How DSS for radiology ordering should be designed to maximize adherence to guidelines

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A dissertation submitted to the University of Dublin,
in partial fulfillment of the requirements for the degree of
Master of Science in Health Informatics

Declaration

I declare that the work described in this dissertation is, except where otherwise stated, entirely my own work, and has not been submitted as an exercise for a degree at this or any other university.

Signed: _____

Usman Ahmad

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Date:_____

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Summary

The dissertation commences with the review of radiology and the diagnostic imaging procedures. One of the greatest challenges for the health care providers is inappropriate imaging because of the radiation risks and costs associated with it. Inappropriate imaging can be reduced if physicians adhere to the clinical guidelines.

The aim of this dissertation is to investigate the barriers of physician's adherence to guidelines and to propose the design features of a good radiology order entry system (ROE) which can help to overcome the barriers of physician's adherence to guidelines.

A detailed research was done on the existing literature of radiology for determining the barriers. The clinical decision support (CDS) features that would address these barriers were then selected and proposed. The current radiology order entry systems (ROE) were assessed with emphasis on their ability to address barriers to adherence to ordering guidelines.

The Radiology order entry systems (ROE) have the potential to reduce inappropriate imaging and improve health care system. The DSS for radiology order entry should be designed in such a way that it reduces inappropriate imaging procedures, patient's radiation exposures and improve the quality and results of advanced imaging procedures.

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Abbreviations

ROE	Radiology Order Entry
CDSS	Clinical Decision Support Systems
CPOE	Computerized Physician Order Entry System
MRI	Magnetic Resonance Imaging
CT	Computed Tomography
NMR	Nuclear Magnetic Resonance
NIA	National Imaging Associates
HMO	Health Maintenance Organizations
CDSC	Clinical Decision Support Consortium
HITSP	Healthcare Information Technology Standards Panel
DIP	Diagnostic Imaging Pathways
KPI	Key Performance Indicator
ICD9	International Classification Of Diseases, Ninth Revision
ACR	American College Of Radiology
ARRA	American Recovery And Reinvestment Act
HITECH	Health Information Technology For Economic And Clinical Health

1 Introduction and Motivation

1.1 Introduction

Radiology is a vital field of health care industry that helps in the diagnosis and treatment of various diseases through medical imaging. However, risks associated with medical imaging are plentiful. Inappropriate imaging not only raises the medical cost but also exposure to radiations. Prevention of inappropriate imaging can be established through implementation of Radiology Order Entry systems in the health care industry. A Radiology Order Entry system uses a standard set of indications to determine the appropriateness of a request and provide instant feedback to the ordering clinician.

1.2 Motivation

I choose Decision Support System (DSS) as the topic for my dissertation because I believe that DSS can really help to improve incidents in health care. I also had a personal experience from which I realized that how much decision support systems can improve health care procedures.

I would like to quote my wife's example. During her pregnancy, she was diagnosed with kidney infection and prescribed an antibiotic at the hospital. However, the pharmacist refused to dispense the prescribed medicine, as it was not suitable for pregnant women. So, we went back to the hospital to get the right prescription. This small experience we had, made me realize that CDSS in hospitals is necessary. If the hospital had implemented CDSS at that time and my wife's symptoms were entered in to the system it would have alerted the doctor when inappropriate medicine was being prescribed.

1.3 Research Question

Hence, this research study aims to explore the features of Radiology Order Entry Systems to help investigate

- "How DSS for radiology ordering should be designed to maximize adherence to guidelines?"

1.4 Overview of Research Approach

Based on our research of the existing literature inappropriate imaging is a major concern in the heath care sector because of the radiation risks and costs associated with it. We then determined the barriers of physician's adherence to guidelines on the basis of the existing literature. A detailed understanding of CDSS and CPOE systems is then provided and role of CDSS in reviewing the appropriateness of diagnostic imaging procedures is discussed. The essential features of a good ROE system that helps physicians to adhere to guidelines are then proposed on the basis of our research. Analysis of the current vendors of ROE systems available in the market is provided with emphasis on their ability to address barriers to adherence to ordering guidelines.

No.	Research Requirements	Research Goals
1	To obtain clinical overview of what Radiology and inappropriate imaging is and its effects on stakeholders	To enable clear understanding of the clinical terminology used in Radiology and role of radiology tests in diagnosis. Identify the drivers of increased imaging utilization, stakeholders and the impact of increased imaging utilization. Further we identify the Risks associated with inappropriate imaging, Why it happens and what can be done.
2.	Overview of Diagnostic imaging guidelines and why physicians don't adhere to diagnostic imaging guidelines.	To identify role of diagnostic imaging guidelines and barriers to physician adherence to guidelines.
3.	To understand Clinical Decision Support and Computerized provider order entry system	To Understand how DSS works and help in making decisions. Identify characteristics of successful Clinical

		decision support and Computerized provider order entry systems.
4.	To identify guidelines for design of Radiology order entry system and its screen design. What design features help to overcome barriers to physician adherence to guidelines identified in earlier chapter	To define design features for good Radiology order entry system which will help to reduce inappropriate imaging and helps physicians to adhere to clinical guidelines.
5	Evaluate current Radiology order entry systems available based on our findings in last chapter	To Evaluate current maturity of ROE systems.

1.5 Overview of Dissertation

To provide a detailed account of this dissertation it is structured in the following way.

Chapter 2 discusses the literature review of Radiology. It provides an overview of radiology background, drivers of increased imaging utilization, stakeholders and the impact of increased utilization, inappropriate imaging, why it happens, what can be done, diagnostic imaging guidelines and barriers to physician adherence.

Chapter 3 details the literature review of Clinical decision support systems (CDSS) and Computerized physician order entry systems (CPOE). This chapter highlights the characteristics and design features of CDSS and CPOE systems. The challenges in designing and implementation of both systems and requirements for their implementation are also presented in this chapter.

Chapter 4 describes the radiology order entry design features to improve ordering. This Chapter highlights the features of a good ROE system and characteristics of ROE screen design determined on the basis of our research. This Chapter focuses on these features to help in overcoming barriers to adherence to guidelines identified in Chapter 2.

Chapter 5 discusses the two major vendors of radiology order entry (ROE) systems available in the market. These two vendors are Med Current's Order Right and RadPort of Nuance health care. This Chapter provides an evaluation of these vendors in accordance with the ROE design features discussed in Chapter 4.

2 Literature Review of Radiology Ordering Issues

The aim of this chapter is to provide the reader with an overview of the problem this research addresses. It first provides a detailed description of radiology background, the drivers of increased imaging utilization and stakeholders of the impact of increased utilization. It then gives a detailed overview of inappropriate imaging, why it happens and what can be done. It also discusses diagnostic imaging ordering guidelines, how they are developed and how can they be implemented. Finally, this chapter ends with the discussion of barriers faced by the clinicians in order to adhere to the guidelines.

2.1 Radiology Background

After the discovery of x-rays in 1898 medical scientists got interested in using radiation for diagnostic purposes. With the pioneer efforts made and its success made them realize the importance of ionizing radiations. This is how radiology came into existence.

Radiology is a medical field that diagnoses and treats diseases within the human body with the use of imaging. Radiologists use different imaging technologies to diagnose or treat diseases. Some of these imaging technologies are X-rays, ultrasound, magnetic resonance imaging (MRI) and computed tomography (CT).

2.1.1 Computed Tomography

In CT imaging x-rays are used with computing algorithms to image the body. During a CT scan a ring shaped equipment containing X-ray generating tubes rotates around the patient's body. An x-ray detector is placed opposite this apparatus that generates cross-sectional image of the body. CT is obtained in axial plane while coronal and sagittal images can be produced by computer reconstruction.

Anatomy of a CT scan

CT scanners give doctors a 3-D view of the body. The images are exquisitely detailed but require a dose of radiation that can be 100 times that of a standard X-ray.

Direction of rotation

Rotating X-ray source

Computed tomography scans are made by rotating an X-ray beam around the patient, imaging the body in a series of slices that a computer stitches together.

Fan-shaped X-ray beam

Motorized platform

CT scan machine

Rotating X-ray detectors

Patient lies on motorized platform

CT scans in the U.S.
(In millions)

2007: **68.7**

1995: **21.0**
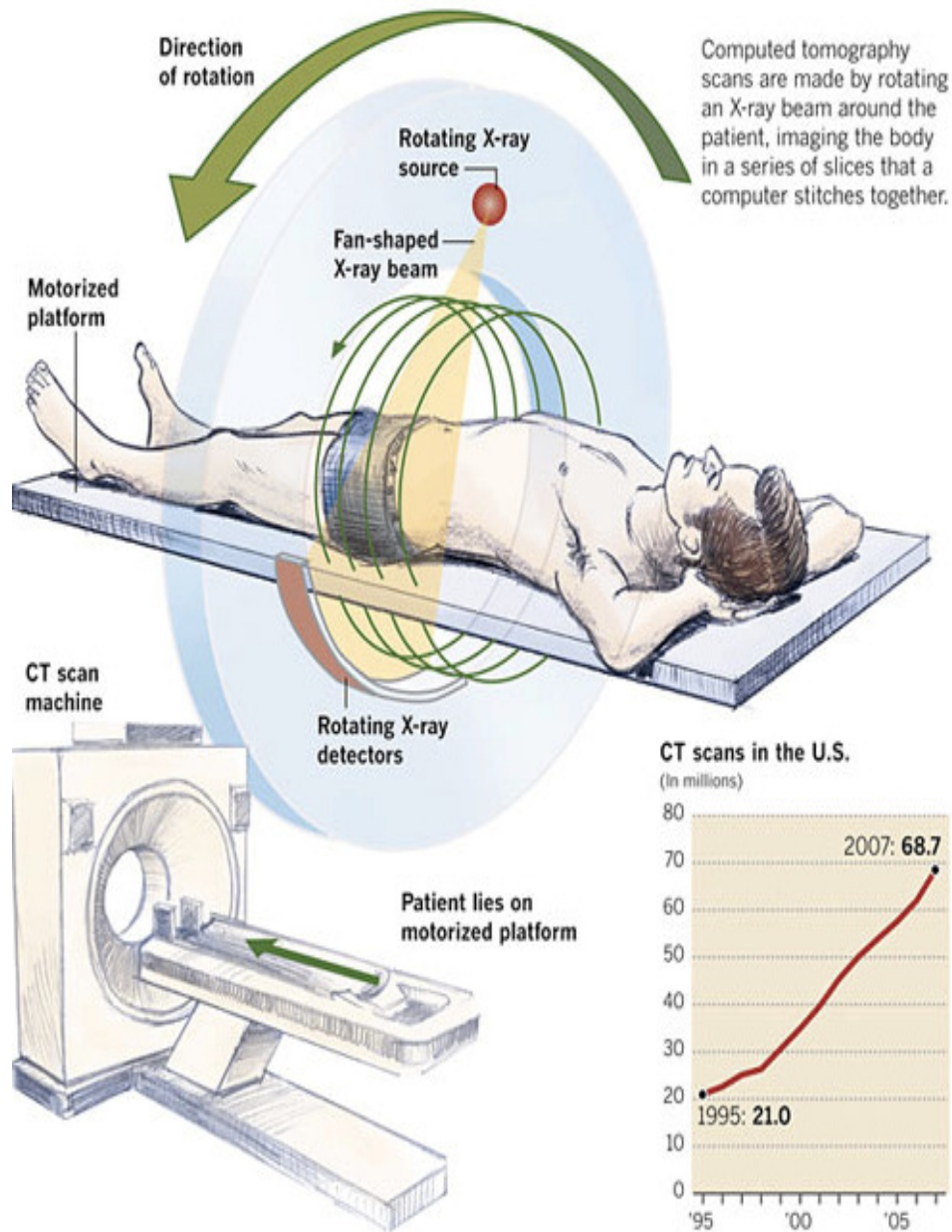
Fig 2. 1 Anatomy Of A CT Scan (WcP.Life.Coach, 2008)

In the last two decades, use of CT scans has increased vastly (Smith Bindman, 2009). In 2007, 72 million scans were performed in United States (Berrington, 2009).

According to an estimate nearly 3 million CT scans were done in UK in 2005-2006 as compared to 1980 figures which were just 0.25 million (UK Department Of Health, 2008) whereas in US number of CT scans performed were 69 million as compared to 2 million in 1980 (International Marketing Ventures, 2008). Below are the graphs showing the rise in CT Scan usage in both UK and USA from 1980 to 2005.
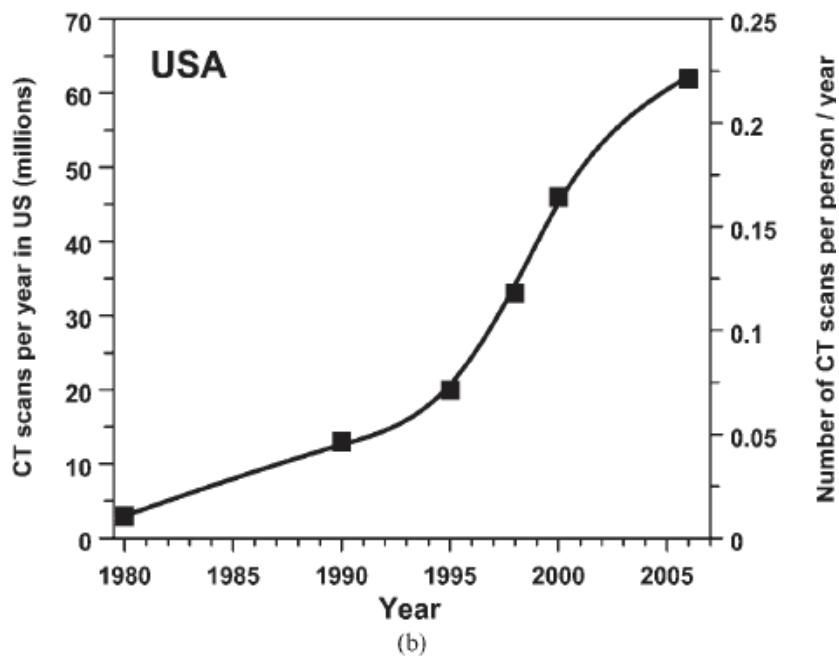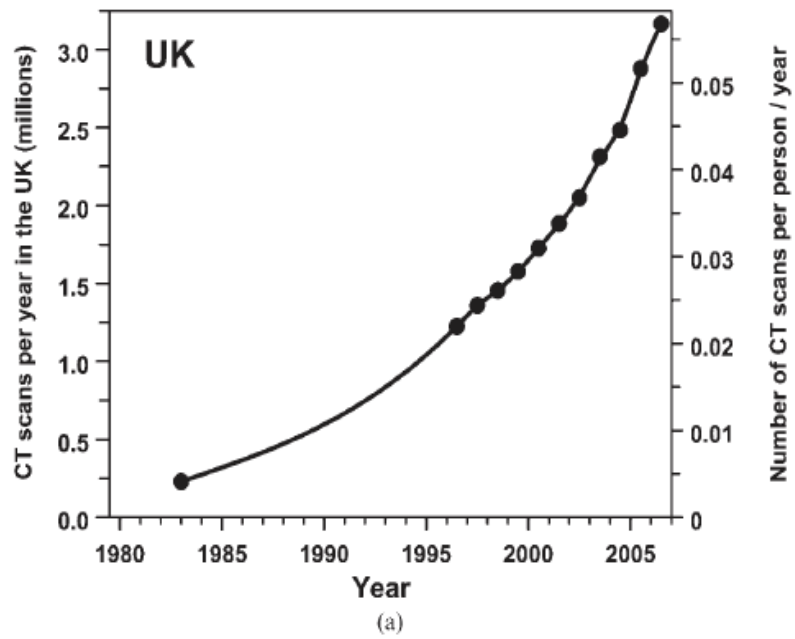
Fig 2. 2 Comparison of CT Scans in UK and USA (E J Hall, 2008)

2.1.2 Magnetic Resonance Imaging

Magnetic Resonance Imaging is a technique used in radiology to visualize internal structure of human body. In MRI nuclear magnetic resonance (NMR) is used to image nuclei of atoms inside the body.
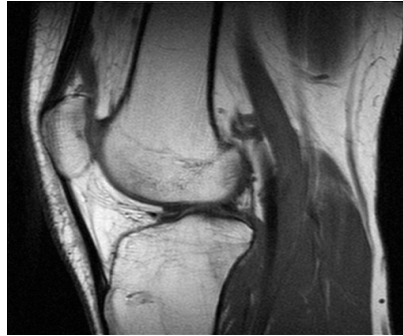
Fig 2. 3 MRI of A Knee (MRI Body, 2011)

A powerful magnetic field is used in an MRI machine to align the magnetization of some atoms in body and radio frequency to change the alignment of magnetization systematically. Because of this, nuclei produce a rotating magnetic field that is detectable by the scanner and this data is recorded to construct an image of the scanned area (Squire, 1997). Strong magnetic field gradients cause nuclei at different locations to rotate at different speeds. 3-D spatial information can be obtained by providing gradients in each direction. Because of its high contrast sensitivity and multiplanar imaging capability, MRI provides more information about the soft tissues of the body especially brain, muscle, heart and cancer.
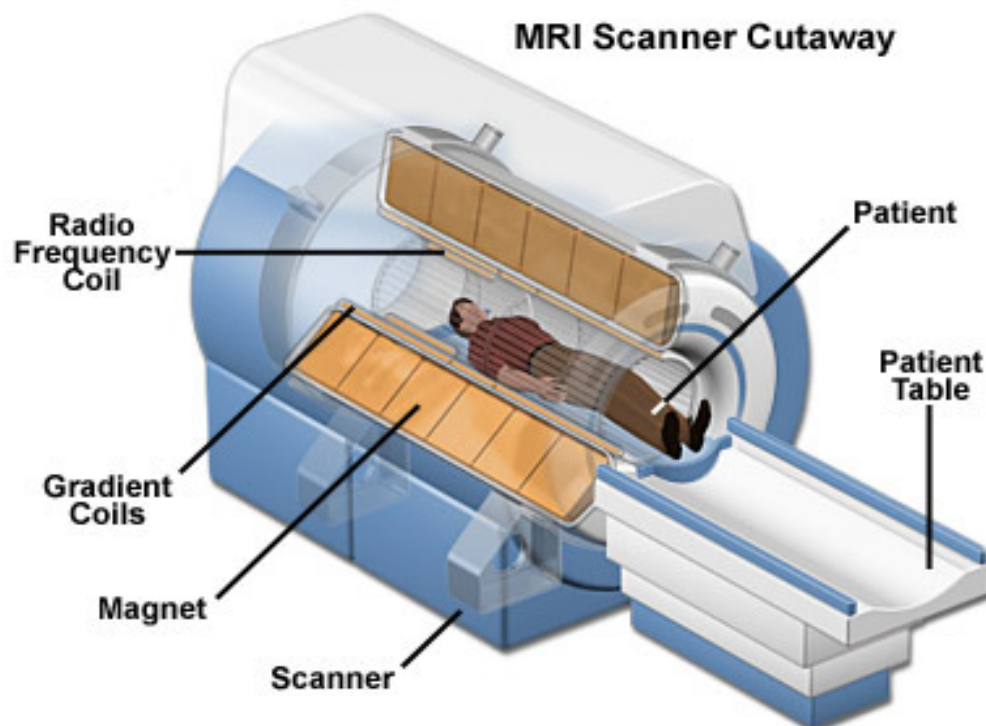
Fig 2. 4 MRI Scanners (National High Magnetic Field Laboratory, 2011)

2.1.3 Ultrasound

To find underground objects ultrasound was developed in World War II and today utilization of this technique is found in every field of health care. Ultrasound is described as a medical process in which optical images of blood flow, tissues and organs of human body can be obtained with the help of high frequency sound waves. These high frequency sound waves are transferred to the concerned area and the echoes produced as a result are saved.

During an ultrasound, an odourless, colourless gel is applied on the area to be studies. This gel helps in conducting sound waves from ultrasound transducer to the tissues of the body. The person conducting the ultrasound then applies the transducer to the skin and short pulses of ultrasound waves are emitted and received.

As the transducer is moved around an image of the organ under study appears on the monitor. The most diagnostically useful images are then stored electronically. These images then help physicians in making decision about final diagnoses.

In a glance, here is a comparison of the medical imaging technologies:

Table 2. 1 Comparison of Medical Imaging Technologies (WcP.Life.Coach, 2008)

Comparing medical imaging technologies

| Type of technology	CT scan	Magnetic resonance imaging (MRI)	Ultrasound	X-ray
Advantages	Fast, detailed images in three dimensions.	Can be more detailed than CT and uses no radiation.	Cheaper than CT and uses no radiation.	Fast and cheap, with a relatively low radiation dose.
Dis-advantages	Requires the most radiation. A chest CT is equivalent to about 100 chest X-rays.	More expensive than CT. Requires patients to remain still for a half hour or more.	Lower image quality than CT, with effectiveness largely dependent on technician skill.	Provides only a 2-D image, with far less detail than other methods.
Common uses	Detecting solid tumors and other problems in the abdomen and chest.	Detecting brain abnormalities and diagnosing soft-tissue injuries.	Fetal ultrasound and diagnosing appendicitis in children.	Diagnosing broken bones, pneumonia and intenstinal blockages.

Sources: Howstuffworks.com, New England Journal of Medicine, IMV Medical Information Division, Medical Imaging & Technology Alliance, Times reporting

PAUL DUGINSKI *Los Angeles Times*

2.2 Drivers of increased imaging Utilization

It is important to understand the positive and negative factors underlying the trend towards more imaging. By doing so, methods could be defined to control the unnecessary utilization of imaging. On the positive side is the prospect of gaining better, rapid diagnoses using up to date, non invasive imaging methods, sometimes instead of more invasive and expensive procedures.

Table 2. 2 Imaging Studies That Replaced Other Examinations (Mark Bernardy, 2009)

Table 1. Imaging studies that replaced other examinations

Prior Evaluation Technique	Current Clinical Practice
Surgical breast biopsy	Image-guided breast biopsy
Pneumoecephalography	CT and MR brain
Surgical drainage of abscess	Image-guided percutaneous drainage
Exploratory laporaotomy	CT abdomen and pelvis
Diagnostic angiography	CTA and MRA
Venography for DVT	Venous ultrasound
Myelography and CT	MRI

Note: CTA = computed tomographic angiography; DVT = deep venous thrombosis; MRA = MR angiography.

This is indeed the most important factor in the swift rise of imaging utilization. It has come from the needs of all medical disciplines and affects patients with a broad range of diseases and conditions. However, in some cases, the amalgamation of advanced medical imaging in to clinical use has surpassed the ability of the clinicians to distinguish the most suitable imaging studies for their patient's condition. Patients often get care from various clinicians and at different facilities. Therefore, duplicate exams are executed because the physician ordering the test does not have access to patient's complete imaging history.

Inappropriate economic incentive for providers, defensive medicine by providers and misguided patient preferences are some of the negative factors. The aging population is also a contributing factor to the increase in imaging utilization. Old

people tend to use more medical facilities including imaging. Most of the increased utilization in imaging is appropriate and adds value to the care of patients (Lichtenberg, 2009). Imaging is also used for examining many diseases and changes in therapy when necessary.

Best practices and clinical algorithms have been established by many professional societies. This shows that imaging is an important characteristic in the work up of many clinical situations (Qaseem A, 2007). However, appropriateness and its relative usefulness guidelines have not been evenly distributed to the medical community which lead to inappropriate usage of medical imaging. One reason for an increase in imaging is the physician's ownership of advanced imaging equipments. Additional services in-office exemption to the 'Stark' conflict-of-interest legislation allows the ordering physician to offer advanced imaging services (CT, MRI and PET) in their offices (US Government Accountability Office, 2009). Over the past 10 years, advanced imaging equipments ownership by non radiologists has increased greatly. This is due to the fact that self referring physicians can amplify their revenue by conducting the examinations in their own offices rather than in independent imaging centres and hospitals. Not all imaging examinations conducted in physicians' offices are inappropriate. Many studies have shown that use of imaging increases when the ordering physician has ownership interest in the equipment (Kouri BE, 2002).

It was shown in a study that average probability of imaging utilization for eight medical situations was greater than two to one when a financial incentive was present as compared to the referral when there was no financial incentive attached (Gazelle GS, 2007). This equals to 100% more imaging done when it was self referred. No such study is known which shows a neutral or unchanged behaviour in physicians after the purchase of imaging equipment. It has also been suggested that radiologist are a reason of inappropriate imaging utilization as they propose needless additional studies. However, there are no convincing studies which can prove that this is an important reason in the overall growth of imaging utilization. In fact, there is evidence to contrary. It was determined in a study comprising of 100,000 examinations that only 8% of the follow up or repeat imaging tests were connected to the radiologist's recommendations (Lee SI, 2007). Majority of these were appropriate recommendations for disease observation or work up of unsuspected clinically important conditions.

Defensive medicine happens when physician makes a decision which is affected by the fear of litigation from the patients. In this situation, imaging studies are ordered to show ordering physicians care and thoroughness. They are used to keep out doubtful but dangerous diagnose. Defensive medicine is universal. In a study of 900 providers was conducted at Massachusetts Medical Society. It was found that 22% of the x-ray examinations, 28% of the CT scans and 24% of the ultrasound examinations were conducted only for defensive reasons (Massachusetts Medical Society, 2009).

 This increased usage of imaging often does not prove beneficial for the patient rather it adds additional costs. Imaging usage is also encouraged by patient's expectations and preferences. As patients now know more about advanced imaging therefore they expect and sometimes demand imaging procedures to evaluate their clinical situation. This awareness is a mixed blessing motivated by media, direct-to-consumer marketing, internet and self help books.

Efficient and suitable education for the patients regarding imaging utilization is difficult to classify, let alone to achieve. Physicians are afraid of losing their patients if they don't provide them with imaging procedures. Patient's choice does matter. For example, in a recent study of colon cancer screening showed that nearly 40% of the patients who were surveyed said no to optical colonoscopy but were ready to go through CT colonography (unpublished data presented to CMS by Brooks Cash, March 3, 2009).

2.3 Stakeholders and the impact of increased utilization

In addition to the patients who have the biggest stake in having the most appropriate imaging examinations performed there are many other stakeholders also.
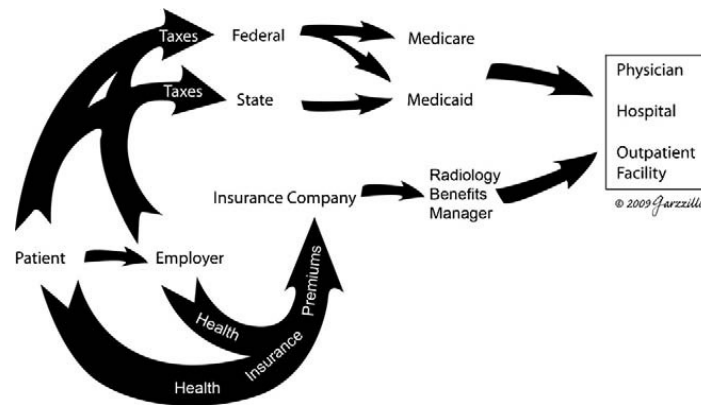
Fig 2. 5 Stakeholders and Funds Flow in Health Care

Hospitals, physicians and medical equipment manufacturers have incentive to perform imaging studies whereas persons paying for health care services have incentive to control costs or raise premiums to be profitable. Almost all of the stakeholders pay for health care but increase in the utilization of imaging services affects each stakeholder in a different way. The challenge is to bring into line all stakeholders incentives with the best results for the patients.

2.4 Inappropriate Imaging

There has been a gradual rise in the use of Diagnostic Imaging especially in the utilization of MRI and CT scans (Canadian Institute of Health Information, 2006). In Australia, 15% of the Medicare budget is allocated to diagnostic imaging and this figure is ever increasing (Canadian Institute of Health Information, 2006). Despite the fact that use of diagnostic imaging proves beneficial to patients, it has been estimated that up to one-third of diagnostic imaging studies are partially or completely inappropriate. (Picano, 2004)

The technologies associated with increase in imaging utilization are becoming more complex. It is not easy for the imaging specialists and the referring physicians to stay current with the right techniques of examination for a particular medical scenario. In the light of this context, a threat develops that examinations will become more technology oriented rather than based on medical requirements and patient benefit (Mendelson, 2010).

According to an estimate 30% of the imaging requests are inappropriate (picano, 2004) in which:

- Imaging is not indicated at all
- Imaging is indicated but the wrong modality is used
- The correct modality is used but the wrong protocol has been applied
- The correct imaging and protocol are used but the timing of investigation is wrong.

Inappropriate test ordering may result because of patient expectations, long waiting periods for most appropriate test or a lack of provider knowledge (stein, 2005). Out of these factors, lack of knowledge provider is the easiest to change and is the target of most interventions. As a result, more focus has been directed to the development of evidence-based practice guidelines and many organizations have developed and published guidelines for diagnostic imaging.

According to National Imaging Associates (NIA) in United States, about one third of the imaging tests are either inappropriate or do not contribute to the clinician's diagnoses. According to a study by NIA, wrong coding ways are used to order a large number of chest CT tests. In 10% to 100% of CTs ordered, there is no proof of a preceding plain film of chest. There is no improvement in this pattern even with the increase in the use of chest CTs (horizontal axis), as shown in the graph below.
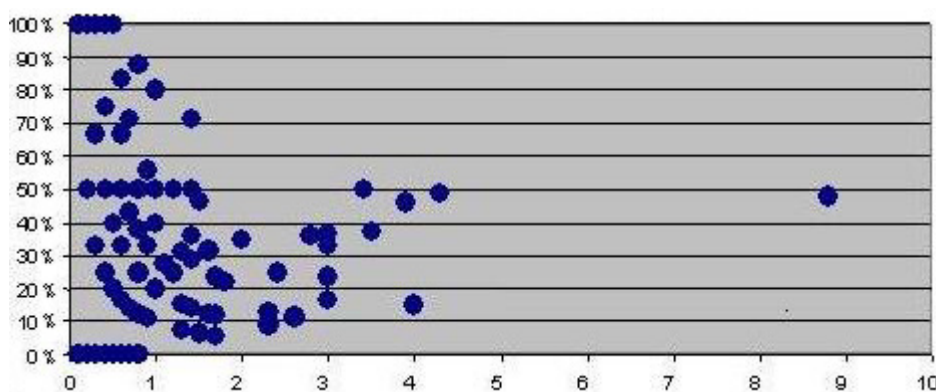
Fig 2. 6 Potential for Abusive Coding Practices

In another study by NIA, it was shown that a large number of MRIs ordered were to meet patient demand rather than diagnostic need. This is indicated by the fact that 105 to 100% of brain MRIs ordered are without enhancement. Enhancement is a pattern that does not improve with increased utilization.
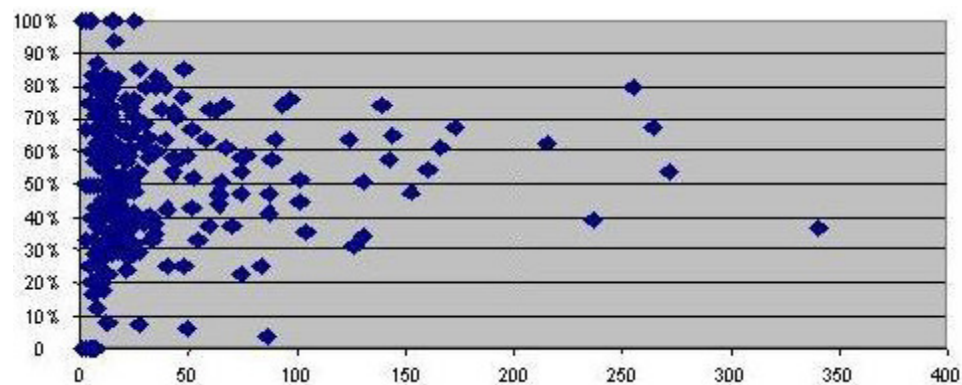
Percent of unenhanced brain MRIs vs. total studies

Fig 2. 7 MRI's Ordered to Meet Patient Demand

Inappropriate tests may result in:

- Missed diagnosis: the patient may be subject to adverse consequences and delay in effective treatment as the test performed was not correct
- Time wastage of imaging specialists and technologists and ineffective allocation of limited health resources.
- A potential for false-positive diagnoses and 'red herrings'

Many issues arise due to inappropriate imaging but we will discuss the two major issues that are radiation cost and radiation risk.

2.5 Radiation Cost

Diagnostic imaging is one of the rapidly growing fields with a projected $100 billion annually in American health care sector. Between 1999-2001, outpatient imaging procedures have increased by 44 %. (National Imaging Associates, Inc.)

In the figure below, it is shown that advanced radiology constitutes only 15% of the total imaging procedures done but it corresponds to half of health plan's overall radiology costs per patient per month.

15% of Volume = 50% of PMPM Cost = 75% of Inflation
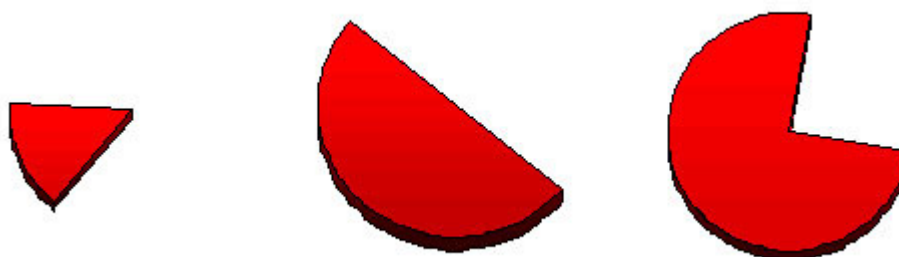
Fig 2. 8 Cost of Advanced Diagnostic Imaging

For many years, the advancement in technology will continue to increase the radiology costs. It was predicted by GE Medical Systems that by 2005 the number of MRI scans performed each year will rise by 100% (Wall Street Journal, 2002)
Annual expenditure on diagnostic imaging rose from $220 to $419 per Medicare beneficiary between 2000 to 2006 (US Government Accountability Office, 2009)

According to National Imaging Associates, Inc. about one third of the advanced imaging test performed are either inappropriate or have no health outcomes or have no contribution to the clinicians treatment. These tests could be performed with the traditional technology and could cut America's spending by $20 billion to $30 billion annually.

In the USA, cost control has been the biggest factor in the efforts to reduce additional utilization of high-cost advanced imaging modalities. 'Radiology Benefits Managements' have been suggested by health maintenance organizations (HMO's). These consist of requirements for preauthorization and advancement of radiology consultation. Also, many education programs have been developed to inform the consumers about the cost.

MRI equipment is expensive. 1.5 tesla scanners cost between $1- $ 1.5 million USD. 3.0 tesla scanners cost between $2- $2.3 million USD.MRI suites construction can cost up to $ 500,000 USD or more (Wikipedia).

2.6 Radiation Risk

Many risks are associated with ionizing radiation (IR). There has been a tremendous increase in ionizing radiation exposure per capita and mostly this increase is because of medical radiations. 75% of these medical radiations are related to CT scanning and nuclear imaging (Fazel, 2009). It is estimated that the radiation exposure from a full body scan is the same as standing 2.4 km away from World War II atomic bomb blasts in Japan (Khamsi, 2007). Table below shows typical organ doses from various radiological examinations:

Table 2. 3 Typical Organ Doses from Various Radiological Examinations (E J Hall, 2008)

Examination	Relevant organ	Relevant organ dose (mGy)
Dental X-ray	Brain	0.005
PA chest X-ray	Lung	0.01
Lateral chest X-ray	Lung	0.15
Screening mammogram	Breast	3
Adult abdominal CT	Stomach	10
Barium enema	Colon	15
Neonate abdominal CT	Stomach	20
CT coronary angiography	Lung	40–100

Few argue that CT scans are more beneficial rather than being harmful. However, most authorities accept the 'stochastic model' according to which ionizing radiations do induce cancer risk in patients. It is estimated that CT scans cause one in one thousand and 430 cancers per year in Australia (Berrington, 2004). In United States, 0.4% of the cancers are due to the CT scans and this may increase as high as 1.5 - 2% with 2007 rates of CT usage (Brenner, 2007). CT scans in children have been estimated to increase the probability of lifetime cancer in them (Brenner, 2001).

In USA, approximately 600,000 abdominal and CT scans are done each year on children under the age of 15 years. It is estimated that 500 of these individuals will eventually die because of cancer that developed due to CT radiations (Brenner, 2001). The graph below represents number of CT Scanners per million population in some countries in 1990's. The data was collected from 1991-1996 survey done by the United Nations Scientific Committee on the effects of atomic radiation (UNSCEAR).
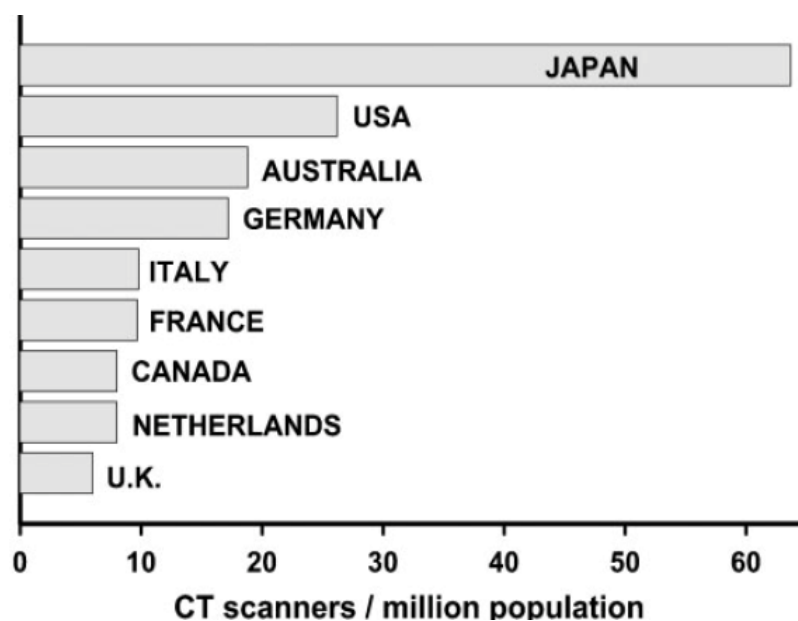
Fig 2. 9 Number of CT Scanners per Million Population in Selected Countries In The 1990's (E J Hall, 2008)

 Radiation risk is age related. It is greatest in children and young adults and increases with multiple examinations. In elders, risk is less as the period to cancer induction and the likelihood of other diseases is more likely to cause patient's death rather than a radiation-induced cancer. The graph below shows the age related estimated lifetime risk associated with the small dose of radiations.
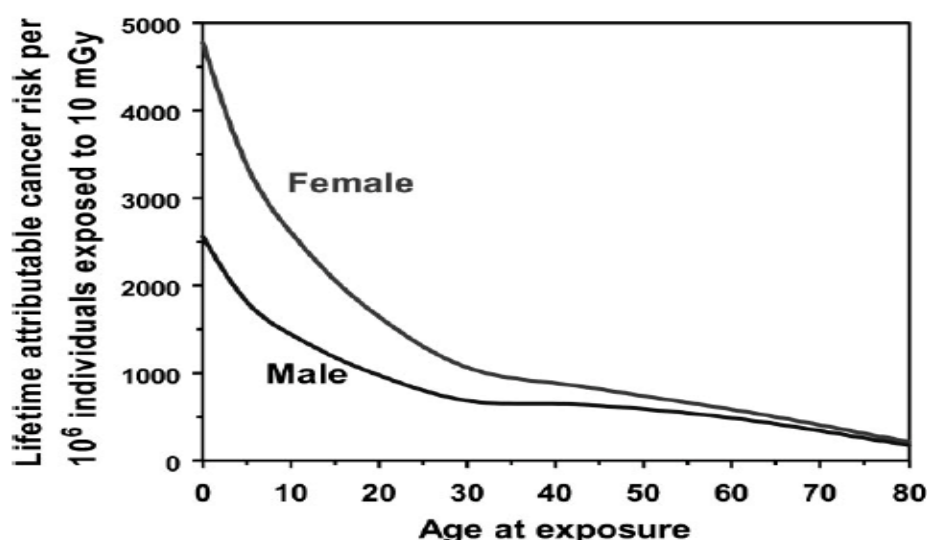
Fig 2. 10 Graph between Cancer Risk and Age at Exposure (E J Hall, 2008)

The use of imaging technologies using radiations eventually result in an increased risk of cancer. This problem can be minimized by avoiding inappropriate imaging utilization and try to get most out of the studies performed in order to achieve great image quality with low radiation dose (Amis, 2007).

2.7 Why it happens

There are various reasons for the inappropriate use of imaging. Some reasons associated with the referrer are lack of knowledge (Taragin, 2009), rejection of clinical paradigm (Schattner, 2006), favour of indiscriminant imaging, need for certainty of diagnoses (Kassirer J, 1989), fear of lawsuits and patients expectation for imaging. As the referring physicians do have enough knowledge of IR therefore it is difficult to minimize patient's radiation exposure. Many doctors including some radiologists are not aware of any connection between IR and cancer induction (Lee CI, 2004). A recent study showed that this subject was taught insufficiently at medical schools (Zhou GZ, 2010). Referrers are also not well informed about non-ionizing alternatives that maybe performed in particular clinical situations. Even if they are aware, jurisdictions may form obstacle in their options for example, inability of GPs to request MR scans in Australia.

2.8 What can be done

It is important for the ordering clinician to define the need of imaging test being ordered. It can be done by asking him/her questions authorized in the Euratom directive of 1988: is imaging displayed? Will it make any change in my diagnoses? Will it do more damage than good? Will it alter my management? Am I asking for the appropriate imaging and in the correct order? Is there a non-ionizing alternative to an x-ray based examination? (Teunen D, 1998)

In reducing inappropriate imaging the role of imaging specialists and consultants is very important. Awareness level should be raised and the referring clinicians should be provided with education on appropriate imaging, assessment of requisition and reviewing the imaging requirement at individual patient level. Financial considerations, lack of time and reluctance to go against the wishes of their clinical colleagues form obstacle for the specialists/consultants in performing their roles.

In solving the problem of inappropriate imaging education of referrers and future referrers (medical students) can play a major part. Various other methods have also been tried such as a license being issued to the referrers which would allow them to request high end investigations such as CT or MR scans. In USA, cost control has been a major factor behind the efforts made to stop unnecessary advanced imaging test. Radiology benefits management which constitutes requirements for preauthorization, privileging and encouragement of radiology consultation and education programs providing cost information to consumers have been introduced by the Health Maintenance Organizations (HMOs). Efforts are also being made to reduce financial incentives to provider **(**Glabman M, 2005**).** In a recent US senate Finance Committee report it was stated that financial penalties would be charged for physicians who order inappropriate imaging habitually **(**US Senate Finance Committee, 2009). Recently, the US Federal Drug Administration has been notified to the hazards of improper IR processes usage through a publishes initiative **(**USFDA Center for Devices and Radiological Health, 2010)

2.9 Diagnostic imaging guidelines

Clinical guidelines are methodically designed statements to help medical professionals and patient decisions about correct health care for a particular clinical situation (Field MJ, 1990). The quality of care can be improved and appliance of effectual approaches to everyday practice can be increased through successful implementation of Clinical guidelines (Chassin MR, 1990).

2.9.1 Guideline development

In efforts to decrease inappropriate imaging and to promote appropriate imaging many radiology colleges and institutions have established sets of imaging guidelines. Some examples are UK Royal College of Radiologists Appropriateness Criteria® of the ACR, "How to make the Best Use of Clinical Radiology Services" and The Royal Australian and New Zealand College of Radiologist's 'Imaging Guidelines'. 'Diagnostic Imaging Pathways' (DIP) is an electronic clinical decision support and educational tool developed in Western Australia. This tool helps in promoting appropriate imaging use and reducing inappropriate imaging.

Evidence and consensus are the two major constituents of proposals in the sets of guidelines. Therefore, their correct admixture has been a significant discussion in the literature. Some arguments are for a more precise evidence-based method than the one currently used largely in the sets of published guidelines and desertion of the consensus methodology **(**Blackmore C, 2006**)** whereas others argue for its retention**.**

The ACR Appropriateness Criteria® (ACR-AC) **(**ACR, 2004-2008**)** are based on evidence and consensus as in DIP. The subjectivity of recommendations and guidelines can be decreased by the means of evidence-based methodology (EBM) whereas consensus and evidence are unable to coexist (Bettmann M, 2006**).**

In the light of diagnostic imaging background, the best available solution is the hybrid methodology used by both the ACR-AC and DIP. Undoubtedly it is a very significant role for those undertaking analyses at the top of the evidence based pyramid (Haynes R, 2001) and for vitally evaluated topics using precise evidence-

based methods. Suitable work based on these methods can be and should be brought together into a complete set of guidelines. It should also be known that in radiology greater levels of evidence are very rare. This is mainly accurate in reference to the studies dealing with the effect of diagnostic imaging on patient management and result (Mackenzie R, 1995).Imaging technology is establishing at such a speed that a method is often engaged on the basis of opinion agreement preceding the appearance of hard evidence for or against its effectiveness.

2.9.2 Guideline implementation

Implementation of a guideline refers to its amalgamation into daily use. The development of evidence based guidelines should go together with their evidence based implementation. (Cheng TL, 1996) Factors which affect the use of guidelines by their future users are complicated. (Freed GL, 1993) The barriers to implementation which constitutes factors affecting physician behaviour are not well understood (Ward JE, 1997).

There is very little proof that support of voluntary adoption of guidelines result in modest change in outcome (Schocken DD, 1997) and they may not be continued. (Klabunde CN, 1997) This has surely been the experience of the authors. Although great efforts have been put into education and marketing but still very little success has been possible in minimizing inappropriate referrals. (Cochi SL, 1986).Very few studies have been conducted on the affect of institution or organization on the actions of a physician and the procedures through which change is possible (Naylor CD, 1990). Many of these studies cannot be applied globally. (Ward JE, 1997) Undoubtedly, there is a need for physicians who are ready to change their practice to implement guidelines.

(Klabunde CN, 1997) The 'Behaviour Change Theory' has a lot to offer, not only in the area of implementation but also in the guideline procedure. (Johnsson M, 1988) Technological problems (constituting slow internet access, lack of hardware, connection level to electronic medical records or IT systems), systematic factors (cultural or behavioural) and lack of agreement with a particular guideline are a few barriers to implementation of guidelines by physicians. The systematic factors include physician's perception of threats to their clinical independence and their

attitudes (implied or verbalised). Fear of litigation and patient's inappropriate expectations for imaging also lead the physicians to non adherence of guidelines.

2.10 Barriers to Physician Adherence

As discussed earlier, inappropriate imaging occurs because physicians do not adhere to the guidelines. Guidelines should be adhered by physicians in order to make diagnostic imaging procedures more timely and accurate thus reducing inappropriate imaging. On the basis of our research on existing literature we have identified barriers due to which physicians are not able to adhere to guidelines.

These barriers will form the basis of the recommendations regarding decision support in radiology ordering systems in section 4.They are discussed in detail below:

2.10.1 Lack of Familiarity

A certain amount of awareness of guideline recommendations does not assure their familiarity and implementation. In a survey of guideline awareness and familiarity, out of 74 only 3 which makes only 4% measured both (Wigder HN, 1996). Lack of familiarity was more common than lack of awareness in all cases.

2.10.2 Lack of Agreement

Clinicians may not be in agreement with a particular guideline or the notion of guidelines in general. When physicians are asked about guidelines in theory they usually show a lack of agreement. From this analysis and others when asked about some particular guidelines physician's lack of agreement is less common (Olesen, 1997).The results of studies that analyze clinician approach to guidelines should be defined with great care when applied to particular guidelines.

2.10.3 Lack of Self-efficacy

Self-efficacy is basically a faith that one can really carry out a particular behaviour. Self-efficacy influences both, whether a particular behaviour is about to be initiated

or continued regardless poor results (Bandura, 1986). For example, greater self-efficacy in prescribing cholesterol-lowering medications was related to clinicians starting therapy consistent with national guidelines (Hyman, 1992). Low self-efficacy occurs due to low confidence in one's capability or inadequate preparation which ultimately leads to poor adaption. Out of all the surveys reporting this barrier 68% involved preventive health care and counselling. This shows that poor self-efficacy might prove to be a common barrier to adherence for such guidelines.

2.10.4 Lack of Outcome Expectancy

Outcome expectancy refers to expectation that a given behaviour will lead to a specific result (Bandura, 1986). If the clinician believes that it will not lead to any fruitful outcome for a particular recommendation, it is less likely that he adopts it. For example, the USPSTF advised clinicians to provide quit smoking counselling. Most of the physicians know and do agree with this (Alexandera,1996). However, many smokers are not counselled during their visit to a physician (Wechsler, 1983). physicians do not adhere to this recommendation because of the belief that they will not succeed (Brown, 1995). Population's quit rate can increase from 3% to 5% through counselling (Kottke, 1994). Considering rate of increase in smoking even this small change is quite beneficial (Wilson, 1988). However, physicians see the patients individually therefore they cannot differentiate success at population level. Negligence in considering the population level success can adversely affect outcome expectancy and lead to non adherence (Cummings, 1989).

2.10.5 Inertia of Previous Practice

Clinicians are so comfortable with their daily practice routine that they might not be able to overcome the inertia of previous practice or they may not have the determination to accept the change. This hurdle in guideline adaption has been explored broadly. In 14 surveys done, more than 20% of the respondents identified it as a barrier to adoption. Prochaska and DiClemente developed a model called readiness for change model (Prochaska, 1983). This model describes behaviour as a range of steps that constitute pre contemplation, preparation, action and maintenance (Prochaska, 1983). This model was applied to physicians approach towards cancer screening guidelines. The results showed that half of the physicians

surveyed were in the stage of thinking and were not ready to change their behaviours yet (Cohen, 1995).

2.10.6 External Barriers

Appropriate knowledge and attitudes are necessary but are not enough for adaption (Solberg, 1997). A physician could still come across some barriers due to patient, guideline or environmental factors which can limit their ability to perform. The external barriers that affect performance of a particular behaviour are different from lack of self efficacy. For example, the counselling abilities of a competent physician can be affected by external barriers such as lack of reminder systems or time limitations which can prevent them from adopting the counselling guidelines. However, the perseverance of these barriers may ultimately influence physician's self-efficacy, outcome expectance or motivation.

2.10.7 Guideline-Related Barriers

In theory, physicians define guidelines as not easy to use or inconvenient. When clinicians were enquired about barriers for particular guidelines more than 10% described them as not easy to use in 6 out of 16 cases which makes a total of 38%. Some other features of guideline may also affect their adoption. Guidelines that propose abolition of an existing behaviour is more difficult to follow rather than the one proposing a new behaviour (Winkler, 1985). Trial ability of a guideline can also help in predicting its adherence (Grilli, 1994).

2.10.8 Patient-Related Barriers

The lack of ability to bring together patient's preferences with guideline recommendation forms a barrier in adoption of these guidelines (Goldman L, 1985). Patients may be unwilling, feel no need of a guideline or may also consider it embarrassing. In all the patient associated surveys, more than 10% of the clinicians pointed them as a barrier to adoption.

2.10.9 Environmental-Related Barriers

Changes such as gaining new resources may be required in practice guideline adoption (Resnicow, 1989). For example, if an anaesthesiologist is not available 24 hours a day it may hinder physician's capability of guideline adoption for decrease in the rate of elective caesarean deliveries (Kosecoff, 1987). Lack of a reminder system and counselling materials, inadequate staff or consultants, increased practice costs and liability and poor compensation are some of the factors which are not in control of a physician.

With the help of sufficient resources and referral privileges clinicians may be able to make up for other external barriers. More than 10% (11 out of 17 cases) of the respondents referred time deficiency as a barrier in adoption whereas it was not a barrier in mammography referral (4 surveys), management of fever (1 survey) and hyperbilirubinemia (1 survey).

This chapter has provided an introduction to Radiology. It has discussed in detail the current technologies like Computed Tomography, Ultrasound and Magnetic Resonance Imaging used by the radiologists to diagnoses different diseases. This chapter has also provided an overview of drivers of increased imaging utilization and its impact. In particular, this chapter has concentrated on Inappropriate imaging, why it happens ,what can be done and what are the guidelines which need to be followed to minimize it.

The clinical practice guidelines are basically statements which are designed to aid the clinicians and patients to take correct healthcare decisions. In guideline development evidence and consensus are two major constituents. A guideline should be implemented into a health care setting in such a way that it amalgamates into daily use. Clinicians and other health care professionals face many barriers in adhering to these guidelines. These barriers include lack of familiarity, lack of agreement, lack of self-efficacy, lack of outcome expectancy, inertia of previous practice, external barriers, guideline related barriers, patient related barriers and environmental related barriers.

3 Literature Review of CDSS and CPOE systems

This chapter aims to provide the reader with an overview of clinical decision support systems (CDSS) and computerized physician order entry systems (CPOE). Specific focus is placed on the features, design and implementation of CDSS and CPOE systems. The requirements for implementation of CDSS systems and success factors of CPOE systems are also outlined in this chapter.

3.1 Background

Since the past 20 years computer systems have widely spread in the field of health care. At first, these systems were used only for administrative and financial purposes. This function of computing systems is still in use today. In addition to this, now these are also used to help clinical decision making and this role is growing day by day.

Computer systems are designed in such a way that they follow commands which are predefined in them. In medicine, these commands varies from plain statements like 'IF THIS HAPPENS THEN DO THE FOLLOWING' relating to a specific laboratory result to a highly complicated medical guidelines which constitutes of hundreds of interrelated rules. The utilization of simple principles managing innumerable decisions that physicians take each day is one of the most successful use of computers in clinical decision making. For example, IF a patient is being diagnosed of lung cancer THEN he should be given an influenza vaccination every year. One of the innovator of computer clinical decision support systems said that in daily care of patients cautious attention to ordinary and boring details can be more significant than brilliance (McDonald CJ, 1988)

There is a major gap between the actual clinical practice and the most favourable patient care. For example, it was found in a survey that in United States only about 70% of the patients got recommended acute care and only 60% received recommended care for constant conditions (Schuster MA, 1998). It was estimated by the Institute of Medicine that 44,000 to 98,000 patients die every year due to

medical errors which can be prevented (Kohn LT, 1999). Even if we use a lesser estimate, this statistic shows that the number of American deaths from medical errors is more than road accidents (43,458), breast cancer (42,297) or AIDS (16,516) (Centres for Disease Control and Prevention (National Centre for Health Statistics). Births and deaths: preliminary data for 1998).

The Institute of Medicine and other key stakeholders recognized computerized physician order entry (CPOE) as a significant approach for making professional practice better and minimizing medical errors (Kohn LT, 1999). CPOE systems can reduce medical errors due to lost, incomplete or illegible orders by requiring the physicians to directly enter orders online (Sittig DF, 1994). Professional care is greatly improved with the integration of clinical decision support systems (CDSS) into CPOE. For example, it was found in a time series study that serious medication errors were reduced by 86% with the help of CPOE system with decision support features (Bates DW, 1999).

Computer decision support systems are defined as computer programs made to help physicians in making analysis and curative decisions for patients. In various clinical settings, it is proved from trials that computer systems help clinicians in providing better care for patients (Thomas H. Payne, 2000).

Clinical decision support (CDS) systems give physicians , patients, staff and other individuals person related information which is cleverly filtered and is accessible at appropriate times to improve health care efficiency (Osheroff JA, 2009). In Unites States, the Institute of Medicine has defined problems with the health care standards and has been stressing upon the use of information technology (IT) including electronic CDS to improve quality (Dick R, Steen, 1997). The Federal Government has been promoting the significance of electronic medical records (EMRs) since 2004. From that time there has been a sluggish but an increase in the adherence of health IT (DesRoches CM, 2008).

 It should be kept in mind that these IT applications in health care are just means to make quality better and not an end in themselves (National Priorities Partnership: priority areas and corresponding goals. National Quality Forum; 2008). Though the availability and accuracy of data can be improved with the help of EMR'S with

Computerized Order Entry (CPOE), it is unclear that the quality and cost of care will be bettered without proper implementation and utilization of CDS (Linder JA, 2007).

3.2 How Can Computers Aid Decision Making

Before going in to a detailed understanding of clinical decision support systems (CDSS) it is necessary to understand that what computers offer to the decision makers and how it can support their work? To answer this question we did a thorough analysis of the existing literature on computers aid in decision making. The resulting relevant material was then categorized on the basis of its features of clinical access, alert reminders, order entry and diagnoses assistance.

3.2.1 Simplify Access to Data Needed To Make Decisions

Computing systems are used by the clinicians to collect laboratory results, radiology reports or the narrative text of notes or consultations. Computing systems are being been used in laboratories and transcription services for data reporting. Reporting of results and making of customized reports or graphs make patterns more clear and thus helps in quicker decision making (Whiting-O'Keefe, 1985). The laboratory data in graphical form can make patterns more clear and easy to understand. If they are amalgamated with display of medications or other interventions they can help the clinicians in deciding a better course of disease (Powsner SM, 1994). This is considered to be the simplest form of decision making for clinicians as it does not require data entry and hence saves time.

3.2.2 Provide Reminders and Prompts

In clinical computing, reminders and prompts are the most helpful tool for clinicians. It has been shown in several reviews that reminders change clinician's attitude in improving delivery of chronic, acute and preventive medical care (Hunt DL, 1998**).** In many different ways reminders can be brought to clinician's attention: before a visit printed sheets can be attached to a chart (McDonald CJ, 1984), on the screen windows can appear or a list of reminders can appear on an electronic cover sheet. Generally, reminders include short messages suggesting a specific action to be taken for a particular patient as depicted in the figure below:

Fig 3. 1 Reminder from the Cover Sheet of the VA CPRS (Thomas H.Payne, 2000)

In some cases, it is important to bring the event into clinician's notice when it occurs like change in laboratory result, hospital discharge etc. Event monitors are applications which send electronic messages from computer systems on the occurrence of events by going through all the new available data or events (Hripcsak G, 1991). A particular rule is run into the system to decide if the physician needs to be informed or if any other decision needs to be taken when an electronic message is received.

3.2.3 Assist in Order Entry

One of the main uses of clinical computing systems is to check the orders which the clinicians have entered in real time. Clinicians are provided with feedback through screen dialog boxes which alert them to drug sensitivity, drug allergy, drug disease and drug laboratory interactions. It has been shown that test ordering can be reduced by 13% if the order entry screens are designed in such a way that they show the results of the previously ordered test for the type being ordered (Tierney

WM, 1987). The applications which allow direct medication order entry are the most difficult to develop but they can reduce serious medication errors (Bates DW, 1994).

3.2.3 Assist in Diagnosis

One of the early uses of computers in health care was to aid the clinicians in establishing diagnoses. Different programs were created to study the historical and physical examination findings, laboratory and test results and then made a list of diagnoses to explain those findings. Examples of such programs include Internist 1, Quick Medical Reference (First Data Bank; San Bruno, CA), DXplain (Laboratory of Computer Science; Boston, MA), and Iliad (Applied Medical Informatics; Salt Lake City, UT) (Berner ES, 1994). The foundation of these systems was laid upon a large set of principles and tables which accounted to the presence and absence of findings with diseases and other conditions.

Although their performance was very good but the requirement that the data should be entered in large amounts limited their use in health care. Now-a-days freestanding applications are less common then the applications which are integrated with patient information in EMRs (Miller RA, 1990**).**

In addition, to use these applications information needed such as presence or absence of symptoms or physical examination findings is not collected in a form which can be processed by decision support systems.

3.3 Characteristics of Successful Computer Decision Support Systems

There is a considerable amount of literature discussing the design, implementation and evaluation of computer decision support systems. From this literature we can describe some features of a successful computer decision support system.

3.3.1 Data Entry and Output

When the computer systems give a recommendation based on a guideline it is best suited if it is based on that patient's information. To make this possible the required information should be in access of the decision support system in machine readable form. In cases where CDS is not integrated with EMR or if the health care provider is using paper based records instead of electronic then the patient data has to be entered in to the system twice by the user, once in to CDS and once in to the medical record. This problem of work flow can cause failure of CDS and work load increment.

The data collected from different sources (laboratory, pharmacy and other systems) is more preferred to the data entered by the physician (Payne TH, 1999)**.** For improving observance of guidelines or changing attitudes of physicians passive display of guideline documents in the literature or on the World Wide Web or in other electronic media is not a reliable method (US Congress, Office of Technology Assessment, 1997)**.**

Another issue is of who is entering the data. In a scenario, where the prescription is written on the paper by a clinician is entered in to the system by a non clinician then the question arises that how will the CDS suggestion for any change would be taken care of? If CDS suggests decreasing the medicine doze with time and by that time physician's communication with the system has ended then how will it be ensured that the change has been made. Many proposals have been suggested for feedback and use issues (For example, email alerts to the clinician's pager) but preference of the system user as to when he should be alerted must also be considered. All these issues must be taken care of in need evaluation, design and planning procedure and also should be tested when the system is implemented.

3.3.2 They save Time

Due to an increase in patient volume, larger requirements for documentation (Iezzoni LI, 1999)**)** and the complications of the modern practice, physicians comparatively have less time available. A very useful method for altering physician's attitude is to make it faster to act in accordance with a recommendation or guideline.

Many strategies exist that help physicians to save time and comply with a guideline. Another suggestion is to save time necessary for visit documentation.

One of the motivation factors behind using a specific application is that the application guides physician through a guideline and simultaneously makes documentation visit faster and hence complies with the guideline (Schriger DL, 1997). Another motivation factor could be the simple and quick ordering of services by the same application. In a few specific clinical scenarios some guidelines can be applied in parts or in full by generating compilation of orders.

For example, guidelines including the ordering of cultures, diagnostic tests and a range of antibiotics are implemented when patients suffering from pneumonia are admitted to the hospital. Order sets or order templates are compilation of orders which can be generated and presented to the physician either in paper form or in order entry application. During the process of ordering orders are easily grouped to save time therefore it is a very helpful procedure for implementation of some types of guidelines.

3.3.3 Work Flow Integration

One of the major issues faced by designers and those implementing CDS is of workflow. It consists of the flow of the system and the procedures needed to provide care. (Carayon P, 2006) It is understandable that CDS that easily fits in a workflow will be used more than the CDS that does not. Therefore, some changes may be required in the workflow in order to deliver effective care. These changes could be done at any stage during the implementation or after the implementation of CDS systems.

The first level of development procedure should include the evaluation of workflow and suitability of CDS system. CDS requirements are determined in the evaluation stage therefore it must be performed thoroughly. If any change requirements in the processes are discovered at evaluation level then these changes must be done before CDS implementation. However, in certain cases CDS may be part of process redesign. Conformity must exist between physician's workflow and CDS timing, design and structure design. This will make CDS more competent but to achieve this

conformity some changes may be required in both workflow and CDS implementation (Berg M, 1997). This is specifically the reason as to why clinicians must be engaged during the structure, design and implementation of CDS system (Osheroff JA, 2009).

Any change in the workflow should be done only for improving the processes and not for a specific CDS as CDS itself may not be flawlessly designed (Stead WW, 2009). After the analysis of workflow and identification of process improvement requirements decisions can be made on how to improve procedures and how CDS can help in improvement.

Also, it is not necessary that there is a single workflow design as every physician has his/her own work style. So he will solely be sharing his views and practices, not all clinicians. It suggests that team should be studying different clinicians and should listen to their practices too. Lastly, it is very important to configure the system according to user needs as this will help in improving efficiency, ease of use and usefulness (Glaser JP, 2009).CDS designers and implementation team should be well aware of other issues that they will face while implementation.

3.3.4 Standards and Transferability

Users need to realize that they may have to put in additional effort even with EMR integrated CDS systems. For example, the decision to implement needs to be made by the user even if sets of reminders are complied into the system. For successful implementation of CDS system some level of modification according to local needs may be required (Miller RA, 2005).

Efforts are already being put in to design principles for data interchange, improve data quality and desired features of CDS (Healthcare Information Standards Panel; 2009) because currently there are no standards/ guidelines / rules that should be built into CDS, Users select rules and alerts that are most applicable to their site.

It is estimated that in CDS development nearly half the cost is spend on physician's time in selection and design of the content (Fields TS, 2008). If commercial knowledge and other sites experience can be used, some time can be saved.

There are many times vocabulary differences among sites, different standards in values, medication formularies, or process of care at different sites and within different CDS.

For example, five different diagnostic decision support systems were examined and it was discovered that every system was established on a different standard for labelling a heart rate. This depicted the standards of the sites where CDS systems were made. One CDS considered normal heart rate to be 90 whereas another considered 120 as normal therefore when purchasing an EMR that supports medical decision support , sites should understand that they have to spend time to make clear the logic built in their CDS. Sometimes they might also have to change its logic according to their needs.

3.3.5 Knowledge Maintenance

As it is very difficult to maintain the records of patients accurately therefore knowledge maintainance proves to be very challenging. Many studies have shown medical records of clinical setting were not kept up to date. For example, information about patient's allergies or medications were changed but changes were not updated. This will result in false alerts which can be critical for patient health. Hence when frequent inaccurate alerts pop up physicians tend to ignore them. This problem of knowledge maintenance is significant not only for alerts and reminders but for all kinds of CDS. That is why it is ver important to check the accuracy of patient data and resolve the issues occurred.

Knowledge maintenance is also associated with the knowledge installed in the CDS. Day by day medical knowledge is growing and new medicines are being discovered. One solution is to use Commercial knowledge bases to provide frequent updates. To make a purchase decision for these commercial systems users should look at the source of the data and the frequency of the updates (Berner ES, 2002).

Another solution is to crate in-house knowledge management system but these systems need considerable amount of resources at local site which may not affordable for small clinical practices.

3.4 Design and Implementation of CDS

A few steps must be kept in mind when planning for a new health IT system. These steps include recognizing the needs and functional requirements such as what is expected from the system etc, taking the decision of building the system or purchasing a commercial one, assembling the system in such a way that it can be easily used in every, planning the implementation process and finding out that how well the system has tackled the defined needs. The design and implementation processes are interrelated in the case of CDS systems. A vast amount of literature is available on the best practices for CDS design and implementation (Iezzoni LI, 1999).

The literature provides specialists view as well as information about the successful use of CDS. A reassessment of the literature was done and the design and features related to the use of CDS were identified (Committee on Maintaining Privacy and Security in Health Care, 1997**).** From this reassessment following findings were concluded:

- In decision support, computer based decision support systems are more effectual than the manual processes
- CDS interventions are expected to be used more that are accessible automatically and fit into the workflow of the physician
- CDS interventions that presents information at the time and place of decision making have more impact
- CDS that suggests actions to be taken for users are more effectual than CDS which only provide assessments

3.5 Requirements for Implementing Computer Decision Support Systems

It is a difficult attempt for any organization to implement computer decision support system, especially order entry system. This process requires determination and patience in accepting the change. Considerable amount of financial and human resources are needed to introduce computer systems into health care settings. It may take a long span of time for the clinicians and other health care professionals to

get use to the change in an environment where computing systems have been implemented (Chin HL, 1995).

A computer infrastructure should also be present in clinical organizations where computing systems are implemented such as databases which consist of patient related information, dependable network connections and workstations at the point of care. There are many uses of printed reports and they help to minimize the workstation usage in examination rooms. On the other hand, order entry programs provide immediate feedback and can be used directly on the mobiles or desktop workstations by physicians.

A large quantity of patient record content is in narrative text form, though there has been recent progress in converting this information using natural language processing techniques (Hripesak, 1999).

Clinical guidelines differ widely in their level of accuracy. Some data can be easily adapted by the clinicians while others consist of more common statements of the approach to a specific problem. There must be a tested, trusted and accurate set of guidelines to be implemented in the automated system for the computer decision support systems to be effectual (East TD, 1992). These guidelines should be tested in real environment in order to improve them as well as edit them until they start performing as expected.

A major concern by all physicians about these computer systems in clinical care is that these systems will take more time and surely which may be the case at early stage (Bates DW, 1994). Another major concern is privacy of data. It must be made in such a way that it protects data privacy. The risk of data privacy revelation can be minimized with the help of policies and technical approaches (Ohno- Machado, 1998).

Clinicians must be motivated to use the system to make CDS more effective. Even though efforts are being made to engage clinicians and integrate CDS into clinical workflow, use of CDS may still be resisted if time pressure is very high in care process. A challenge to CDS implementation is that the background of medicine has always highlighted individual physician independence. According to a survey,

changes in the systems are not always welcomed by the physicians as they are concerned about their independence (Varonen H, 2008). Moreover, physicians are also concerned about their dependence on the outside machines and the legal as well as the ethical consequences related to it.

There are some bases for these concerns. For example, CDS is not a part of the currently used health care. Though CDS systems often offer useful advices but this advice is not always foolproof .These concerns of physicians are not new and not limited to CDS. When blood pressure cuff was introduced in the last century, physicians were concerned about being dependent upon them to determine the blood pressure of the patient instead of the palpation skills used at that time. With the passage of time, physicians got more familiar as well as comfortable with the cuffs (Crenner CW, 1998). As CDS is quite new in health care, physicians are not very familiar with its use but with time their interest will develop.

3.6 Computerized Physician Order Entry Systems (CPOE)

Computerized physician order entry systems (CPOE) are computer applications which electronically accept physicians orders for diagnosis and treatment services instead of recording them on order sheets or prescription pads by the physician (California Health Care Foundation, 2000). These orders can be laboratory, medication or diagnosis tests orders etc. The computer can alert physicians about the potential problems after comparing them against the standards for allergy checks, dosing or reaction with other medications. CPOE is implemented by many health care facilities as a part of their approach to minimize health care costs and improve medical safety (Committee on quality health care, 1999)

The implementation of CPOE is more than an information technology change. It is the redesigning of complex clinical processes by integration of technology at key points to optimize ordering (Andrew M. Steele). The major goals of CPOE include:

- To improve the accuracy of orders
- To minimize the time to care delivery
- To make critical information more easily available

- To minimize the time for order confirmation
- To reduce the potential for human error
- To improve the clinical decision support at the point of care
- To improve the communication among the health care professionals

3.6.1 Features Of CPOE

On the basis of the literature review we determined the features of a good CPOE system. For an error prone CPOE system it should have the following essential features.

CPOE should be well integrated with other clinical systems. It should have bidirectional interfaces to radiology, laboratory and pharmacy systems (Andrew M. Steele). The interface design of CPOE systems should make the process of ordering less complex by specifically mapping to the workflow patterns of the clinicians. The response time for CPOE systems should be good so it can speed up the clinician ordering process. It should also be reliable so that it can process the crucial orders without any delay.

A good CPOE system should have minimal screen layers so as to facilitate the users in navigating the system (maximum 3 layers) (Gardiner, 1987). The alerts on the CPOE interface should be displayed on a prominent position making them more noticeable. The screen components should be organized into related groups and should be separated by space and alignment. The icons on the CPOE interface should be aligned in such a way that the user can easily click on them. The active and passive elements on the screen should be easily distinguished. This can be done by the use of tick boxes and pick lists. The important elements on the interface should be highlighted with prominent colors so that it is easier for the physicians to notice them. The users of the CPOE systems should be provided with clues in the interface so that it can help them in ordering medicines. These clues play a central role in controlling the CPOE user interaction.

CPOE systems also help in addressing the deficiencies related with paper based

ordering. CPOE helps in reduction or elimination of finding patient charts location, orders which are overlooked by the health care staff and overrule rates from electronic drug dispense system thus making sure that more orders will be viewed by the pharmacist. It also helps in minimizing the transcription errors occurred due to manual data entry (Andre M. Steele).

3.6.2 Benefits of CPOE

CPOE replaces paper order, makes relevant information available at the point of ordering, reduce costs, improve ordering process, increases patient safety and reduces medication errors. Thus the benefits of CPOE can be categorized as follows.

3.6.2.1 Optimizing Ordering process

CPOE helps in re-engineering of the whole process of order entry so that the personnel's responsible for making decision are involved directly in order entry. This enables the system to provide real- time feedback regarding orders appropriateness as well as improving the communication of the orders (Glaser JP, 1993). CPOE can improve the ordering processes by eliminating lost orders. The initial record of the order is directly made in the database therefore follow up on overdue orders can be done. With the help of CPOE, records for specific patients can be regularly monitored and the medical staff is alerted when a duplicate order is placed (Ogura H, 1985). In order entry process CPOE can help in reducing hospital expenditure on the pre-printed forms (Hodge MH, 1990).

3.6.2.2 Conscious Decision Making

Conscious decision making is when the physician is presented with alternate tests at the time of ordering. Each alternate test will show radiation dosage, cost and benefits related for specific test. It can also help in minimizing laboratory costs by presenting the physician with predictions of test abnormalities which is based upon the predictive equations derived from the particular patient's data. Based on the clinical information in the system, CPOE can automatically suggest certain curative orders for review before they become active. Physicians can also be

informed about the charges of the test before order completion with the help of CPOE. This can help in significant decrease in the number as well as cost of the tests ordered by the physicians (Tierney WM, 1990).

3.6.2.3 Clinical Decision Support

The integration of clinical decision support systems with the order entry process proves to be the greatest benefit of CPOE. For the implementation of clinical decision support an up to date and accurate knowledge base is required which is difficult to maintain (East T, 1991). Clinical Decision support systems can help the physicians by automatically calculating drug dosage based upon the patient's age, weight and sex (Halpern NA, 1992). It can also provide online laboratory manuals, textbooks or Medline database for the physician (McDonald CJ, 1986). Clinical decision support systems generate alerts for the physicians when the test is being ordered. These alerts could be related to specific drugs being ordered to whom the patient is allergic to or concurrent drugs ordered by multiple practiners etc.

3.6.2.4 Physician Time Optimization

The decision support and process improvement aspects of CPOE provide the physicians competitiveness and satisfaction. If CPOE is implemented properly it should save physicians time. Orders can be placed from anywhere in the hospital by physicians. Web based CPOE systems allow physicians to log in from their homes or offices and carry out order entry in a timely and accurate manner (Teich JM, 1993). Also, the number of telephonic calls for order inquiries can be minimized (Allen SI, 1986).

3.6.2.5 Success Factors For CPOE implementation

Few health care facilities use CPOE systems despite it helps in reducing costs, improving care quality and increase patient safety. Although CPOE helps in reducing costs, improving care quality and increase patient safety but still a few health care facilities use CPOE systems. The reason for this is that there are many obstacles in implementation of these systems. It is basically a clinical process facilitated by technology. For implementation of CPOE redesigning of clinical

processes is required which can only be achieved with physicians extraordinary commitment to the process.

One of the essentials requirements for the implementation of CPOE systems is the support from the medical and executive leadership. The leadership should agree with the objectives of CPOE. They should be clear as to why they want to pursue it and what are their expectations. Many CPOE system implementations failed as they did not fit with the clinical processes or the physicians were resistant to accept the changes in process. Therefore it is necessary that physicians must participate in process redesign like in development of user interface design etc. When implementing CPOE systems the policies and procedures for both new and ongoing processes must be defined. The changes in the workflow must be planned with great care so that multiple operational transitions can be addressed easily.

In conclusion, this chapter provides an overview of clinical decision support systems (CDSS) and computerized physician order entry system (CPOE). This chapter highlights their characteristics and design features .The challenges in designing and implementation of both systems and requirements for their implementation are also presented in this chapter.

4 Radiology Order Entry Design to Improve Ordering

The aim of this chapter is to discuss the design of radiology order entry (ROE) systems to reduce inappropriate imaging on the basis of my research of the existing literature. ROE design should be such that physicians can easily order appropriate tests by adhering to clinical guidelines. As determined from the literature review if physicians adhere to guidelines ROE ordering can be improved. The design features are suggested on the basis of the existing literature and my research on the current ROE systems used in health care such as Order Right, Nuance etc. The design features have been divided in to two categories 1) Features of ROE 2) ROE screen design and how each of the features will solve the barriers identified in section 2.10

4.1 Radiology Order Entry

Radiology is one of the medical field that has benefitted from the advancement in information technology. Great developments have been made in creation of images, their storage and retrieval. These advancements have moved imaging to the nucleus of medical practice and decision making.

This dissertation has discussed inappropriate imaging (section 2.4). Inappropriate imaging occurs due to referrer lack of knowledge (Taragin, 2009), favor of indiscriminant imaging, need for certainty of diagnoses (Kassirer J, 1989), and fear of lawsuits and patients expectation for imaging. Another major reason for inappropriate imaging is that health care professionals fail to follow the clinical guidelines. Inappropriate imaging can be prevented by implementing Radiology Order Entry Systems (ROE). Radiology Order Entry System uses a standard set of indications to determine the appropriateness of a request and provide instant feedback to the ordering clinician.
 Clinical Decision Support Systems (CDSS) have also been discussed in this dissertation (section 3.4).   CDS systems are computer applications that help

clinicians in making clinical decisions. These systems provide filtered information to health care professionals at appropriate times. CDS embedded ROE systems help the physicians to choose appropriate tests on the bases of the implemented guidelines.

When ordering an exam the clinicians and other health care staff should enter the clinical data in the system to justify the order. On the basis of this clinical information, the decision support system gives a yield score from 1 to 9. Score (1-3) are considered to be low utility scores and inappropriate for ordering. Score (4-6) is the medium utility score. Physician can continue with the ordering of the test but he should be suggested with the alternative tests. high score (7-9) indicates that requested test is strongly recommended.

Fig 4. 1 Appropriateness scores (Daniel I. Rosenthal, 2006)

Here is an example of a test ordered with low utility score for the clinical indications provided. In the Fig 4.2, a lumbar spine CT test had low utility score. The system showed alternate procedures like x-rays, MR for this test. The non clinician staff tried to proceed with the order. The next screen indicated that the responsible physician needs to approve the test because of the low score. Message will appear if users of order entry system will try to order duplicate test as shown in figures below.

You are receiving this message because the exam you have requested has a low utility 'red rate' score for the clinical indications provided. This exam may not be scheduled until Smith, John -- Medicine Service reviews the low utility score and approves the exam.

OK

This exam has already been ordered for the patient and requires approval by: Smith, John -- Medicine Service. Your order will not be saved at this time.

OK

Fig 4. 2 Order Process For a Lumbar Spine CT Scan (Vartan M. Vartanians, 2010)

On the basis of the literature survey, the primary features of ROE system were proposed. These features can be subdivided into two categories like:

1. Features of ROE
2. ROE screen design

4.1.1 Features of ROE

The design of radiology order entry system should help physicians in ordering of appropriate tests as per clinical guidelines. Features of an ideal Radiology order entry system (ROE) should address the following issues

1. Minimizing the amount of inappropriate imaging procedures
2. Avoiding the patient exposure to radiations
3. Increasing ordering clinicians knowledge base
4. Making better the quality and results of advanced imaging procedures
5. Prioritizing the radiology procedures according to their criticality

Following features should be part of an ROE system for its successful implementation.

4.1.1.1 Web Based

An ROE system should be web-based and can easily work over an intranet. An ROE system should be available to mass general physicians and other partner facilities for ordering and scheduling exams.

There should be a repository of latest rules over the Internet from where ROE system can download latest patches to keep system up to date. Being online can also help when a doctor wants to consult some other doctor on complex cases. Many medical institutions use a Web-based radiology order entry system to request and schedule outpatient diagnostic imaging exams.

4.1.1.2 Updates and Order Tracking

ROE is the main link between radiology department and the referring physician. ROE can offer latest updates on new and existing imaging tests by using banners and postings. This will benefit radiology department as their products are being marketed and physicians who are getting the latest updates. ROE system should also have tracking ability through which it can be in touch with the radiology departments about issues as request for changes, inquiries and so on. ROE system can also deliver the examination results back to the ordering physician.

4.1.1.3 Security and Privileges

All the communication with ROE systems should be secured and in accordance with the Health Insurance Portability and Accountability Act or similar legislation and

other jurisdictions. The system must be able to recognize the person who is placing the order and should also verify whether he is authorized to do so or not. The individual placing the order should be the clinician or the person nominated by the physician (such as nurse, assistant etc) but in every case the responsible physician must be known. Privileges should be defined so system would be able to recognize user and its authority to order tests.

4.1.1.4 Examination Specification

ROE system knowledge base should be well defined for providing detail specification to carry out an examination. For example, when a spine imaging examination is ordered, ROE system should indicate the level (cervical, thoracic, and lumbar). In the case of extremity imaging, it is not possible to complete an order without signifying the side. The ordering clinician should be made clear of the parts to be included in the examination. For example, in the examination of shoulders the 'views' included in the plain film should be clear. ROE systems should also have the ability to handle requests for a change in examination. ROE should have default processes in case the referring clinician does not wish to indicate details of the examination.

For a protocol to be selected and an examination to be billed correctly, sufficient information should be gathered. To assign an ICD9 (International Classification of Diseases, Ninth Revision) code, adequate clinical data should be provided. It is very difficult for the users to identify between the known conditions and the conditions to be ruled out. That is why; an examination specific list of indications should be generated from which the user can pick out the most relevant one. These lists must be lengthy enough to have all the reasons for which an examination is ordered but should be short enough from the user's perspective so that he is not forced to go over the list quickly. The field of 'free text' is significant as many details may not be present in the list of common indications. These lists can be edited by the radiology department that makes it easier to add or delete required fields.

To avoid confusions, ROE system should use very simple and easy to understand terms as many users are not aware of technical terms as ICD9.

4.1.1.5 Feedback

A good ROE system should have the feature of providing feedback to the physicians on the basis of the tests ordered by them. It should collect the scores for every physician and exam type they ordered. This data can then be analyzed and feedback can be provided to the physician. This feature will help physicians in adhering the guidelines and thus reducing inappropriate imaging.

4.1.1.6 Insurance Coverage

In health care environment where insurer preauthorization is required, it is difficult for the clinicians as well as the radiology departments to manage insurance procedures. Therefore, a good ROE system would ask the users for any insurance preauthorization needed before allowing the examination to be conducted. A warning should be generated that the patient might be responsible for the bill if the indication is not in accordance with the medical policy of the third party payer. ROE should be able to provide the payer systems with preauthorization codes via electronic feeds.

 These systems should also have the ability as well as flexibility to be in touch with the payer systems and have reporting features through which they can verify that appropriate examinations are being requested. Examinations such as mammography and bone densitometry can only be repeated only on annual and biannual basis. Alerts should be generated by the system when the examination being ordered breaches the insurance requirements.

4.1.1.7 Scheduling

The office staff members can schedule appointments for the patients after the physician has used ROE system to order an examination. This ability of ROE systems is a great time saver and provides convenience to both patients as well as the office staff. The best time and place available for the test is then decided. The scheduling system should provide instant access to scheduling at one or multiple sites in order to work correctly. Moreover, it should also allow searches based on the nearest available appointments, appointments within a specific time and multiple linked appointments.

The system should save and move all the data entered if a rescheduling is needed for the same exam on a different date. It is not possible to do the same for a different exam as there is a requirement for examination related histories. ROE systems should provide the patient with a print out of the date and time of exam, preparatory instructions and directions to examination center. These instructions can be faxed or emailed to the patients and system is automatically updated if there is any change before the exam date.

4.1.1.8 Safety Alerts

The system should provide alerts when an exam is being ordered for the patient with a medical history of allergies or any other reactions but still allow the scheduling. ROE should block the scheduling of examination for patients with implanted devices or other risks. Also, when previously exams are performed on one side such as right knee and a request is made again, the system should generate alerts for error possibility.

4.1.1.9 Maintenance

ROE requires updates and alterations with time to keep up to date with the modification in examinations, technology and practice. The system should sum up its every constituent including histories, examinations etc so that elements that are not used can be eliminated.

The features of ROE discussed above will reduce inappropriate imaging like safety alerts, examination specification, updates of guidelines and security and privileges. However, some of the features like web based, insurance coverage, scheduling and maintenance of the systems will improve the overall radiology order entry systems.

4.1.2 ROE Screen Design

User interface design is the design of computers and software applications with the focus on the user experience and interaction (Wikipedia). The purpose of user interface design is to make the users interaction as simple

and effective as possible. Many good systems fail to provide desired outcomes as their interfaces are difficult to use and thus lead to undesired results. There is a need to implement Human Computer Interaction (HCI) study that will help in better designing of user friendly screens. This includes font sizes, vocabulary, color, icon sizes etc.

The design features discussed below should be part of a good ROE screen design.

4.1.2.1 Interface Design

The ROE system design should be basic, simple and easy to use. Often the systems interfaces are created in such a complicated manner that clinicians are not able to adjust to it and therefore cannot utilize the full benefits of the system features. Poor ROE interface design and less usage leads to medical errors and may even lead to disaster if critical information is not presented in an effectual way. It has been shown that ROE interface design faults do lead to errors in orders. For example, numerous adverse drug incidences resulted from poor interface design rather than from human error (J.Horsky, 2005).

4.1.2.2 Timing of Alerts

In the workflow of ROE timing of the alerts to appear on the screen is very critical. Alerts that are generated too early or too late lead to errors. In some published studies it was shown that when medications were ordered by physicians the alerts that appeared either too early or too late led to errors. (R.Koppel, 2005). In one study, orders were cancelled and the users were stopped from being aware of the drug allergy interactions when the system failed to generate alerts at the right time (C.Zhan, 2006).

Depending upon the urgency of the alerts there should be separate dialog boxes for them. If the alert is very critical the location and size of the alert should be different then the alerts with medium or low criticality.

4.1.2.3 Logging Procedures

Physicians find the logging procedures time consuming and difficult to use. Therefore, they prefer prescribing manually rather than through computer systems. Sometimes physicians order medications from those computers from which the other physician has not yet logged out (R.Koppel, 2005). Consequently, physicians sign those orders which they do not enter themselves. This could result in either some other patient receiving medications or the right patient not receiving the correct medication.

4.1.2.4 Pick Lists and Drop Down Menus

ROE systems should restrict the use of long lists in drop down menus and pick lists which make it easy for the users to select different options. The lists should not be too long as they are difficult to use and need scrolling down by the user (M.C.Beuscart, 2005). Drop down lists should cover all the available options but at the same time should be concise enough to avoid confusion for users.

4.1.2.5 Documentation and Data Entry Options

The users of the ROE system can enter data with efficiency by using documentation templates (M.C.Beuscart-Zephir, 2005). These documents are very helpful as they reduce double or triple charting .The structure of ROE communication depends upon a cognitive model of classifying orders. This model is usually not shared by the physicians. Therefore, it becomes difficult for the other health staff to enter data and thus the process is prolonged (C.H.Cheng, 2003). To make data entry more easy and simple, the physicians should be provided with a detail understanding of the cognitive model.

The adjoining fields on the data entry screen can often be misunderstood (J.Horsky, 2005). These misunderstanding can generate alerts which can delay the procedure. It was shown in a study that by using grey boxes for highlighting time slots for drug dispensing by the nurses were usually misunderstood by the physicians as fields in which no data could be entered (M.C.Beuscart-Zephir, 2005). ROE should have a feature of help on each field so that the vague fields can be better understood.

4.1.2.6 Screen Display and Layout

The effects of suboptimal screens exhibited on medication ordering systems have been discussed in several studies (J.Horsky, 2005). It becomes difficult for the health care professionals to find the required information if there is a poorly conceptualized graphical representation. The users are required to make more effort and go through extensive search if the presentation of the alerts on the screen is poorly conceptualized. This delays the ordering procedure and chances of medication errors increases (J.Horsky, 2004). If the orders entered in the system have a poor display it becomes difficult to review them (J.Horsky, 2004). This results in user scrolling through many screens and depending upon his own memory about the order (J.Horsky, 2003). If a patients' medication history is on several pages it becomes difficult for the physician to see complete medical record and thus medication error can occur (R.Koppel, 2005). On the other hand, if too much information is present on a single screen it becomes confusing for the physician to go through all of it (J.Horsky, 2004). The difference in the layout and appearance of screen entry forms, data labels and values led to errors in stop time for drugs (J.Horsky, 2005).

4.1.2.7 Radiation Exposure

ROE should have the feature of showing radiation dosage with every tests ordered. When the physician orders the test the amount of radiation exposure to patient should be shown on the screen and alternate tests suggestions should be displayed on the ROE screen.

4.2 Statistical Feedback

In the last two decades, use of CT scans has increased vastly (Smith Bindman, 2009). In 2007, 72 million scans were performed in United States (Berrington, 2009). From this, it is very clear that the use of diagnostic imaging is increasing day by day and so is data gathered by radiology departments. The question here arises as how to leverage this data and get maximum benefit from it to improve radiology ordering practice

The radiology order entry systems (ROE) should have a feature of analyzing outcomes and improving clinical as well as business decisions. This feature should be introduced at the point of radiology order entry. When the physician is ordering a particular test there should be a tab on the ROE interface providing the physician with the statistical data related to the test. This tab will provide all the historical data related to that particular test with low and high utility score. Information provided should be in tabular and graphical form.

This data can be utilized to provide the physician with an overview of previous similar tests ordered. Physician can check these results to see their outcomes. This shows the physician whether the ordered test provided the desired outcome or whether another test was ordered. The results for tests with comparable appropriateness scores can also be checked. Furthermore, the physician can access the notes of the previous tests which can help in providing a better understanding of the diagnosis history.

If physician want to order MRI scan for shoulder. He will get low ,medium or high utility score based on the symptoms entered in radiology order entry system. At this point statistical data based on score and symptoms entered will be available to the physician. This data can be in graphical form showing the positive or negative results which help physician in appropriate ordering.

This feature can help in overcoming the guideline adherence barriers of outcome expectancy, lack of self-efficacy and lack of agreement. This is further discussed in detail in section 4.3.

ROE feature of statistical feedback could become a significant factor in improving radiology ordering practice.

4.3 ROE and Guideline Related Barriers

Section 2.10 discussed barriers to adherence to guidelines which results in inappropriate imaging. Some of these barriers can be addressed by ROE design

features and rest of barriers need health care administrative actions to improve appropriate ordering

Lack of Familiarity was the first barrier discussed. In health industry, a general trend is found that people are aware of guideline recommendation existence but they are not familiar with the use of it. Physicians may be oblivious to details of guidelines and thus usually do not know what factors need to be considered while ordering tests. The question here arises that how can they be made familiar. A well designed decision support system with integrated guidelines will help in overcoming this barrier. The decision support will analyze the guidelines on the basis of the symptoms entered by the physician and test will be ordered. At the same time a well advertised and easily recognized icon should also be introduced on the ROE interface. If the physician is not convinced with low utility score for a test he can use this icon to see the guideline on the basis on which score has been calculated. . With every use they will become more and more familiar with them.

The next barrier that we have discussed is lack of agreement. It is commonly seen that physicians often are not in agreement with a specific guideline or with the concept of guidelines in general. Common behavior of physicians in this regard is that when they are asked about general guidelines they are in disagreement with it but when questioned about some specific guidelines lack of agreement is less common. This barrier could be overcome if the physicians are shown positive results of using guideline recommendations. This could be done either in theory, presentation or graphical form. An ROE system should have a feature of history trend of guideline recommendations showing encouraging results. These results should be presented for every year, every quarter and every month. This will help in motivating the physicians and encouraging them to use guideline recommendations. This can be done with the help of a well recognized tab on the screen showing history of previously ordered test results for a particular test. This is an example of the statistical feedback feature proposed in section 4.2. Another aspect of lack of agreement for low utility score could be that from physicians past experience the test should have been ordered. At this point, ROE decision support system should give an option of identifying the gap between guidelines which will go to the internal

guideline committee for further discussion. This can be done by introducing a tab on the ROE interface for reviewing the specific guideline.

The next two factors discussed are lack of self- efficacy and outcome expectancy. Self-efficacy refers to the belief that one can carry out a specific behavior. Lack of confidence in skills and incomplete preparation that ultimately results in less adherence to guidelines are due to low self- efficacy. On the other hand, outcome expectancy refers to the expectation that a specific behavior will result in a specific outcome. If the physician do not have faith that his desired result will be achieved by the recommended guideline then it is less likely that he adopts it. Outcome expectancy is related to the expectations of the health care professionals.

These two barriers can be resolved with the help of statistical feedback feature of ROE systems (see section 4.2). Physicians are able to see the history of previously ordered tests with low and high utility score. Information provided is in tabular and graphical form. This shows the physician whether the ordered test provided the desired outcome or whether another test was ordered. The historical data provided guides the physician in ordering the right test. Hence, increasing his self efficacy and outcome expectancy.

Inertia of previous practice is the next factor discussed. Most physicians are not able to overcome this factor and therefore are not able to adhere to guideline recommendations. This factor can be partially overcome by implementing guidelines in decision support systems which help in ordering appropriate tests. A well designed ROE interface can also help to overcome this barrier. Features such as speech recognition and intuitive interface should be introduced. In addition to this, easy to understand terminologies should be introduced. Also, health care professionals should be given demonstrations about guidelines showing them their ease of use, rapid speed and reduced number of steps as compared to the manual practice. Another aspect could be to provide health care staff incentives to use guideline recommendations such as making it part of their Key Performance Indicators (KPI). This will motivate them to use guidelines.

Some external barriers also cause hindrance in adherence to guidelines. These barriers could be patient related, environment related or guideline related. Some other external barriers could be that the health care environment does not have enough computers or not enough staff to operate them. This barrier could not be overcome with the help of ROE design and should be discussed separately.

The next barrier to adherence is guideline related. Physicians usually describe guidelines as difficult and not easy to use. ROE decision support system will solve this barrier as the guidelines will be analyzed on the basis of symptoms provided. A high or low score will be given to the test which will show its appropriateness.

The last barrier that we have discussed is the patient related barrier. Sometimes patients are not willing to accept the advice from ROE system. The ROE system should show the radiation dosage for each test which will help physician in convincing the patient about the criticality of the test. The feature of statistical feedback will also help in overcoming this barrier. The statistics of previously ordered similar tests can help physician in convincing the patient for the appropriateness or inappropriateness of test.

4.4 Conclusion

This chapter has discussed the ROE design features which will help in overcoming barriers to adherence to guidelines (Section 2.10). Some of these barriers can be addressed with the ROE design and for the rest health care administrative actions should be taken. Even the most promising clinical guidelines will not yield positive outcomes if the ROE design is not good enough. Therefore, the ROE system should be designed in such a way to ensure amalgamation of guideline integration and provide maximum benefit to the physicians for the guidelines implemented.

5 Evaluation of Current Technologies

In health care field the use of clinical decision support solutions is increasing day by day (Stephen Herman, 2011). Today, clinical decision support systems for medical imaging are in the beginning phases of development and adaptation. Lately, great attention has been paid to the idea of diagnostic imaging ordering (Stephen Herman, 2011).

In past, when clinicians were unsure about a specific test, they consulted colleagues or secure data such as books or journals. After that, they used to seek guidance from American College of Radiology (ACR). ACR has published criteria for diagnostic imaging for more than 130 topics. Whereas, now a day's clinical decision support systems are used for reviewing the appropriateness of diagnostic imaging procedures at the point of care. There are several order entry systems available in market. Further research showed that MedCurrent's OrderRight and Nuance are the two major vendors of ROE currently being used by many health care facilities. The analysis done on these two vendors is based on the documentation available on internet.

5.1 Order Right System

5.1.1 Introduction

The promoters of Order Right claim that inappropriate test ordering can be reduced or eliminated by its help (Steven Grest, 2010).This system provides physicians with instant appropriateness scores for each patient before ordering of the test. Order Right then shows only the most appropriate tests that should be conducted.

Though Order Right is based on the principles of the American College Of Radiology (ACR), it allow changes to be made according to the necessity of clinical facilities or business requirements of health plans. Order Right provides the health care professionals with the appropriateness criteria (based on 1-9 scoring system designed by ACR).

Unnecessary radiation exposure is a great concern among the physicians. Order Right can determine the amount of unnecessary patient exposure (using a 4 point scale) for the ordering clinician. Hence, the physician can refrain patient from radiation exposure by following Order Right's appropriateness criteria. It can also indicate the level of criticality (a priority score) and the knowledge base source that determines the rules used to assign the appropriateness score. This system can also provide the reference text and clinical citations on the rationale behind the appropriateness scores and the recommended radiology procedures.

5.1.2 How Does Order Right Function

Order Right allows the physicians to order appropriate radiology procedures for their patients. According to the promoters of Order Right, it provides a vastly improved radiology workflow by making the radiology procedures more timely, accurate and fast. It has an additional capability of obtaining pre-authorizations from its participating insurance providers.

Order Right establishes a customized application to connect the payers, diagnostic imaging facilities and physicians. This application uses the appropriateness criteria for radiology procedures.

Fig 5. 1 Order Right: Medical Appropriateness Decision Support (www.medcurrent.com)

On the basis of the criteria defined by American College of Radiology (ACR) Order Right helps in:

- Elimination of inappropriate ordering
- Improving scheduling of radiology procedures
- Elimination of phone and paper based orders which are more prone to error and are time consuming

Order Right will issue pre-authorization code and appropriateness scores to the physicians and imaging facilities. Pre-authorizations codes are useful in US health care where physicians have to claim from insurance companies.

According to Steve Herman MD of Order Right "If the system determines that there may be other more appropriate procedures for the patient than the one ordered, it presents these more appropriate options. As well, it allows the referring physician to initiate the order by providing clinical information only and then have the system recommend the most appropriate study to order. Additionally, the doctor is given an

explanation behind the given appropriateness score and a link to reference text in the medical literature that supports these options, as well as a metric for the patient's radiation dosage. This patient-specific information empowers ordering physicians to select the most appropriate imaging order."

5.1.3 Benefits of Order Right

Order Right is a clinical decision support tool that helps in improving patient care by reducing inappropriate procedures and minimizing costs. Some benefits of Order Right System are as follows:

- introduces an easy to use decision support workflow sequence into the ordering process
- Ensuring the ordering of appropriate tests to improve patient care
- Helps in delivering better quality and results of imaging procedures
- Minimizes patient radiation exposure
- Manages radiology use in a cost effective way
- Decreases the overhead cost of claims and denials
- Paves the way for pre-authorization by payers
- Improves the relationship of referring physicians
- System can be easily accessible through web or via EMR
- Provides instantaneous clinical feedback

5.2 Nuance

5.2.1 Introduction

The health care providers are in quest of finding ways for effective management, providing ordering physicians better services and meeting health care reform requirements due to the application of American Recovery and Reinvestment Act (ARRA) in 2009 and Health Information Technology For Economic And Clinical Health (HITECH) act, looming pay-for-performance (P4P) initiatives and a general

increase in competition among the radiology facilities (White Paper, Nuance). The providers of diagnostic imaging can improve the radiology ordering procedure results with the help of closed-loop radiology environment.

Close-loop radiology is the management of order to delivery cycle to improve imaging usage, reduce cost and increase patient care. Close-looped radiology workflow solutions provide a complete end-to-end solution for the physicians ordering tests, the radiologists and the decision support analysts. It covers the ordering of appropriate exams, pre-certification, reporting, communication, data mining and analysis of results.

The Nuance Healthcare uses Close loop radiology workflow to provide the administrators and radiologists with a constant view of the order, from providing care to the end results of medical procedures and allows analysis that can lead to improvement at every stage. The imaging documentations and communication software's provided by nuance are RadPortTM, Powerscribe® 360, VeriphyTM, and RadCubeTM. RadPort is an evidence-based clinical decision support system that guides appropriate high-tech diagnostic image order entry and is discussed in detail in next section.
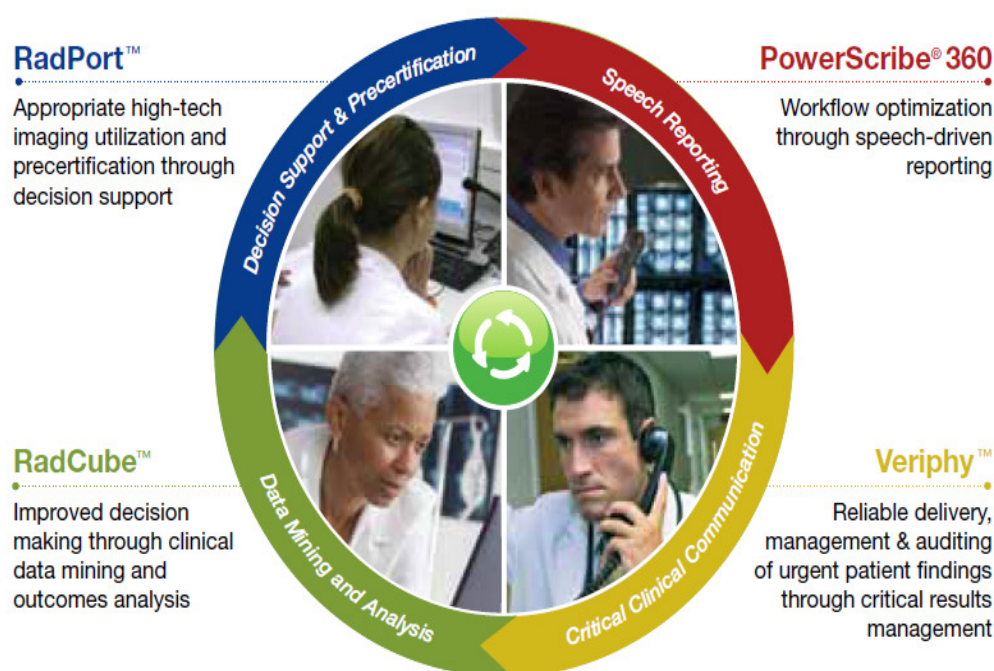

Fig 5. 2 Software's Provided By Nuance (Nuance.com)

5.2.2 RadPort TM

5.2.2.1 Overview

RadPort is a secure, evidence based web application for guiding appropriate order entry of diagnostic imaging. This ordering should satisfy the precertification requirement and should integrate with computerized physician order entry (CPOE) and electronic medical record (EMR). Based on American College of Radiology (ACR) scoring methodology the appropriateness of each test can be checked thus ensuring maximum clinical appropriateness.

5.2.2.2 Features

RadPort's appropriateness criteria for scoring is based on the American College of Radiology (ACR)'s appropriateness criteria. This scoring system is derived in association with Massachusetts General Hospital therefore the scoring techniques are constantly analyzed and updated by a committee of radiology and clinical experts. When the clinical data of the patient is entered in to the system by the referring physician RadPort integrates this info with patient's demographics to provide a utility score for the requested test. A high score depicts that the ordered exam is correct ad should be conducted whereas a low score indicates the inappropriateness of the test. RadPort then displays the alternative choices of tests with their corresponding scores. It also provides reference material for the physician to ensure that next time correct test is ordered.

Many times ordering physicians order the tests despite their low utility score. However, if the test is ordered physician has to enter his reason for ordering the test. RadPort gathers this information to help with editing of future decision support rules and modifications. It also collects the scores for every physician and exam type they ordered. This data can then be analyzed by a facility with the help of RadPort and provides a feedback to the ordering physicians.

Nuance Health Care claims the following benefits of Radport :

> ➢ RadPort reduces the ordering time up to 80%
> ➢ It meets the requirements of precertification
> ➢ It helps in minimization of phone calls
> ➢ It helps in management of high-tech imaging usage
> ➢ Patient care can be improved with the help of RadPort
> ➢ Inappropriate ordering can be reduced with its help
> ➢ The practices of the ordering clinicians can be improved with RadPort

They're a two other tools provided by nuance that work in conjunction with RadPort. They are Power Scribe 360 and Veriphy. PowerScribe is a radiology reporting platform that integrates, in a single solution speech recognition technology, capturing of data, workflow of multisites and structures reporting whereas Veriphy provides solutions for Critical Test Management (CTM) and Critical Test Result Management (CRTM). It automates the delivery and confirmation of its receipt and helps in voice communication documentation for Critical Test Results (CTRs). It also automates read-backs by the medical staff in laboratories.

5.3 Analysis of Vendors on the basis of proposed design features of ROE

From the analysis of the current vendors Order Right and Nuance's RadPort solution we have determined their features in accordance to the characteristics of a good ROE system as indicated in chapter 4. Both Order Right and RadPort are secure , web-based solutions. A good ROE system should be continuously updated and well maintained. RadPort's scoring methodology is derived in association with Massachusetts General Hospital therefore the scoring techniques are constantly analyzed and updated by a committee of radiology and clinical experts. Another feature of an ROE system is its scheduling ability. Order Right provides the facility of scheduling tests from the ROE system that is a great time saver and provides convenience to patients as well as to office staff. Order Right also checks for the insurance pre-authorization before allowing examinations to be conducted. Order

Right gives options of alternate tests to the physician in case of low score and also empowers physicians by providing the link to the detailed guidelines.

As proposed in Chapter 4, a good ROE system should have the feature of determining the radiation exposure for every test being ordered. Order Right has the ability to determine the radiation dosage for every test ordered . A good ROE system helps in increasing the knowledge base of the physician. Order Right indicates the knowledge base source that determines the rules used to assign the appropriateness score.

RadPort's appropriateness criteria for scoring is based on the American College of Radiology (ACR)'s appropriateness criteria. This scoring system is derived in association with Massachusetts General Hospital therefore the scoring techniques are constantly analyzed and updated by a committee of radiology and clinical experts whereas Order Right shows reference text for the rationale behind the scores. Both Radport and Order Right provide alternative choices of tests with their corresponding scores. The reference material for physicians is also provided by both Order Right and RadPort to ensure that right test is ordered next time. In RadPort, continuous feedback is provided to the physician through collection of the scores for every physician and exam type ordered by them. This data is then analyzed by a facility and feedback is provided.

Both RadPort and OrderRight lack critical feature of statistical feedback proposed in section 4.1.1 which provide the physician with an overview of previous similar tests ordered. This shows the physician whether the ordered test provided the desired outcome or whether another test was ordered.

On the basis of our analysis of the documentation available for OrderRight and Nuance following is a table of their design feature comparison:

Design Features	Order Right (MedCurrent)	RadPort (Nuance)
Web Based	✔	✔
Updates Guidelines	✔	✔
Order Tracking	✔	N/A
Security and Privileges	✔	✔
Examination Specification	N/A	N/A
Insurance Pre-authorization	✔	N/A
Scheduling	✔	✔
Safety Alerts	✔	✔
Maintenance	✔	✔
Alternate Ordering Suggestions	✔	✔
Radiation Exposure	✔	N/A
Statistical Feedback	N/A	N/A

Both RadPort and Order Right have some features of a good ROE system but missing few critical features like Statistical feedback. There is a need for a solution that offers a complete set of features to eliminate inappropriate imaging.

6 Conclusion

6.1 Introduction

This research study aims to establish that "How DSS for radiology ordering should be designed to maximize adherence to guidelines?". It also analyzed the current vendors of ROE on the basis of the design features proposed in this study.

6.2 Research Summary

A literature review based on the existing literature of radiology was conducted. Inappropriate imaging was identified as a major concern in diagnostic imaging because of the high costs and radiation risks associated with it. It was then determined that clinical guideline implementation could help in reducing inappropriate imaging. The barriers to physicians adherence to guidelines were then identified and proposed on the basis of the existing literature.

The study then described in detail clinical decision support systems (CDSS) and computerized physician order entry systems (CPOE). The characteristics of CDSS and CPOE systems were identified and documented along with their design features.

The study then went on to describe the radiology order entry (ROE) design to improve ordering. As per clinical guidelines the design of radiology order entry (ROE) should help physicians in ordering appropriate tests. It also addresses the issues of radiation exposure and improving the quality and results of the advanced imaging procedures. Radiology Order Entry System uses a standard set of indications to determine the appropriateness of a request and provide instant feedback to the ordering clinician.

The features of a good radiology order entry (ROE) systems were then proposed. One of major findings of this research is ROE feature "Statistics Feedback" which is not available in any of the current systems available. This feature will help in analyzing outcomes and improving clinical decisions. This feature will provide all the

historical data related to that particular test with low and high utility score. The data can be utilized to provide the physician with an overview of previous similar tests ordered and also if the ordered test has provided desired result. As ROE is the main link between the radiology department and the referring physician therefore it should offer latest updates and provide order tracking. All the communication with ROE systems should be secured and in accordance with the Health Insurance Portability and Accountability Act. ROE system knowledge base should be well defined for providing detail specification to carry out an examination. It can also help in insurance coverage and scheduling of appointments for the patients. Safety alerts should also be provided in a good ROE system. To keep up to date with the modification in examinations, technology and practice ROE should be continuously updated.

The interface design of ROE systems should be simple and easy to use. In the workflow of ROE timing of the alerts to appear on the screen is very critical as alerts generated too early or late could lead to errors. There should be a restriction in the maximum use of drop down menus and pick lists which make it easy for the users to select different options. The log in and out procedures should be easy and convenient to use. These design features were proposed to overcome the barriers to adherence to guidelines discussed earlier in the research.

Few of the barriers identified in this research can be addressed with ROE design features and rest of barriers need health care administrative actions to improve appropriate ordering. Physicians may be oblivious to details of guidelines and thus usually do not know what factors need to be considered while ordering tests. This barrier can be overcome if an icon is introduced on the ROE interface. With the help of this icon, physicians will be able to see which guidelines are implemented for a particular test. With every use they will become more and more familiar with them. An ROE system should have a feature of history trend of guideline recommendations showing encouraging results which will motivate physicians to use guideline recommendations.

The current vendors of the radiology order entry (ROE) were evaluated on the basis of the design features identified and proposed in our research. The vendors discussed are MedCurrent's Order Right and RadPort of Nuance. Order Right's

knowledge base shows reference text for the rationale behind the scoring system and gives more options for appropriate tests. RadPort   also provides alternative choices for tests with their corresponding scores. It also gathers information to help with editing of future decision support rules and modifications.

6.3 Limitations

The limitation of this research study is that the design features proposed are not implemented in a real time ROE system. The proposed features should be implemented in any existing radiology order entry system (ROE) and feedback from the physicians should be collected. Moreover the workflow of ROE systems is not discussed in detail. Further work should be done on the integration of workflow with ROE. The workflow should be considered while designing the ROE system.

6.4 Future Work

"The present is big with the future" Rudyard Kipling……

The ability of the radiology order entry systems (ROE) to optimize order entry process would prove to be very beneficial in maximizing adherence to guidelines. Further research should be done on the effectiveness of ROE systems in real time environment. Tools should be designed on the basis of the recommendations suggested in Chapter 4 and implemented in a health care environment for its evaluation and feedback purposes. The current ROE technology is immature and developing rapidly. As the adoption of ROE systems will increase there will be an increase in the knowledge of using these systems as well.

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Appendix 1: Diagnostic Imaging Referral Guidelines

A. Head (including ENT problems)

Clinical / Diagnostic Problem	Investigation	Recommendation [Grade]	Comment	Dose
A01. Congenital disorders *(For children see section L)*	MRI	Indicated [B]	Definitive exam for all malformations. CT may be needed to define bone and skull base anomalies. Sedation or GA may be required for infants and young children. *(For congenital disorders in children see L01 and L02)*	0
A02. Acute stroke	CT	Indicated [diagnosis B, treatment A]	A policy of CT for most strokes as soon as reasonably possible is to be encouraged, but at least within 48 hours, as this will ensure accurate diagnosis of the cause, site, and appropriate primary treatment and secondary prevention.	II
	MRI	Specialized investigation [B]	MRI should be considered in young patients with stroke, in patients presenting late where it is essential to know whether they have previously had a hemorrhage, and in suspected posterior fossa stroke in patients in whom it is important to demonstrate the site of the stroke lesion.	0
	US carotids	Indicated only in specific circumstances [B]	Should only be performed in: (1) those in whom carotid endarterectomy is contemplated for secondary prevention; (2) suspected dissection; or (3) young patients, whether disabling or non-disabling ischemic stroke.	0
A03. Transient ischemic attack (TIA) *(See also B05)*	CT	Indicated [B]	May be normal. Can detect established infarction and hemorrhage and exclude disease processes that can mimic stroke syndromes, such as glioma, extracerebral hemorrhage, and cerebritis.	II
	US carotids	Indicated [B]	To assess suitability for carotid endarterectomy or angioplasty. Angiography, MRA, and CTA are alternatives to show the vessels. MRI and NM can be used to show function.	0
A04. Demyelinating and other white matter disease	MRI	Indicated [A]	MRI is viewed as the most sensitive and specific investigation for establishing a diagnosis of multiple sclerosis. The diagnosis is made by demonstrating dissemination of clinical events and lesions in space and time.	0
A05. Space occupying lesion (SOL)	CT	Indicated [B]	CT is often sufficient in supratentorial lesions.	II
	MRI	Indicated [B]	MRI is more sensitive for early tumours, in resolving exact position (useful for surgery), and for posterior fossa lesions. MRI may miss calcification.	0

Clinical / Diagnostic Problem	Investigation	Recommendation [Grade]	Comment	Dose
A06. Headache: acute, severe, subarachnoid hemorrhage (SAH)	CT	Indicated [B]	The clinical history is critical. A clinician should be able to diagnose patients who have classical migraine or cluster headaches without CT. SAH headache comes on typically in seconds, rarely in minutes, and almost never over more than 5 minutes. CT will provide evidence of hemorrhage in up to 98% of patients with SAH if performed on a modern scanner within the first 48 hours of ictus. An LP should still be performed on all patients (delayed 12 hours after ictus for xanthochromia) with suspected SAH but with negative CT. CT is indicated in patients with acute-onset headache with focal neurological signs, nausea or vomiting, or GCS (Glasgow Coma Score) below 14. An LP is the diagnostic test of choice for meningitis unless there are focal signs or a significantly depressed level of consciousness.	II
	MRI / NM	Specialized investigation [C]	MRI is better than CT for inflammatory causes. SPECT may be the most sensitive investigation for encephalitis and can provide evidence of circulatory derangement in migraine.	0 / II
A07. Headache: chronic *(See also A13)* *(For children see section L)*	CT / MRI	Indicated only in specific circumstances [C]	In the absence of focal features imaging is not usually useful. The following features significantly increase the odds of finding a major abnormality on CT or MRI: • Recent onset and rapidly increasing frequency and severity of headache • Headache causing to wake from sleep • Associated dizziness, lack of coordination, tingling or numbness *(For headache in children see L08)*	II / 0
	SXR, XR sinus, XR cervical spine	Indicated only in specific circumstances [B]	XR is of little use in the absence of focal signs / symptoms.	I / I / I
A08. Pituitary and juxtasellar problems	MRI	Specialized investigation [B]	Urgent referral when vision is deteriorating.	0
	SXR	Not indicated [C]	Patients who require investigation need MRI or CT.	I
A09. Posterior fossa signs	MRI	Indicated [A]	MRI is the investigation of choice. Multislice CT is an acceptable alternative.	0

Clinical / Diagnostic Problem	Investigation	Recommendation [Grade]	Comment	Dose
A10. Hydrocephalus, shunt function	CT	Indicated [B]	CT is adequate for most cases; MRI is sometimes necessary and may be more appropriate in children. US is first choice for infants. *(For hydrocephalus in children see L06)*	II
	XR	Indicated [C]	If there is evidence of hydrocephalus on CT, XR can demonstrate the whole shunt system.	I
(For children see section L)	NM	Indicated [C]	A radionuclide shunt study can evaluate shunt function.	II
A11. Middle or inner ear symptoms (including vertigo)	CT	Specialized investigation [B]	Evaluation of these symptoms requires ENT, neurological, or neurosurgical expertise.	II
A12. Sensorineural hearing loss *(For children see section L)*	MRI	Specialized investigation [B]	MRI is much better than CT, especially for acoustic neuromas. *(For hearing loss in children see L05)*	0
A13. Sinus disease	XR sinus	Indicated only in specific circumstances [B]	Acute sinusitis can be diagnosed and treated clinically. If it persists past 10 days on appropriate treatment, XR sinus may be required. Signs on XR sinus are often non-specific and encountered in asymptomatic individuals. *(For sinus disease in children see L09)*	I
(For children see section L)	CT sinus	Specialized investigation [B]	CT is useful to demonstrate the presence and distribution of disease and sinonasal anatomy. Low-dose technique is desirable. CT is indicated for failure of maximal medical treatment, development of complications (such as orbital cellulitis), or if malignancy is suspected.	II
A14. Dementia and memory disorders, first-onset psychosis	CT	Indicated only in specific circumstances [A]	Yield is low, even in younger patients; neurological signs and rapid progression increase it. Over the age of 65, CT can be reserved for patients with an onset within the last year or an atypical presentation, rapid unexplained deterioration, unexplained focal neurological signs or symptoms, a recent head injury (preceding the onset of dementia), or urinary incontinence and/or gait ataxia early in illness.	II
	NM	Specialized investigation [B]	Brain perfusion SPECT may be useful in the diagnosis of Alzheimer's Disease.	II
	MRI	Not indicated [B]	More sophisticated examinations have no proven clinical value, although they may be used in research.	0
	SXR	Not indicated [A]	SXR should only ever be used to show clinically relevant abnormalities of the skull bones.	I

B. Neck – Soft tissues (for spine)

Clinical / Diagnostic Problem	Investigation	Recommendation [Grade]	Comment	Dose
B01. Thyroid nodules	US	Indicated only in specific circumstances [B]	US is excellent for differentiating between thyroid and extrathyroid masses, for guiding aspiration or biopsy (particularly in difficult-to-palpate or small thyroid nodules), and for the detection of associated lymphadenopathy in thyroid malignancy. In generalized thyroid enlargement or multinodular goitre US readily shows retrosternal extension; real-time studies show effect of neck extension, etc. CT / MRI is needed to demonstrate full retrosternal extent and tracheal compromise. NM has no role in the initial evaluation of thyroid nodules.	0
	US-guided FNAC / FNAC	Indicated [B]	Thyroid nodules are extremely common; the majority are benign. Conventional fine-needle aspiration (FNAC) (without imaging) is the most cost-effective initial investigation.	0 / 0
	NM	Indicated only in specific circumstances [B]	Thyroid scanning may be used to assess nodules following biopsy which has demonstrated a follicular neoplasm with no definite features of malignancy, or in the case of a benign nodule when the serum TSH is suppressed.	II
B02. Thyrotoxicosis	NM	Indicated [B]	NM can differentiate between Graves' disease, toxic nodular goitre, and subacute thyroiditis. Provides functional information about nodules. Also useful in thyroiditis.	II
B03. Ectopic thyroid tissue (e.g. lingual thyroid)	NM	Indicated [C]	NM excellent for small ectopic rests of thyroid tissue.	II
B04. Hyperparathyroidism	US / NM / CT / MRI	Specialized investigation [C]	Seek advice. Diagnosis made on clinical / biochemical grounds. Imaging can assist in pre-operative localization but may not be needed by experienced surgeons. Much depends on local policy and available technology and expertise. US, NM, CT, and MRI are all accurate in the un-operated neck. MRI is probably evolving as the best investigation for ectopic and residual tumours. Super-selective venography for sampling after previous imaging may be useful.	0 / II / II / 0
B05. Asymptomatic carotid bruit	US carotids	Indicated only in specific circumstances [B]	US not usually valuable as evidence suggests that surgery is not recommended for asymptomatic carotid stenosis.	0

Clinical / Diagnostic Problem	Investigation	Recommendation [Grade]	Comment	Dose
B06. Swallowed or inhaled foreign body *(See also J27-J29)* *(For children see section L)*	Lateral XR soft tissues of neck	Indicated only in specific circumstances [B]	The majority of foreign bodies are not seen on XR. The clinical history and findings are more accurate indicators of the presence of a foreign body. Direct examination of the oropharynx, laryngoscopy, and endoscopy are the investigations of choice. *(For swallowed or inhaled foreign body in children see L26 and L31)*	I
B07. Neck mass of unknown origin	US	Indicated [C]	First-line investigation for characterization of neck mass. May be combined with FNAC.	0
	CT / MRI	Indicated only in specific circumstances [C]	CT / MRI may be indicated if the full extent of the lesion is not determined by US, for identifying other lesions, and for staging.	II / 0
B08. Salivary obstruction	US / Sialogram	Indicated [C]	For intermittent, food-related swelling. MR sialography may be preferred in some centres.	0 / II
	XR	Indicated only in specific circumstances [C]	Where there is calculus in the floor of the mouth, XR may be all that is required.	I
B09. Salivary mass	US	Indicated [B]	US is the initial investigation of choice for a suspected salivary mass; it can be combined with FNAC, if necessary. It is extremely sensitive and has high specificity.	0
	MRI / CT	Specialized investigation [B]	Whenever deep lobe involvement or extension into deep spaces is suspected, MRI or CT should be carried out.	0 / II
B10. Dry mouth: connective tissue disease	US / Sialogram / NM	Specialized investigation [C]	Not commonly required. Sialogram may be diagnostic, but NM provides better functional assessment. MR sialography is also used here.	0 / II / II
B11. Temporomandibular joint dysfunction	MRI	Specialized investigation [B]	XRs do not often add information as the majority of temporomandibular joint problems are due to soft tissue dysfunction (usually subluxation of the intra-articular disk) rather than bony changes, which appear late and are often absent in the acute phase.	0

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C. Spine (for trauma)

Clinical / Diagnostic Problem	Investigation	Recommendation [Grade]	Comment	Dose
General				
C01. Congenital disorders	MRI	Indicated [B]	MRI defines all spinal malformations and excludes associated thecal abnormality. CT may be needed to delineate bone detail. Sedation or GA may be required for infants and young children. *(For congenital disorders in children see L01, L02)*	0
(For children see section L)	XR	Specialized investigation [C]	E.g. full-length standing XR for scoliosis. *(For congenital disorders in children see L01, L02)*	I
C02. Myelopathy: tumours, inflammation, infection, infarction, etc.	MRI	Indicated [B]	MRI is the initial investigation of choice for all spinal cord lesions, to evaluate cord compression and to give an indication of post-operative prognosis.	0
	CT / CTM	Specialized Investigation [B]	CT may be needed if better bony detail is required. CT myelography (CTM) only if MRI is contraindicated.	II / II
	NM	Specialized investigation [B]	NM is still widely used to screen for metastases and to identify focal skeletal lesions (such as osteoid osteoma).	II
Cervical spine				
C03. Possible atlanto-axial subluxation	XR	Indicated [B]	Lateral cervical spine XRs in flexion and extension with the patient in supervised comfortable flexion should reveal any significant subluxation in patients with rheumatoid arthritis, Down's syndrome, etc.	I
	MRI	Specialized investigation [B]	MRI in flexion / extension shows effect on cord when XR is positive or neurological signs are present.	0
C04. Neck pain, brachialgia, degenerative change	XR	Indicated only in specific circumstances [B]	Neck pain generally improves or resolves with conservative treatment. Degenerative changes begin in early middle age and are often unrelated to symptoms.	I
	MRI	Specialized investigation [B]	Consider MRI and specialist referral when pain affects lifestyle or when there are neurological signs. CT myelography may occasionally be required to provide further delineation or when MRI is unavailable or impossible.	0

Clinical / Diagnostic Problem	Investigation	Recommendation [Grade]	Comment	Dose
Thoracic spine **C05.** Pain without trauma: degenerative disease	XR	Indicated only in specific circumstances [C]	Degenerative changes are invariably present from middle age onwards. Imaging is rarely useful in the absence of neurological signs or pointers to metastases or infection. Consider more urgent referral in elderly patients with sudden pain to show osteoporotic collapse or other forms of bone destruction. NM can be considered to document the extent and activity of arthitic change and to screen for the presence of metastatic disease.	I
	MRI	Specialized investigation [C]	MRI may be indicated if local pain persists or is difficult to manage, or if there are long tract signs.	0
Lumbar spine **C06.** Chronic back pain with no pointers to infection or neoplasm	XR	Indicated only in specific circumstances [C]	Degenerative changes are common and non-specific. Main value of XR is in younger patients (e.g. < 20 years) with spondylolisthesis, ankylosing spondylitis, etc., or in older patients (e.g. > 55 years). In cases where management is difficult, negative findings may be helpful. NM can be considered to document the extent and activity of arthitic change and to screen for the presence of metastatic disease.	II
	MRI	Specialized investigation [C]	If symptoms persist or are severe or where management is difficult or there is no response to conservative methods, MRI is considered the first-choice investigation. Imaging findings need to be interpreted with caution because many imaging 'abnormalities' occur with high frequency in asymptomatic individuals and therefore have an uncertain relationship with back pain. The significance of imaging findings depends upon correlation with clinical signs. Negative findings may be helpful. CT may be considered if MRI is unavailable or contraindicated.	0
	CT	Specialized investigation [C]	If symptoms persist and are unresponsive to conservative methods.	III

E. Cardiovascular system

Clinical / Diagnostic Problem	Investigation	Recommendation [Grade]	Comment	Dose
E01. Acute central chest pain: myocardial infarction	CXR	Indicated [B]	CXR must not delay admission to a specialized unit. CXR can assess heart size, pulmonary edema, tumour, etc., and can exclude other causes. Portable radiograph preferable.	I
E02. Chronic ischemic heart disease and assessment after myocardial infarction	CXR	Indicated only in specific circumstances [B]	May be helpful only if signs or symptoms have changed, when comparison with the CXR obtained at presentation.	I
	US echo-cardiography	Indicated [A]	Allows assessment of residual LV contraction, valves, and complications such as myocardial rupture. Can easily be used sequentially, particularly if hemodynamic clinical deterioration is noted.	0
	NM (myocardial perfusion imaging)	Indicated [B]	Appropriate method of determining prognosis / diagnosis, ischemic burden, and specific ischemic zone. Either pharmaceutical or exercise stress can be used in conjunction with isotopes. Tl-201 imparts a higher radiation burden but may be a better prognostic / viability agent. Tc-99m has a higher energy and allows concomitant assessment of LV contraction to be made via gated imaging. Particular uses are: • Prognostic assessment • Diagnosis in atypical or asymptomatic individuals • Assessing patients for revascularisation strategies • Risk stratification prior to non-cardiac surgery	II
	NM (radionuclide angiography: MUGA or ERNVG)	Specialized investigation [B]	Can assess both LV and RV function after myocardial infarction. Echocardiography is the preferred technique for assessment of LV contraction, etc.	III
	Angiography	Indicated [B]	Only technique currently available for detailed assessment of coronary artery anatomy. Essential prerequisite for interventional strategies and sometimes to establish diagnosis.	III
	MRI	Specialized investigation [B]	The role of MRI perfusion is still to be evaluated.	0
E03. Chest pain: aortic dissection	CXR	Indicated [B]	Mainly to exclude other causes; rarely diagnostic.	I
	US trans-esophageal echo-cardiography (TEE)	Indicated [B]	TEE is a useful and accurate bedside technique, but not as good as CT for aortic arch.	0
Continued	CT	Indicated [B]	CT with IV contrast is the most reliable and practical technique.	III

Clinical / Diagnostic Problem	Investigation	Recommendation [Grade]	Comment	Dose
E03. Chest pain: aortic dissection *Continued from page 28*	MRI	Specialized investigation [B]	MRI is accurate and assesses any change in longitudinal extent, but practical difficulties can limit imaging potential. Useful for sequential follow-up.	0
E04. Pulmonary embolism *(See also E13)*	CXR	Indicated [B]	CXR should be the preliminary investigation to demonstrate consolidation and pleural effusion, but a normal CXR does not exclude a pulmonary embolus.	I
	NM (ventilation / perfusion scintigraphy)	Indicated [B]	Ventilation / perfusion (V:Q) scintigraphy can be diagnostic if used selectively in patients without COPD or consolidation on CXR, or less often if used non-selectively. A normal perfusion scintigram excludes clinically significant pulmonary emboli.	II
	Spiral CT	Indicated [B]	Spiral CT is the investigation of choice, is as accurate as pulmonary angiography in the detection of pulmonary emboli, and reliably excludes clinically important pulmonary embolism. It is the investigation of choice for patients with COPD or an abnormal CXR, and may be used following a non-diagnostic V:Q scintigram.	III
E05. Pericarditis, pericardial effusion	US echo-cardiography	Indicated [B]	Useful for assessment of concomitant pathology (e.g. effusion). Can make assessment of size of pericardial effusion, suitability for drainage, development of tamponade, etc. Best for sequential follow-up.	0
	CXR (including left lateral)	Indicated [B]	May reveal concomitant pathology (e.g. tumour) or calcification in pericardium.	I
E06. Suspected valvular cardiac disease	CXR	Indicated [B]	Used for initial assessment and when there is a change in the clinical picture.	I
	US echo-cardiography	Indicated [B]	Best method of sequential follow-up. TEE may be needed for prosthetic valves.	0
	MRI	Indicated [B]	Can be useful but is generally impracticable. Contraindicated for many prosthetic valves. Useful in the context of congenital heart disease.	0
E07. Clinical deterioration following myocardial infarction	CXR	Indicated [B]		I
	US echo-cardiography	Indicated [B]	US may show remediable complications (ventriculoseptal defect, papillary rupture, aneurysm, etc.).	0
E08. Hypertension *(See also H03)* *Continued*	CXR	Indicated [B]	Assesses cardiac size and possible associated pathology such as coarctation or rib erosion from collaterals.	I
	US echo-cardiography	Indicated [B]	Most practical method of assessing LV hypertrophy.	0

Clinical / Diagnostic Problem	Investigation	Recommendation [Grade]	Comment	Dose
E12. Abdominal aortic aneurysm	US	Indicated [A]	Useful in diagnosis, determination of maximal diameter, and follow-up. CT preferable for suspected leak but should not delay urgent surgery.	0
	CT / MRI	Indicated [A]	CT (especially spiral) and MRI for relationship to renal and iliac vessels. There is increasing demand for detailed anatomical information because of increasing consideration of percutaneous stenting.	III / 0
E13. Deep vein thrombosis	US	Indicated [A]	More sensitive with colour flow Doppler. Most clinically significant thrombi are detected. There is increasing experience with US for calf vein thrombi. May show other lesions.	0
	Venography	Indicated only in specific circumstances [B]	Extensive variation according to US expertise and local therapeutic strategy. Radionuclide venography may be used to provide additional diagnostic information in some centres.	II
E14. Peripheral Vascular Disease	Angiography	Specialized investigation [A]	Local policy needs to be determined in agreement with vascular surgeons, especially with regard to therapeutic interventions. US used in some centres as first investigation.	III
	CTA / MRA	Specialized investigation [C]	CTA and MRA are increasingly used for diagnosis.	III / 0