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Integrating the Radiology Information System with Computerised Provider Order Entry: The Impact on Repeat Medical Imaging Investigations

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Abstract. Repeat and redundant procedures in medical imaging are associated with increases in resource utilisation and labour costs. Unnecessary medical imaging in some modalities, such as X-Ray (XR) and Computed Tomography (CT) is an important safety issue because it exposes patients to ionising radiation which can be carcinogenic and is associated with higher rates of cancer. The aim of this study was to assess the impact of implementing an integrated Computerised Provider Order Entry (CPOE)/Radiology Information System (RIS)/Picture Archiving and Communications System (PACS) system on the number of XR and CT imaging procedures (including repeat imaging requests) for inpatients at a large metropolitan hospital. The study found that patients had an average 0.47 fewer XR procedures and 0.07 fewer CT procedures after the implementation of the integrated system. Part of this reduction was driven by a lower rate of repeat procedures: the average inpatient had 0.13 fewer repeat XR procedures within 24-hours of the previous identical XR procedure. A similar decrease was not evident for repeat CT procedures. Reduced utilisation of imaging procedures (especially those within very short intervals from the previous identical procedure, which are more likely to be redundant) has implications for the safety of patients and the cost of medical imaging services.

Keywords. Computerised Provider Order Entry, Evaluation, Health informatics; Medical Imaging, Radiology Information Systems; Picture Archiving Communication Systems

Introduction

Australian government funding for healthcare reached AUD$66.9 billion for the 2014-2015 financial year, accounting for 16.1% of total federal government spending in Australia[1]. In the United States of America (US), total spending on healthcare reached USD$2.6 trillion in 2010, accounting for 17.9% of GDP[2]. Researchers have estimated that medical imaging procedures represent some 5-10% of US healthcare expenditure[3]. Medical imaging procedures make an invaluable contribution to the

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examination, diagnosis, monitoring/documentation and treatment of medical conditions[4]. However, there are also potential patient safety implications with medical imaging due to the exposure of patients to carcinogenic ionising radiation[5]. Computed tomography (CT) procedures are particularly implicated because of higher relative rates of ionising radiation[6]. CT procedures are the largest source of medically-related exposure to ionising radiation in the US[7].

Repeat imaging requests within 7 days of the previous request have been shown to represent 9.2% of all imaging requests[8], contributing considerably to health care costs and potentially unnecessary exposure to ionising radiation. Repeat imaging requests can be intentional, where a clinician is aware that a procedure has already been performed but the resulting image or interpretation has been lost, unavailable or of inadequate quality, thus necessitating a new request. This may also occur when there has been a change in the patient's status and new imaging diagnostic information is required[9, 10]. Repeat imaging requests may also be unintentional, where the clinician is unaware that the procedure has already been performed[9, 10].

Computerised Provider Order Entry (CPOE) systems can provide rapid and reliable two-way communication between clinicians and the medical imaging department. Radiology Information Systems (RIS) have been in use since the mid-1960s [11] providing functions such as scheduling of patient appointments, tracking patients through the steps of acquiring images in addition to their entire radiology history, results reporting, and billing[12]. Picture Archiving and Communication Systems (PACS) make high resolution digital images available and easily accessible to all treating clinicians as the patient moves through the health care system. PACS also eliminates the potential for lost films and unavailable images which in the past contributed to repeat imaging procedure requests[13]. Improvements in data integrity and communication are expected to lead to fewer occurrences of unnecessary imaging procedures[3]. On the other hand, a large 2008 survey of office-based American physicians reported that physicians were more likely to order an imaging procedure when the hospital information system allowed them to access electronic reports from their computer workstation; especially in the case of advanced imaging procedures (CT, Magnetic Resonance Imaging [MRI], or Positron Emission Tomography [PET]) and if the system featured PACS-like functionality that allowed them to see the actual image[14]. The aim of this study was to assess the impact of implementing an integrated CPOE/RIS/PACS system on the number of XR and CT imaging procedures (including repeat imaging requests) for inpatients at a large Sydney hospital.

1. Method

1.1. Setting

This study centred on a medical imaging department located within an 855-bed teaching hospital in Sydney, Australia. The department received imaging requests across a comprehensive set of modalities including X-ray, Computed Tomography, Ultrasound, Angiography, Magnetic Resonance Imaging, and Fluoroscopy. In January 2006, the study hospital introduced a Computerised Provider Order Entry (CPOE) system using an off-the-shelf solution: Cerner PowerChart (version 2004.01). The imaging results reporting system was an in-house designed computer system called HOSREP. Despite both the hospital and imaging department using computerised systems, they were not integrated with each other. Therefore imaging procedure requests created in the CPOE were not communicated electronically to the imaging department, and reports were not communicated electronically back though the CPOE system. Additionally, the imaging department at the time used film-based image capture. In October 2009, a GE Healthcare Centricity RIS was introduced to replace HOSREP. The new RIS was fully integrated with the existing hospital CPOE. The RIS included PACS functionality thereby eliminating the use of photographic film for image capture. All images were captured, stored, and communicated digitally.

1.2. Data Analysis

Data describing all procedures undertaken in the imaging department for inpatients for the months of January and July 2009 (Pre-period) were extracted from HOSREP RIS. Equivalent data describing all of the procedures undertaken for inpatients during January and July 2010 (Post-period), and January and July 2011 (Follow-up period) were extracted from the GE Healthcare Centricity RIS/PACS system.

The mean number of imaging procedures per patient were calculated by dividing the number of procedures by the number of patients. Repeat procedures were defined as those procedures when an identical procedure code was ordered for the same patient. The delay between the repeat and the previous procedure was based on the date and time of the patient appointments. All data analyses were conducted in SPSS version 22. Inferential statistics utilised univariate ANOVA methods and 95% Confidence Intervals (CIs) for the differences in rates between time-periods used Dunnett's C correction for multiple comparisons. Research approval was obtained from both the University and the relevant Area Health Service Human Research Ethics Committee.

2. Results

The mean rates of imaging procedures per patient for the three study periods (Pre-, Post-, and Follow-up) are shown in Table 1. The implementation of integrated RIS/PACS was associated with a reduction from a rate of 3.02 XR procedures per inpatient in the Pre-period to 2.55 XR procedures per inpatient in the Post-period. The 95% CIs for the difference ranged from a reduction of 0.17 to 0.78 XR procedures per inpatient. These reductions were maintained during the Follow-up period. On the other hand, the reduction in the rate of CT procedures was much smaller: from an average of 1.38 in the Pre- period to 1.31 CT procedures in the Post- period, and the 95% CIs contained a zero-magnitude difference score.

The following analyses assessed the impact of the integrated RIS/PACS on repeat CT and XR procedures within a short interval of the previous identical procedure. Figure 1 shows the mean cumulative number of repeat XR and CT procedures per patient from the time of the previous identical procedure. After the introduction of integrated RIS/PACS, each inpatient had an average of 0.13 fewer repeat XR procedures within 24-hours of the previous XR procedure. These reductions were maintained in the Follow-up period. There was no major change in the rate of repeat CT procedures within 24-hours of the previous CT procedure, following the introduction of integrated RIS/PACS.

Table 1. Mean rate of CT and XR procedures/patient, and the mean change in rate relative to the Pre- period

		Mean rate of procedures per inpatient (No. of procedures / No. of inpatients)	
	Pre-	**Post-**	**Follow-up**
XR	3.02 (4161/1378)	2.55 (3807/1495)	2.58 (4254/1650)
Mean change (reference group: Pre-) (95% CIs)		-0.47 (-0.78, -0.17)	-0.44 (-0.75, -0.13)
CT	1.38 (1175/854)	1.31 (1255/959)	1.30 (1239/951)
Mean change (reference group: Pre-) (95% CIs)		-0.07 (-0.15, 0.02)	-0.07 (-0.16, 0.01)

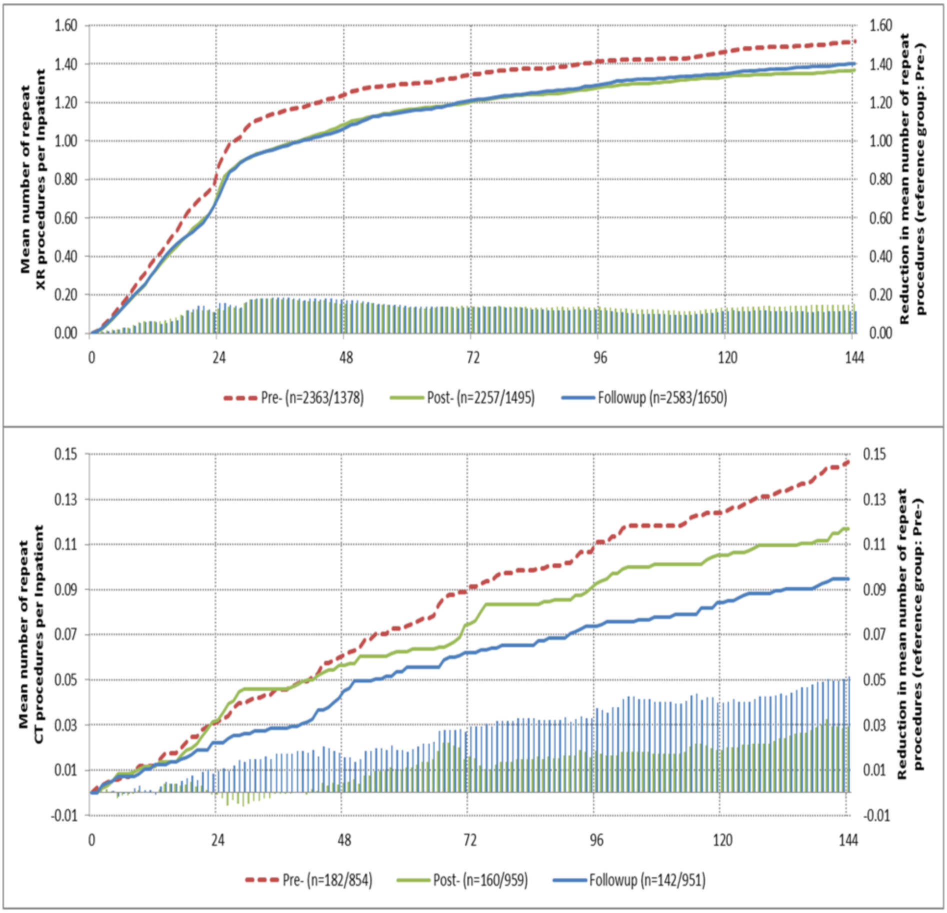

Figure 1. Mean number of repeat XR (top) and CT (bottom) procedures per patient pre- and post-implementation of RIS/PACS and at one-year Follow-up. The X-axis shows the time interval between the previous procedure and the repeat procedure. Column charts show reduction in mean repeat procedure rate for Post- and Follow-up periods (reference group: Pre-). The legends shows the total number of repeat procedures and patients.

3. Discussion

This study showed that the implementation of RIS/PACS integrated with CPOE resulted in a reduction in imaging procedure requests per inpatient. This decrease was mainly driven by a drop in the number of X-Ray procedures. One possible mechanism by which integrated RIS/PACS has influenced this rate is the secure and reliable communication of digital images eliminating the need for a repeat XR caused by a lost or misplaced film[3].

A US-based before-and-after study compared the change in imaging request rate and volume between a US hospital where PACS was implemented, and a similar hospital that did not get PACS[15]. In contrast to the findings of the present study, that study reported that inpatient imaging procedure utilisation increased at a faster rate at the PACS hospital (43% increase) than the non-PACS hospital (27% increase)[15]. This relative increase occurred for XR procedures but, as with our results, the PACS hospital experienced a smaller relative increase in CT procedures (31%) than the non-PACS hospital (38%)[15]. Interestingly, the average length of stay at the PACS hospital was 14% shorter in 1996 than in 1993, while it was only 8% shorter at the non-PACS hospital[15]. It was not possible to determine whether more intense utilisation of imaging procedures resulted in faster diagnoses and treatment and earlier discharge.

A systematic review of the impact of CPOE systems (published in 2011) provided evidence of the impact of CPOE on the appropriateness and efficiency of medical imaging services[16]. These benefits were related to features associated with CPOE such as electronic reminders[17] and other sources of decision support[18]. The value of CPOE, as part of an integrated Electronic Medical Record (EMR) system includes enhanced clinical access to information including at the point of patient care. This benefit involves the availability of information about what (and when) images had been previously requested for a patient[3].

4. Limitations

The present study utilised a dataset extracted from the RIS which contained data only for patients who had at least one imaging procedure. Calculations of the rate of imaging procedure utilisation are therefore inflated by the exclusion of patients who did not have any imaging procedure. Additionally, this study did not compare changes in imaging request rates with a “control” hospital site where no system changes occurred during the study period.

5. Conclusion

The findings from this study showed that the implementation of RIS/PACS integrated with CPOE was associated with lower overall utilisation of XR imaging procedures. Some of this reduced utilisation was due to fewer imaging procedures repeated within a short time interval from the previous procedure. Electronic ordering and reporting of imaging procedures, through integrated RIS/PACS, has the ability to improve the communication and accessibility of information between the clinical team and the imaging department[19]. This has important implications for patient safety, particularly as the elimination of some underlying reasons for repeat imaging (e.g., the loss of films), can help to reduce the cost burden of potentially unnecessary procedures to the health system, and decrease patient exposure to potentially harmful radiation.

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Preface

There's never been a more exciting time to be involved with health informatics. In the last few decades, health informaticians have established the knowledge base and practical expertise to facilitate the development of ever-more capable technical systems, increasing connectivity, expanding access and greater mobility of e-health and information management systems. We have seen the evolution from simple computer based records to systems that allow intra-organisational, national, even international communication and information exchange. We have also seen progress in e-health and most recently m-health, facilitating access to information and advice almost anytime, anywhere. The health informatics community is now building on this strong foundation, taking a central role in the digital transformation of the healthcare sector. The Australian National Health Informatics Conference (HIC), Australia's premier health informatics event, is a key avenue for facilitating this transformation. This Conference, organised by the Health Informatics Society of Australia (HISA), with the support of the Australasian College of Health Informatics (ACHI), provides the ideal professional and social environment for clinicians, researchers, health IT professionals, industry and consumers to integrate, educate and share their knowledge to drive innovative thinking, to enhance services and allow greater consumer involvement. This is emphasised in the primary theme of the 2016 Conference: Digital Health Innovation for Consumers, Clinicians, Connectivity, Community.

The papers in this volume reflect this theme, highlighting the cutting edge research evidence, technology updates and innovations that are seeing the digital transformation of the healthcare sector. The papers are indicative of the wide spectrum of work encompassing major theoretical concepts, examples of key applications of new technologies and important new developments in the field of health informatics. They emphasise the central role that health informatics and e-health play in connecting information systems, being smart with data, and enhancing both practitioner and consumer experience in healthcare interactions. Welcome to the innovation boom.

This year's program maintains the high standard of papers for which the conference is well-known. All papers were blind-peer reviewed by three experts in the field of health informatics. These reviewers are widely considered to be prominent academics and industry specialists. The contribution of the Australasian College of Health Informatics, particularly the voluntary participation of Fellows, in supporting this review process is gratefully acknowledged. Similar contributions made by many senior and experienced members of the Health Informatics Society of Australia is also acknowledged. Forty papers underwent the initial review and feedback process. Resubmitted papers were then validated by the Scientific Program Committee to ensure that reviewers' recommendations were appropriately addressed or rebutted. In total 20 papers were selected for inclusion in this volume. Congratulations to all the authors.

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