remnants and some residual aneurysms by ICGV. DSA is necessary for quality of surgery assessment in complex aneurysms. Better image quality is possible with lower dose of radiation, according to the results obtained by Pearl et al [186].

CO2-DSA gave better results than conventional DS in detecting Type I and Type II direct endoleaks in EVAR procedure. This is because CO2-DSA had higher sensitivity and specificity than conventional DSA [187]. In the studies of Wacker et al., in 2014, C-arm CT used as a supplementary imaging tool with DSA for better localization and classification of endoleaks than DSA alone in EVAR repair [188].

2.12.7 Screening Programs to Prevent Rupture and Mortality

Using the success of Gloucestershire screening program, [189] showed that mortality rates due to ruptured AAA was 50%, but preventable by national screening program using ultrasound examination in UK. Screening prevented mortality by 42%, equivalent to around 6000 annual deaths of men due to ruptured AAA.

In a dissertation, Hager J.[190], investigated on how to reduce mortality rates from ruptured AAA. Mortality rate due to ruptured AAA was about 80%. Prevalence of AAA detected by screening was 23%, about half of what was predicted. For men of 70 plus, screening was not effective as they were already known to have AAA due to opportunistic detection. In spite of this result, the author recommended screening of 65 plus men based on cost-effectiveness.

A screening program by Veterans Affairs mandate according to SAAAVE Act done during 2007-2008 was evaluated by Lee et al [191]. AAA prevalence was 5.1% of screened population. Size distribution was: 83% of 3-4.4 cm, 13% of 4.5-5 cm and 4% larger than 5 cm. Cost per patient was $53. The results of a similar recent study were reported by Shreibati, et al. in 2012 [192]. The screening program as per SAAAVE Act on Medicare beneficiaries. There was negligible impact of the Act on AAA rupture, all-cause mortality and medical reimbursement. Communication failures at various points can cause poor outcomes for patients as was demonstrated by Berlin [193]. According to Shreibati et al, there was no significant impact on AAA screening, AAA rupture or all-cause mortality due to Screening Abdominal Aortic Aneurysms Very Efficiently (SAAAVE) Act. Medicare USA began the program in 2007. This prompted Harris, et al. in 2012, to suggest a rethink on the program [194].

The factors involved in a typical screening work are available from the thesis of Lacke [195]. Screening procedures for asymptomatic, adults of 50-85, who have average risk of getting colorectal cancer was determined. Probability distributions for effectiveness variables of 25 procedures were constructed. Expected utility and unit costs were built into the model and procedures were ranked as per preferential order based on these parameters. A similar system may be possible when screening for aneurysm is considered.

The AAA screening program of Veteran Affairs Western New York Healthcare System (VAWNYHS) 2010-2012 was evaluated for its surgical outcomes by Malecki [196]. Patients who were identified for aneurysm prior to elective surgery in the screening program had shorter hospital stay compared to those who were not. The screening program detected a larger number of aneurysms than in the previous clinical trials. Cost-effective integrated care delivery was made possible by the screening program. VA clinical reminder system can be expanded.

UK National AAA screening program for persons aged 65 and above was started in 2009. The success of Gloucester and Chichester programs paved the way for more extensive national screening program, as discussed by [197]. It covers about 80000 persons per year. It involves an abdominal ultrasound scan and determination of aortic diameter. Further action is based on observed aortic diameter of the individual. The initial results of 2009-2012 showed that more than 98% of screened persons had aortic diameter less than 3 cm. The cost-effectiveness of national screening to identify less than 2% risky AAA patients from 80000 persons is being evaluated[198]. From the results on 188 men, observed that only 12% people never smoked and the rest were either still smoking or were past smokers. Other top risk factors were: known treated hypertension, treated dyslipidemia, ischemic heart disease, diabetes and family history. [199]cited the work of [200] to justify screening for aneurisms of persons with family history. Bor et al. had found that history of familial aneurysm was the only significant risk factor for follow-up aneurysm screening. As small aneurysms have high potential for rapid growth to become big and rupture, [201] advocated screening of all people at 35 and again at 50 to give younger people a chance for early detection before rupture and older people another chance for detection before age-related risks take over. He also suggested repeat annual check-up for those with small aneurysms to assess growth so that fast growing ones heading for rupture can be detected early and treatment can be devised before rupture. Costs are justified even considering low incident rate of aneurysms as small aneurysms are also included.

Recommendations for an effective screening, surveillance and referral program were given by Robinson et al. [202] for Australia. Chun et al., noted in 2013 that more number of smaller aneurysms were detected in a screening program of Veterans Affairs which started in 2007. Over 2007-2011, inappropriate screening decreased due to increased awareness and proper application of screening guidelines. Surveillance guidelines are required for small and medium aneurysms are necessary for future [203]. Lalka et al, reviewed various imaging techniques available for screening, diagnosis, non-operative surveillance ,and open and endovascular repair of AAA [204].

In a comment on the paper by Harrison et al. [205], van der Vliet et al. [206] concluded that late secondary endoleak interventions need to be done only when there is enlargement of aneurysm sac and therefore it is sufficient to screen for aneurysm growth. This can be done using serial, plain, thick (5 mm) sliced, non-contrast CT scanning or duplex ultrasound (DUS). Thus the need to combine plain abdominal angiography may seem roundabout procedure. No great cost saving or reduction in radiation exposure is achieved even by the findings of Harrison et al. From a detailed study, Hager J. [190] concluded that screening 65 years old men is the best available method to minimize mortality from ruptured AAA.

2.13 Diagnostic Imaging Guidelines

The screening guidelines of Canadian Society for vascular surgery requires revision based on new evidence [207]. In Canada, ultrasound screening of 65-75 old men is done and is cost-effective. Relative risk of AAA-related mortality is 0.49 for this group compared to no screen. There is little benefit by screening of men beyond 75 years old. Screening of women over 75 years not recommended. Individualized check-up women over 65 years is adequate. No follow-up screening is required for AAA size less than 3 cm. Although annual screening of individuals with 3-4.4 cm is routinely done, evidence for this is weak. Screening every two years may be enough. Screening for popliteal aneurysm may be beneficial. There is no benefit by screening men or women less than 65 years. Physical examination of can supplement screening wherever necessary. As advances in surgery techniques reduce AAA-related mortality rates, the cost-effectiveness of screening needs to be reviewed periodically.

A set of guidelines on clinical practices for endovascular AAA repair was given by Walker et al [208]. The guidelines deals with endovascular repair, its indications and contradictions, EVAR requirements of patients, procedural assessment before repair containing detailed imaging methods and scoring systems, endograft types and their suitability, technical aspects of surgical procedure and post-operative management. Another set of guidelines on the same topic was published for European Society for Vascular Surgery [209]. There was also an earlier set of guidelines of Society for Vascular Nursing (SVN) Task Force published by Smith, et al [210]. This covers mostly the nursing and patient care aspects of pre-operative, intraoperative and post-operative stages. The guidelines uses evidence-based best practices approach. A set of guidelines for peripheral arterial disease was published by Hirsch, et al, on behalf of ACC/AHA (American College of Cardiology/American Heart Association) and collaborated by many other related organizations. This contains information on classification of levels of evidence and standards of their acceptance. The diseases included are: lower extremity, renal, mesenteric and abdominal aortic aneurysms [211].

American College of Cardiology Foundation (ACCF) and American Heart Association (AHA) jointly published a set of guidelines for diagnosis and management of patients with TA [212]. This contains recommendations for imaging and detection/identification/evaluation of genetic syndromes, familial TA and dissections, bicuspid aortic valve and associated congenital variants in adults; estimation of pre-test risk of thoracic aortic dissection; initial evaluation and management of acute thoracic aortic disease; surgical intervention for acute thoracic aortic dissection and intramural hematoma without intimal defect, history; physical examination of thoracic aortic disease; medical treatment of patients with thoracic aortic diseases, asymptomatic patients with ascending aortic aneurysm and symptomatic patients with TA; open surgery for ascending aortic aneurysm, aortic arch aneurysms, descending thoracic aorta and thoracico-abdominal aortic aneurysm; counselling and management of chronic aortic diseases in pregnancy, aortic arch and thoracic aortic atheroma and athero-embolic diseases; periprocedural and perioperative management; surveillance of thoracic aortic disease and previously repaired patients and employment and lifestyle in patients with thoracic aortic disease.

Several guidelines are being published by a variety of organizations within countries an internationally. It is appropriate to evaluate these guidelines with respect to their usefulness in routine clinical practices. Ferket, et al., in 2012 reviewed the guidelines published on screening for AAA during 2003-2010. Of 2415 titles, seven were included in this study. These were: USPSTF2005, ACC2005, NSC2007, CSVS2007, CCS2005, SVS1 of 2004 and SVS2 of 2009 [213]. Unfortunately, some of the more recent ones discussed above were not included. Some changes in the classification systems of ICD in different years could also affect evaluation.

There was consensus across the guidelines regarding one time screening of elderly men to detect and treat aneurysms of larger than 5.5 cm size. For smaller aneurysms and other target groups, prediction models and effectiveness analysis are needed.

American Image Management (AIM) guidelines on diagnostic imaging, known as (AIM,2010) [214] contains imaging protocols for various parts of the body using CT, MRI, PET, CTA, MRA and other imaging methods including proton beam treatment. These have also been published in parts as updated versions later in 2014.

American College of Radiology (ACR) has also published appropriateness criteria for AAA interventional planning and follow-up [215]. It contains rating for appropriateness for planning pre-endovascular repair or open repair and for follow-up after these repairs with a note by experts. Best practices guidelines on clinical decision support systems has been published by ACR and Radiology Business Management Association (RBMA) jointly (ACR, et al., 2012). This contains evidence-based best practices related to all heath care service components aimed at best patient outcomes. Other ACR guidelines are on development of evidence tables for diagnostic studies (ACR, 2013), literature search process (ACR, 2013), non-traumatic aortic disease (ACR, 2013), procedure information like contrast used and PET (ACR, 2013) and topic review process (ACR, 2013). All these appropriateness criteria (as they are called) follow a standard format containing explanatory notes by experts.

National Guidelines Clearing House is a database for evidence-based clinical practices guidelines prepared by various organizations for comparison, synthesizes guidelines prepared by different agencies on the same topic for similarities and differences and serves as an electronic platform for exchanging information on such guidelines and is also a source of annotated bibliography database. Two of these deal with cardiovascular diseases [216].

2.13.1 Hospital Compliance of ACR Guideline on Abdominal Aortic Aneurysm

Huber et al.[217], collected NIS data for 1994-1996. Most patients were white males. Majority of repairs were done at large, urban and non-teaching hospitals. The hospital mortality rate was 4.2%. There was 32.4% incidence of complications. Home discharge rate was 91.2%. Bad outcome was experienced in 12.6%. Bad outcome was related to age, gender, complications and comorbidities (patient classifications) and hospital size and year of procedure. The authors concluded that outcome after open repair of intact AAA in US was good. However, only white males visiting the hospitals and procedures done only at large, urban non-teaching hospitals shows skewed behavior of AAA detection and treatment. There may be a certain degree of not falling in line with ACR guidelines in some respects. However, this is not clear from the results as only short-term data were selected and the methods used were unable to detect this.

Extent of compliance with long term surveillance recommendations following EVAR and type B aortic dissection was found poor due to lack of coordinated approach. Cases of 204 patients (171 EVAR, 33 type B dissection) were evaluated. Of 171 EVAR, 100 were AAA, 45 TA, 12 TAA, 7 iliac artery and 7 proximal graft extensions. Medium follow up period was 28±10.5 months. Overall, 56% were lost to follow-up and 11% never returned after initial hospitalization [218]. Lakhani at al.[219], reported increase in non-routine radiological communications especially of critical finings in a tertiary hospital during 1997-2005 due to increasing compliance with ACR guidelines. According to Benjamin et al.[220], compliance of the radiologist with hospital guidelines for non-routine communication of diagnostic imaging results gave better outcomes in a general hospital. Such communications were required most for CT, followed by MRI and ultrasound.

Good correlation was found Gilk et al. [221] between 2013 updated ACR guidelines on MR safe practices and the Joint Commission's Sentinel Event Alert No 39 on MR safety as the Environment of Care standards. About 90% of US academic Emergency Departments deviated from ACR guidelines on contrast practices for abdominal and pelvic CT imaging, observed [222]. According to Abramson et al.[223], there are wide variations with respect to compliance on ACR guidelines by different hospitals. Some reports on compliance of hospitals with ACR guidelines on fluoroscopy and CT were cited and discussed by [224]. Quality Assurance protocols, tracking exposure time and direct measurement of patient exposure time all based on ACR guidelines have improved compliance in reducing radiation exposure in some hospitals.

Besides these reports on some factors related to compliance of hospitals with ACR guidelines, many individual hospitals have reported receiving awards and certificates of ACR imaging compliance.

In general, there is no direct studies on effect of extent of ACR compliance on aneurysm deaths. The findings discussed above only indicate lack of compliance on certain aspects of ACR guidelines, but nothing to connect them with aneurysm mortality. The importance of this study is evident from this research gap.

2.13.2 Cost Effectiveness

A comparison of cost-effectiveness and cost-utility ratios of EVAR and OAR was done by Tarride et al. [225] at Ontario Canada in a one year observational study. EVAR was more cost-effective compared to OAR in high risk patients. Point estimates showed EVAR better than OAR with respect to incremental cost per life year gained and incremental cost per QALY. But bootstrap method showed high degree of uncertainties regarding costs and QALYs with less uncertainty regarding life years gained. In a similar comparison as part of DREAM project in Netherlands, Prinssen et al. did not obtain cost-effectiveness for EVAR over OAR in terms of QALY at one year post-operatively. Overall survival benefit was only marginal for EVAR over OAR and it was associated with significant increase in costs [226].

Analysis of clinical and fiscal outcomes of clinical pathways from admission to discharge of select cases enabled identification of methods to optimize resource use, nursing pattern and hospital stay of the patient. Reduction in charges by 33% compare to baseline before implementation of pathway was achieved [227]. Walsh, 2012 observed that health care expenditure statements contained substantial unexplained variation with regard to adjusted costs and length of hospital stay within and between hospitals. This demonstrates scope for cost reduction and length of stay so that declining reimbursement can be managed better and maintain operating margins can be kept at safe levels [228].

In a Canadian attempt, Blackhouse et al., compared the cost-effectiveness of EVAR and OR using a decision model with 10 years horizon. The primary outcome was QALY (quality adjusted life years). Costs and benefits of both perioperative and postoperative outcome values obtained from data sources were incorporated. Incremental cost per year of QALY were $268337 for EVAR against the incremental cost per life year of $444129. The incremental cost per QALY of EVAR remained at the level of $295715 irrespective of age, and time horizon. Based on commonly referred willingness to pay thresholds, EVAR was not as cost-effective as OAR [229].

On the basis of their detailed study, Silverstein et al., reviewed the evidence for three scenarios on AAA: screening decisions, monitoring and referring patients for surgery based on sizes of aneurysms and assessing patients who have symptoms related to AAA [230]. The effectiveness and cost-effectiveness were evaluated using the results of four RCTs. Cost effectiveness analysis was done using Markov model. It showed ultrasound screening of white men above 65 (or even 55) of age is effective as well as cost effective. This does not support the current recommendations of US Preventive Services Task Force to do a one-time screening of men aged 65-75 who have smoked at any time. Patients with asymptomatic AAA of size below 5.5 cm should have at least one annual screening and increase it to half yearly or quarterly when it reaches 5.0 cm size. AAA larger than 5.5 cm need to be repaired if the risk associated with it is acceptable. Repairs should be done at centers where less than 6% operative mortality is recorded for elective open repair. Cessation of smoking is beneficial for patients with small aneurysms. In the case of patients with known AAA or its risk factors like age more than 50, smoking, white and male, ultrasound imaging should be done to confirm presence of AAA or other causes of abdominal/back pain. If AAA is detected, a CT scan should be done to eliminate the possibility of rupture and referred to the concerned surgeon. For patients with recent or severe symptoms, direct CT scan bypassing initial ultrasound route is to be done. This can identify whether it is an aneurysm with or without retroperitoneal hemorrhage and other complications and reveal the pre-operative anatomy. If AAA rupture is suspected, the patients should be intensively monitored. For those, who are not hypotensive, an immediate CT scan with contrast can facilitate accurate surgical approach and save lives. For hypotensive patients, surgery should be done immediately without waiting for further imaging.

Giardina et al. [231] listed their scenarios as: no AAA detected, unknown small AAA of size 3-3.9 cm, followed-up small AAA (1 year), unknown medium-sized AAA (4-4.9 cm), followed-up medium-sized AAA (6 months), unknown large AAA (>5 cm), elective repair, emergency repair, post elective repair AAA, post emergency-repair AAA, rejected large AAA, and death, all transitioned as six monthly cycles. Values and probabilities were assigned using data from research results. An attendance rate of 62% was considered for cost workings. Screening for AAA was cost-effective based on a threshold of willingness to pay at 50000 Euros per QALY.

According to Ehlers et al. [232], screening of men above 65 for AAA was not cost-effective in the Danish context. Invited or uninvited men of 65 or higher were hypothetically selected. Published results were used as data sources. For short term and long term effects of AAA screening, a hybrid decision tree and a Markov model were developed. Monte Carlo simulation was used for probabilistic sensitivity analysis. Relationships of cost effectiveness acceptability gains expected value of perfect information and against expected net avoidable deaths were graphed. The validation pf the model was done by calibrating base case outcomes and expected activity levels against recent evidence from scientific data. For a threshold level of willingness to pay threshold at £30000, the estimated effectiveness cost per QALY was £43485. This indicated that the probability of AAA screening to be cost effective to be less than 30%. However, another Danish study by Søgaard, et al., in 2012 obtained high cost-effectiveness when screening and rescreening were considered. The threshold was £20000. One time rescreening after five years of men having an aortic diameter ranging 25-29 mm at the initial screening benefitted 452 men per 100000 of the initially screened and life time screening every five ears benefitted 794 men per 100000. The cost effectiveness ratios of the two options were estimated. The rescreening cost-effectiveness was higher than that of one time screening strategy. Therefore and screening and rescreening at least once is cost-effective and beneficial [233].

Cardiovascular and chronic pulmonary diseases increase AAA risks. Hence, Lindholt et al., evaluated whether screening program for males could be restricted to this group. The screening was attended by 78.8% of the high risk group, out of whom 6.7% had AAA. Of the remaining population, 75.8% were screened and 2.9% had AAA. If only high risk group was screened, 72.9% less men would have been screened which would have detected AAA in 46.1% persons. This would have prevented 46.7% AAA related deaths. As screening decreased mortality of both high risk and low risk groups, with mortality ratio of 0.22 [234].

Thus, high risk group can prevent only less than half the AAA deaths. Therefore, there is no advantage by selective screening of high risk group alone.

Selective screening of patients, who were referred to the vascular laboratory for arterial examination was cost-effective, according to Mani, et al., although they had inferior long term survival and therefore operated less frequently [235]. Fleming, et al., in spite of lack of direct evidence, conclude from their review that men of 65-75 years can be screened for mortality reduction [236].

In a Swedish study, Wanhainen et al., used a Markov simulation cohort model. Screening 60 years old men was as effective as screening when they were 65 years old with more life years gained as an added benefit. A trade-off between high prevalence of AAA and lower life expectancy was noticeable [237]. This removed the expected benefits of screening high risk groups like smokers and cardiovascular patients. Overall, in the long term, screening men for AAA may be cost-effective.

On reviewing eight cost-effectiveness models published during 1993-2007, Schmidt et al., observe that out of eight models reviewed, one model recorded additional costs due to loss of life years. Expected life gains of 0.02 to 0.28 Lys were observed in the case of the remaining seven models gave. Six models gave QALY 0.15 to 0.59 QALY [238]. Overall, AAA screening program may confer gains of additional life years and quality of life at extra costs of acceptable levels, when screening is done on men of 65 years or above.

2.14 Summary of Literature Review

Some skewness in aneurysm management in the US are indicated in a number of works. These are:

- Not all aneurysm patients are treated.
- Due to not being insured, inability to cover the costs prevent many patients getting any treatment.
- All those reaching hospital are not diagnosed and some are left out.
- Many factors prevent many diagnosed persons from getting treated.
- Disparities of age, ethnicity, gender and socio-economic status are visible.

Right services are not always guaranteed to all patients equally when presented in the hospital. Thus, improper diagnosis, or using inappropriate imaging method, misdiagnosis, not referring for right treatment and presence of other complications and comorbidities contribute to such problems.

Patients treated may not survive due to patient level factors like old age, sickness, late intervention and psychological difficulty to adjust life after the treatment.

Hospital contexts which can lead to death of patients are: incorrect diagnosis due to wrong imaging protocols and incorrect treatment due to wrong diagnosis or any of the several other hospital factors.

Imaging techniques are used for diagnosis and treatment of aneurysms. ACR has published guidelines to hospitals for safe and effective imaging practices with various imaging equipment. However, hospitals vary in their resources and human capabilities. These include: type of hospital, location, funding, physical facilities, types of imaging equipment, human resources and their competencies, costs and prices, other logistics and management style. These determine how the resources and capabilities are deployed and to what extent the guidelines are complied with.

The three basic questions in this regard are-

1. Does the imaging method influence mortality during hospitalization among aortic aneurysm patients who underwent interventional repair? Could a different imaging method have been more suitable for better diagnosis for more appropriate intervention and thus reduce mortality?
2. Does the extent of compliance on ACR imaging guidelines by the hospital impact in-hospital mortality of aneurysm patients in the hospital? Whatever be the imaging method used, did the hospital fully comply with ACR guidelines on imaging procedures? Do inadequacies of compliance increase mortality?
3. What is the role of various patient characteristics and hospital contexts on in-hospital mortality with respect to the relationship between imaging procedure adopted and interventional repair?

Two more associated questions are-

1. Does compliance guarantee significant reduction in in-hospital mortality rates? If so, how to determine the extent of compliance both in terms of items complied/not complied and extent of compliance?
2. What factors, related to or other than compliance determine in-hospital mortality rates?

These questions need urgent answers. The following chapters describe how these questions were addressed and what answers were obtained.

The next chapter (Materials and Methods) outlines the methodology followed for this study on finding answers to the above questions.

CHAPTER III: MATERIALS AND METHODS

3.1 Overview

In the previous chapter on Review of Literature, works related to aortic aneurysm, its types, prevalence, diagnosis and treatment were evaluated in detail. Use of various imaging techniques both for diagnosis and repair procedures for treatment of aortic aneurysms was specifically examined. It was noted that various guidelines exist regarding the facilities, equipment, actual imaging protocols and interpretation of imaging results.

This study utilized a series of processing methods on the NIS data, data mining techniques and statistical procedures to attain its goals. Data cleaning, recoding, extraction were used to arrange the raw data for the analysis. Statistical analysis such as frequencies, correlation, Chi-square analysis, logistic regression and multinominal logistic test were applied. All of these different methodologies were used to analyze and process a big data set derived from multiple years from 2008 to 2012 and geographically collected from more than 4,300 hospitals across the United States of America, as given in **Figure 6**.

Figure 6: Data from Hospitals Have Participated Across the United States.

3.2 Objectives, Variables and Statistical Analysis Procedures

The NIS data set on different variables covering the period of 2008-2012 were used in this project. The variables required to fulfil different objectives are as given in **Table 4.**

Table 4: Relationship of Objectives, and Statistical Analysis Procedures

No	OBJECTIVE	STATISTICAL TESTS APPLIED
1	To study the relation between imaging modalities and in-hospital mortality among aortic aneurysm patients through US hospitals.	Pearson Chi-Square test
		McNemar's test
		ANOVA test
		Logistic Regression test
2	To compare in-hospital mortality of EVAR with OAR when different diagnostic imaging techniques are used in both cases.	Pearson Chi-Square test
		McNemar's test
		ANOVA test
		Logistic Regression test
3	To evaluate the effect of using ACR recommended imaging methods and extent of compliance on in-hospital mortality.	Pearson Chi-Square test
		Gamma Correlation test
		Logistic Regression test
4	To determine among different patient characteristics, and hospital context, those factors which can be used for prediction and thereby reduction of in-hospital mortality to desire levels.	Logistic Regression test
5	To determine among significant predictor factors, which type of diagnostic imaging performed is associated with in-hospital mortality.	Multinominal Logistic test

3.3 Data Availability

Availability of the required data is a major factor in the ability to perform the above tests. In this project, all the required data are to be sourced from NIS data set. Hospitals may have not have given cause of death properly. They may have automatically assumed that aneurysm patients died due to aneurysm only. Aneurysm as the specific cause of death may be absent. Even if it is possible to get data on number of patients who underwent different repair procedures, records may not allow classification of repair procedures versus death data. Similar problem may arise with respect to imaging procedures also. Compliance % may not be indicative of specific influence of ACR unless it is very high. At medium or low percentage values, the specific parameters on which there is compliance may also be important. Thus, the type of data available in NIS data set and its relationship with ACR guidelines is important. These are described below.

3.4 NIS Dataset

There are two parts: the core file and the hospital file.

The core file has the data elements depicted in **Table 5.** The first core element of DX_n and PR_n deal with ICD-9 diagnostic and repair procedural codes respectively. Other elements relate to mortality and patient classifications. The patient classifications include age, gender, race, insurance type, admission type as source and the calendar year to which the data pertains.

Table 5: NIS Core Data Elements

Core File Element	Variable in the Study	Type	Description
DXn	AORTIC ANEURYSM DIAGNOSIS	Nominal	ICD-9 Diagnosis Codes
DXCCSn	COMORBIDITIES	Nominal	Clinical Classification Software
PRn	INTERVENTIONAL REPAIR AND IMAGING PROCEDURES	Nominal	ICD-9 Procedure Codes
DIED	IN-HOSPITAL MORTALITY	Ordinal	Died during hospitalization
AGE	AGE GROUP BASED ON WHO STANDERIZATION	Ordinal	Age in group at admission from 1-21 age groups.
FEMALE	GENDER	Nominal	The sex of the patient (Male or Female)
RACE	RACE	Nominal	The race and ethnicity of patient
PAY1	INSURANCE TYPE	Nominal	indicates the expected primary payer
SOURCE	ADMISSION TYPE	Nominal	Source of Admission to Point of Origin for Admission or Visit
LOS	LENGTH OF STAY	Ratio	length of stay from (0 day as same day stays to greater than 365 days)
YEAR	YEAR	Ratio	Calendar year (2008-2012)

In the hospital file **Table 6**, information on location and type, bed size and geographical region are available. This is the core NIS file on hospital.

Table 6: Data Elements in NIS Hospital Files

Hospital File Element	Variable in the Study	Type	Description
H-LOCTCH	HOSPITAL LOCATION	Nominal	hospital's location and teaching status
H-BEDSZ	HOSPITAL BED SIZE	Ordinal	hospital bedsize
HOSP_REGION	HSOPITAL REGION	Nominal	The hospital's census region was obtained from the AHA Annual Survey of Hospitals

In this study, six types of aortic aneurysms are covered. These are: ruptured and intact thoracic aortic aneurysms (rTA and TA), ruptured and intact abdominal aortic aneurysms (rAAA and AAA) and ruptured and intact thoracico-abdominal aortic aneurysms (rTAA and TAA). Surgical repair by OAR and EVAR are the intervention procedures. The main imaging procedures are CT, MRI, Ultrasound and DSA. The sub-categorization of data elements is given in **Figure 7.**

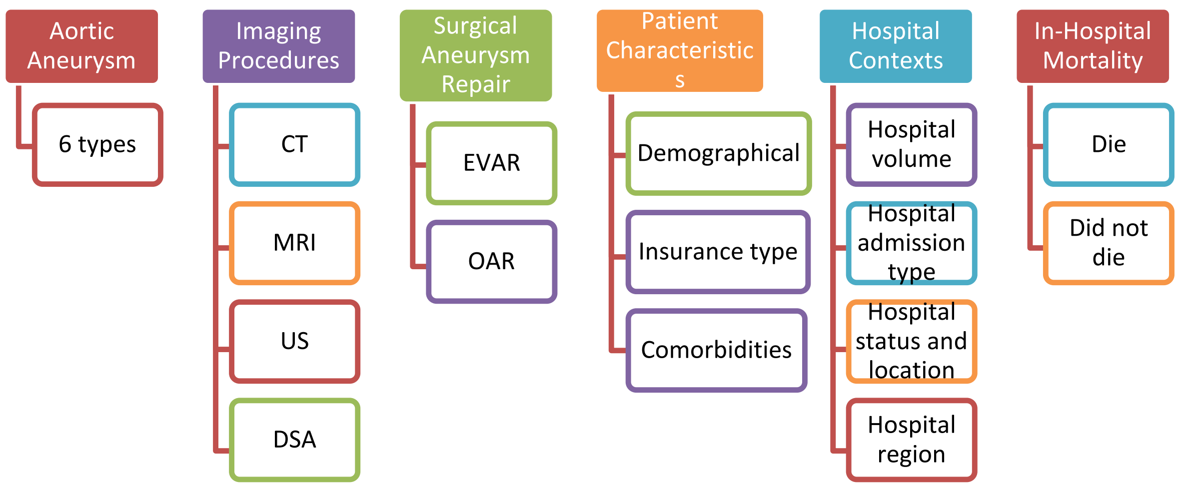

Figure 7: Sub-categorization of Data Elements Used in This Study

Patient characteristics and hospital contexts have already been described above. There are further sub-classifications for both patient and hospital factors as given in **Table 7**.

Table 7: Sub-classifications of Patient Characteristics and Hospital Contexts

Variable	Attributes
Patient characteristic Variables	
Race	**White**
	Black
	Hispanic
	Asian or Pacific Islander
	Native American
Gender	Male
	Female
Age	**Between** Group **10** (45 and 49 years old) ***and*** Group **20** (95 -99 years old)
Insurance Type	Medicare
	Medicaid
	Private
	Self-pay
Comorbidities	**Lipid metabolism**
	Hypertension
	Diabetes
	Respiratory disease and failure
	Acute myocardial infarction
	Heart failure
	Renal failure
	Anemia
Hospital Context Variables	
Hospital Volume	Small
	Medium
	Large
Admission Type	**Emergency**
	Urgent
	Elective
Status and Location	Rural
	Urban non-teaching
	Urban teaching
Hospital Region	**Northeast**
	Midwest
	South
	West

Hospitals are classified into small, medium or large based on their bed size and whether it is rural or urban and teaching or non-teaching. The classification differs with regions as presented in **Table 8.**

Table 8: Size Classifications of USA Hospitals in Different Geographical Regions

BEDSIZE CATEGORIES			
Location and Teaching Status	**Hospital Bedsize**		
	Small	Medium	Large
NORTHEAST REGION			
Rural	1-49	50-99	100+
Urban, nonteaching	1-124	125-199	200+
Urban, teaching	1-249	250-424	425+
MIDWEST REGION			
Rural	1-29	30-49	50+
Urban, nonteaching	1-74	75-174	175+
Urban, teaching	1-249	250-374	375+
SOUTHERN REGION			
Rural	1-39	40-74	75+
Urban, nonteaching	1-99	100-199	200+
Urban, teaching	1-249	250-449	450+
WESTERN REGION			
Rural	1-24	25-44	45+
Urban, nonteaching	1-99	100-174	175+
Urban, teaching	1-199	200-324	325+

3.5 NIS Sampling Framework

Number of US hospital organizations sourced were 47. Their websites are listed in **Table 9.**

Table 9: Websites of Participating USA Hospital Organizations

State	Website of Partner Organization
Alaska	http://www.ashnha.com/
Arizona	http://www.azdhs.gov/plan/crr/ddr/index.htm
Arkansas	http://www.healthyarkansas.com
California	http://www.oshpd.ca.gov
Colorado	http://www.cha.com
Connecticut	http://www.chime.org
Florida	http://ahca.myflorida.com/SCHS/index.shtml
Georgia	https://www.gha.org/
Hawaii	http://www.hhic.org
Illinois	http://www.idph.state.il.us
Indiana	http://www.ihaconnect.org
Iowa	http://www.ihaonline.org
Kansas	http://www.kha-net.org
Kentucky	http://www.chfs.ky.gov
Louisiana	http://dhh.louisiana.gov
Maine	http://mhdo.maine.gov/imhdo/
Maryland	http://www.hscrc.state.md.us
Massachusetts	http://www.mass.gov/chia
Michigan	http://www.mha.org
Minnesota	http://www.mnhospitals.org
Mississippi	http://www.msdh.state.ms.us/
Missouri	http://www.mhanet.com
Montana	http://www.mtha.org/index.htm
Nebraska	http://www.nebraskahospitals.org/
Nevada	http://chia.unlv.edu
New Hampshire	http://www.dhhs.state.nh.us
New Jersey	http://www.nj.gov/health/healthcarequality
New Mexico	http://www.health.state.nm.us
New York	http://www.health.state.ny.us/nysdoh/sparcs/sparcs.htm
North Carolina	http://www.shepscenter.unc.edu/data/nc-hospital-discharge-data/
North Dakota	http://www.mnhospitals.org
Ohio	http://www.ohanet.org
Oklahoma	http://www.ok.gov/health/
Oregon	http://www.oahhs.org/
Pennsylvania	http://www.phc4.org
Rhode Island	http://www.health.ri.gov
South Carolina	http://rfa.sc.gov/
South Dakota	http://www.sdaho.org
Tennessee	http://www.tha.com
Texas	http://www.dshs.state.tx.us/thcic/
Utah	http://health.utah.gov/hda/
Vermont	http://www.vahhs.org
Virginia	http://www.vhi.org
Washington	http://www.doh.wa.gov/
West Virginia	http://www.hca.wv.gov
Wisconsin	http://www.dhs.wisconsin.gov/
Wyoming	http://www.wyohospitals.com/

3.6 Disease and Procedures Coding

For the six types of aneurysms included in this study, the corresponding ICD-9 codes are as given in **Table 10.**

Table 10: ICD-9 codes for the Six Types of Aneurysms Included in This Study

ICD_9-CM Codes	Abbreviations	Description
4411	**rTA**	Ruptured Thoracic Aortic Aneurysm
4412	**TA**	Thoracic Aortic Aneurysm
4413	**rAAA**	Ruptured Abdominal Aortic Aneurysm
4414	**AAA**	Abdominal Aortic Aneurysm
4416	**rTAA**	Ruptured Thoracicoabdominal Aortic Aneurysm
4417	**TAA**	Thoracicoabdominal Aortic Aneurysm

The ICD-9 CM codes and clinical classification codes for co-morbidities are given in **Table 11.** These ICD-9 and classification software codes will be used for identification of aortic aneurysm co-morbidities given in NIS database.

Table 11: Aortic Aneurysm Comorbidities

COMORBIDITIES	Clinical Classification Software Code	ICD-9-CM Diagnosis
lipid metabolism	53	2720 2721 2722 2723 2724
Hypertension	98-99	4011 4019 4010 40200 40201 40210 40211 40290 40291 4030 40300 40301 4031 40310 40311 4039 40390 40391 4040 40400 40401 40402 40403 4041 40410 40411 40412 40413 4049 40490 40491 40492 40493 40501 40509 40511 40519 40591 40599 4372
Diabetes	49-50	24900 25000 25001 7902 79021 79022 79029 7915 7916 V4585 V5391 V6546 24901 24910 24911 24920 24921 24930 24931 24940 24941 24950 24951 24960 24961 24970 24971 24980 24981 24990 24991 25002 25003 25010 25011 25012 25013 25020 25021 25022 25023 25030 25031 25032 25033 25040 25041 25042 25043 25050 25051 25052 25053 25060 25061 25062 25063 25070 25071 25072 25073 25080 25081 25082 25083 25090 25091 25092 25093
Respiratory disease and failure	131-133-134	5173 5185 51851 51852 51853 51881 51882 51883 51884 7991 V461 V4611 V4612 V4613 V4614 V462 5131 514 515 5160 5161 5162 5163 51630 51631 51632 51633 51634 51635 51636 51637 5164 5165 51661 51662 51663 51664 51669 5168 5169 5172 5178 5183 5184 51889 5194 5198 5199 7825 78600 78601 78602 78603 78604 78605 78606 78607 78609 7862 7863 78630 78631 78639 7864 78652 7866 7867 7868 7869 7931 79311 79319 7942 V126 V1260 V1261 V1269 V426 470 4710 4711 4718 4719 4720 4721 4722 4760 4761 4770 4772 4778 4779 4780 4781 47811 47819 47820 47821 47822 47824 47825 47826 47829 47830 47831 47832 47833 47834 4784 4785 4786 47870 47871 47874 47875 47879 4788 4789 5191 51911 51919 5192 5193 7841 78440 78441 78442 78443 78444 78449 7847 7848 7849 78499 7861 V414 V440 V550
Acute myocardial infarction	100	4100 41000 41001 41002 4101 41010 41011 41012 4102 41020 41021 41022 4103 41030 41031 41032 4104 41040 41041 41042 4105 41050 41051 41052 4106 41060 41061 41062 4107 41070 41071 41072 4108 41080 41081 41082 4109 41090 41091 41092
Heart failure	108	39891 4280 4281 42820 42821 42822 42823 42830 42831 42832 42833 42840 42841 42842 42843 4289
Renal failure	157	5845 5846 5847 5848 5849 586
Anaemia	60- 61	2851 28241 28242 2825 28260 28261 28262 28263 28264 28268 28269

3.7 ACR Guideline Compliance

ACR appropriateness guidelines for diagnostic imaging of aneurysm is listed in Fig 4. Procedural guidelines with relative rating and relative radiation level are given for CT, CTA, MRA, DSA, US and X-ray imaging. In this study, only the first four, which are more commonly used in aneurysm diagnosis are included. As was discussed in Review of Literature, compliance with all the items in the guidelines by hospitals is not reported. On the other hand, partial non-compliance with certain items have been reported. However, no report has connected the extent of compliance with in-hospital mortality in aneurysm cases.

ACR rating scales are given in **Table 12**. According to ACR scale, scores of 1, 2 and 3 indicate “Usually not appropriate” status and above this score up to 6 indicates “May be appropriate” and 7-9 score indicates “Usually appropriate” status. Even if all the guidelines are met, the rating is not “Appropriate” but a tentative “Usually appropriate”. Similarly, when even if all the items are not complied with, the rating will be a soft “Usually not appropriate” rather than “Not appropriate”. This is a serious drawback of the rating. In this study, scores 1, 2 and 3 are combined as 1 to indicate “Usually not appropriate”, 4-6 as “May be appropriate” and 7-9 as “Usually appropriate” compliance level. However, such ratings do not say anything about the seriousness of lapses in compliance levels. This may make it difficult to relate compliance level with in-hospital mortality. But this study attempts exactly that. NIS dataset and ICD_9 codes are not fully incompatible and support all these sophisticated imaging types to be investigated. Therefore, the rating scale system of ACR guideline has been used instead of all sophisticated radiological procedures as illustrated in **Table 13**.

Table 12: ACR Appropriateness Diagnostic Imaging Criteria for Aneurysm Repair

American College of Radiology
ACR Appropriateness Criteria®

Radiologic Procedure	Rating	Comments	RRL*
CTA abdomen and pelvis with contrast	9	For evaluation of known AAA without thoracic aortic involvement. Noncontrast sequence is not necessary for interventional planning.	☢☢☢☢☢
CTA chest abdomen pelvis with contrast	8	Useful for patients with suspected AAA but no prior workup of the thoracic aorta. Study of choice for workup of suprarenal AAA or thoracoabdominal aneurysm.	☢☢☢☢☢
CT abdomen and pelvis without contrast	6	At physician's discretion, chest may not be included. Appropriate for patients with contraindication to iodinated contrast. Occasionally depicts density differences between the blood pool and aortic wall/mural thrombus. Otherwise, further luminal assessment with MRI, US, or DSA would be preferred.	☢☢☢☢
MRA abdomen and pelvis without and with contrast	6	Alternative to CTA in patients with known AAA not involving the thoracic aorta and in whom iodinated contrast is contraindicated. See statement regarding contrast in text under "Anticipated Exceptions."	O
CT chest abdomen pelvis without contrast	5	Appropriate for patients with contraindication to iodinated contrast. Occasionally depicts density differences between the blood pool and aortic wall/mural thrombus. Otherwise, further luminal assessment with MRI, US, or DSA would be preferred.	☢☢☢☢
Digital subtraction angiography (DSA) aorta	5	May be appropriate in select cases, including patients who require pre-operative embolization of branch vessels or those requiring further characterization of the aortic lumen with an alternative contrast agent (such as CO_2) or intravascular US.	☢☢☢
MRA chest abdomen pelvis without and with contrast	5	Alternative to CTA in patients with contraindication to iodinated contrast who have had no prior evaluation of thoracic aorta. See statement regarding contrast in text under "Anticipated Exceptions."	O
MRA chest abdomen pelvis without contrast	4	Appropriate for patients with severe renal dysfunction.	O
MRA abdomen and pelvis without contrast	4	Appropriate for patients with severe renal dysfunction. At physician's discretion, chest may not be included.	O
US aorta abdomen with Doppler	3	Useful screening tool, but insufficient for AAA treatment planning. May be used in tandem with DSA in the absence of cross-sectional imaging, or as an adjunct to noncontrast CT for luminal evaluation.	O
X-ray chest abdomen pelvis	1		☢☢☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Table 13: ACR Rating Scale Adopted for This Study

ACR Rating Scale		The Study Rating Scale	
1,2,3	Usually not appropriate	1	Usually not appropriate
4,5,6	May be appropriate	2	May be appropriate
7,8,9	Usually appropriate	3	Usually appropriate

3.8 Statistical Modelling Analysis

Descriptive statistics, Frequencies, ANOVA, Correlation, Chi-Square, Logistic Regression, and Multinominal Logistic were used for analyzing the data obtained in this work. These are described below.

Data for this research were obtained from the Nationwide Inpatient Sample (NIS) from the Health Care Utilization Project (HCUP) between 2008 and 2012. HCUP comes under the Department of Health and Human Services of the United States government. NIS is the largest all payer database in the United States with data on approximately 8 million discharges per year [239,240]. NIS database contains information on admission and discharge diagnosis, patient demographics, procedures, complications, hospital stay, charges, in-hospital mortality, discharge destination, and associated comorbidities. The principal author completed the HCUP data-use agreement training course and the HIPAA-compliant HCUP NIS data use agreement was signed before analyzing the data. The subjects were selected from NIS database using the diagnostic and procedural International Classification of Disease, Ninth Revision; Clinical Modification (ICD-9- CM) codes. Demographic characteristics and comorbidities of each group were compared. Outcome parameters, in hospital mortality. Statistical analysis was performed using Frequencies, Analysis of Variance (ANOVA), Chi-Squared test (Pearson, McNemar's test), Correlation (Gamma), Logistic Regression test, and Multinominal Logistic Regression test. All analysis was performed using SPSS software (version 22.0.0.0, SPSS Inc).

3.9 Research Design

The criteria to select the six types of aortic aneurysms considered in this project are explained in **Figure 8.**

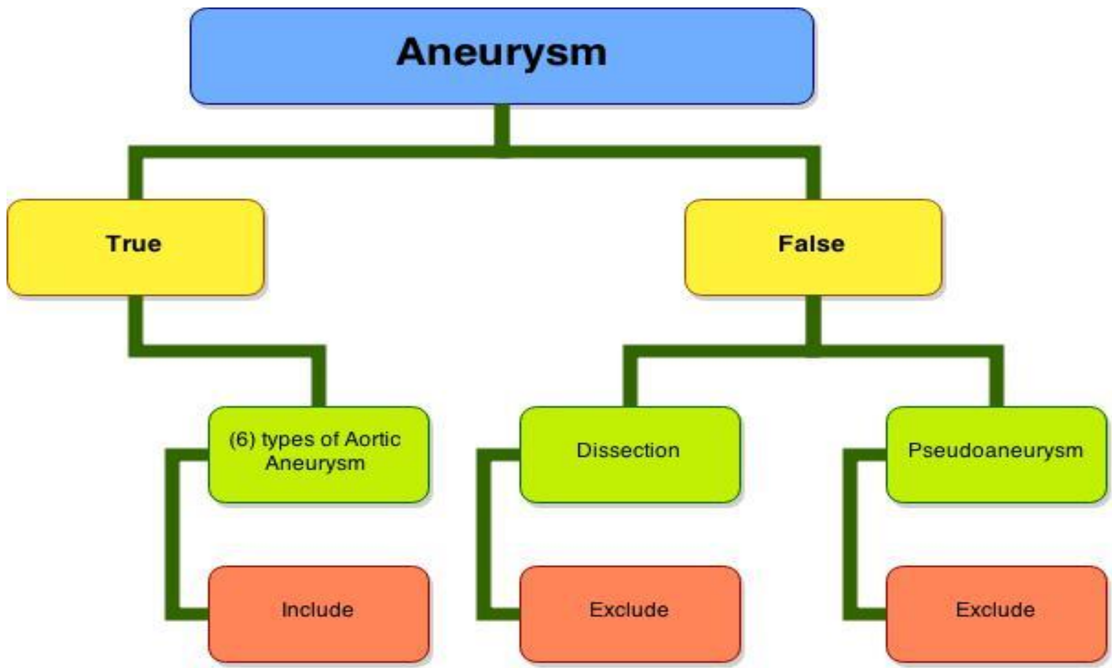

Figure 8: Schematic Process of Selecting the Six Aortic Aneurysm Types in This Study

Out of the aneurysms available in the NIS data set, the false ones are separated and excluded out. The true aortic aneurysms are classified into the six types as per ICD-9 codes specified in **Table 10.** The selection processes of samples and variables are explained in **Figure 9.**

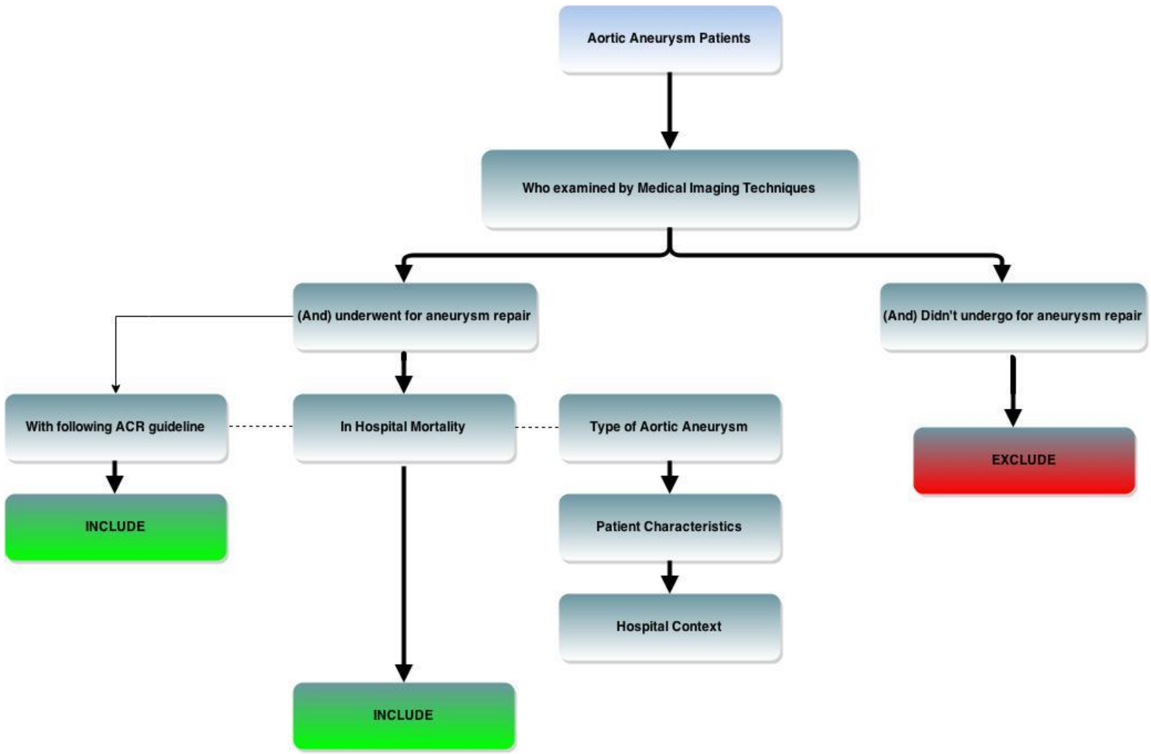

Figure 9: Schematic Explanation of Samples Selection and Variables in This Study

Accordingly, patients who did not undergo any repair procedure are first excluded. Among the patients who underwent repair procedure, those who were not imaged are excluded. Now the selected sample consists of only patients who underwent any repair procedure for aneurysm and were imaged. In-hospital mortality of such patients in the 47 hospitals are collected. These mortality during hospitalization are factored according to aneurysm type, patient characteristics, hospital contexts and compliance with ACR guidelines.

3.10 Sample size

Using the data filtering method on aneurysm patient data from NIS database, a net sample size of 38263 patient records were obtained for statistical analyses described above for the five-year period covering 2008-2012. Results of the statistical analyses are given in the next chapter.

CHAPTER IV: RESULTS OF DATA ANALYSIS

4.1 Introduction

In this chapter of this study, statistical result have been performed by using various modelling analyses. A promising best practice and imaging management associated with interventional repair in a sample data of 38,263 patients' record with aortic aneurysms, this study expect to help in identifying the most appropriate practical use and management of imaging techniques and assess the level of national guideline compliance to examine the aortic aneurysm patients.

Patient characteristics including (patient demographics, insurance type, and comorbidities) and hospital contexts containing (hospital location, hospital bed size, and hospital region) are expected to have a strong association with negative consequences (in-hospital mortality) and would relevant for clinical decision making and to attain the best practice. This study expect to find what objectives have addressed for and to test patient characteristics and hospital contexts are statistically significant with in-hospital mortality.

4.2 Data Filtering Process

According to a preliminary data collected, the data filtering process is as given in **Figure 7.**

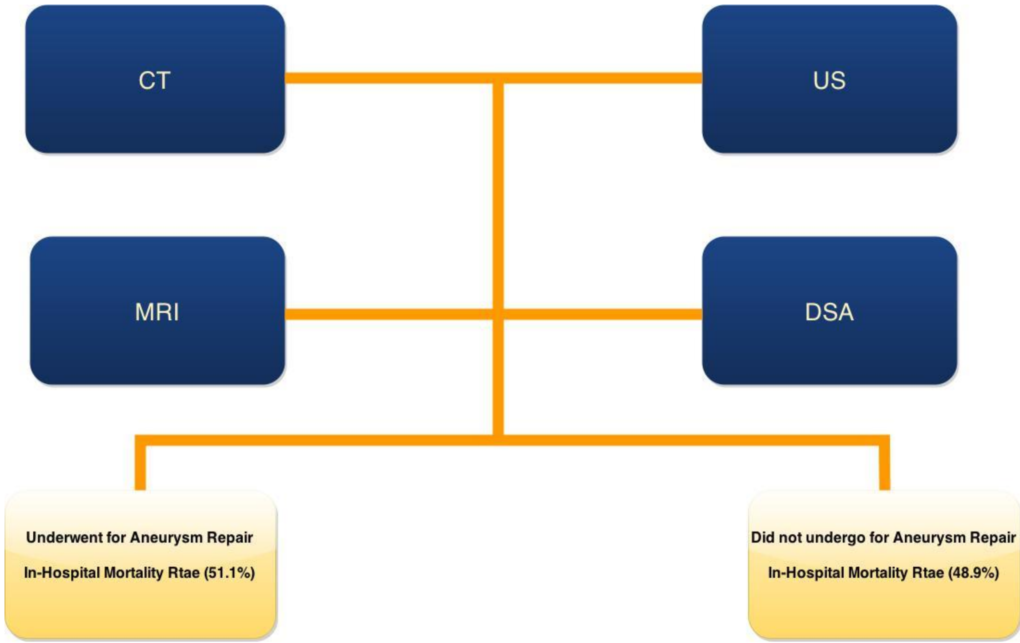

Figure 10: Data Filtration methods Used in the Study with In-Hospital Mortality Outcome.

An aortic aneurysm patient can be admitted with various diagnoses and conditions. These conditions can impact other components of the aortic aneurysm patient's including health care management and procedures performed. After undergoing any of the four diagnostic imaging procedure, only 51% underwent repair procedure and the rest 49% did not undergo any repair procedure. Thus only about half of the total aneurysm patients of USA are available for us to study impact of any factor on in-hospital mortality. This means a large majority of these patients are left out of the study. Reasons for not undergoing repair procedure may be medical or personal. If aneurysm is not serious enough to undergo repair, it is fine. If patient characteristics or hospital contexts play a role in this matter, it needs serious investigation.

4.3 Result of Descriptive Statistic and Frequencies

Basically the main data are collected through the year 2008, 2009, 2010, 2011 and 2012 from a two large files merged (Core and Hospital) of the National Inpatient Sample (NIS).

4.3.1 Aortic Aneurysm Distribution According to Types

Data on the number of patients diagnosed with different types of aortic aneurysm are given in **Table 14** with their frequency percentages and cumulative percentages.

The type of aortic aneurysm which is most frequent is the abdominal aortic aneurysm (AAA). This occurs in about 73% of all cases. Thoracic aneurysm with about 20% cases ranks second. These two together accounted for about 94% of total aneurysm detection. Ruptured abdominal aortic aneurysm occur in about 2.5% patients compare to ruptured thoracico-abdominal aneurysm with nearly 0.2%. Frequency of ruptured compared to unruptured cases of both abdominal aortic and thoracic aneurysms were almost proportional. All other types occur at very low frequencies. The data are pictorially given in **Figure 8.**

Table 14: Frequencies Distribution of Different Types of Aortic Aneurysms in US Hospitals

Aortic Aneurysm Type	Frequency	Valid Percent	Cumulative Percent
	n	%	%
rTA	283	.7	.7
TA	7885	20.6	21.3
rAAA	971	2.5	23.9
AAA	28102	73.4	97.3
rTAA	70	.2	97.5
TAA	952	2.5	100.0
Total	38263	100.0	

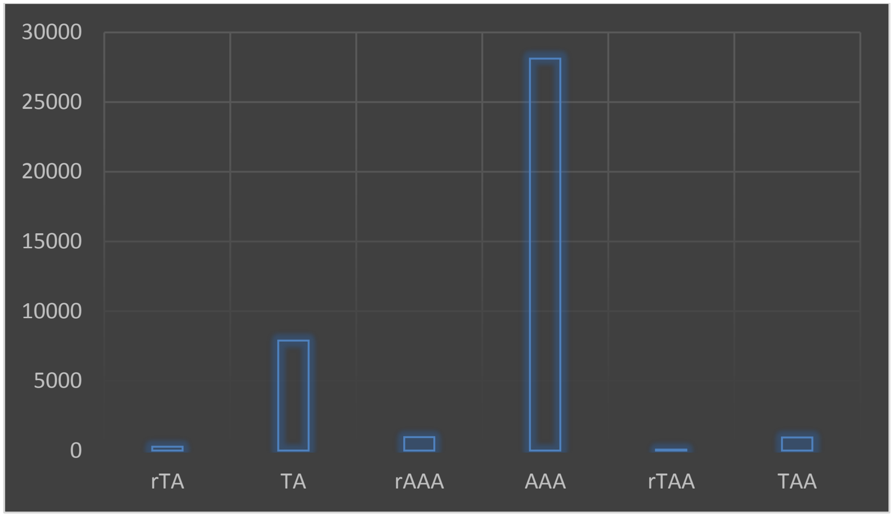

Figure 11: Frequencies Distribution of Different Types of Aortic Aneurysms among US Patients

The above findings were related to some preliminary results on data collected to obtain a feel of the problems and issues of aneurysm detection and intervention. The results of detailed analysis obtained from the data collected in this project are presented in the following sections.

4.3.2 Aneurysm Repair Frequencies

There are two important repair procedures: Endovascular repair (EVAR) and open surgery (OAR) repair. EVAR is considered very promising due to advantages overweighing disadvantages. OAR is still preferred in a large number of cases. Also, OAR may be the best and the only option in the case of ruptured aneurysms. However, EVAR followed by OAR is done when EVAR could not achieve the desired outcome.

In **Table 15,** the relative distribution in number and percentage of aneurysm patients who underwent any of these three intervention options are classified. OAR was done in about 63% of cases and EVAR was done only in 23% cases. OAR after unsuccessful EVAR was done in 14% cases. The same is also presented in **Figure 9**. It is significant that OAR had to be done in 14% patients after EVAR.

Table 15: Relative Frequencies of Repair Procedures on Aortic Aneurysm patients

Interventional Aneurysm Repair		Frequency	Valid Percent	Cumulative Percent
		n	%	%
	EVAR	8798	23.0	23.0
	OAR	23958	62.6	85.6
	EVAR+OAR	5507	14.4	100.0
	Total	38263	100.0	

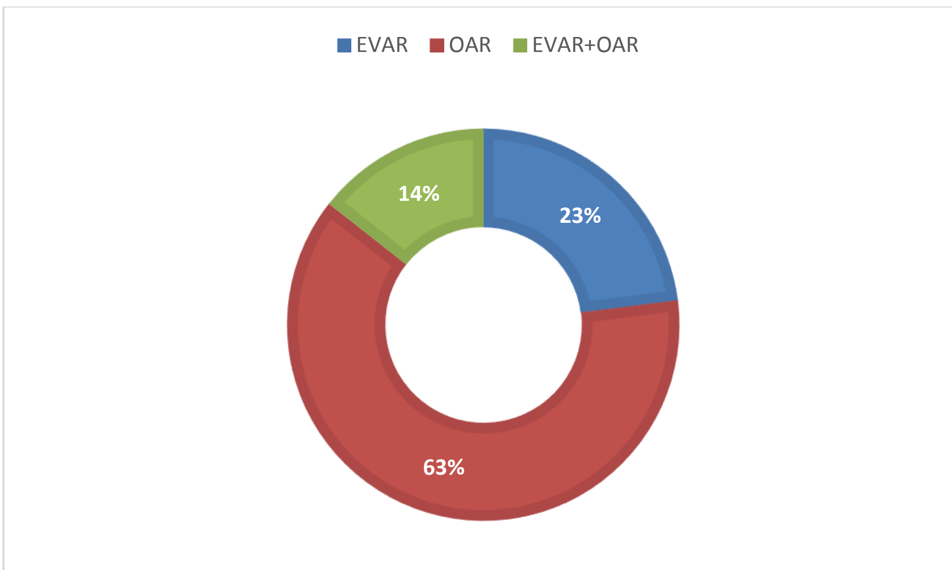

Figure 12: Distribution of Interventional Aortic Aneurysm Repair in US Hospital between 2008 and 2012

4.3.3 Frequencies of Aneurysm Diagnostic Imaging by Different Modalities

Number and frequency of aneurysm patients who underwent different diagnostic imaging methods during 2008 and 2012 are presented in **Table 16**. It lists the frequency of four most common advanced imaging modalities. Ionizing imaging method (DSA) was the most frequently used imaging method. It was used in nearly 86% of patients. The second most common type of medical imaging preformed in inpatient setting was US. MRI and CT were used only in less than 2% cases each. These results are figuratively shown in **Figure 10.**

Table 16: The Most Common Diagnostic Imaging Performed in US Hospitals between 2008 and 2012

Medical Imaging Techniques	Frequency	Valid Percent	Cumulative Percent
	n	%	%
CT	523	1.4	1.4
MRI	112	.3	1.7
US	4879	12.8	14.4
DSA	32749	85.6	100.0
Total	38263	100.0	

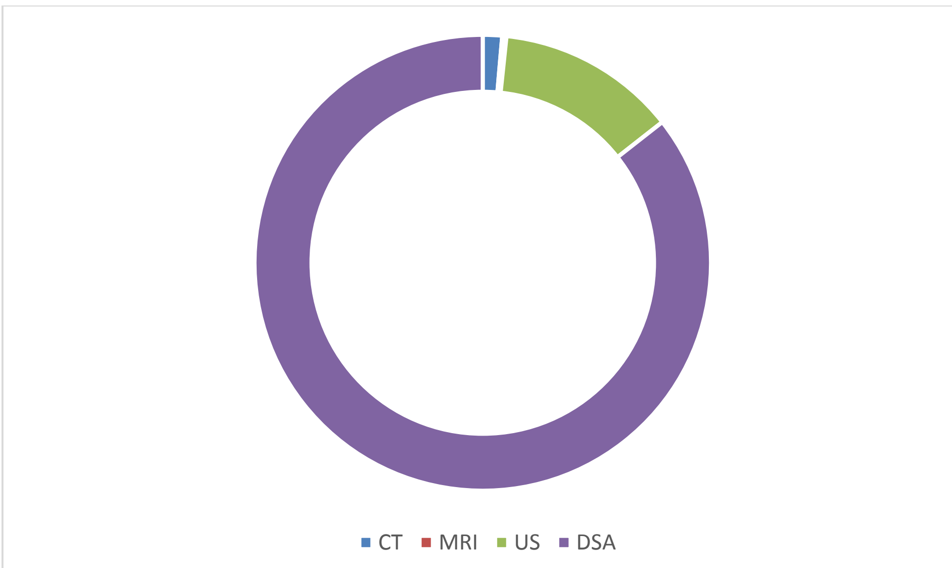

Figure 13: Distribution of Diagnostic Imaging Modalities in US Hospital between 2008 and 2012

Aneurysm is a chronic disease usually affecting people towards the end of their lives. This makes detection and intervention procedures highly risky. A majority of aneurysm patients do not report to the hospitals. Among those reported, repair procedure is not done on a good majority. It is notable that imaging helps proper diagnosis eventually leading to reduction of mortality. Abdominal aortic aneurysm is most common with roughly 73% accounted, followed by thoracic aortic aneurysm. All others occur in very low frequencies compared to these. Although EVAR is promising, OAR is still the choice method, probably as the best method to deal with emergency and urgent admissions of ruptured aneurysms. In spite of other more promising methods becoming increasingly available, DSA is still the gold standard for diagnostic imaging. Such techniques like MRI and CT were used very rarely.

4.3.4 Patient Characteristics

Patient characteristics which are related to aneurysm and studied in this project were: demographical factors including (gender, age, race), insurance type and comorbidities. In the following sections, the results obtained on each patient characteristics with respect to diagnostic imaging method is dealt separately.

4.3.4.1 Patient Age

The first basis of this study was susceptibility to aortic aneurysms based on age of the person. The age group classification of WHO is followed for most researches on effect of age on any disease. This age group classification is given in **Table 17**, and is followed in reporting the findings of this study.

Table 17: WHO Classification of Age Group among Population

WHO age group classification	Age
1	0-4
2	5-9
3	10-14
4	15-19
5	20-24
6	25-29
7	30-34
8	35-39
9	40-44
10	45-49
11	50-54
12	55-59
13	60-64
14	65-69
15	70-74
16	75-79
17	80-84
18	85-89
19	90-94
20	95-99
21	100- Above

The general trend of age group frequency distribution of aneurysm incidence in numbers as per WHO is given in **Figure 11**. The findings of this study on 38263 patients of aortic aneurysm patients in US hospitals during 2008-2012 are given in **Figure 8**.

The WHO general trend shows that detectable frequencies of aortic aneurysms are found only in persons above age group 9 as per WHO age group classification. Thus, higher likelihood of detecting aneurysm is among persons above 45 years old. The frequency increases with advancing age till it stabilizes around 75-84 years of age. Then the likelihood declines. It is also possible, that chances of persons living beyond 75-85 are less and therefore frequency decreases. It is certainly more advantageous to look at the frequency as percentage of aortic aneurysm patients within the total population of each age group.

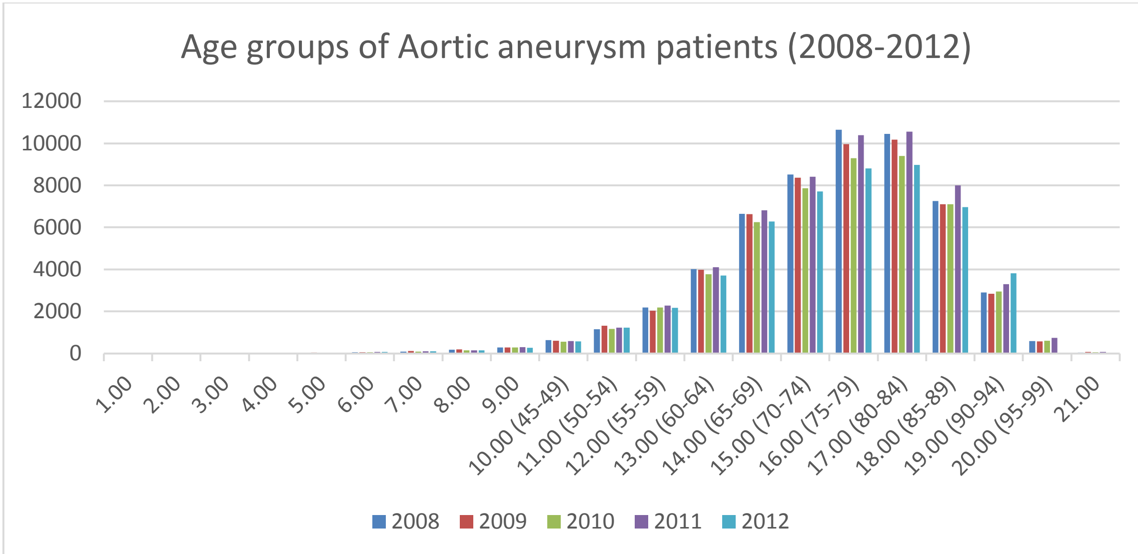

Figure 14: Age Groups of Population Affected by Aortic Aneurysms

In this study, the sample size was 38,263 patients inclusive of both genders (Male and Female) age 45 to 99 years old, and the average age of the patients was 72.37 years with a standard deviation of 9.6. The patients' age distribution is shown in **Figure 12.** The data obtained in this work confirmed the WHO data. The peak frequency was observed among patients of about 75-84 years age tapering either side to almost zero below 40 and nearer to 100 years of age.

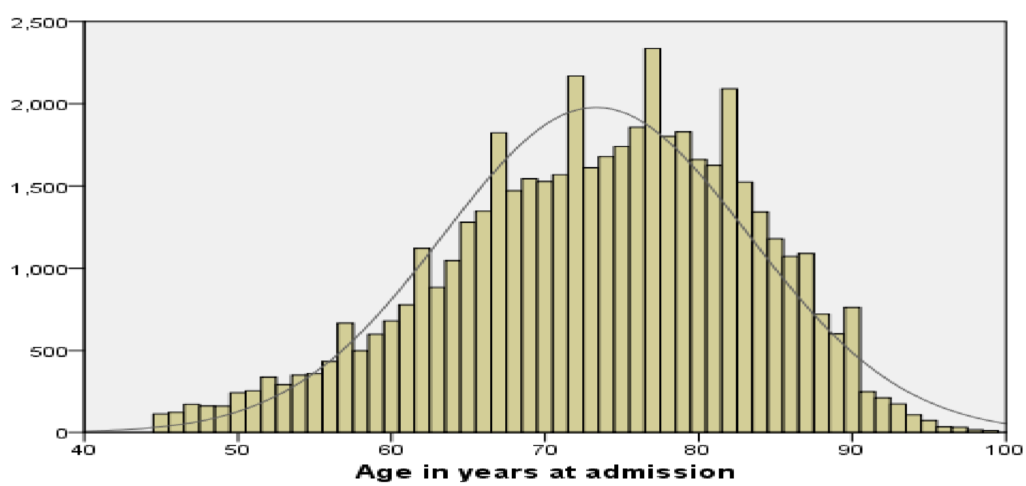

Figure 15: The Age Distribution of Aortic Aneurysms in US Population

This gives an indication of the effect of age on the prevalence of aneurysm. The frequency distribution of age of patients detected with aneurysm is presented in **Figure 12.** The data obtained in this work confirmed the WHO data. The peak frequency was observed among patients of about 75-85 years age tapering wither side to almost zero below 40 and nearer to 100.

4.3.4.2 Age and Diagnostic Imaging Modalities

The data on the number and percentage frequencies of aneurysm patients diagnosed using different imaging methods are given in **Table 18**.

Among imaging methods, peak incidence detected by DSA was in the age groups of 15 and 16 or 70-79 years of age. In the case of ultrasound, there was a wider incidence in the age group 14 and 16 (65 to 79 years of age). For MRI the peak was spread in the 15-17 (70 to 84 years of age) range. For CT, it was in the 16-17 (75-84) age groups, as illustrated in **Table 19**. The shift in peak may be more a reflection of disease prevalence than age determining the imaging method. However, it appears that MRI and CT were used more frequently among 80 to 84 years age group.

Table 18: Age with Respect to Diagnostic Imaging of Aortic Aneurysm

Patients Demographics			Medical Imaging Modalities				Total	***P***
			CT	MRI	US	DSA		
WHO Age Group Classifications	10.00	Count	2	0	195	421	618	
		%	0.3%	0.0%	31.6%	68.1%	100.0%	
	11.00	Count	12	2	287	919	1220	
		%	1.0%	0.2%	23.5%	75.3%	100.0%	
	12.00	Count	16	3	446	1685	2150	
		%	0.7%	0.1%	20.7%	78.4%	100.0%	
	13.00	Count	30	13	618	3128	3789	
		%	0.8%	0.3%	16.3%	82.6%	100.0%	
	14.00	Count	66	8	775	5426	6275	
		%	1.1%	0.1%	12.4%	86.5%	100.0%	
	15.00	Count	71	20	785	6173	7049	
		%	1.0%	0.3%	11.1%	87.6%	100.0%	
	16.00	Count	116	19	777	6616	7528	
		%	1.5%	0.3%	10.3%	87.9%	100.0%	
	17.00	Count	103	30	597	5271	6001	
		%	1.7%	0.5%	9.9%	87.8%	100.0%	
	18.00	Count	68	14	289	2530	2901	
		%	2.3%	0.5%	10.0%	87.2%	100.0%	
	19.00	Count	32	2	105	546	685	
		%	4.7%	0.3%	15.3%	79.7%	100.0%	
	20.00	Count	7	1	5	34	47	
		%	14.9%	2.1%	10.6%	72.3%	100.0%	
Total		Count	523	112	4879	32749	38263	**<0.0001**
		%	1.4%	0.3%	12.8%	85.6%	100.0%	

Table 19: Age Group Peaks of Aortic Aneurysm Incidence among US Patients Detected by Different Imaging Methods

IMAGING METHOD	PEAK ANEURYSM INCIDENCE
DSA	70-79 YEARS
US	65-79
MRI	70-84
CT	75-84

4.3.4.3 Patient Race

Relative frequencies in numbers of the race to which the aneurysm patients belonged is presented graphically in **Figure 13**.

Out of the total 38263 patients sampled, 33388 were whites. Thus whites could be more prone to aneurysm. Blacks had an incidence frequency of only 6.1%. An incidence of about 4.3% was recorded in the case of Hispanic patients. Aneurysm incidence was much less frequent in the case of other races. Whites form the majority of the US citizens and other races are far less in numbers. Therefore, mere numerical data may not give correct picture on extent of incidence and render comparisons impossible. These purposes are served only if the number of aneurysm patients are converted to percentages based on population of respective races.

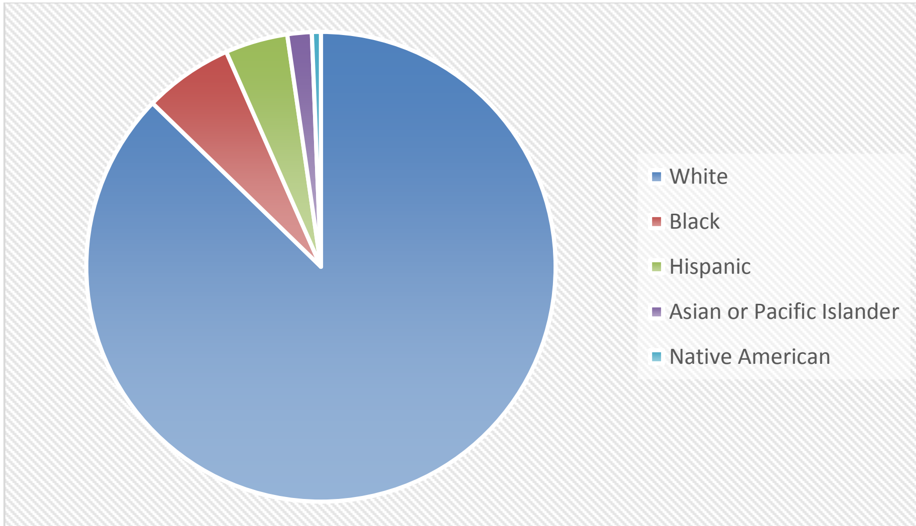

Figure 16: NIS Race Distribution between 2008 and 2012.

The imaging frequency data obtained on race to which the patient belongs with respect to diagnostic imaging are given in **Table 20.** Although it is dangerous to state that a particular race has a greater chance of getting aneurysm, valid relationship between the two have often been reported. For all races, frequency for imaging methods decreased in the order: DSA, US, CT, MRI as was in the case of other patient characteristics. This does not imply any specific association of imaging method with any particular race, as imaging methods are determined based on disease condition.

Table 20: Race with Respect to Different Diagnostic Imaging Methods

Patient Demographics			Medical Imaging Modalities				Total	***P***
			CT	MRI	US	DSA		
Race	White	Count	405	86	4196	28701	33388	
		%	1.2%	0.3%	12.6 %	86.0%	100.0 %	
	Black	Count	61	18	338	1928	2345	
		%	2.6%	0.8%	14.4 %	82.2%	100.0 %	
	Hispanic	Count	31	6	213	1400	1650	
		%	1.9%	0.4%	12.9 %	84.8%	100.0 %	
	Asian or Pacific Islander	Count	24	1	111	506	642	
		%	3.7%	0.2%	17.3 %	78.8%	100.0 %	
	Native American	Count	2	1	21	214	238	
		%	0.8%	0.4%	8.8%	89.9%	100.0 %	
Total		Count	523	112	4879	32749	38263	**<0.0001**
		%	1.4%	0.3%	12.8 %	85.6%	100.0 %	

4.3.4.4 Patient Gender

The majority of aortic aneurysm patients are male representing approximately 70% of all data. Female represented roughly around 30%. The Literature Review chapter has covered and discussed many findings related to this aspect. The data are illustrated in **Figure 14.**

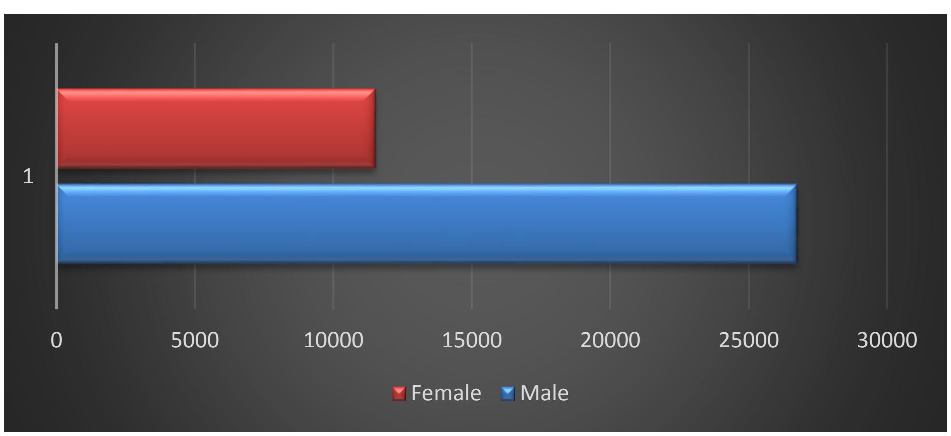

Figure 17: NIS Gender Distribution between 2008 and 2012.

In Table 4.8, data on gender with respect to imaging is presented. Out of a total of 38263 patients, 70% were males and 30% were females. This ratio was more or less maintained in the case of ultrasound and DSA as imaging methods. Higher number of males were imaged than females with any imaging method. Nonetheless, ratio was narrower in the case of CT and MRI. For both genders, DSA was the most frequent imaging method as presented in **Table 21**. Compared to this, frequency was much less for any other imaging method. Overall finding is that DSA was the most frequently used imaging method followed by ultrasound irrespective of gender. However, it cannot be said that use of any specific imaging method was determined by or related to gender.

Table 21: Gender Distribution of Aortic Aneurysm Patients with Respect to Diagnostic Imaging Methods

Patients Demographics			Medical Imaging Modalities				Total	***P***
			CT	MRI	US	DSA		
Gender	Male	Count	306	71	3361	23007	26745	
		%	1.1%	0.3%	12.6%	86.0%	100.0%	
	Female	Count	217	41	1518	9742	11518	
		%	1.9%	0.4%	13.2%	84.6%	100.0%	
Total		Count	523	112	4879	32749	38263	
		%	1.4%	0.3%	12.8%	85.6%	100.0%	**<0.0001**

4.3.4.5 Patient Health Insurance

This denotes whether and how the medical expenses related aortic aneurysm is met by any insurance scheme. The relative frequency of aneurysm patients covered by different reimbursement schemes is shown in **Figure 15** and **Table 22**. Only about 2% of the patients met their medical expenses by themselves. About 77% availed Medicare and about 18% availed private insurance. Out of the imaging methods, generally Medicare and private insurance were more common.

These variations may be related to maximum limit payable by the insurance scheme and the relative cost of imaging method. As insurance type determines affordability of health care, cost of imaging method could have an effect on imaging method opted by any particular patient. If different imaging methods give comparable results, this factor may not matter much in the overall outcome.

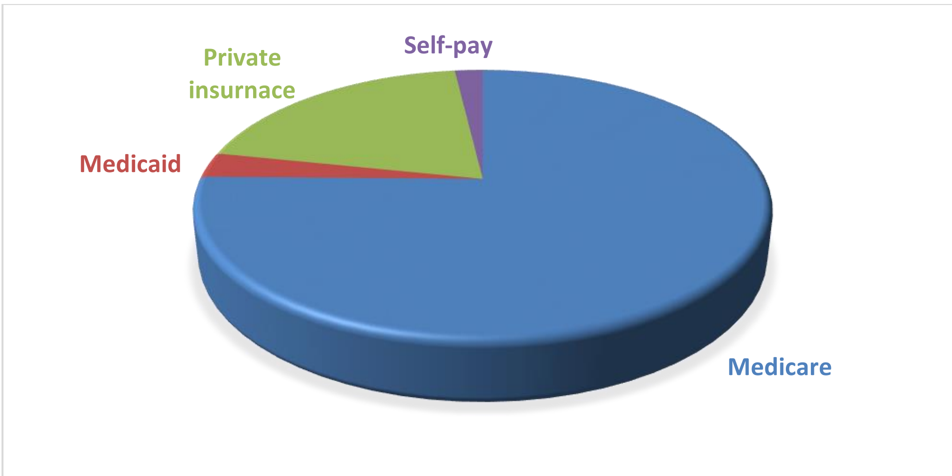

Figure 18: NIS Medical Insurance Type Distribution of Aortic Aneurysm Patients.

Table 22: Insurance Type with Respect to Medical Imaging Techniques

Patient Health Insurnace			Medical Imaging Procedures				Total	***P***
			CT	MRI	US	DSA		
Insurance Type	Medicare	Count	426	91	3168	25116	28801	
		%	1.5%	0.3%	11.0%	87.2%	100.0%	
	Medicaid	Count	19	1	187	937	1144	
		%	1.7%	0.1%	16.3%	81.9%	100.0%	
	Private insurance	Count	66	20	1423	6087	7596	
		%	0.9%	0.3%	18.7%	80.1%	100.0%	
	Self-pay	Count	12	0	101	609	722	
		%	1.7%	0.0%	14.0%	84.3%	100.0%	
Total		Count	523	112	4879	32749	38263	**<0.0001**
		%	1.4%	0.3%	12.8%	85.6%	100.0%	

4.3.4.6 Patient Comorbidities

The study also included assessment of the type of comorbidities associated with aneurysm and any influence of this on the imaging method used. The commonly associated comorbidities are given in **Figure 16**. Hypertension with 34% incidence is the most common comorbidity. The least incidence is in the case off lipid metabolism with 4%. Anaemia, diabetes and heart failure are also major comorbidities. The data on the relationship of imaging method with comorbidities, given in **Table 23** mostly follows the general imaging frequency trends. DSA was used maximum, followed by US and MRI and CT contributing only very low frequencies of imaging. All differences are statistically significant at the 0.05 level.

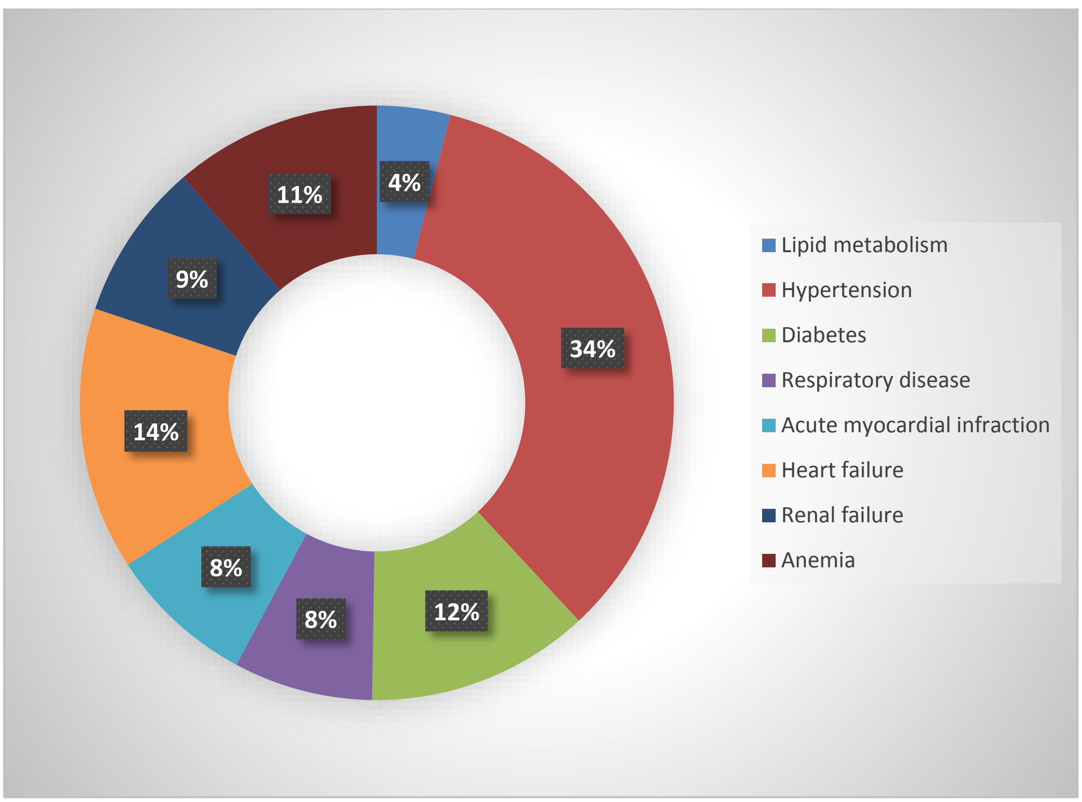

Figure 19: Comorbidities are Commonly Associated with Aortic Aneurysm

Table 23: Comorbidities with Respect to Diagnostic Imaging Procedures

Patient's Comorbidities			Medical Imaging Procedures					***P***
			CT	MRI	US	DSA	Total	
Comorbidities	Lipid metabolism	Count	11	2	128	1287	1428	
		%	0.8%	0.1%	9.0%	90.1%	100.0%	
	Hypertension	Count	134	39	1026	11008	12207	
		%	1.1%	0.3%	8.4%	90.2%	100.0%	
	Diabetes	Count	30	8	415	3900	4353	
		%	0.7%	0.2%	9.5%	89.6%	100.0%	
	Respiratory disease	Count	78	11	498	2130	2717	
		%	2.9%	0.4%	18.3%	78.4%	100.0%	
	Acute myocardial infraction	Count	5	4	56	2793	2858	
			0.2%	0.1%	2.0%	97.7%	100.0%	
	Heart failure	Count	95	10	687	4328	5120	
		%	1.9%	0.2%	13.4%	84.5%	100.0%	
	Renal failure	Count	71	23	619	2360	3073	
		%	2.3%	0.7%	20.1%	76.8%	100.0%	
	Anemia	Count	63	9	1186	2780	4038	
		%	1.6%	0.2%	29.4%	68.8%	100.0%	
Total		Count	487	106	4615	30586	35794	**<0.0001**
		%	1.4%	0.3%	12.9%	85.5%	100.0%	

4.3.4.7 Summary of Patient Characteristics

The above-discussed results are summarized in **Table 24**. WHO age groups 14 to 17 (65-85 years) accounted for about 70% of the disease incidence. About 87% patients were whites and 6.1 % were blacks and 4.3% were Hispanics. Males accounted for about 70% patients. Only less than 2% patients paid for the expenses on their own. The remaining over 98% patient were either covered by Medicare or private insurance to pay their bills. As the large majority do not need to pay themselves, cost of treatment is not a constraint for aneurysm patients not reporting to hospitals. The most common comorbidities associated with aneurysm were hypertension, diabetes, anaemia and heart failure, together accounting for 72% of patients. As out of 38263 sampled, only 35794 were accounted by comorbidities, it may mean remaining 2419 patients did not have any comorbidities.

Table 24: Summary of Patient Ccharacteristics Frequencies in the Study Sample.

Patient characteristics		Frequency *n*	Valid Percent %
Patient Characteristic (WHO Age Classification)	10.00	618	1.6
	11.00	1220	3.2
	12.00	2150	5.6
	13.00	3789	9.9
	14.00	6275	16.4
	15.00	7049	18.4
	16.00	7528	19.7
	17.00	6001	15.7
	18.00	2901	7.6
	19.00	685	1.8
	20.00	47	.1
	Total	38263	100.0
Patient Characteristic (Race)	White	33388	87.3
	Black	2345	6.1
	Hispanic	1650	4.3
	Asian or Pacific Islander	642	1.7
	Native American	238	.6
	Total	38263	100.0
Patient Characteristic (Gender)	Male	26745	69.9
	Female	11518	30.1
	Total	38263	100.0
Patient Medical Insurance	Medicare	28801	75.3
	Medicaid	1144	3.0
	Private insurance	7596	19.9
	Self-pay	722	1.9
	Total	38263	100.0
Patient Co-morbidities	Lipid metabolism	1428	4.0
	Hypertension	12207	34.1
	Diabetes	4353	12.2
	Respiratory disease	2717	7.6
	Acute myocardial infraction	2858	8.0
	Heart failure	5120	14.3
	Renal failure	3073	8.6
	Anemia	4038	11.3
	Total	35794	100.0

4.3.5 Hospital Contexts

Hospital contexts include: bed size, location, teaching status, region and admission type. Frequency of patients for each of these with respect to imaging methods is presented below

4.3.5.1 Hospital Bed Size

As the graphically presented data in **Figure 17** shows, higher number of aneurysm patients reported in large hospitals and t number decreased through medium and small size hospitals. Larger hospitals will have facilities to accommodate larger number of patients and this might have reflected in the case of aneurysm patients also.

Imaging methods maintained the trend of highest value for DSA followed by US, CT and MRI in the decreasing order. Frequency of patients imaged by different methods increased from small to large hospitals. Frequency increase from medium to large was much higher than from small to medium (from 7802 to 26983 compared to 3127 to 7802). This may be probably due to large differences in categorisation of hospitals according to bed size in different states of USA. About 71% of imaging procedures were done in large hospitals reflecting the heavy workload in those hospitals as illustrated in **Table 25.**

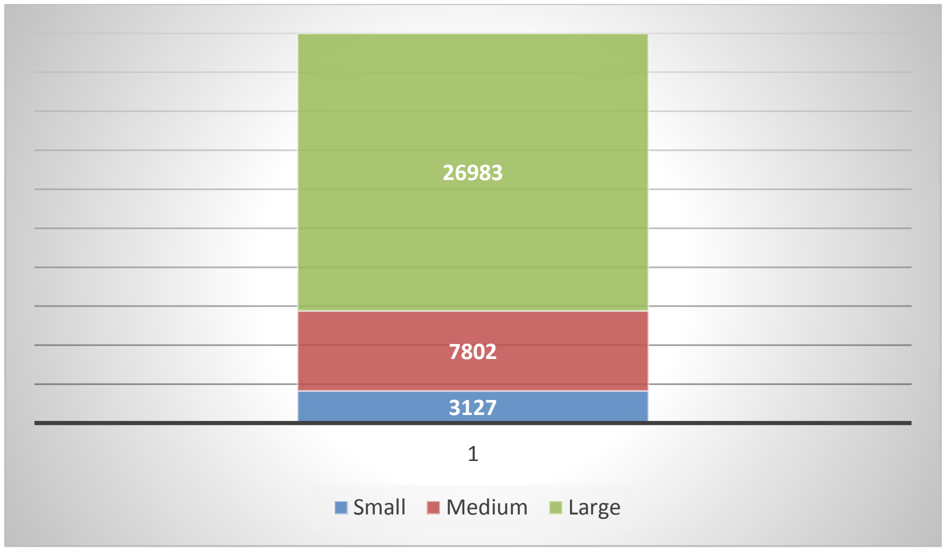

Figure 20: NIS Hospital Bed Size Distribution of Aortic Aneurysm Patients.

Table 25: Hospital Bed Size with Respect to Diagnostic Imaging Methods

Hospital Contexts			Medical Imaging Procedures				Total	***P***
			CT	MRI	US	DSA		
Bed size of hospital	Small	Count	81	9	305	2732	3127	
		%	2.6%	0.3%	9.8%	87.4%	100.0%	
	Medium	Count	154	26	908	6714	7802	
		%	2.0%	0.3%	11.6%	86.1%	100.0%	
	Large	Count	285	74	3635	22989	26983	
		%	1.1%	0.3%	13.5%	85.2%	100.0%	
Total		Count	520	109	4848	32435	37912	**<0.0001**
		%	1.4%	0.3%	12.8%	85.6%	100.0%	

4.3.5.2 Hospital Location and Teaching Status

Figure 18 shows the most frequently performed aortic aneurysm procedures during hospital stay between 2008 and 2012. There were 37, 912 hospitals stays in US. About 95 percent of all stay were in urban hospitals. Out of this, 55% were accounted by urban teaching and 40% by urban non-teaching hospitals. Only 5% was done in rural hospitals.

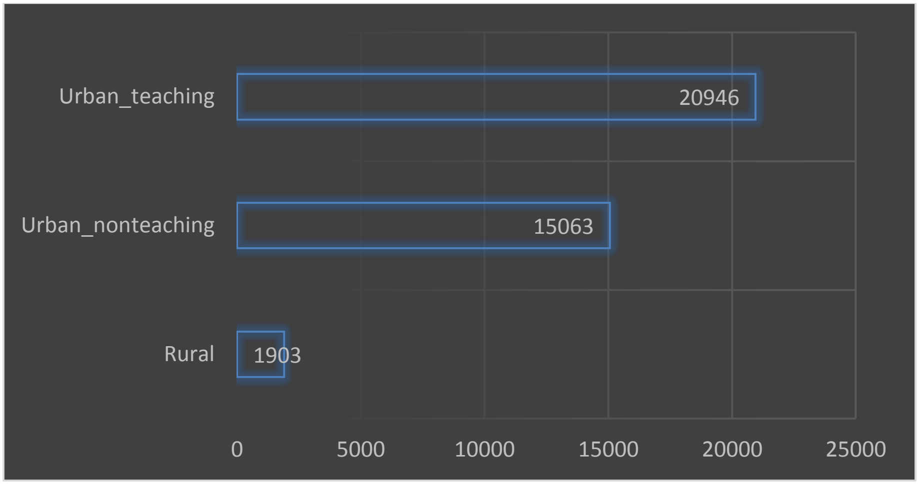

Figure 21: Hospital Location and Teaching Status Distribution between 2008 and 2012.

In **Table 26**, frequencies of imaging aneurysm patients in rural, urban-teaching and urban-non-teaching hospital categories with respect to imaging methods are given. Most imaging were done in urban teaching followed by non-teaching hospitals. Much less imaging was done in rural hospitals. The frequency of methods decreased through DSA, US, CT and MRI, with DSA accounting for about 86% of all hospitals. The capacity of large hospitals to handle large workloads is reflected here. Rural hospitals might lack imaging facilities also.

Table 26: Imaging Frequencies of Aortic Aneurysm Patients with Different Medical Imaging Methods in Hospital of Different Locations and Teaching Status

Hospital Contexts			Medical Imaging Procedures				Total	***P***
			CT	MRI	US	DSA		
Location/teaching status of hospital	Rural	Count	35	2	155	1711	1903	
		%	1.8%	0.1%	8.1%	89.9%	100.0%	
	Urban_nonteaching	Count	187	43	1491	13342	15063	
		%	1.2%	0.3%	9.9%	88.6%	100.0%	
	Urban_teaching	Count	298	64	3202	17382	20946	
		%	1.4%	0.3%	15.3%	83.0%	100.0%	
Total		Count	520	109	4848	32435	37912	**<0.0001**
		%	1.4%	0.3%	12.8%	85.6%	100.0%	

4.3.5.3 Hospital Regions

Frequency of patients imaging at hospitals of different geographical region of the country may be indicative of the relative prevalence of the disease in various geographical areas. Data on this aspect are presented in **Figure 19.**

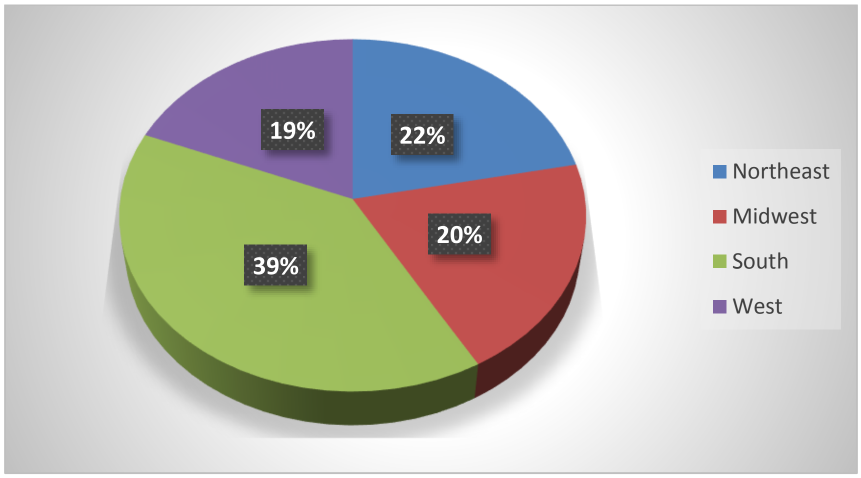

Figure 22: NIS Hospital Region Distribution of Aortic Aneurysm Patients from 2008 and 2012.

Southern region (39%) recorded maximum frequency of imaging, followed by North-eastern (22%) region over all imaging methods. DSA was used most frequently in Southern region. Use of US was almost equal in Western and Mid-western regions. As shown in **Table 27**, use of CT and MRI was highest in North-east followed by South. These findings may be indicative of highest prevalence of aortic aneurysm in South and Northeast USA and adoption of different imaging methods in different regions.

Table 27: Frequencies of Imaging Modalities used for aortic Aneurysm Patients in Hospitals Located in different Geographical Regions of USA

Hospital Contexts			Medical Imaging Procedures				Total	***P***
			CT	MRI	US	DSA		
Region of hospital	Northeast	Count	230	36	1402	6670	8338	
		%	2.8%	0.4%	16.8%	80.0%	100.0%	
	Midwest	Count	37	10	955	6635	7637	
		%	0.5%	0.1%	12.5%	86.9%	100.0%	
	South	Count	157	44	1499	13388	15088	
		%	1.0%	0.3%	9.9%	88.7%	100.0%	
	West	Count	99	22	1023	6056	7200	
		%	1.4%	0.3%	14.2%	84.1%	100.0%	
Total		Count	523	112	4879	32749	38263	**<0.0001**
		%	1.4%	0.3%	12.8%	85.6%	100.0%	

4.3.5.4 Admission Types

The data related to different types of aortic aneurysm admissions in US hospitals are given in **Figure 20.**

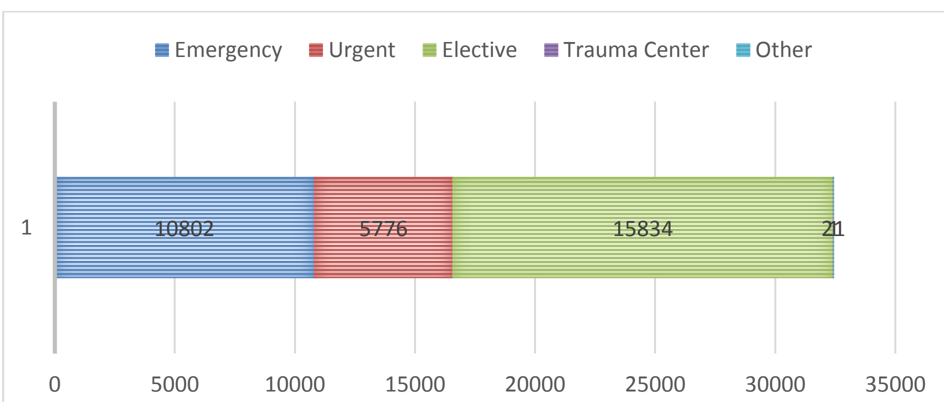

Figure 23: Admission Type of Aortic Aneurysm Patients in US Hospitals.

Out of a total number of 32, 434 cases, elective admission dominated with 48.8% of valid data, followed by about 33.3% for emergency admissions. The latter is alarming as emergency admissions are usually associated with ruptured aneurysms and may lead to in-hospital mortality in spite of best treatment given as it may be too late for any intervention to be successful. Urgent also is almost equally critical which accounted for about 17% admissions. Emergency and urgent together constitutes about 51% against 48.8% of elective admissions.

Table 28: Imaging Frequencies Using Different Methods of Aortic Aneurysm Patients Admitted in US Hospitals.

Hospital Contexts		Medical Imaging Procedures				Total	***P***
		CT	MRI	US	DSA		
Admission type	Emergency	340	59	1084	9319	10802	
	Urgent	53	10	469	5244	5776	
	Elective	73	20	2263	13478	15834	
	Trauma Center	0	0	2	19	21	
	Other	0	0	1	0	1	
Total		466	89	3819	28060	32434	**<0.0001**

Different imaging methods may be used for different admission types. Thus more than 90% imaging was done with DSA in the case of emergency and urgent admissions compared to only about 79% for elective admissions (**Table 28**). Contrary to what was theorised, emergency plus urgent and elective admissions recorded almost equal 40-42% proportion of total patients for all imaging modalities. Overall, highest frequency (13478) was observed for DSA in the case of elective admissions and the lowest frequency of 10 was recorded by MRI for urgent admissions. On the other hand, US was highest in elective followed by emergency admissions. CT and MRI were highest in emergency followed by urgent admissions. Trauma centre and other admission types recorded very low frequencies to make any significant impact. Thus irrespective of admission type, DSA is the choice method followed by US.

4.3.5.5 Summary of Hospital Contexts

As is summarised in **Table 29,** large, urban teaching and non-teaching located especially in Southern region accounted for majority of aneurysm admissions either elective or emergency.

Table 29: Summery of Hospital Contexts in the Study Sample.

Hospital Contexts		Frequency *n*	Valid Percent %
Bed size of hospital	Small	3127	8.2
	Medium	7802	20.6
	Large	26983	71.2
	Total	37912	100.0
Location/teaching status of hospital	Rural	1903	5.0
	Urban_nonteaching	15063	39.7
	Urban_teaching	20946	55.2
	Total	37912	100.0
Region of hospital	Northeast	8338	21.8
	Midwest	7637	20.0
	South	15088	39.4
	West	7200	18.8
	Total	38263	100.0
Admission Type	Emergency	10802	33.3
	Urgent	5776	17.8
	Elective	15834	48.8
	Trauma Centre	21	.1
	Other	1	.0
	Total	32434	100.0

4.3.6 Medical Imaging Modalities Associated with Interventional Aneurysm Repair for Aortic Aneurysm Types

Frequency data pertaining to the diagnostic imaging methods used in either EVAR or OAR intervention procedure with respect to different aneurysm types are presented in **Table 30.** When EVAR was done using single imaging methods, DSA was most preferred followed by US, CT and MRI in the decreasing order. When two imaging method were combined, DSA with US recorded the highest imaging frequency, as shown also in **Figure 21**. This was followed by DSA+CT and DSA+MRI. The same trend was observed in the case of OAR also. OAR combinations recorded higher frequencies than EVAR combinations, as OAR was the preferred intervention procedure.

The trend was maintained for each aneurysm type as well. In **Table 31**, overall frequency was highest for AAA followed by TA, rAAA and TAA in the decreasing order. This reflects the relative incidence and prevalence of aneurysm type rather than any preference of imaging for a specific aneurysm type. More than 70% of all imaging and interventions were done on AAA followed by about 21% for TAA, together accounting for about 90% of all aneurysm care.

Table 30: Utilizing of Different Imaging Methods for EVAR and OAR with Different Aortic Aneurysm Types

Medical Imaging Modalities Associated with Interventional Aneurysm Repair			All-listed Aortic Aneurysm Diagnosis						Total
			rTA	TA	rAAA	AAA	rTAA	TAA	
	EVAR+CT	Count	1	1	8	27	1	0	38
		%	2.6%	2.6%	21.1%	71.1%	2.6%	0.0%	100.0%
	EVAR+MRI	Count	0	1	0	3	0	2	6
		%	0.0%	16.7%	0.0%	50.0%	0.0%	33.3%	100.0%
	EVAR+US	Count	6	39	14	195	1	4	259
		%	2.3%	15.1%	5.4%	75.3%	0.4%	1.5%	100.0%
	EVAR+DSA	Count	21	314	204	7076	4	99	7718
		%	0.3%	4.1%	2.6%	91.7%	0.1%	1.3%	100.0%
	EVAR+DSA+CT	Count	2	13	8	69	1	2	95
		%	2.1%	13.7%	8.4%	72.6%	1.1%	2.1%	100.0%
	EVAR+DSA+MRI	Count	1	0	1	4	0	0	6
		%	16.7%	0.0%	16.7%	66.7%	0.0%	0.0%	100.0%
	EVAR+DSA+US	Count	6	102	18	529	1	20	676
		%	0.9%	15.1%	2.7%	78.3%	0.1%	3.0%	100.0%
	OAR+CT	Count	2	64	37	356	1	25	485
		%	0.4%	13.2%	7.6%	73.4%	0.2%	5.2%	100.0%
	OAR+MRI	Count	1	16	2	79	0	8	106
		%	0.9%	15.1%	1.9%	74.5%	0.0%	7.5%	100.0%
	OAR+US	Count	78	2256	120	1994	9	163	4620
		%	1.7%	48.8%	2.6%	43.2%	0.2%	3.5%	100.0%
	OAR+DSA	Count	114	3928	463	15806	34	520	20865
		%	0.5%	18.8%	2.2%	75.8%	0.2%	2.5%	100.0%
	OAR+DSA+CT	Count	7	67	23	183	5	7	292
		%	2.4%	22.9%	7.9%	62.7%	1.7%	2.4%	100.0%
	OAR+DSA+MRI	Count	1	18	1	44	1	4	69
		%	1.4%	26.1%	1.4%	63.8%	1.4%	5.8%	100.0%
	OAR+DSA+US	Count	43	1066	72	1737	12	98	3028
		%	1.4%	35.2%	2.4%	57.4%	0.4%	3.2%	100.0%
Total		Count	283	7885	971	28102	70	952	38263
		%	0.7%	20.6%	2.5%	73.4%	0.2%	2.5%	100.0%

Of the two intervention procedures, about 78% was by OAR and remaining 22% was by EVAR. For both procedures, DSA was most frequently used imaging method. Combination of DSA with US was next highest frequent. Other imaging methods were used in very low frequencies. The results of this are tabulated in **Table 31** as well as in **Figure 21.**

Table 31: Imaging Frequencies for Different Aortic Aneurysm Types

Medical Imaging Modalities Associated with Interventional Repair	Frequency *n*	Valid Percent %	Cumulative Percent %
EVAR+CT	38	.1	.1
EVAR+MRI	6	.0	.1
EVAR+US	259	.7	.8
EVAR+DSA	7718	20.2	21.0
EVAR+DSA+CT	95	.2	21.2
EVAR+DSA+MRI	6	.0	21.2
EVAR+DSA+US	676	1.8	23.0
OAR+CT	485	1.3	24.3
OAR+MRI	106	.3	24.5
OAR+US	4620	12.1	36.6
OAR+DSA	20865	54.5	91.1
OAR+DSA+CT	292	.8	91.9
OAR+DSA+MRI	69	.2	92.1
OAR+DSA+US	3028	7.9	100.0
Total	38263	100.0	

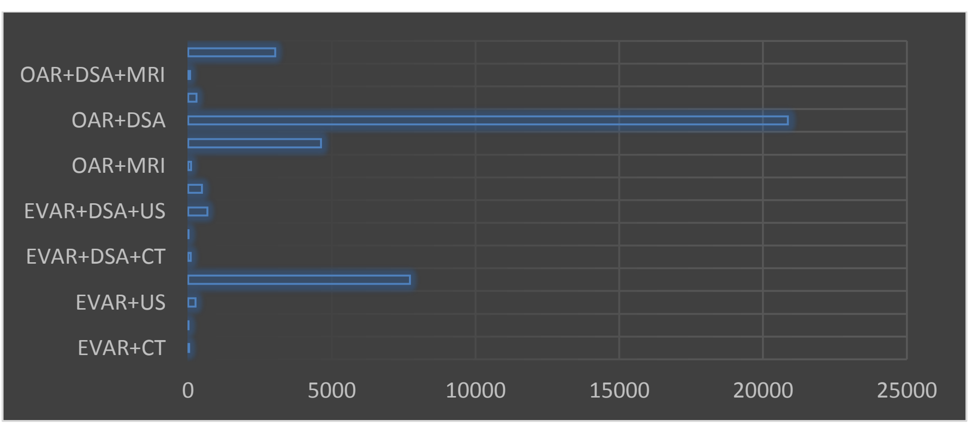

Figure 24: Imaging Techniques Associated with Interventional Repair in US Hospital between 2008 and 2012.

4.3.7 Mean Length of Stay and Imaging Procedure

Table 32 gives the data on mean length of stay as affected by imaging procedure for aortic aneurysm patients who underwent for interventional repair procedures. Length of stay was lowest when DSA was used as the imaging procedure. The mean length of stay for CT and US was about 10 days and they did not differ significantly. MRI required the longest stay.

Table 32: Mean Length of Stay (In Days) For Imaging Method (Means with the Same Superscript Letter Do Not Differ Significantly)

IMAGING PROCEDURE	MEAN LENGTH OF STAY (DAYS)	STANDARD ERROR	95% CONFIDENCE INTERVAL (DAYS)	
			LOWER LIMIT	UPPER LIMIT
CT	10.038[b]	0.463	9.131	10.945
MRI	14.284[c]	1.219	11.894	16.673
US	10.864[b]	0.212	10.448	11.280
DSA	6.831[a]	0.115	6.606	7.055

4.3.7.1 Mean Length of Stay and In-Hospital Mortality

Data on effect of in-hospital mortality or otherwise on length of stay are presented in **Table 33.** In-hospital mortality was associated with longer stay in the hospital. The patient died in the hospital when the mean length of stay was 12 days and did not die when it was only 9 days. However, in the case of patients who stayed only 9 days, it is not clear whether the patient died after discharge from the hospital even before 12 days. It is quite possible that the patient who was discharged after 9 days, died at home on 10th day. If the patient is certain to die after 9 days, hospital may discharge rather than keep the patient longer. On the other hand, even after trying best for 12 days, the patient might die. The difference between the two mean values was significant.

Table 33: Mean Length of Hospital Stay as Affected by Mortality

DIED IN THE HOSPITAL	MEAN LENGTH OF STAY (DAYS)	STANDARD ERROR	95% CONFIDENCE INTERVAL	
			LOWER LIMIT	UPPER LIMIT
DID NOT DIE	8.907	0.182	8.550	9.264
DIED	12.101	0.638	10.851	13.351

4.3.7.2 Combined Effect of Medical Imaging Method and In-Hospital Mortality on Length of Stay

Data related to the combined effect of imaging method and mortality on length of stay is presented in **Table 34**.

Table 34: Combined Effect of Imaging Method and Mortality on Length of Hospital Stay (Differences between Means within Each Mortality Group Followed by the Same Letters Are Not Significant)

IMAGING METHOD	DIED IN HOSPITAL	MEAN	STANDARD ERROR	95% CONFIDENCE INTERVAL	
				LOWER LIMIT	UPPER LIMIT
CT	DID NOT DIE	9.075a	0.308	8.471	9.679
	DIED	11.000a	0.873	9.290	12.710
MRI	DID NOT DIE	12.317b	0.652	11.040	13.595
	DIED	16.250b	2.350	11.644	20.856
US	DID NOT DIE	9.191c	0.098	8.999	9.382
	DIED	12.537d	0.413	11.727	13.346
DSA	DID NOT DIE	5.044e	0.037	4.971	5.117
	DIED	8.617f	0.226	8.174	9.060

Only the differences between mortality means in the case of US and DSA were significant. In imaging methods, in-hospital mortality occurred with longer stay even when differences between means were non-significant for the same imaging method. The mean length of stay was shortest (5 days) for DSA when the patient did not die in the hospital and when the stay extended to 9 days, the patient died in the hospital. At 95% confidence level also, maximum lengths of stay for the patient not dying or minimum/maximum stay for patient dying in the hospital were almost the same.

In the case of CT, the patient did not die for hospital stay up to 9 days, but died in the hospital when the stay was extended to 11 days. There is not much difference between upper limit for death not to occur and lower limit for death to occur at 95% confidence limits. But if the patient survived 9 days, the possibility of death is only on 11-12 days.

For MRI, the patient may not die till mean stay period is 12 days, but may die if it is extended by another four days. At the lower limit of 95% confidence level, the patient may or may not die when staying for 11 days. Nonetheless, if this is escaped, extension to 13 days may see the patient safe and extension to 21 days may lead to death.

In the case of US, patient did not die for a stay up to 9 days. But extension to 13 days resulted in death. The 95% confidence for upper limit of stay could be placed only on more or less the same period of stay. On the other hand, extending the stay up to 12-13 days can lead to death. Thus, there is a clear demarcation between dying (12-13 days) and not dying (9-10 days).

Compared to DSA, longer stays without resulting in death was possible for CT, MRI and US. MRI allowed up to 12 days stay without death. Both CT and US tolerated about 9 days without death. The shortest time required for in-hospital death also was in the case of DSA recording 8.617. Maximum advantage was with MRI for which death occurred only after 16 days stay. In the case of both CT and US, death could occur when the stay was 12-13 days.

4.4 Achievement of Objectives of This Study

In the above sections of this chapter, patient factors and hospital contexts in relation to incidence of aortic aneurysm and imaging methods were discussed. In this section, how these factors affected in-hospital mortality are discussed. The main aim of this study was to examine whether extent of compliance with ACR guidelines on imaging methods has any relationship with in-hospital mortality. This aim was converted into a set of objectives. Methods to achieve the objectives consist of identifying and collecting the data required for the objective and analyzing the data using the most appropriate statistical method to yield valid conclusions regarding the objective. **Table 35** illustrates this point with respect to this study.

Table 35: List of Variables required and Most Appropriate Statistical Methods of Data Analysis to Achieve the Objectives of This Study

No	OBJECTIVE	VARIABLES REQUIRED	STATISTICAL TESTS APPLIED
1	To study the relation between imaging modalities and in-hospital mortality among aortic aneurysm patients through US hospitals.	Medical imaging procedures and patients died patients during hospitalization (CT, MRI, US, DSA) Vs (M)	Pearson Chi-Square test McNemar's test ANOVA test Logistic Regression test
2	To compare in-hospital mortality of EVAR with OAR when different diagnostic imaging techniques are used in both cases.	Medical imaging along with interventional aortic aneurysm repair procedures and patients who died during hospitalization (EVAR_CT, EVAR_MRI, EVAR_US, EVAR_DSA, OAR_CT, OAR_MRI, OAR_US, OAR_DSA) Vs (M)	Pearson Chi-Square test McNemar's test ANOVA test Logistic Regression test
3	To evaluate the effect of using ACR recommended imaging methods and extent of compliance on in-hospital mortality.	Appropriateness of imaging criteria and in-hospital mortality. In-hospital mortality and compliance level	Pearson Chi-Square test Gamma Correlation test Logistic Regression test
4	To determine among different patient characteristics, and hospital context, those factors which can be used for prediction and thereby reduction of in-hospital mortality to desire levels.	Different patient characteristics, and hospital context with in-hospital mortality among aortic aortic aneurysm patients who examined by diagnostic imaging and underwent for repair. (age, race, gender, insurance type, comorbidities, H. bed size, H. location, H. status &M)	Logistic Regression test
5	To determine among significant predictor factors, which type of diagnostic imaging performed is associated with in-hospital mortality.	Significant factors of patient characteristics, and hospital contexts where diagnostic imaging along with repair are used. (ISPRs & Significant factors)	Multinominal logistic test

Mortality was considered as the dependent variable for conclusions based on data. The relationship of imaging and intervention procedures with mortality rate is negative. This is because proper diagnostic imaging facilitates better diagnosis and correct intervention procedures to save life and thus improve survival rate.

Objective 1

The ultimate focus is on compliance of hospitals with ACR guidelines on imaging methods in relation to in-hospital mortality. Implicit in this objective is the hypothesis that not complying with ACR guidelines leads to increase in in-hospital mortality. However, before that there is need to demonstrate relationship between imaging methods and in-hospital mortality. Only if this relationship is valid, the question of following any imaging guidelines becomes relevant. So, first the relationship between imaging methods and in-hospital mortality needs to be demonstrated. The results given in **Table 36** to **50** is aimed at this.

Irrespective of imaging methods, with increasing number of patients imaged, the percentage mortality decreased. Thus any diagnostic imaging was effective in reducing in-hospital mortality. This observation demonstrates that with more imaging, mortality can be reduced. Early detection and appropriate intervention procedures are facilitate by diagnostic imaging. This could be the reason for the observed effect. All statistical tests were significant at 1% level, except ANOVA result for MRI giving significance only at 5% level.

Comparing different imaging methods, lowest mortality percentage of 2.6% was observed for DSA followed by US, MRI and CT in the increasing order of mortality percentage. Thus there is a relationship between imaging method and in-house mortality.

These results validate Objective 1 enabling further analysis of data to achieve other objectives. Summarized data on effect of imaging methods on mortality rates are presented in **Table 36**.

Table 36: Crosstab Result of In-Hospital Mortality of Aortic Aneurysm Patients as Affected by Imaging Procedures

Imaging Procedures			Died during hospitalization		Total
			Did not die	Died	
	CT	Count	465	58	523
		%	88.9%	11.1%	100.0%
	MRI	Count	104	8	112
		%	92.9%	7.1%	100.0%
	US	Count	4619	259	4878
		%	94.7%	5.3%	100.0%
	DSA	Count	31881	865	32746
		%	97.4%	2.6%	100.0%
Total		Count	37069	1190	38259
		%	96.9%	3.1%	100.0%

Detailed analytical results for each imaging method is separately given in **Tables 37 to 48.** McNemar test was done to further examine the risk estimate via odds ratio for mortality effects for each imaging method.

Table 37: Effect of CT Imaging on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Crosstab

			Died during hospitalization		Total
			Did not die	Died	
CT	.00	Count	36604	1132	37736
		% within CT	97.0%	3.0%	100.0%
	1.00	Count	465	58	523
		% within CT	88.9%	11.1%	100.0%
Total		Count	37069	1190	38259
		% within CT	96.9%	3.1%	100.0%

Table 38: McNemar Test Results on Effect of CT Imaging on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients of USA

Chi-Square Tests

	Value	Exact Sig. (2-sided)
McNemar Test		.000[a]
N of Valid Cases	38259	

a. Binomial distribution used.

Table 39: Risk Estimate of Effect of CT Imaging On Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Risk Estimate

	Value	95% Confidence Interval	
		Lower	Upper
Odds Ratio for CT (.00 / 1.00)	4.033	3.051	5.333
For cohort Died during hospitalization = Did not die	1.091	1.058	1.125
For cohort Died during hospitalization = Died	.270	.211	.347
N of Valid Cases	38259		

Table 40: Effect of MRI Imaging on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Crosstab

			Died during hospitalization		Total
			Did not die	Died	
MRI	.00	Count	36965	1182	38147
		% within MRI	96.9%	3.1%	100.0%
	1.00	Count	104	8	112
		% within MRI	92.9%	7.1%	100.0%
Total		Count	37069	1190	38259
		% within MRI	96.9%	3.1%	100.0%

Table 41: McNemar Test Results on the Effect of MRI Imaging on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Chi-Square Tests

	Value	Exact Sig. (2-sided)
McNemar Test		.000[a]
N of Valid Cases	38259	

a. Binomial distribution used.

Table 42: Risk Estimate of the Effect of MRI Imaging on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Risk Estimate

	Value	95% Confidence Interval	
		Lower	Upper
Odds Ratio for MRI (.00 / 1.00)	2.406	1.169	4.949
For cohort Died during hospitalization = Did not die	1.044	.991	1.099
For cohort Died during hospitalization = Died	.434	.222	.848
N of Valid Cases	38259		

Table 43: Effect of Ultrasound (US) Imaging on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Crosstab

			Died during hospitalization		
			Did not die	Died	Total
US	.00	Count	32450	931	33381
		% within US	97.2%	2.8%	100.0%
	1.00	Count	4619	259	4878
		% within US	94.7%	5.3%	100.0%
Total		Count	37069	1190	38259
		% within US	96.9%	3.1%	100.0%

Table 44: McNemar Test Results on the Effect of Ultrasound (Us) Imaging On Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Chi-Square Tests

	Value	Exact Sig. (2-sided)
McNemar Test		.000[a]
N of Valid Cases	38259	

a. Binomial distribution used.

Table 45: Risk Estimate of the Effect of Ultrasound (Us) Imaging on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Risk Estimate

		95% Confidence Interval	
	Value	Lower	Upper
Odds Ratio for US (.00 / 1.00)	1.954	1.697	2.251
For cohort Died during hospitalization = Did not die	1.027	1.020	1.034
For cohort Died during hospitalization = Died	.525	.459	.601
N of Valid Cases	38259		

Table 46: Effect of DSA Imaging on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Crosstab

			Died during hospitalization		Total
			Did not die	Died	
DSA	.00	Count	5188	325	5513
		% within DSA	94.1%	5.9%	100.0%
	1.00	Count	31881	865	32746
		% within DSA	97.4%	2.6%	100.0%
Total		Count	37069	1190	38259
		% within DSA	96.9%	3.1%	100.0%

Table 47: McNemar Test Results on the Effect of DSA Imaging on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Chi-Square Tests

	Value	Exact Sig. (2-sided)
McNemar Test		.000[a]
N of Valid Cases	38259	

a. Binomial distribution used.

Table 48: Risk Estimate of the Effect of DSA Imaging on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Risk Estimate

	Value	95% Confidence Interval	
		Lower	Upper
Odds Ratio for DSA (.00 / 1.00)	.433	.380	.494
For cohort Died during hospitalization = Did not die	.967	.960	.973
For cohort Died during hospitalization = Died	2.232	1.971	2.527
N of Valid Cases	38259		

Odds ratio for CT imaging against other imaging methods was 4.033 making it four times riskier compared to other methods. Within CT, chances of mortality was only 0.270 compared to chances of not dying at 1.091. The 95% confidence limits were narrower for not dying (1.058 to 1.125) and wider (0.211 to 0.347) for dying. Thus the risk is wider for dying compared to not dying. This reflected in the overall effect of CT becoming riskier compared to other imaging methods.

Against other imaging methods, odds ratio for MRI was 2.406. Thus MRI was twice riskier than other methods with respect to mortality. Within MRI, chances of mortality was lower at 0.434 compared to chances of not dying at 1.044. Here too, 95% confidence limits were narrow (0.991 to 1.099) for not dying and very wide (0.222 to 0.848). Thus risk of mortality is wider compared to not dying. The odds for lower risk of dying when MRI used.

Odds ratio was 1.954 for US compared to all other imaging methods. This means, chances of mortality is twice that of the risk of mortality with other imaging methods. Within US, risk of dying was 0.525 with a 95% confidence range of 0.459 to 0.601. On the other hand, the odds ratio for not dying was higher at 1.027 with a 95% confidence range of 1.020 to 1.034. Thus both odds favored lower risk of dying with US.

The number of patients who underwent DSA diagnostic imaging was the maximum. The accuracy and the reliability of estimates is high due to this. Mortality risk compared to other methods was the minimum at 0.433. Thus the risk of dying with DSA was less than half of the risk due to other methods. The odds ratio for not dying was 0.967 with the 95% confidence range of 0.960 to 0.973. Odds ratio for dying was 2.232 with the 95% range of

1.971 to 2.527. Not dying had narrower range than dying. Therefore, within DSA, risk is higher for dying by more than two times compared to not dying.

Table 49 summarizes the odds ratios of the four imaging methods. Among imaging methods, Risk of mortality decreases through CT, MRI, US to DSA. Odds ratio for not dying is higher than that for dying. Thus any diagnostic imaging will help to reduce mortality. Specifically, odds are highest for not dying and the lowest in the case of CT. Odds for not dying decreases through CT, MRI, US to DSA. On the other hand, odds for dying is highest for DSA and the lowest for CT. Odds ratio for dying increases through CT, MRI, US to DSA. The 95% confidence ranges of US is within the range of MRI for all odds ratios. Thus, although mortality rate was lowest for DSA, risk of dying is highest and of not dying is lowest for this imaging method. CT shows best promise in this regard.

Table 49: Comparison of Odds Ratios Estimated By McNemar Tests on In-Hospital Mortality of Aortic Aneurysm Patients Under Four Diagnostic Aortic Aneurysm Imaging Methods in USA

IMAGING METHOD	ODDS RATIO AGAINST OTHER IMAGING METHODS	ODDS RATIO FOR NOT DYING (WITH 95% CONFIDENCE RANGE)	ODDS RATIO FOR DYING (WITH 95% CONFIDENCE RANGE)
CT	4.033 (3.051 to 5.333)	1.091 (1.059 to 1.125)	0.270 (0.211 to 0.347)
MRI	2.406 (1.169 to 4.949)	1.044 (0.991 to 1.099)	0.434 (0.222 to 0.848)
US	1.954 (1.697 to 2.251)	1.027 (1.020 to 1.034)	0.525 (0.459 to 0.601)
DSA	0.433 (0.380 to 0.494)	0.967 (0.960 to 0.973)	2.232 (1.971 to 2.527)

Logistic regression analysis showed highly significant Chi-square values for likelihood ratio and linear-by-linear association (**Table 50**). The likelihood ratio result indicates that the model works better with a predictor than without. Linear-by-linear association value indicates strong linearity of the predictive model for odds of mortality to happen.

Table 50: Chi-Square Test Results of Effect of Imaging Methods on Frequencies of In-Hospital Mortality Rates among Aortic Aneurysm Patients in USA

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	218.711[a]	3	.000
Likelihood Ratio	162.050	3	.000
Linear-by-Linear Association	218.193	1	.000
N of Valid Cases	38259		

a. 1 cells (12.5%) have expected count less than 5. The minimum expected count is 3.48.

Since ANOVA test for all imaging methods were highly significant, individual model for each imaging method is possible. Effect of each imaging methods as a predictor is high after controlling the effects of other imaging methods, as indicated by highly significant Wald values for all imaging methods. These are evident from **Table 51**.

Table 51: ANOVA Test on Effect of Imaging Methods on Frequencies of In-Hospital Mortality Rates among Aortic Aneurysm Patients in USA Hospitals

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
CT	Between Groups	1.511	1	1.511	112.354	.000
	Within Groups	514.340	38257	.013		
	Total	515.851	38258			
MRI	Between Groups	.018	1	.018	6.062	.014
	Within Groups	111.654	38257	.003		
	Total	111.672	38258			
US	Between Groups	9.981	1	9.981	89.929	.000
	Within Groups	4246.077	38257	.111		
	Total	4256.058	38258			
DSA	Between Groups	20.442	1	20.442	166.463	.000
	Within Groups	4698.152	38257	.123		
	Total	4718.594	38258			

The results of multiple logistic regression tests on the four imaging methods are given in the series **Table 52**.

Table 52: Parameters of Predictive Probabilistic Equation from Logistic Multiple Regression Test on the Effect of Imaging Methods on Frequencies of In-Hospital Mortality Rate among Aortic Aneurysm Patients in USA Hospitals

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	CT	1.395	.142	95.793	1	.000	4.033	3.051	5.333
	Constant	-3.476	.030	13268.490	1	.000	.031		

a. Variable(s) entered on step 1: CT.

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	MRI	.878	.368	5.687	1	.017	2.406	1.169	4.949
	Constant	-3.443	.030	13575.699	1	.000	.032		

a. Variable(s) entered on step 1: MRI.

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	US	.670	.072	86.643	1	.000	1.954	1.697	2.251
	Constant	-3.551	.033	11413.384	1	.000	.029		

a. Variable(s) entered on step 1: US.

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	DSA	-.837	.067	157.089	1	.000	.433	.380	.494
	Constant	-2.770	.057	2347.157	1	.000	.063		

a. Variable(s) entered on step 1: DSA.

From the regression test results, the equation for odds of each imaging method is given by-

Ln (odds Died) = -3.476-1.395*CT

Ln (odds Died) = -3.443+0.878*MRI

Ln (Odds Died) = -3.551+0.670*US

Ln (Odds Died) = -2.770-0.837*DSA

From B (Exp) values, maximum probability of mortality rate is likely to be 4.033 times for CT, 2.406 times for MRI, 1.954 times for US and 0.433 times for DSA when compared to the effect of any other imaging method in each case. Only in the case of DSA, the maximum probability of mortality is lower than any other method. These results demonstrate that maximum probability of mortality can vary with imaging methods.

Objective 2

The aim here was to see whether there is any difference in mortality specifically due to imaging method or intervention procedure or their interaction. In the previous objective, although the relationship between diagnostic imaging and mortality was established, mortality outcome is related to intervention procedures to a greater extent. If this is not the case, the role of imaging method in mortality is substantially unequivocal.

From **Table 53**, EVAR recorded better survival than OAR as was observed in the Review of Literature. The mortality rate increased from 0.8 for DSA to about 2.6 percentages for US and CT. As the total number of patients was only six for MRI, this is not considered here. In the case of OAR, using DSA, US, MRI and CT recorded progressively higher mortality percentages of 3.3, 5.5, 7.5 and 11.8 respectively. In both cases of EVAR and OAR, DSA recorded lowest mortality followed by US. Thus, whatever the intervention procedure, DSA is the choice method followed by US.

Although chi-square tests were highly significant, ANOVA tests were significant only for EVAR+DSA and all combinations of OAR.

The distinct interactive effects of imaging and intervention procedures validates Objective 2. The interactive effect of imaging method versus intervention on mortality rate is summarized in **Table 54**. Mortality rate was lower with EVAR than with OAR. Mortality rate was least with DSA and highest for CT. The combination of EVAR+DSA recorded the lowest mortality rates. As MRI was done only on six patients in the case of EVAR, its mortality rate is distorted. The interactive effects are presented in **Table 53.**

Table 53: Interactive Effect of Diagnostic Imaging Methods and Intervention Procedures on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Repair procedures associated with diagnostic imaging			Died during hospitalization		
			Did not die	Died	Total
	EVAR+CT	Count	37	1	38
		%	97.4%	2.6%	100.0%
	EVAR+MRI	Count	6	0	6
		%	100.0%	0.0%	100.0%
	EVAR+US	Count	252	7	259
		%	97.3%	2.7%	100.0%
	EVAR+DSA	Count	8424	70	8494
		%	99.2%	0.8%	100.0%
	OAR+CT	Count	428	57	485
		%	88.2%	11.8%	100.0%
	OAR+MRI	Count	98	8	106
		%	92.5%	7.5%	100.0%
	OAR+US	Count	4367	252	4619
		%	94.5%	5.5%	100.0%
	OAR+DSA	Count	23457	795	24252
		%	96.7%	3.3%	100.0%
Total		Count	37069	1190	38259
		%	96.9%	3.1%	100.0%

Table 54: Interactive Effects of Imaging Methods and Interventions on Frequencies of In-Hospital Mortality Rates of Aortic Aneurysm Patients in USA

DIAGNOSTIC IMAGING METHOD	PER CENT OF IN-HOSPITAL MORTALITY FOR REPIR INTERVENTIONAL METHOD USED	
	EVAR	**OAR**
CT	2.6	11.8
MRI	0.0	7.5
US	2.7	5.5
DSA	0.8	3.3

All Chi-Square values were highly significant in this test. Highly significant likelihood ratio demonstrates non-interference from other predictors. Linearity of the model is also strong as indicated by the highly significant Linear-by-linear association value. The analysis is given in **Table 55**.

Table 55: Chi-Square Analysis of Effect of Imaging and Intervention Methods on Frequencies of In-Hospital Mortality Rate among Aortic Aneurysm Patients in USA

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	361.384[a]	7	.000
Likelihood Ratio	355.528	7	.000
Linear-by-Linear Association	89.858	1	.000
N of Valid Cases	38259		

a. 3 cells (18.8%) have expected count less than 5. The minimum expected count is .19.

Tables 56 to **82** gives the results of ANOVA, Chi-Square for McNemar test and risk estimates of all combinations of imaging method with intervention procedures.

Table 56: Interactive Effects of EVAR with CT on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Crosstab

			Died during hospitalization		Total
			Did not die	Died	
EVAR_CT	.00	Count	37032	1189	38221
		% within EVAR_CT	96.9%	3.1%	100.0%
	1.00	Count	37	1	38
		% within EVAR_CT	97.4%	2.6%	100.0%
Total		Count	37069	1190	38259
		% within EVAR_CT	96.9%	3.1%	100.0%

Table 57: McNemar Test Results on Interactive Effect of EVAR with CT on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Chi-Square Tests

	Value	Exact Sig. (2-sided)
McNemar Test		.000[a]
N of Valid Cases	38259	

a. Binomial distribution used.

Table 58: Risk Estimate on Interactive Effect of EVAR with CT on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Risk Estimate

	Value	95% Confidence Interval	
		Lower	Upper
Odds Ratio for EVAR_CT (.00 / 1.00)	.842	.115	6.140
For cohort Died during hospitalization = Did not die	.995	.944	1.049
For cohort Died during hospitalization = Died	1.182	.171	8.184
N of Valid Cases	38259		

Table 59: Interactive Effects of EVAR with MRI on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Crosstab

			Died during hospitalization		
			Did not die	Died	Total
EVAR_MRI	.00	Count	37063	1190	38253
		% within EVAR_MRI	96.9%	3.1%	100.0%
	1.00	Count	6	0	6
		% within EVAR_MRI	100.0%	0.0%	100.0%
Total		Count	37069	1190	38259
		% within EVAR_MRI	96.9%	3.1%	100.0%

Table 60: McNemar Test Results on Interactive Effect of EVAR with MRI on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Chi-Square Tests

	Value	Exact Sig. (2-sided)
McNemar Test		.000[a]
N of Valid Cases	38259	

a. Binomial distribution used.

Table 61: Risk Estimate on Interactive Effect of EVAR with MRI on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Risk Estimate

		95% Confidence Interval	
	Value	Lower	Upper
For cohort Died during hospitalization = Did not die	.969	.967	.971
N of Valid Cases	38259		

Table 62: Interactive Effects of EVAR with US on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Crosstab

			Died during hospitalization		Total
			Did not die	Died	
EVAR_US	.00	Count	36817	1183	38000
		% within EVAR_US	96.9%	3.1%	100.0%
	1.00	Count	252	7	259
		% within EVAR_US	97.3%	2.7%	100.0%
Total		Count	37069	1190	38259
		% within EVAR_US	96.9%	3.1%	100.0%

Table 63: McNemar Test Results on Interactive Effect of EVAR with US on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Chi-Square Tests

	Value	Exact Sig. (2-sided)
McNemar Test		.000[a]
N of Valid Cases	38259	

a. Binomial distribution used.

Table 64: Risk Estimate on Interactive Effect of EVAR with US on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Risk Estimate

	Value	95% Confidence Interval	
		Lower	Upper
Odds Ratio for EVAR_US (.00 / 1.00)	.864	.407	1.836
For cohort Died during hospitalization = Did not die	.996	.976	1.016
For cohort Died during hospitalization = Died	1.152	.554	2.397
N of Valid Cases	38259		

Table 65: Interactive Effects of EVAR with DSA on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Crosstab

			Died during hospitalization		Total
			Did not die	Died	
EVAR_DSA	.00	Count	28645	1120	29765
		% within EVAR_DSA	96.2%	3.8%	100.0%
	1.00	Count	8424	70	8494
		% within EVAR_DSA	99.2%	0.8%	100.0%
Total		Count	37069	1190	38259
		% within EVAR_DSA	96.9%	3.1%	100.0%

Table 66: McNemar Test Results on Interactive Effect of EVAR with DSA on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Chi-Square Tests

	Value	Exact Sig. (2-sided)
McNemar Test		.000[a]
N of Valid Cases	38259	

a. Binomial distribution used.

Table 67: Risk Estimate on Interactive Effect of EVAR with DSA on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Risk Estimate

	Value	95% Confidence Interval	
		Lower	Upper
Odds Ratio for EVAR_DSA (.00 / 1.00)	.213	.167	.271
For cohort Died during hospitalization = Did not die	.970	.967	.973
For cohort Died during hospitalization = Died	4.566	3.591	5.806
N of Valid Cases	38259		

Table 68: Interactive Effects of OAR with CT on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Crosstab

			Died during hospitalization		
			Did not die	Died	Total
OAR_CT	.00	Count	36641	1133	37774
		% within OAR_CT	97.0%	3.0%	100.0%
	1.00	Count	428	57	485
		% within OAR_CT	88.2%	11.8%	100.0%
Total		Count	37069	1190	38259
		% within OAR_CT	96.9%	3.1%	100.0%

Table 69: McNemar Test Results on Interactive Effect of OAR with CT on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Chi-Square Tests

	Value	Exact Sig. (2-sided)
McNemar Test		.000[a]
N of Valid Cases	38259	

a. Binomial distribution used.

Table 70: Risk Estimate on Interactive Effect of OAR with CT on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Risk Estimate

	Value	95% Confidence Interval	
		Lower	Upper
Odds Ratio for OAR_CT (.00 / 1.00)	4.307	3.247	5.713
For cohort Died during hospitalization = Did not die	1.099	1.064	1.136
For cohort Died during hospitalization = Died	.255	.199	.328
N of Valid Cases	38259		

Table 71: Interactive Effects of OAR with MRI on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Crosstab

			Died during hospitalization		
			Did not die	Died	Total
OAR_MRI	.00	Count	36971	1182	38153
		% within OAR_MRI	96.9%	3.1%	100.0%
	1.00	Count	98	8	106
		% within OAR_MRI	92.5%	7.5%	100.0%
Total		Count	37069	1190	38259
		% within OAR_MRI	96.9%	3.1%	100.0%

Table 72: McNemar Test Results on Interactive Effect of OAR with MRI on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Chi-Square Tests

	Value	Exact Sig. (2-sided)
McNemar Test		.000[a]
N of Valid Cases	38259	

a. Binomial distribution used.

Table 73: Risk Estimate on Interactive Effect of OAR with MRI on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Risk Estimate

	Value	95% Confidence Interval	
		Lower	Upper
Odds Ratio for OAR_MRI (.00 / 1.00)	2.553	1.239	5.261
For cohort Died during hospitalization = Did not die	1.048	.993	1.107
For cohort Died during hospitalization = Died	.410	.210	.801
N of Valid Cases	38259		

Table 74: Interactive Effects of OAR with US on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Crosstab

			Died during hospitalization		Total
			Did not die	Died	
OAR_US	.00	Count	32702	938	33640
		% within OAR_US	97.2%	2.8%	100.0%
	1.00	Count	4367	252	4619
		% within OAR_US	94.5%	5.5%	100.0%
Total		Count	37069	1190	38259
		% within OAR_US	96.9%	3.1%	100.0%

Table 75: McNemar Test Results on Interactive Effect of OAR with US on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Chi-Square Tests

	Value	Exact Sig. (2-sided)
McNemar Test		.000[a]
N of Valid Cases	38259	

a. Binomial distribution used.

Table 76: Risk Estimate on Interactive Effect of OAR with US on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Risk Estimate

	Value	95% Confidence Interval	
		Lower	Upper
Odds Ratio for OAR_US (.00 / 1.00)	2.012	1.744	2.320
For cohort Died during hospitalization = Did not die	1.028	1.021	1.036
For cohort Died during hospitalization = Died	.511	.446	.585
N of Valid Cases	38259		

Table 77: Interactive Effects of OAR with DSA on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Crosstab

			Died during hospitalization		Total
			Did not die	Died	
OAR_DSA	.00	Count	13612	395	14007
		% within OAR_DSA	97.2%	2.8%	100.0%
	1.00	Count	23457	795	24252
		% within OAR_DSA	96.7%	3.3%	100.0%
Total		Count	37069	1190	38259
		% within OAR_DSA	96.9%	3.1%	100.0%

Table 78: McNemar Test Results on Interactive Effect of OAR with DSA on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Chi-Square Tests

	Value	Exact Sig. (2-sided)
McNemar Test		.000[a]
N of Valid Cases	38259	

a. Binomial distribution used.

Table 79: Risk Estimate on Interactive Effect of OAR with DSA on Frequency of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Risk Estimate

	Value	95% Confidence Interval	
		Lower	Upper
Odds Ratio for OAR_DSA (.00 / 1.00)	1.168	1.033	1.320
For cohort Died during hospitalization = Did not die	1.005	1.001	1.008
For cohort Died during hospitalization = Died	.860	.764	.969
N of Valid Cases	38259		

The estimated odds ratios and their implications are discussed separately for EVAR and OAR combinations of imaging below.

EVAR Combinations of Imaging

Compared to other combinations, EVAR+CT had an odds ratio of 0.842 (95% confidence range: 0.115 to 6.140). But the upper limit is about six times the average risk. Within this combination, odds ratio for not dying was 0.995 (range: 0.944 to 1.049). For dying, the ratio was higher at 1.182 (0.171 to 8.184). Thus, there is less than an even chance of mortality when EVAR+CT is used although eight times risky situation can occur as per the upper limit. In the case of EVAR+MRI, odds ratio and its range were less than one demonstrating lower than even chance of mortality for this combination. For EVAR+US combination, on an average, there was less than even chance of mortality (0.864) compared to other combinations. However, the upper limit was nearly twice (1.836) this value, doubling the mortality risk. Within the combination, risk of not dying was almost even both for mean and range of values. On the other hand, mean risk of dying was around even with upper limit being more than double at 2.397. When EVAR+DSA is considered, both mean and range are less than a quarter (0.213, 0.167 to 0.271) risky compared to other combinations. Within the combination, risk of not dying is around 0.970 for both mean and range. However, the risk of dying is 4.566 times with the range varying between 3.5 and 5.8. When the risk of dying is more than the odds of not dying, the combination is inferior. This places DSA at a disadvantageous position. For other combinations, chances of dying or not dying were almost even with upper limit for the 95% confidence level becoming high for CT and US.

OAR Combinations of Imaging

For OAR+CT combination, mortality risk was 4.307 times other combinations with the range varying between 3.247 and 5.713. Within the combination, risk of dying is only one-fourth (0.255, .199 to 0.328) of risk of not dying (1.099, 1,064 to 1.136). In the case of OAR+MRI, the mortality risk is 2.553 times (1.239 to 5.261) higher than for other combinations. Within OAR+MRI, risk of dying was only 0.410 (0.210 to 0.801) and the odds for not dying was 1.048 (0.993 to 1.107). For OAR+US, there was 2.012 (1.744 to 2.320) dying chance over other methods. Within the combination, chances of dying was 0.511 (0.446 to 0.585) against chances of survival at 1.028 (1.021 to 1.036). In the case of OAR+DSA, the mortality risk was 1.168 (1.033 to 1.320) compared to other methods. Within the combination, chance of not dying was 1.005 (1.001 to 1.008) as against the chance of dying at 0.860 (0.764 to 0.969).

Overall, comparing different methods, high mortality risk was noted for OAR+CT. Within combinations, the risk of mortality for all combinations were less than the chance of survival. The highly significant likelihood ratio of 355.528 indicates that the model as a whole fitted better with predictors than without. Linear-by-linear association is also strong.

ANOVA (**Table 80**) showed significance only for EVAR+DSA and all combinations of OAR.

Table 80: ANOVA on Interactive Effects of Intervention Procedures with Imaging Methods on Frequencies of In-Hospital Mortality of Aneurysm Patients in USA

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
EVAR_CT	Between Groups	.000	1	.000	.029	.865
	Within Groups	37.962	38257	.001		
	Total	37.962	38258			
EVAR_MRI	Between Groups	.000	1	.000	.193	.661
	Within Groups	5.999	38257	.000		
	Total	5.999	38258			
EVAR_US	Between Groups	.001	1	.001	.144	.705
	Within Groups	257.246	38257	.007		
	Total	257.247	38258			
EVAR_DSA	Between Groups	32.708	1	32.708	190.299	.000
	Within Groups	6575.513	38257	.172		
	Total	6608.221	38258			
OAR_CT	Between Groups	1.524	1	1.524	122.124	.000
	Within Groups	477.328	38257	.012		
	Total	478.852	38258			
OAR_MRI	Between Groups	.019	1	.019	6.944	.008
	Within Groups	105.687	38257	.003		
	Total	105.706	38258			
OAR_US	Between Groups	10.179	1	10.179	96.121	.000
	Within Groups	4051.171	38257	.106		
	Total	4061.349	38258			
OAR_DSA	Between Groups	1.435	1	1.435	6.182	.013
	Within Groups	8877.464	38257	.232		
	Total	8878.898	38258			

Table 81 provides parameters of predictive probabilistic equations for all combinations of imaging methods and EVAR. **Table 82** provides parameters of predictive probabilistic equations for all combinations of imaging methods and OAR.

Table 81: Parameters of Predictive Probabilistic Equations for Interactive Effect of EVAR with Imaging Methods on Frequencies of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	EVAR_CT	-.172	1.014	.029	1	.865	.842	.115	6.140
	Constant	-3.439	.029	13621.907	1	.000	.032		

a. Variable(s) entered on step 1: EVAR_CT.

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	EVAR_MRI	-17.764	16408.711	.000	1	.999	.000	.000	.
	Constant	-3.439	.029	13633.331	1	.000	.032		

a. Variable(s) entered on step 1: EVAR_MRI.

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	EVAR_US	-.146	.384	.144	1	.705	.864	.407	1.836
	Constant	-3.438	.030	13546.827	1	.000	.032		

a. Variable(s) entered on step 1: EVAR_US.

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	EVAR_DSA	-1.549	.124	156.433	1	.000	.213	.167	.271
	Constant	-3.242	.030	11326.436	1	.000	.039		

a. Variable(s) entered on step 1: EVAR_DSA.

From **Tables 81**, in the case of EVAR combinations, Wald test was significant only for combination with DSA showing the effect of other predictors interfering with the effect of

EVAR. According to B (Exp) values, the maximum probability of mortality was 0.842 times for CT, 0.864 times for US and 0.213 times for DSA compared to any other imaging method. Here too DSA, with least likelihood, was best. The logistic equations for EVAR combinations are-

Ln (Odds Died) = -3.439-0.172*EVAR+CT

Ln (Odds Died) = -3.439-17.764*EVAR+MRI

Ln (Odds Died) = -3.438-0.146*EVAR+MRI

Ln (Odds Died) = -3.242-1.549*EVAR+DSA

It is notable that the constants for all the combinations were more or less the same value. There were only six patients in the case of EVAR-MRI and hence the reliability of results in this regard is suspect.

Table 82: Parameters of Predictive Probabilistic Equations for Interactive Effects of OAR with Imaging Methods on Frequencies of Aortic Aneurysm Patients in USA

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	OAR_CT	1.460	.144	102.561	1	.000	4.307	3.247	5.713
	Constant	-3.476	.030	13281.235	1	.000	.031		

a. Variable(s) entered on step 1: OAR_CT.

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	OAR_MRI	.937	.369	6.458	1	.011	2.553	1.239	5.261
	Constant	-3.443	.030	13577.047	1	.000	.032		

a. Variable(s) entered on step 1: OAR_MRI.

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B) Lower	Upper
Step 1[a]	OAR_US	.699	.073	92.305	1	.000	2.012	1.744	2.320
	Constant	-3.551	.033	11500.865	1	.000	.029		

a. Variable(s) entered on step 1: OAR_US.

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B) Lower	Upper
Step 1[a]	OAR_DSA	.155	.062	6.170	1	.013	1.168	1.033	1.320
	Constant	-3.540	.051	4809.906	1	.000	.029		

In the case of OAR combinations (**Table 82**), all Wald tests were highly significant. Thus no effect of other predictors interfered with the effect of these combinations. B (Exp) values indicated the odds to be 4.307 times for CT, 2.553 times for MRI, 2.012 times for US and 1.68 times for DSA combinations compared to any other combination in each case. Although DSA was best among OAR, its combination with EVAR gave much lower maximum likelihood of mortality. Logistic equations for odds in the case of OAR combinations are-

Ln (Odds Died) = -3.476+1.460*OAR+CT

Ln (Odds Died) = -3.443+ 0.937*OAR+MRI

Ln (Odds Died) = -3.551+ 0.699*OAR+US

Ln (Odds Died) = -3.540+ 0.155*OAR+DSA

It is notable that all the regression coefficients were positive values. Thus the overall, interactive effects of imaging methods with interventions were significant. Thus both these factors affect mortality rates. Even with the same intervention, imaging methods have differential effects. Therefore, imaging methods assume great importance here. As per the objective of this study, strong interactive effect of intervention and imaging method were noticed.

Objective 3

The aim was to evaluate the effect of using ACR recommended imaging methods and extent of compliance on in-hospital mortality. The data on the relationship between using ACR compliant imaging methods in terms of the rating scales and frequency of in-hospital mortality of total reported aortic aneurysm patients is given in **Table 83**.

Maximum patients reported in hospitals rated as “May be appropriate” The mortality rate was 5.6%. A sizeable number of patients reported in “Usually not appropriate” rated hospitals also. Mortality rate in this case was 10.4%. Only very few patients reported in hospitals rated with highest compliance. Although mortality rate was zero here, only four patients reported here and therefore, the result may not be reliable. Still, a mortality rate below 5.6% can be assumed in this case. Thus, extent of compliance with ACR guidelines is related with mortality rate. Lower the compliance, higher the mortality. This point is more directly illustrated by **Table 84.** All the statistical tests were highly significant.

Effect of Strictly and Fully ACR Compliant Imaging Procedures on In-Hospital Mortality Rate

If compliance level is critical in determining mortality rate, use of imaging methods in strict compliance with ACR should reduce mortality substantially. However, there can be variations among imaging methods to produce this effect. This aspect was studied and the data are presented in **Table 83.**

Table 83: The Effect of Using Strictly and Fully ACR Compliant Radiological Methods on Frequencies of In-Hospital Mortality of Aortic Aneurysm Patients in USA

ACR radiological procedures			Died during hospitalization		
			Did not die	Died	Total
	CTA	Count	4	0	4
		%	100.0%	0.0%	100.0%
	CT_Abdomen & Pelvis	Count	199	27	226
		%	88.1%	11.9%	100.0%
	CT_Thoracic	Count	224	26	250
		%	89.6%	10.4%	100.0%
	US	Count	4619	259	4878
		%	94.7%	5.3%	100.0%
	DSA	Count	31881	865	32746
		%	97.4%	2.6%	100.0%
Total		Count	36927	1177	38104
		% within ACR	96.9%	3.1%	100.0%

CTA had very few number of patients reported and hence zero mortality obtained here is suspect. CT imaging of abdomen and pelvis as well as thoracic regions recorded similar mortality rate in the range of 10.5-12.0. The mortality rate was only 5.3% for US and was the lowest 2.6% for DSA. Based on length of stay, DSA was found undesirable in the earlier discussions. However, mortality rate itself is minimum for DSA and this may be associated with short period of hospital stay. All statistical tests were highly significant. Therefore, if ACR compliant procedures are used, DSA method is most effective followed by US in reducing mortality rate.

Earlier, in **Table 83**, mortality rate for different imaging methods (irrespective of ACR compliance) was presented. The mortality rates in both tables agree.

Chi-Square tests gave highly significant Likelihood ratio and Linear-by-linear values. Thus the model fitted better with predictors and the relationship is strongly linear **(Table 84**).

Table 84: Chi-Square Test Results on Effect of ACR Compliant Radiological Procedures on Frequency of In-Hospital Mortality among Aortic Aneurysm Patients in USA

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	206.255[a]	4	.000
Likelihood Ratio	152.579	4	.000
Linear-by-Linear Association	197.995	1	.000
N of Valid Cases	38104		

a. 2 cells (20.0%) have expected count less than 5. The minimum expected count is .12.

Gamma test and other tests have relatively low negative value indicating negative relationship between ACR compliance and mortality. Gamma= -0.328, which also indicate a strong degree of inverse correlation. Thus, higher the compliance, lower is the mortality rate (**Table 85** to **88)**.

Table 85: Effect of ACR Compliance Levels of Hospitals on Frequencies of In-Hospital Mortality of Aortic Aneurysm Patients in USA

ACR_Compliance_Rating			Died during hospitalization: Did not die	Died during hospitalization: Died	Total
	Usually not appropriate	Count	4619	259	4878
		% within ACR_Compliance_Rating	94.7%	5.3%	100.0 %
		% within Died during hospitalization	12.5%	22.0%	12.8%
	May be appropriate	Count	32304	918	33222
		% within ACR_Compliance_Rating	97.2%	2.8%	100.0 %
		% within Died during hospitalization	87.5%	78.0%	87.2%
	Usually appropriate	Count	4	0	4
		% within ACR_Compliance_Rating	100.0%	0.0%	100.0 %
		% within Died during hospitalization	0.0%	0.0%	0.0%
Total		Count	36927	1177	38104
		% within ACR_Compliance_Rating	96.9%	3.1%	100.0 %
		% within Died during hospitalization	100.0%	100.0%	100.0 %

Table 86: Mean Effects of Increasing Compliance with ACR Appropriateness Criteria on In-Hospital Mortality Rate of Aortic Aneurysm Patients in USA

Compliance Level	In_Hospital Mortality Percentage
Usually not appropriate	5.3
May be appropriate	2.8
Usually appropriate	0

Table 87: Chi-Square Test Results on Effect of ACR Compliance Levels of Hospitals on Frequencies of In-Hospital Mortality of Aneurysm Patients in USA

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	92.255[a]	2	.000
Likelihood Ratio	78.896	2	.000
Linear-by-Linear Association	92.252	1	.000
N of Valid Cases	38104		

a. 2 cells (33.3%) have expected count less than 5. The minimum expected count is .12.

Table 88: Gamma Test Results on Frequencies of In-Hospital Mortality of Aneurysm Patients as Affected by ACR Compliance Levels of Hospitals in USA

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Gamma	-.328	.032	-7.617	.000
N of Valid Cases		38104			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Table 89: Parameters of Predictive Probabilistic Equation for Effect of ACR Compliance by Hospitals on Frequencies of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	ACR_compliance_rating	-.676	.215	9.909	1	.002	.508	.334	.775
	Constant	-1.472	.417	12.472	1	.000	.229		

a. Variable(s) entered on step 1: ACR_compliance_rating.

Accordingly the odds relationship for ACR compliance with mortality rate is given by the equation-

Ln (Odds) = -1.472-0.676* ACR compliance rating

As the equation will result in negative estimate, odds for mortality decreases when ACR compliance of hospitals increases. Significant Wald test value indicates no interference of other predictors on the relationship. Also, the odds for mortality compared to not dying is only 0.508 given by B (Exp) in **Table 89**.

Thus all the above findings validate Objective 3.

Objective 4

The fourth objective was to identify a predictor from patient factors and hospital contexts which can be used for prediction and reduction of in-hospital mortality rate. **Table 90** gives the analysis of this data.

Wald values for the effects of gender, age group, comorbidities, admission type were highly significant. Others were non-significant. This indicates non-interference of other predictors in the case of significant effects and possible interference of other predictors in the case of non-significant effects. The B (Exp) values varied narrowly just over 1 for all effects except hospital region and admission type. B (Exp) values were less than 1 for hospital region and admission type suggesting very low impact of these on mortality outcomes.

Table 90: Parameters for Probabilistic Equations for Effect of Patient Factors and Hospital Contexts on Frequencies of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	Gender	.323	.063	26.248	1	.000	1.381	1.220	1.562
	Age_Group	.202	.019	115.275	1	.000	1.224	1.180	1.270
	Race	.084	.043	3.785	1	.052	1.088	.999	1.185
	Comorbidities	.373	.015	615.166	1	.000	1.452	1.409	1.495
	Insurance Type	.004	.045	.007	1	.933	1.004	.919	1.097
	Hospital_BEDSIZE	.075	.050	2.214	1	.137	1.077	.977	1.189
	Hospital_LOC/TEACH	.060	.055	1.210	1	.271	1.062	.954	1.182
	Hospital_REGION	-.019	.030	.403	1	.526	.981	.925	1.041
	Admission Type	-.624	.037	288.852	1	.000	.536	.499	.576
	Constant	-8.950	.411	474.803	1	.000	.000		

a. Variable(s) entered on step 1: Gender, Age_Group, Race, Comorbidities, Insurance Type, Hospital _BEDSIZE, Hospital _LOC/TEACH, Hospital _REGION, Admission Type.

The odds equation as per logistic multiple regression test for these effects is-

Ln (Odds) = -8.950+0.323*Gender+0.202*Age group+0.373*Comorbidities-0.624* Admission type.

A detailed analysis of each factor was done to exactly identifying the predictors. The results are presented in **Table 91.**

Table 91: Parameters of Probabilistic Equations for Effect of Components of Patient Characteristics and Hospital Contexts on Frequencies of In-Hospital Mortality of Aneurysm Patients in USA

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	Male	-.335	.064	27.582	1	.000	.715	.631	.811
	Age_Group			103.601	10	.000			
	[Age_10]= (45-49)	-2.597	.631	16.933	1	.000	.074	.022	.257
	[Age_11]= (50-54)	-2.101	.507	17.145	1	.000	.122	.045	.331
	[Age_12]= (55-59)	-1.611	.465	12.032	1	.001	.200	.080	.496
	[Age_13]= (60-64)	-1.692	.453	13.934	1	.000	.184	.076	.448
	[Age_14]= (65-69)	-1.655	.440	14.132	1	.000	.191	.081	.453
	[Age_15]= (70-74)	-1.395	.437	10.210	1	.001	.248	.105	.583
	[Age_16]= (75-79)	-1.297	.435	8.891	1	.003	.273	.116	.641
	[Age_17]= (80-84)	-.984	.435	5.130	1	.024	.374	.159	.876
	[Age_18]= (85-89)	-.942	.439	4.605	1	.032	.390	.165	.922
	[Age_19]= (90-94)	-.487	.455	1.147	1	.284	.614	.252	1.498
	Race			16.117	4	.003			
	White	-.087	.423	.042	1	.837	.917	.400	2.099
	Black	-.271	.439	.379	1	.538	.763	.322	1.805
	Hispanic	-.254	.449	.320	1	.572	.776	.321	1.871
	Asian or Pacific Islander	.526	.455	1.336	1	.248	1.693	.693	4.134
	Comorbidities			890.585	7	.000			
	Lipid metabolism	-2.685	.454	34.997	1	.000	.068	.028	.166
	Hypertension	-1.935	.125	241.184	1	.000	.144	.113	.184
	Diabetes	-2.195	.213	106.013	1	.000	.111	.073	.169
	Respiratory disease	-.128	.116	1.208	1	.272	.880	.701	1.105
	Acute myocardial infraction	-.419	.125	11.275	1	.001	.658	.515	.840
	Heart failure	-.569	.106	28.648	1	.000	.566	.459	.697
	Renal failure	.950	.090	112.071	1	.000	2.587	2.169	3.085
	Insurance Type			19.901	3	.000			
	Medicare	-.710	.203	12.248	1	.000	.492	.330	.732
	Medicaid	-.564	.263	4.608	1	.032	.569	.340	.952
	Private insurance	-.917	.209	19.218	1	.000	.400	.265	.602
	Admission Type			302.224	5	.000			
	Emergency	18.017	29809.126	.000	1	1.000	66765437.965	.000	.
	Urgent	17.660	29809.126	.000	1	1.000	46716007.831	.000	.
	Elective	16.679	29809.126	.000	1	1.000	17529787.032	.000	.
	Trauma Center	-.249	50040.572	.000	1	1.000	.779	.000	.
	Other	19.162	29809.126	.000	1	.999	209839686.961	.000	.
	Constant	-.532	.640	.693	1	.405	.587		

a. Variable(s) entered on step 1: Gender, Age_Group, Race, Comorbidities, Insurance Type.

Wald values indicating non-interference of other predictors were significant for the effects of age groups up to 18 (up to 89 years) were highly significant. The chances of living beyond 90 years are low any way. Among comorbidities, lipid metabolism, hypertension, diabetes, acute myocardial infection, heart failure and renal failure recorded significant effects. All insurance types had significant effects, although overall effect did not show significance. Although overall effect of admission types was significant, individual components were non-significant. Thus, likelihood of interference from other predictors on odd relationship exists in the case of age group 19, respiratory disease as a comorbidity and all admission types. All the B (Exp) values were less than one for gender, age group, race except Hispanic (1.893 times probability), renal failure (2.587 times probability) and extremely high values for all admission types except trauma center.

Now the above logistic multiple regression for overall effects of main predictors can be more precisely derived in terms of significant components of main predictors as follows-

Ln (Odds) = -0.532-0.335*Male-2.597*Age10-2.101*Age11-1.611*Age12-1.692*Age13-1.655*Age14-1.395*Age15-1.297*Age16-0.984*Age17-0.942*Age18-2.685*Lipid metabolism-1.935*Hypertension-2.195*Diabetes-0.419*Acute myocardial infarction-0.569*Heart failure+0.950*Renal failure-0.710*Medicare-0.564*Medicaid-0.917*Private insurance

Overall, among various patient factors and hospital contexts, age up to 90 years and comorbidities associated with metabolism, heart and renal functions and insurance types are good predictors of mortality. The slopes of the functional relationships were negative, except for renal failure. This indicates that increase of any of the factor can increase chances of mortality.

The above findings support objective 4.

Objective 5

This objective relates patient factors and hospital contexts with imaging methods and consequent effect on mortality. The data for all imaging methods are given in **Tables 92** to **95.**

Table 92: Parameters for Probabilistic Equation for Effect of CT Imaging on Components of Patient Characteristics and Hospital Contexts on Frequencies of In-Hospital Mortality of Aortic Aneurysm Patients in USA

CT[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
.00	Intercept	.889	.549	2.619	1	.106			
	[Age_CAT=10.00]	4.604	1.095	17.691	1	.000	99.877	11.688	853.480
	[Age_CAT=11.00]	2.805	.534	27.597	1	.000	16.525	5.803	47.058
	[Age_CAT=12.00]	3.035	.508	35.712	1	.000	20.791	7.685	56.249
	[Age_CAT=13.00]	3.086	.478	41.665	1	.000	21.896	8.578	55.894
	[Age_CAT=14.00]	2.637	.441	35.835	1	.000	13.972	5.892	33.131
	[Age_CAT=15.00]	2.685	.438	37.515	1	.000	14.662	6.209	34.624
	[Age_CAT=16.00]	2.324	.431	29.007	1	.000	10.215	4.385	23.796
	[Age_CAT=17.00]	2.173	.432	25.333	1	.000	8.789	3.770	20.488
	[Age_CAT=18.00]	1.861	.438	18.068	1	.000	6.428	2.726	15.159
	[Age_CAT=19.00]	1.182	.458	6.651	1	.010	3.261	1.328	8.008
	[Age_CAT=20.00]	0[b]	.	.	0	.	.	.	.
	Male	.410	.094	19.113	1	.000	1.506	1.254	1.810
	FEMALE	0[b]	.	.	0	.	.	.	.
	Lipid metabolism	.613	.329	3.464	1	.063	1.845	.968	3.518
	Hypertension	.339	.155	4.795	1	.029	1.403	1.036	1.900
	Diabetes	.726	.224	10.510	1	.001	2.067	1.332	3.205
	Respiratory disease	-.638	.172	13.705	1	.000	.529	.377	.741
	Acute myocardial infraction	2.199	.466	22.304	1	.000	9.018	3.620	22.463
	Heart failure	-.071	.165	.188	1	.665	.931	.674	1.287
	Renal failure	-.299	.176	2.883	1	.090	.742	.525	1.047
	Anemia	0[b]	.	.	0	.	.	.	.
	Medicare	.605	.338	3.199	1	.074	1.831	.944	3.552
	Medicaid	.011	.404	.001	1	.979	1.011	.458	2.232
	Private insurance	.597	.347	2.961	1	.085	1.816	.920	3.585
	Self-pay	0[b]	.	.	0	.	.	.	.

a. The reference category is: 1.00.

b. This parameter is set to zero because it is redundant.

Table 93: Parameters for Probabilistic Equation for Effect of MRI Imaging on Components of Patient Characteristics and Hospital Contexts on Frequencies of In-Hospital Mortality of Aortic Aneurysm Patients in USA

MRI[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
.00	Intercept	20.182	1.108	331.528	1	.000			
	[Age_CAT=10.00]	18.094	2882.894	.000	1	.995	72148512.624	.000	.[b]
	[Age_CAT=11.00]	2.179	1.268	2.956	1	.086	8.840	.737	106.016
	[Age_CAT=12.00]	2.833	1.264	5.023	1	.025	17.004	1.427	202.642
	[Age_CAT=13.00]	1.644	1.083	2.304	1	.129	5.177	.619	43.271
	[Age_CAT=14.00]	2.694	1.080	6.222	1	.013	14.797	1.781	122.927
	[Age_CAT=15.00]	2.019	1.046	3.726	1	.054	7.534	.969	58.542
	[Age_CAT=16.00]	2.057	1.044	3.885	1	.049	7.826	1.012	60.546
	[Age_CAT=17.00]	1.459	1.035	1.987	1	.159	4.302	.566	32.716
	[Age_CAT=18.00]	1.449	1.052	1.898	1	.168	4.260	.542	33.489
	[Age_CAT=19.00]	1.993	1.239	2.586	1	.108	7.336	.647	83.227
	[Age_CAT=20.00]	0[c]	.	.	0	.	.	.	.
	Male	.213	.204	1.094	1	.296	1.238	.830	1.847
	FEMALE	0[c]	.	.	0	.	.	.	.
	Lipid metabolism	.448	.783	.327	1	.567	1.565	.337	7.265
	Hypertension	-.347	.371	.876	1	.349	.707	.341	1.462
	Diabetes	.144	.488	.087	1	.768	1.155	.444	3.004
	Respiratory disease	-.600	.451	1.771	1	.183	.549	.227	1.328
	Acute myocardial infraction	.462	.602	.590	1	.442	1.588	.488	5.163
	Heart failure	.217	.461	.221	1	.638	1.242	.503	3.065
	Renal failure	-1.140	.396	8.303	1	.004	.320	.147	.695
	Anemia	0[c]	.	.	0	.	.	.	.
	Medicare	-16.194	.329	2427.701	1	.000	9.267E-8	4.866E-8	1.765E-7
	Medicaid	-15.166	1.030	216.799	1	.000	2.592E-7	3.442E-8	1.951E-6
	Private insurance	-16.228	.000	.	1	.	8.957E-8	8.957E-8	8.957E-8
	Self-pay	0[c]	.	.	0	.	.	.	.

a. The reference category is: 1.00.

b. Floating point overflow occurred while computing this statistic. Its value is therefore set to system missing.

a. This parameter is set to zero because it is redundant.

Table 94: Parameters for Probabilistic Equation for Effect of US Imaging on Components of Patient Characteristics and Hospital Contexts on Frequencies of In-Hospital Mortality of Aortic Aneurysm Patients in USA

US[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B) Lower Bound	95% Confidence Interval for Exp(B) Upper Bound
.00	Intercept	1.462	.500	8.544	1	.003			
	[Age_CAT=10.00]	-1.393	.495	7.900	1	.005	.248	.094	.656
	[Age_CAT=11.00]	-1.054	.491	4.608	1	.032	.348	.133	.912
	[Age_CAT=12.00]	-.870	.489	3.166	1	.075	.419	.161	1.092
	[Age_CAT=13.00]	-.610	.487	1.564	1	.211	.544	.209	1.413
	[Age_CAT=14.00]	-.415	.486	.731	1	.392	.660	.255	1.710
	[Age_CAT=15.00]	-.286	.485	.347	1	.556	.751	.290	1.946
	[Age_CAT=16.00]	-.177	.485	.133	1	.715	.838	.324	2.169
	[Age_CAT=17.00]	-.118	.486	.059	1	.808	.889	.343	2.303
	[Age_CAT=18.00]	-.086	.488	.031	1	.859	.917	.352	2.387
	[Age_CAT=19.00]	-.566	.496	1.299	1	.254	.568	.215	1.502
	[Age_CAT=20.00]	0[b]	.	.	0	.	.	.	.
	Male	.067	.036	3.522	1	.061	1.069	.997	1.146
	FEMALE	0[b]	.	.	0	.	.	.	.
	Lipid metabolism	1.460	.100	213.404	1	.000	4.307	3.541	5.239
	Hypertension	1.481	.048	945.034	1	.000	4.396	4.000	4.831
	Diabetes	1.355	.063	464.056	1	.000	3.876	3.426	4.384
	Respiratory disease	.588	.061	91.946	1	.000	1.800	1.596	2.030
	Acute myocardial infraction	3.054	.140	477.418	1	.000	21.206	16.124	27.890
	Heart failure	.905	.054	276.904	1	.000	2.472	2.222	2.750
	Renal failure	.385	.058	44.550	1	.000	1.470	1.313	1.646
	Anemia	0[b]	.	.	0	.	.	.	.
	Medicare	-.151	.124	1.482	1	.223	.860	.674	1.097
	Medicaid	-.068	.145	.222	1	.638	.934	.702	1.241
	Private insurance	-.427	.122	12.253	1	.000	.652	.513	.829
	Self-pay	0[b]	.	.	0	.	.	.	.

a. The reference category is: 1.00.

b. This parameter is set to zero because it is redundant.

Table 4.83 PARAMETERS OF PROBABILISTIC EQUATION FOR EFFECT OF ULTRASOUND IMAGING ON FREQUENCIES OF IN-HOSPITAL MORTALITY OF AORTIC ANEURYSMPATIENTS IN USA

Table 95: Parameters for Probabilistic Equation for Effect of DSA Imaging on Components of Patient Characteristics and Hospital Contexts on Frequencies of In-Hospital Mortality of Aortic Aneurysm Patients in USA

DSA[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B) Lower Bound	95% Confidence Interval for Exp(B) Upper Bound
.00	Intercept	-.207	.365	.323	1	.570			
	[Age_CAT=10.00]	.166	.360	.213	1	.644	1.181	.583	2.388
	[Age_CAT=11.00]	-.110	.354	.096	1	.756	.896	.448	1.792
	[Age_CAT=12.00]	-.306	.350	.762	1	.383	.737	.371	1.463
	[Age_CAT=13.00]	-.545	.348	2.447	1	.118	.580	.293	1.148
	[Age_CAT=14.00]	-.718	.346	4.306	1	.038	.488	.248	.961
	[Age_CAT=15.00]	-.830	.346	5.756	1	.016	.436	.222	.859
	[Age_CAT=16.00]	-.886	.346	6.572	1	.010	.412	.209	.812
	[Age_CAT=17.00]	-.892	.346	6.647	1	.010	.410	.208	.807
	[Age_CAT=18.00]	-.858	.348	6.059	1	.014	.424	.214	.840
	[Age_CAT=19.00]	-.314	.358	.772	1	.380	.730	.362	1.473
	[Age_CAT=20.00]	0[b]	.	.	0	.	.	.	.
	Male	-.116	.034	11.900	1	.001	.891	.834	.951
	FEMALE	0[b]	.	.	0	.	.	.	.
	Lipid metabolism	-1.419	.096	219.404	1	.000	.242	.200	.292
	Hypertension	-1.389	.046	908.111	1	.000	.249	.228	.273
	Diabetes	-1.327	.061	476.748	1	.000	.265	.236	.299
	Respiratory disease	-.464	.058	63.320	1	.000	.629	.561	.705
	Acute myocardial infraction	-2.977	.130	521.562	1	.000	.051	.039	.066
	Heart failure	-.841	.052	260.571	1	.000	.431	.389	.478
	Renal failure	-.311	.055	31.527	1	.000	.733	.657	.817
	Anemia	0[b]	.	.	0	.	.	.	.
	Medicare	.111	.119	.868	1	.352	1.117	.885	1.410
	Medicaid	.067	.139	.233	1	.629	1.070	.814	1.405
	Private insurance	.373	.117	10.174	1	.001	1.453	1.155	1.827
	Self-pay	0[b]	.	.	0	.	.	.	.

a. The reference category is: 1.00.

b. This parameter is set to zero because it is redundant.

Wald tests for the effects of all age categories, male gender and all comorbidities except lipid metabolism, heart failure and renal failure were significant at 5% or higher level. This means, if CT is considered as the imaging method, mortality rate will be predictable by the above patient factors and hospital contexts. No interference of other predictors occurs the case of significant effects and such interference is possible in the case of non-significant effects. The logistic multiple regression test showed high values for B (Exp) for all age categories till 16. Values were fairly high beyond this age group also. Except for acute myocardial infarction, for all other effects, B(Exp) values were about one or less. Thus, in the case of CT, age group seems to have definite effect in increasing the probability of mortality.

In the case of MRI, age groups had non-significant effect. Only renal failure and Medicare and Medicaid ha significant effects. The sample size was low in the case of MRI. This might have affected reliability. However, the results show the effect of cost of imaging as insurance types had significant effect. B(Exp) values were very high for age categories and insurance type.

In the case of US, age groups 10 and 11 an all the comorbidities had significant effects. Therefore, comorbidities need to be considered seriously when US is used as imaging method. The B(Exp) values for comorbidities were very high.

For DSA, the effects of age groups 14 to 18, male gender and all comorbidities were significant. None of the B(Exp) values were very high. Thus the factors of maximum probability of mortality were different for different imaging methods.

Comparison of Predictors for Different Imaging Methods

To summarize the results of objective 5, significant predictors of various imaging methods were compiled for a comparison of predictors for different imaging methods. The compiled data are given in **Table 96.**

Table 96: Comparison of Imaging Methods for Significant Patient Characteristics and Hospital Contexts as Mortality Predictors for Predictive Probability Equations on Frequencies of In-Hospital Mortality of Aortic Aneurysm Patients in USA

Diagnostic Imaging Modalities	**Patients Factors**
CT	All age categories above 10, male gender, hypertension, diabetes, respiratory diseases, acute myocardial infection
MRI	Age groups 12, 15 and 16, renal failure, Medicare, Medicaid
US	Age group 10 and 11, all comorbidities, private insurance
DSA	Age groups 14 to 18, gender, all comorbidities, self-pay

Although age groups was a common predictor for all imaging methods, the sensitivity of different age categories varied as proved by the significance level. All age groups were significant predictors for CT. All age groups 14 and above were significant for DSA. MRI and US were intermediate between the two. Whereas all comorbidities were predictors for US and DSA, only certain comorbidities were predictors for CT and MRI. Gender, expressed in terms of the observed high susceptibility of males, was also a common factor.

Clearly, imaging method determines predictors of mortality. The result points to the need to devise predictive equations for each imaging method separately rather than a comprehensive one applicable to all imaging methods.

4.5 Summary of Chapter IV Results

Preliminary study of available data confirmed that AAA and TA are the most frequent aortic aneurysm types in USA. OAR was used about three times more frequently than EVAR although increasing evidence favors use of the latter more frequently. Among imaging methods, DSA and US are most frequently used although CT and MRI are emerging as promising methods. According to WHO age grouping, aortic aneurysm patients are more frequent in the age groups of 12 and beyond. US and DSA tend to be used for patients of 65-79 group and CT and MRI are more common for 70-84 group. Whites, blacks and Hispanic races show higher frequencies of aortic aneurysm than other races. More males are affected than females. However, these patient characteristics do not reflect in the general pattern of imaging methods used. Only very few patients meet health care expenses on their own. Most people depend on Medicaid and Medicare and private insurance sources. Various comorbidities can cause serious problems in diagnosis and treatment options of aneurysm. Hypertension, heart failure, diabetes and anaemia are major comorbidities in frequencies. Frequency of aortic aneurysm patient in large hospitals, urban teaching hospitals and south, west and northwest regions are more than others. Most admissions were emergency or elective. But none of these have any effect on imaging method used.

Whether EVAR or OAR as intervention procedure, DSA followed by US had been used in largest frequencies. Length of hospital stay is a critical factor.

Longer stay can lead to death of the patient. The ranges of values for not dying often includes the mean stay period for death to occur. In that case, it is not certain when stay is prolonged towards death to occur. Although there is some effect of imaging method on length of stay, it may be related to time taken for the procedure and recovery rather than possibility of death.

After considering the basic details of aortic aneurysm and frequencies of imaging methods and intervention procedures, achievement of objectives was attempted through a series of data analyses suitable for each purpose. These analyses demonstrated clear effect of imaging method on mortality, interactive effect of imaging method and intervention procedure, effect of extent of compliance with ACR guidelines on diagnostic imaging on mortality and possibility of using some patient characteristics and hospital contexts as predictors in probability equation models.

Mortality was least with DSA and highest for CT. It was higher for OAR than for EVAR. All statistical tests were highly significant. Odds ratio and risk factor also reflected the relationship of imaging method with mortality. Based on parameters of logistic multiple regression tests, logistic model for odds of mortality were estimated for all imaging methods and combinations of imaging methods with intervention procedures. When ACR guidelines were increasingly complied for imaging methods, mortality decreased from 10.4% for non-compliance to zero for full compliance. As most patients in the stud visited less compliant hospitals, improved compliance of these hospitals should reduce mortality. Patients also need to go only to highly compliant hospitals rather than nearby ones. This will also reduce mortality significantly.

Among predictors tested, age and comorbidities emerged as strong predictors compared to all others. It is possible to sharpen the logistic equation for each imaging method using specific age group predictor rather just the age and specific comorbidity associated with the effectiveness of the imaging method. Such equations were formed based on the results obtained from detailed analyses of predictors.

CHAPTER V: DISCUSSION AND STUDY LIMITATION

The aim of this research was to find out whether extent of compliance with ACR diagnostic and interventional imaging guidelines by US hospitals influences in-hospital mortality rates of patients diagnosed with different types of aneurysms. The findings were expected to provide predictors of mortality outcomes under a given set of patient factors and hospital contexts. Need for any change in the guidelines or practices to reduce aneurysm mortality rates could be identified and recommended.

Data on hospital records of aneurysm patients were extracted from US NIS database and after filtration and cleaning, a net sample size of 38263 patient records were obtained for further analysis. The findings from analyses of these data are reported in the previous chapter on Results. In this chapter, implications of these findings are discussed to derive useful conclusions in line with the objectives of this study.

Preliminary results had confirmed that out of the six main aortic aneurysm types, abdominal aortic aneurysm (AAA) was the most wide-spread type. About 75% of all aortic aneurysms was either AAA or rAAA. Another 21% of aneurysms belonged to thoracic aneurysm (TA). Thus, AAA and TA are the two types of aneurysms of specific concern. Although rupturing almost ensures death, only 3.4% patients reported with ruptured aneurysm of any type. If only these patients die, overall mortality rate should be around 3.4%. As was evident from Table 32, overall mortality indeed was a close 3.1%. Now the question arises: which imaging methods were more commonly used in the case of ruptured aneurysms? As was shown in **Table 31**, DSA or US in combination with OAR or EVAR were more frequent in the case of both ruptured and intact aneurysms. Thus, no specific imaging method was chosen for ruptured aneurysms. However, it is not certain that most of the mortalities occurred in the case of ruptured aneurysms only. It is also not certain that any other imaging method would have reduced mortality of patients with ruptured or intact aneurysms. As is evident from **Table 36**, imaging methods were related to mortality rates: DSA recorded lowest rate. All other imaging methods recorded higher than 3.4%. The importance of choosing the best imaging method to determine whether a detected swelling is an aneurysm was stressed by Brisman et al. [241]. According to Thompson et al. [242] CT was unable to predict site of endoleaks as precisely as duplex imaging, but was able to detect increasing diameter of blood vessels. Duplex imaging was less invasive with less cost than CT. Dinsmore et al. [243], compared MRI with CT, thoracic aortography, and 2-D ECG to find MRI superior in detecting aneurysm in more patients than by others CT missing a small aneurysm in the case of TA. Korogi et al.[244], found CT angiography a good non-invasive method to detect asymptomatic intact or ruptured aneurysms. The 3D visualization of CTA depicted the delineating features of each aneurysm better.

MRI and duplex sonography were equal in detection of AAA, but MRI being non-ionizing, was to be preferred according to the observations of Fox et al. [245]. For post-operative evaluation of after EVAR of AAA, either duplex ultrasound or CTA can be used [246]. However, Sprouse et al. [247] noted difference in the maximal AAA diameter measurable by either US or CT. According to Franklin et al. [248] 3D CTA and intra-arterial DSA were comparable, but 3D CTA was less reliable to rule out aneurysm presence although it was superior for anatomy. Although under sub-optimal conditions, Colour duplex US was superior to CT scans n detecting endoleaks with good sensitivity and a negative predictive value [249]. Effective first line surveillance of post-EVAR using Colour Duplex US reduced cost, avoided ionizing radiations and nephrotoxic contrast agents at the same time giving high efficiency compared to conventional CT scans was reported by Gray et al. [250] (2012). Rand et al. [92] in their guidelines, compared different imaging methods used for detection of endoleaks after EVAR repair. The comparisons included CT, MSCT, colour duplex and contrast enhanced US, MRI and plain radiography. Even if other methods are used, DSA is required to determine the type and source of already detected endoleaks. Cantisani et al. [251] compared colour duplex US, contrast-enhanced US, CTA and MRA for detection of endoleaks after EVAR repair of AAA. The accuracy of contrast-enhanced US was significantly better than Colour duplex US and equal to CTA and MRA in detecting endoleaks. Contrast-enhanced US may better classify endoleaks missed by other methods. Evidently, all these findings suggest that DSA or US are standards of comparison, different imaging methods can give different results with respect to their ability to detect or measure what is required, its efficiency, sensitivity and negativity aspects. All these methods have several variants and improvements to enhance detection accuracy and efficiency. In this study, the methods were compared only in a general way. Different hospitals might have used different variants of the same imaging method. For example, in the case of US, simple US, colour duplex US or contrast-enhanced US might have been used in different hospitals offering varying results. This aspect has not been studied here.

The age group vulnerability to be beyond 45 years as was reported by many workers. However, the range of age groups diagnosed with different imaging methods differed. The age ranges were: CT 75-84, MRI 70-84, US 65-79, DSA 70-79. Since frequency of patients imaged by DSA were maximum, most patients were in the age group of 70-79. That leaves a large number of patients in the age range of 65-70 to be imaged with US since that was next highest in frequency. Patients beyond 79 were exclusively covered b CT or MRI. As the frequency of MRI-imaged patients was quite small, it can be safely assumed that most of the patients in the age range above 79 were imaged by CT. Highest mortality of 11.1% was recorded in the case of CT, age effect would have confounded the findings. The life span of people 80 or above cannot be expected to be long. Thus, the patients of 80 years an above were naturally vulnerable death. Would they have lived longer if DSA was used in their case? No research could be found to answer this question.

Hypertension, heart failure, diabetes and anaemia are the main comorbidities which may be associated with diagnosis and/or treatment of aneurysm. Vlak et al. [252] observed higher incidence of unruptured intracranial aneurysm in patients with comorbidities of polycystic kidney disease, brain tumor, pituitary adenoma or atherosclerosis. Hypertension, coronary artery disease, stroke, peripheral vascular disease, diabetes, renal failure, obesity, carcinoma were detected as comorbidities of AAA [253]. Five post-operative comorbidities were associated with higher mortality due to ruptured infrarenal AAA by Panneton et al. [254]. Association of increased mortality rates with pre-existent kidney failure and dysrhythmia, but not with uncomplicated hypertension, cardiovascular disease, chronic obstructive pulmonary disease, diabetes, arterial occlusive disease an ischemic heart disease in intact and ruptured aneurysm patients was reported by Katz et al. [255]. Thus, unless presence of any comorbidity increases risk of mortality, it is not relevant with respect to aneurysm. Interestingly, the authors also found lower mortality rates in large volume hospitals compared with smaller volume hospitals. According to Lange et al. [256] octogenarians with AAA had comorbidities of cardiac disease, impaired renal functions and pulmonary disease resulting in declaring some of them as unfit for operations and a few others developing post-operative complications. These complications increased mortality rate of this age group. In a review of comorbidities, Gijsen et al. [257] proposed a model of causes and consequences of comorbidities associated with various types of diseases. Association of comorbidities was shown to influence mortality rate, treatment strategy, complications of treatment and quality of care which can also influence mortality. In the case of intrarenal AAA, high risk was defined as age 60 years or more with any one or more comorbidities of cardiac, renal or pulmonary nature [258]. Bush et al. [259] observed that higher mortality rates were observed in the case of AAA patients with comorbidities of ischemic coronary heart disease, myocardial infarction, congestive heart failure, chronic obstructive pulmonary disease, liver disease or malignancy. Many authors have demonstrated the superiority of EVAR over OAR in the case of elderly aneurysm patients with high risk comorbidities. Hence, in this study, as CT was mostly performed among persons over 80 years, EVAR+CT should show very low mortality rate when comorbidities have high risk ratios. The risk factor was less than 1 (0.842) for EVAR+CT combination (Objective 2 results above) although comorbidities of hypertension, diabetes, respiratory disease and acute myocardial infection had almost two times risk of mortality (for acute myocardial infection 9 times risk). But respiratory disease, renal failure and heart failure had lower than 1 risk. Thus the contentions of the above findings are proved. Mostly patients in the age range of 70 to 79 were imaged using DSA. Risk factor due to any comorbidity was less than 1 in this case. Mortality rate was lowest in the case of DSA as no compounding risk factor existed to increase mortality risk. However, this type of study on correlating comorbidities with imaging methods-mortality relationships has not been reported.

None of the hospital factors affected mortality rate. Test results for Objective 4 above showed the effect of admission type to be highly significant, but risk factor was even in all cases. Elective (15834) and emergency (10802) admissions were done mostly. For CT highest number of admissions were emergency and for DSA and US highest number of admissions were elective. Size of hospital did not have any impact on mortality rate although indirectly it can be said that where more CT was performed, the likelihood of mortality was high as highest mortality rate was found in the case of CT among all imaging methods as per the results of tests for objective 2 above.

Mean length of stay in the hospitals can be a decisive factor of mortality as was discussed in connection with the results obtained in this study reported above. These results indicate higher risk of mortality for DSA and lower risk for other methods based on length of stay causing death to happen. Already DSA was shown to be the maximum used imaging method. This raises a question: Is the high mortality rate for aortic aneurysm due to using DSA as the imaging method, which is associated with mortality within short stays? Can mortality be avoided by switching to other imaging methods, preferably, MRI? Differences in means and confidence limits were wider in the case of US. This gives some clear latitude for clinical decisions when in-hospital mortality threat is high with longer hospital stay. Thus US becomes an effective alternative for MRI.

It appears, there is a safe period of hospital stay for each imaging method beyond which there is higher risk of mortality. As was observe from Table 30 above, there is a definite period of hospital stay for death not to occur. If the stay is extended significantly beyond this period, death occurs. However, more extended stay in the safe environment of hospital (compared to home) cannot be the cause of death. Thus, period of hospital stay is determined by the need for stay till completion of the treatment procedure. Extended stay may be indicative of post-operative complications during the recovery period till discharge. In the case of abdominal surgery, pulmonary complications can increase hospital stay. Comorbidities can extend the length of hospital stay according to Lawrence et al. [260]. Sinclair et al. [261] attributed shorter hospital stays to faster post-operative recovery. Mean stay period was 10 days (9-15 days) for protocol patients and 15 days (11-40 days) for control patients. Thus hospital stays of 11-15 days may be either due to rapid recovery or due to slow recovery. However, Knaus et al. [262] noted significant effects of patient factors and hospital contexts on hospital stay. Mean length of stay with EVAR was about 50% lower than OAR for descending thoracic aneurysm patients, although they overlapped in the 14-17 days range, as was noted by Bavaria et al. [263]. Thus there is always a possibility that the type of treatment intervention determines length of stay. From Table 39 above, EVAR combinations with any imaging method had lower mortality rate than those with OAR and it was the lowest for EVAR+DSA combination. However, length of stay for the two types of interventions are not available. It is likely that EVAR required shorter stays than OAR and faster recovery ensured lower mortality.

The objectives of the study were specifically verified using various tests appropriate to the specific objective. The objectives were to establish that imaging methods had distinct influence on mortality rates, to compare the two intervention procedures in interaction with the imaging methods, to evaluate the impact of compliance with ACR guidelines on mortality rates, to examine the scope of using any patient factor or hospital context as predictors of mortality rates and to assess which imaging method is associated with mortality rate as affected by any of the significant predictors.

All requirements of Objective 1 were met and hence this was achieved. Risk estimations on mortality due to different factors using different methods have been reported. Relative mortality risk of 0.77 (0.61-0.98, p.03) at five years after EVAR was estimated by Molyneux et al. [264] . The authors used Kaplan-Meier analysis to estimate survival rates from which mortality rates were computed. In a comparison of early open surgery with US monitoring of AAA, the UK Small Aneurysm Trial Participants (1998) obtained one month operative mortality risk value of 5.8% for the surgery group.

Odds ratio was highest for CT compared to other imaging methods and was in favor of not dying was higher than that in favor of dying for all imaging methods. Thus imaging methods influenced reduction of mortality rate. While log multiple regression test is useful to estimate odds ratio of numeral variables, McNemar test is suitable for ordinal variables. Using chi square and logistic regression methods, Johnston [265] identified mortality risks of various factors. With best subsets and step-wise logistic multiple regression tests, odds ratios of 1.23 (1.1.1-1.41) and 1.23 (1.03-1.47) were reported by Brian et al. [266]. Odds ratios for different factors were estimated using multiple logistic regression test by Kadoglou et al. [267] with values of ranging from 1.1010 to 1.998. McNemar test for odds ratio was used by Villablanc et al. [268] for inter-observer agreement, and McDonald et al. [269] for causal relationship between contrast exposure and acute kidney injury.

In the case of objective 2, the aim was to evaluate the interactive effect of EVAR and OAR with imaging methods. Interaction between imaging method and intervention procedure is possible as the latter is determined by the results of diagnosis. Wenmert [270] (2014), in a thesis work, compared two fluoroscopy systems used for EVAR with respect to image quality in X-ray diagnosis. The proposed system was able to compare the image quality of two fluoroscopic systems. Thus, quality of image is important for good diagnosis, which is required for selecting the best intervention. The four imaging methods selected for this study vary in their characteristics and ability to produce quality images. Image quality also depends on equipment factors, observation of correct protocols and patient characteristics. Thus, both patient characteristics and hospital contexts are important. This leads to the third objective.

Objective 3 was meant to verify whether compliance with ACR guidelines will indeed reduce mortality. When fully compliant imaging procedures were evaluated for mortality, there was decisive decrease in mortality rates. This verified the contention of this objective. Usefulness of ACR compliant MRI for diagnosis of giant cell arteritis was demonstrated by Narvaez et al. (2005) [271]. Compliance with ACR criteria for patients qualifying for any imaging procedure was found highly useful in comparing different imaging methods for different arthritis types in the studies by Pipitone et al. (2008) [272]. In the case of coronary CTA, Miller et al. (2010) [273] found about 46% of the CTA studies in their institution covered indications not covered by the ACR appropriateness criteria. Sistrom (2008) [274] supported ACR appropriateness guidelines and its conversion into online searchable form. This can be incorporated into clinical decision making systems of hospitals. This will enhance compliance. Methods used for development and review of criteria for updating them are sound. Two action points emerge out of this data-

1. There are a large number of hospitals which are in the lower rating categories if total patients in the rating category is any indication. If these hospitals improve their compliance levels, mortality rate can be reduced substantially.

2. Now most patients are reporting in hospitals of low rating category. If they switch to higher rating categories, mortality rate can be reduced significantly.

The latest ACR imaging appropriateness criteria for pulsatile masse suspected to be AAA were discussed by Desjardins et al. (2013) [275]. US is the initial imaging method when a pulsatile mass is to be confirmed as aneurysm. For patients for whom US is unsuitable, non-contrast CT can be used. When aneurysm reaches the size required for intervention or is clinically symptomatic, contrast-enhanced multi-detector CT angiography (CTA) is best for diagnostic and pre-intervention planning assessment. CTA can accurately determine location, size, extent of aneurysm and branching vessels affected. If CTA cannot be performed, MRA can be substituted. Catheter angiography is useful for patients who show contraindications against both CTA and MRA. ACR reviews its guidelines every two years and updates its appropriateness criteria based on accruing evidence. These criteria show that different imaging methods are to be used for different situations. Although US can be substituted by CT, it cannot be substituted by other methods. CTA and MRA are to be used on special conditions depending on patient suitability only. There is no mention of DSA although catheter angiography can substitute CTA or MRA. Evidently, the imaging methods used for patients in this study were not according to these criteria as DSA was most frequently used method followed by US. It should have been US, CTA and MRA in the decreasing order of frequency. Overall, neither ACR guidelines cover all clinical indications nor hospitals comply with the basic criteria on which imaging method to be used when.

Objective 4 was meant for identification of patient factors and hospital contexts which can be used for predictive purposes. Only gender, age group, comorbidities and admission types were significant among the major factors. Thus out of hospital contexts, only admission types was significant. Detailed single factor logistic multiple regression analysis specified exact sub-components of each of the major factors and some additional factors like insurance type, but none of the admission types were significant. Therefore the general predictive equation for expected probability of mortality was expanded to a more

Failure to rescue (FTR) was studied by Waits et al. (2014) [276] as an important aspect of reducing mortality in the case of aneurysms. Hospitals which lack structural characteristics and safety culture for timely recognition and management of emergencies and complications after EVAR or OAR need to improve. There are several works on this aspect. Generally smoking and comorbidities are identified as predictors as demonstrated by the work of Brown et al. [277] for aneurysm to occur and of Strachen [278] for mortality due to aneurysm. This study is related to mortality predictors. Along with comorbidities, age was a predictor of mortality in the case of patients surviving surgery for ruptured aneurysm in the study of Chen et al.[279]. Age was a strong predictor of surgical outcome in the findings of Wiebers [280] in the case of intracranial aneurysm. In addition to age and comorbidities, Greving et al. [281] geographical region was a predictor of rupture of intracranial aneurysm. In a study on in-hospital mortality of ruptured AAA by Antonopoulos et al. [282], age and comorbidities were predictors. However, unless such probability equations give values within acceptable limits of true values, they are not very useful. This was not demonstrated in most studies.

The results of objective 5 were to be used for identifying the predictive factor associated with each specific imaging method. There were variations in predictors of mortality probability within age groups and comorbidities. For MRI, US and DSA, insurance type was significant. This means when lower probability of mortality can be predicted for all age groups, CT can be used as the imaging method. If no comorbidities are diagnosed, MRI can be used. For all comorbidities, either US or DSA can be used. When hypertension, diabetes, respiratory disease or myocardial infarction are indicated, CT can be used. Male gender was specified for CT and DSA. Probably cost considerations lead to preferential choice of DSA or US.

Applying the above result to a hospital where all imaging facilities are available, when registering the patient, age is recorded. This determines the age group. Thus the first filter for decision on imaging method is age group. CT can be used for all age groups. MRI can be used for age groups 12, 14, 15 and 16 (55-79) only. US can be used for only age groups of 10 to 12 (45-59). DSA can be used only for age groups of 14 to 18 (65-89). Either CT can be done as the first scan or younger persons diagnosed using MRI or US and older persons using DSA. The second filter is comorbidities. During initial physical examination, some comorbidities can be identified from the patient. Otherwise, existence of any comorbidity needs to be clinically ascertained. Once any comorbidity is detected, US or DSA or selectively CT can be used. Selection of any of these depends on using insurance type as the third filter. If no comorbidity is detected MRI can be done.

But all hospitals may not have all imaging facilities or expertise. Hence, the clinician decides the imaging method depending on available facilities. It need not necessarily be the ideal imaging method considering the above discussed aspects. Thus chances of a hospital not complying with many items of appropriateness criteria for diagnostic imaging are high. This was reflected in a large number of patients diagnosed in hospitals rated usually not appropriate or may be appropriate categories rather than usually appropriate category. There is no "definitely appropriate" category in ACR rating standards. So at present, most patients are diagnosed in hospitals which are less than perfectly complying with ACR imaging guidelines. This study has established good relationship between ACR compliance and mortality (**Tables 85, 87**) and imaging method and mortality (**Table 36).**

However, as was seen in the report of Desjardins et al. (2013) specific imaging method is considered appropriate for specific situations by ACR. Certainly this is not complied with. Overall it appears, hospitals should increase their compliance with ACR appropriateness criteria for diagnostic imaging by adhering to imaging methods prescribed for each situation. Hospital contexts were not important determinants although most patients reported in urban teaching or non-teaching hospitals. This may be just the reflection of population distribution between urban and rural areas increasing the chances of aneurysm in areas of higher populations. Important patient factors are age and presence of comorbidities. Other patient factors like gender or race are not important. Similarly, among hospital contexts, admission or insurance types are also not very important. This means, hospitals need to focus only on the two factors of age and comorbidities to assign suitable imaging methods as per ACR. Both are known or found out at the initial stages of diagnosis itself. Thus, it is possible to use suitable imaging method for any patient without difficulty. One factor which has received little attention is a detailed survey and study on the physical and logistical facilities and expertise available in hospitals against ACR guidelines. This information needs to be used for calibrating diagnostic imaging methods.

STUDY LIMITATION

The study relied on diagnosis and procedure of only the ICD-9 coding registered in NIS dataset. NIS data does not include all the sophisticated diagnostic imaging procedure codes. Differentiation of pre- and post- operative imaging is not available in ICD-9 codes and is not indicated in NIS data also. This study was limited to the study of most common aneurysms and not all.

CHAPTER VI: SUMMARY, SUGESSTION FUTURE RESEARCH

Recognizing the high mortality rates in certain aneurysm conditions, factors related to this were examined. Imaging methods have important role in diagnosis and treatment interventions. ACR has published appropriateness criteria for diagnostic imaging. It was contended that if hospitals followed ACR guidelines, it would improve diagnosis and in turn intervention procedure also. The study was aimed at this aspect and develop predictors for mortality due to imaging methods and intervention procedures. Patient characteristics like age, gender, race, comorbidities and insurance type for medical reimbursement and hospital contexts like size, location, geographical region, type and admission types were included as variables for the study. The basic variables were four imaging methods and their combinations with EVAR and OAR upon which the patient characteristics and hospital contexts were superimposed. NIS data for the period of 2008-2012 from more than 4,300 US hospitals were used. After prescribed data cleaning procedures, net sample size of 38263 patients was obtained for detailed study. Apart from descriptive statistics, ANOVA, Chi Square, Logistic multiple regression, McNemar and Gamma tests were used for dealing with different objectives of the study.

AAA and TA were most frequent aneurysm types. DSA and US were the most frequent imaging methods. OAR was much more frequently used than EVAR. Age group, male and comorbidities had distinct effects on aneurysm frequency. More patients went to urban teaching and urban noon-teaching, large volume hospitals for emergency and elective admissions and were supported by medical reimbursement schemes. However, none of these patient characteristics or hospital contexts had any effect on frequency-based ranking of imaging methods or intervention procedures.

Results supported the view that imaging methods have distinct effect on mortality. DSA recorded lowest and CT recorded highest mortality. Out of the intervention procedures, EVAR had lower mortality than OAR. However, in combination, OAR with DSA as the imaging method recorded lowest mortality. There was distinct effect of hospital stay on these mortalities due to imaging methods with longer than 10 days for any imaging method increasing mortality risk.

Definite effect of ACR compliance was observed. With increasing compliance, mortality rate reduced and became zero with full compliance. Thus, improving ACR compliance and patients selecting only compliant hospitals will reduce aneurysm mortality significantly.

Results of logistic multiple regression were used for the development of probability equations for mortality with imaging methods alone and in combination with intervention procedures. From a detailed analysis of patient characteristics and hospital contexts, age group and comorbidities emerged as the most important predictors of mortality probability. Other factors were less important as they provided inconsistent results.

Overall, imaging methods affect mortality and increasing compliance with ACR appropriateness criteria reduces mortality considerably. Probability of in-hospital mortality can be predicted using models with imaging methods with or without intervention procedures and adding age and comorbidity as predictors.

FUTURE RESEARCH

Only five years data were included in this study. A more detailed study may need to be done for firm conclusions. Compatibility between NIS data and ICD codes need to be tested by using ICD-10 Instead of ICD-9 to verify whether compatibility improves by this.

Although several works reported increasing use of CT and MRI, this was not reflected in a data set as recent as 2008-2012. Similarly, increasing use of EVAR compared to OAR was also not reflected. This needs further investigation. How far probabilistic estimates of mortality based on predictors will be closer to actual figures is not clear either from published works or from this study. This aspect needs further study by developing such equations and comparing actual with estimates.

There is enough evidence that hospitals are less than fully compliant with ACR appropriateness criteria. However, their number is not known. A survey of US hospitals to evaluate numbers of fully compliant, partially compliant and non-compliant hospitals need to be done. The latter two need to be persuaded to fully comply with ACR criteria.

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