The impact of a health IT changeover on Medical Imaging Department work processes and turnaround times

A mixed method study

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Keywords

Medical Imaging, Picture Archiving and Communication Systems, Radiology Information Systems, Evaluation, Health Informatics

Summary

Objectives: To assess the impact of introducing a new Picture Archiving and Communication System (PACS) and Radiology Information System (RIS) on: (i) Medical Imaging work processes; and (ii) turnaround times (TATs) for x-ray and CT scan orders initiated in the Emergency Department (ED).

Methods: We employed a mixed method study design comprising: (i) semi-structured interviews with Medical Imaging Department staff; and (ii) retrospectively extracted ED data before (March/April 2010) and after (March/April 2011 and 2012) the introduction of a new PACS/RIS. TATs were calculated as: processing TAT (median time from image ordering to examination) and reporting TAT (median time from examination to final report).

Results: Reporting TAT for x-rays decreased significantly after introduction of the new PACS/RIS; from a median of 76 hours to 38 hours per order ($p<.0001$) for patients discharged from the ED, and from 84 hours to 35 hours ($p<.0001$) for patients admitted to hospital. Medical Imaging staff reported that the changeover to the new PACS/RIS led to gains in efficiency, particularly regarding the accessibility of images and patient-related information. Nevertheless, assimilation of the new PACS/RIS with existing Departmental work processes was considered inadequate and in some instances unsafe. Issues highlighted related to the synchronization of work tasks (e.g., porter arrangements) and the material set up of the work place (e.g., the number and location of computers).

Conclusions: The introduction of new health IT can be a "double-edged sword" providing improved efficiency but at the same time introducing potential hazards affecting the effectiveness of the Medical Imaging Department.

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1. Introduction

Picture Archiving and Communication Systems (PACS) in hospital settings is commonly associated with efficiency gains resulting from improved image accessibility and elimination of misplaced or lost films [1–3]. PACS is seen as a means to streamline the exchange of information between the Medical Imaging Department and hospital physicians, contributing to improved decision making and quality of patient care [4]. Originally an in-house system within some large hospitals, PACS has evolved into a large-scale technology that is increasingly linked with other systems such as the Electronic Medical Record (EMR), Radiology Information Systems (RIS), and Decision Support Systems (DSS) [5, 6].

Improvements in the exchange of information across different systems have meant that the boundaries between PACS, RIS, and EMR have continued to blur [5, 6]. Nevertheless, there remain major challenges associated with introducing health information technology (IT), such as PACS and RIS, and for ensuring they complement work processes within the Imaging Department [7]. Integration issues, such as the inability to seamlessly transfer data electronically (thus requiring manual workarounds, such as data re-entry) [8], can have major consequences for how work is organised, planned, and carried out, and can affect the success and sustainability of health IT [9]. A review of evidence related to health IT, particularly the introduction of an EMR, noted the importance of increased attention to the circumstances and context of its implementation and use [7].

Prior research in this area has confirmed that the successful utilisation of health IT is more than just a technical issue [10]. Jorritsma et al. [11] identified contrasting levels of usability between PACS of identical functionality, prompting the authors to underscore the need to examine both subjective data involving Medical Imaging staff as well as measuring objective metrics when assessing PACS. A study by Hurlen et al. [12] investigated the effect of PACS on the time associated with reporting imaging results back to physicians (i.e., turnaround time [TAT] – a commonly used indicator of Medical Imaging performance [13]). Hurlen et al. found that, over a two-year period, the median TAT for final imaging reports initially decreased from 23 to 13 hours, only to return to 22 hours one year later. The authors noted that the potential reasons for this were changes in work processes and the withdrawal of key implementation personnel who went back to their previous tasks and positions, thus, removing an accessible and ready avenue for problem-solving [12]. Such findings strongly suggest that the success and sustainability of health IT are affected not only by their technical functionality but also the overall context (e.g., the underlying work processes) into which they are implemented [14]. We undertook a mixed method study to assess the impact of introducing a new PACS/RIS on: (i) work processes within a Medical Imaging Department; and (ii) TAT for x-ray and CT scan orders initiated in the Emergency Department (ED) before (March/April 2010) and after (March/April 2011 and 2012) the PACS/RIS changeover.

2. Methods

2.1 Study Setting

This study was conducted at a 750-bed teaching hospital in Sydney, Australia. During the study period (2010–2012) the hospital's Medical Imaging Department provided services to approximately 220 patients each day. In 2010, the Department comprised 33.6 full-time equivalent (FTE) radiographers and 8.3 radiologists. This changed to 33.4 FTE radiographers and 10.5 radiologists in 2011, and 35.6 FTE radiographers and 10.7 radiologists in 2012.

In November 2010, the hospital implemented an enterprise-wide PACS and RIS (GE Centricity; GE Healthcare, Milwaukee, USA). Prior to this, the hospital had a hybrid system comprising IT systems (with limited information exchange capability between systems) and concurrent paper-based processes. For example, the hospital had mini-PACS (Central Data Networks, Wollongong, Australia), which allowed electronic x-ray images to be viewed in the ED (all other hospital wards used hard copy films). However, hard copy x-ray films were still provided to ED physicians who generally looked at the hard copy images in preference to the electronic images. The mini-PACS data storage was also limited and where comparison with historic images was required, hard copy films had to be

manually retrieved. Additionally, while results reports were electronically documented in the Imaging Department they were sent to a printer in the ED and the printed reports were then reviewed by ED physicians.

The hospital also had an in-house developed RIS, which was not linked to the mini-PACS. This RIS was used for patient registration, patient scheduling, and results reporting, as well as for tracking the location of hard copy films. The new RIS also performed these functions but did not have equivalents of some internally developed features of the previous system, such as staff rostering and a porter module. The new PACS/RIS interfaced with the hospital's existing EMR (Cerner Powerchart; Cerner Corporation, Kansas City, USA), which was used by physicians to enter imaging orders and review result reports. In the old system physicians similarly entered orders in the EMR, which were electronically sent to the RIS, but the orders were also printed and manually transported to the Imaging Department. The changeover to the new PACS/RIS was intended to provide improved information exchange between IT systems, allowing the entire process from order entry to results reporting to be digitized.

2.2 Study Design

We employed a mixed method approach to investigate the impact of the changeover to the new PACS/RIS. The qualitative aspect involved 11 semi-structured interviews with Departmental staff, conducted between May and September 2011 after PACS/RIS implementation. Participants were sampled purposively to capture a range of perceptions of the new system. The sample included four radiologists, a radiology registrar, three radiographers, a clerical manager, a registered nurse, and a system administrator (an IT staff member).

Participants were asked a series of questions (▶Table 1), which aimed to identify changes to work processes in the immediate aftermath of the introduction of the new PACS/RIS. The semi-structured format of the interviews drew on a socio-technical approach as outlined by Stoop and Berg [15] to investigate organisational communication issues (e.g., work flows and communication with other departments), technical issues (e.g., compatibility between systems) and professional issues (e.g., satisfaction with the system). This approach offered a context-rich snapshot of Medical Imaging staff perceptions of the changes they encountered. The strength of this approach is that it allowed us the means to undertake a naturalistic enquiry to describe social phenomena in words rather than numbers [16]. Interviews were conducted one-on-one and lasted on average 30 minutes (ranging from 12 to 53 minutes). Each interview was digitally recorded and professionally transcribed.

Quantitative data were retrospectively extracted for a two-month time period (March and April 2010) prior to introduction of the new PACS/RIS, along with data from two time periods after the introduction of the new PACS/RIS (March and April 2011 and 2012). The data represented ED imaging orders and the corresponding final result reports for immediate plain x-rays and CT scans. We chose to focus on the ED as it is a setting where time savings are of particular importance. It is not uncommon for patients to be discharged from the ED before test results are available, which previous research has shown can lead to a failure to follow-up results or delayed/missed diagnoses [17, 18]. The issue of test result follow-up is not unique to this study site, and many health care planners in Australia and internationally are conscious of the need to implement measures to monitor test follow-up because of the potential consequences for patient care [19].

Identifying variations in the data across the different years required the research team to undertake an extensive and time-consuming assessment of variables to ensure the congruence of all data fields used to make valid comparisons. This involved regular meetings with Medical Imaging Department officers proceeding the data extraction. For example, in 2010, requests for the imaging of multiple body parts could be included in a single order, while in 2011/2012 each body part had to be entered as a separate order. Single orders with multiple body parts from the 2010 data were therefore recalculated as multiple orders (corresponding with the number of body parts) to make them congruent with the 2011/2012 data.

A total of 13,096 imaging orders placed by ED physicians were included for assessment of TAT. This represented 5,999 orders for patients attending and then subsequently discharged home from

the ED (ED discharged patients) and 7,097 orders for ED patients who were subsequently admitted to a hospital ward (ED admitted patients).

2.3 Analysis

The qualitative data were analysed inductively [20]. Two researchers (MP and AH) independently read and coded recurrent concepts emerging from the data. These findings were compared and discussed amongst the research team, and common themes were identified.

For the quantitative analysis, we calculated TATs as two distinct intervals of time: processing TAT and reporting TAT. Processing TAT was calculated as the median time from image ordering to image examination. Reporting TAT was calculated as the median time from image examination to completion of the final report. The data do not represent the time to provisional reports, which are usually completed within an hour of the examination and sent electronically to the EMR. Sometimes verbal reports are provided prior to the final reporting becoming available when ED staff request the opinions of radiology registrars for after-hours x-rays. Verbal reports were not included in the data and we also excluded imaging orders where physicians deliberately scheduled a delayed completion time.

Median TATs and 95% confidence intervals, calculated from Kaplan Meier survival analysis, were compared across time. For processing TAT we also calculated the percentage of examinations undertaken within four hours and percentage undertaken within two days of the imaging order. For reporting TAT we calculated the percentage of final reports completed within: (i) four hours, (ii) two days, and (iii) seven days from the time of the examination. These intervals were chosen by the research team to provide a descriptive and temporal overview of the findings. The Agresti-Coull method [21] was used to calculate 95% confidence intervals relevant to these percentages. Significance in differences between median times were assessed using the Kruskal-Wallis test and differences in percentages using Fisher's exact test. Quantitative analysis was completed using SAS (Version 9.3).

3. Results

Five key themes emerged from the interviews: (i) accessing information; (ii) lost functionality – patient portering; (iii) viewing and reporting of images; (iv) communicating images and reports; and (v) system changeover issues.

3.1 Accessing Information

Changeover to the new PACS/RIS was perceived to improve access to information. As all images were available electronically, staff no longer had to track, search, or transport hard copy films. In addition, the new PACS/RIS allowed staff to easily view patient bookings and the examinations that were scheduled across the entire Department via a "multi-view" function. Within the old RIS, viewing was limited to one type of imaging modality at a time, making it more difficult to obtain an overview of Departmental activities.

"I no longer have to deal with the daily issues of 'where is my film?'; that is now dealt with in a digital sense so in that realm it's been fantastic." (CR5 Radiographer)

"It's made things, I think, more efficient. It's a lot easier now to find out what is going to happen for the rest of the day, in terms of the lists of [who has] been booked for a CT. Before, it was able to be done but it wasn't as easy…now we can sit at a workstation and look at the program and the RIS can find out what's going on in the whole Department; so what's happening in Ultrasound, what's happening in CT, what's happening in General…it's also easier to get access to those images as well." (CR7 Radiology Registrar)

3.2 Lost Functionality – Patient Portering

The old RIS contained a porter module, which enabled radiographers to log when the patient's examination had finished and select the transfer mode required to take the patient back to the ward (e.g., wheelchair, bed, nurse escort, etc.). Once this was logged, a porter was automatically notified that the patient was ready for pick-up. As well as aiding straightforward notification to porters, the system monitored how long patients waited in the Department before they were returned to the ward.

The new RIS did not contain a porter module. This created several problems, including inconvenience to patients left waiting for longer periods to be taken back to the wards. The system administrator reported that although there was ongoing work to create an interface between the previous porter module and the new PACS/RIS, problems continued to persist. The loss of functionality resulted in a manual work process being developed. An Excel spreadsheet was created each day with a patient list generated from information obtained via the new RIS. This spreadsheet had to be manually updated by Department staff to document when porters were telephoned and notified about patient pick-ups.

"The last system that we had, had a very good part on transferring patients. It was nice and clear on…where the patient is, tracking them, how the patient is going. But now, this one doesn't have the same features." (CR11 Radiographer)

3.3 Viewing and Reporting of Images

Participants consistently indicated that there were insufficient numbers of new PACS workstations within the Department. A further drawback reported by radiologists was the lack of a 3D-viewing module to reconstruct thin slices from CT scans. As a consequence, radiologists had to use a modality workstation, independent of the new PACS/RIS, to reconstruct and view images in 3D. A separate computer then had to be used to access the RIS to commence reporting. In such cases, participants highlighted that it was of utmost importance that the images being examined corresponded with the patient for whom the report was being produced, as the modality workstation and RIS were not linked. Radiologists described incidents where they found themselves creating a report for one patient using images belonging to a different patient. This poses a major patient safety issue.

"There is no 3D-viewer that came with this package so the radiologists still have to go to the modality workstation, independent of the RIS, look at the data in 3D, reconstruct it…have a look in the different planes, then come back to the RIS and report it that way." (CR5 Radiographer)

"If we want to look at thin images…we have to use the old workstations that we used to use that have thin section imaging, which is really not ideal because unfortunately those images aren't actually linked to the RIS, so theoretically you could look at the wrong patient…you can be reporting a patient in the RIS and not actually have the correct images up because they're not linked." (CR9 Radiologist)

Prior to the introduction of the new PACS/RIS, all imaging reports were dictated, sent for transcription by a typist, and returned to the radiologist for validation. With the new PACS/RIS voice recognition (VR) was introduced, though its use was not mandatory. Participants expressed mixed views regarding whether the advantages of VR outweighed the disadvantages. Some reported that the VR software was not fast enough and failed to accurately capture spoken words. Others indicated that it took longer to use VR than to dictate reports for transcription. Nevertheless, many believed that VR saved time in the long run as it eliminated the need to validate typist-transcribed reports. Any changes to a VR-generated report were able to be performed immediately whilst the images were still displayed on the screen, rather than having to revisit the images at a later stage once the typed reports had returned.

"Initially reporting the image was a lot quicker because we'd just dictate to a phone and [in] a few hours it would be typed and then we'd check it. But now, we have…voice recognition, so it does take longer. But in saying that, once we get the report done then and there, [it's] done. So even if it takes a little longer now, it saves time because we wouldn't be going back to fix up the typos…or fix up the things that we need to change later on. It's probably a little bit better that way because…if we do dictate and three hours later the report needs to be changed, we can't quite remember the images, so if we do it then and there, at least we've got the images right next to us." (CR7 Radiology Registrar)

3.4 Communicating Images and Reports

There were conflicting perceptions as to whether or not the communication of images to the referring physician had improved. Some participants believed that hospital-wide access to electronic images allowed for better and easier communication between the Imaging Department and physicians. With electronic access to images, discussions could take place over the phone between the radiologist and the referring physician with each viewing the images in their respective locations. Other participants felt that, while it was beneficial for referring physicians to view images almost instantaneously at any location within the hospital, there was a risk that they may choose not to wait for the radiologist's report or consult with the radiologist. Participants considered that this could lead to an incorrect interpretation of images, by either a physician or by a radiologist, as important clinical information may not be communicated. This in turn may lead to further investigations being carried out for a potentially incorrect diagnosis.

"Some of the people say they don't come down to the Department as much as they used to. So I guess that's a bit of a shame because you often find that you get additional clinical information that you didn't have when you chat to them and that does change your interpretation." (CR9 Radiologist)

3.5 System Changeover Issues

The main changeover issue identified by participants was a lack of sufficient training in the use of the new system and limited ongoing support. Radiographers, for example, reported being educated about the system months in advance of its introduction, which meant that by the time the new PACS/RIS was introduced the training had been forgotten. Participants also felt that communication with, and involvement of, different staff, both before and during changeover, was inadequate. The interviewed nurse expressed feeling excluded and disregarded when it came to the PACS/RIS changeover, believing it was because of assumptions by the implementers that nurses wouldn't need to use the system.

"The system we have is not user-friendly. It's not intuitive. And because of the lack of training and because of the poor user interface, it just makes it a lot harder to use." (CR8 Radiologist)

"I would have actually sat down with the people who are going to use it. Talk to the radiologists, talk to the radiographers, talk to the clerical staff…they'll have different needs…so I would speak to the people that are going to actually use it." (CR9 Radiologist)

"We all agree that PACS is a good thing, it's just the implementation of it was really poor." (CR3 Registered Nurse)

3.6 Turnaround Time (TAT)

In the time period after introduction of the new PACS/RIS there was a statistically significant decrease in the median *reporting* TAT for x-rays both for ED discharged and admitted patients (►Table 2). TATs for ED discharged patients decreased by 50%, from a median of 76 hours (95%CI 73–82 hours) in 2010 to 38 hours (95%CI 35–40 hours) in 2012 ($p<.0005$), and for admitted patients by 58%, from 84 hours (95%CI 79–87 hours) in 2010 to 35 hours (95%CI 28–39 hours) in 2012 ($p<.0005$). The proportion of final x-ray reports completed within two days of examination improved significantly from 27% completed within two days in 2010 to 60% in 2012 for discharged patients ($p<.0005$). There was a similar significant finding for admitted patients ($p<.0005$).

4. Discussion

The findings from this study provide a valuable juxtaposition of qualitative findings (based on participant perceptions) about the effect of the new PACS/RIS system on work processes, alongside an assessment of the effect of the new system on TAT as a key indicator of Medical Imaging performance. This comparison provides insights into potential implementation hazards, their causes and their likely impact on Departmental performance. The most significant change across the period 2010 to 2012 occurred in *reporting* TAT (time from image examination to completion of the final re-

port) for x-rays, which decreased by 38 hours for ED discharged patients and 49 hours for ED admitted patients. This decrease is likely due to the availability of voice recognition (VR) in the new RIS [22], which participants in this study felt increased their efficiency. Interestingly, VR availability did not translate into a decrease in median *reporting* TAT for CT scans for ED discharged patients. This may be due to a number of reasons. Firstly, the sample size for CT scan orders was relatively small, making it difficult to detect any significant changes. Secondly, the baseline *reporting* TAT was substantially shorter for CT scans compared to x-rays (median 19 hours compared to 76 hours in 2010 respectively) so there were much greater time savings to be made for x-rays. And thirdly, findings from the qualitative interviews indicated inefficiencies in CT scan reporting due to the lack of a 3D-viewing module for reconstructing thin slices in the new PACS. The lack of a 3D-viewer meant that different computers across different locations had to be accessed in order to undertake the tasks of viewing and reporting results. This third reason, in particular, underscores the need to examine the impact that the changeover to new health IT has on work processes and how this in turn affects performance indicators such as TAT.

TAT is a commonly-used performance indicator associated with measuring efficiency of the Medical Imaging Department [13]. However, there are many steps involved, from the point of order entry to final report completion (including the time taken to prepare a patient, the presentation and work-up of images, the number and quality of the images, the number of available radiologists and the interpretation and diagnostic reconciliation of images) some of which do not directly involve PACS/RIS that can confound the interpretation of TAT results [20]. In our study, the use of an overall TAT indicator (as is common practice) would have indicated a decrease in TAT for x-rays, but we would not have been able to localise the timeframe in which the most significant change occurred. This finding draws attention to the potential limitations of using overall TAT as a sole measure of the impact of PACS/RIS on Imaging Department efficiency.

Prior research by van de Wetering et al. [3], on the impact of PACS on workflow, emphasised the importance of providing a holistic perspective of the workings of the PACS system across different parts of the Imaging Department. Their findings showed that the successful implementation, diffusion, and sustainability of health IT is very much shaped by: a) the context in which it is implemented; and b) the usability and fit with existing work processes. These variations in context may also be related to remuneration systems for Medical Imaging (across different countries) that influence the production and communication of the final report, which can affect processes and workflows [23]. Participants in this study perceived that the new PACS/RIS led to gains in efficiency, particularly regarding accessibility of images and patient-related information, but the findings also highlighted specific organizational issues arising from the system changeover. The new system affected the synchronization of work tasks, whereby Department staff had to initiate workarounds to compensate for the lack of previous functions (e.g., patient portering). The potential efficiency benefits of the new system were also limited by the material set up of the work place as staff needed to access separate computers for different functions. This issue also introduced potential for errors with implications for patient safety. These findings resemble those of Kennedy and Seibert [24] who reported problems related to the assimilation of PACS with existing hospital and radiology information systems, which they described as the challenge of fitting PACS workflow into "real world" environments.

Finally, the PACS/RIS changeover experience of the Medical Imaging Department in this study underscores the importance of understanding health IT implementation as part of an intensive quality improvement and change management process [8]. For instance, one of the disruptive changeover processes revealed in our study concerned the training provided to staff. Whilst training is a recognised and essential feature of any IT implementation, its purpose is not a one-way teaching process. Instead, training strategies need to be informed by feedback about the problems and difficulties associated with the new system, its usability, and its effects on work processes [25]. This can help to promote change management, quality improvement, and IT system enhancement [26].

4.1 Limitations

The source of evidence in this study was limited to one Medical Imaging Department, which may not be immediately generalizable to other settings. The data produced by the semi-structured inter-

views are based on perceptions of our participants and cannot be taken as numerical values of efficiency or effectiveness. Nevertheless, the findings are contextually-rich and provide valuable indicative lessons for other Imaging Departments, physicians, IT designers, researchers, and health care administrators more broadly. The analysis of the quantitative data may have been confounded by changes in staffing levels (with the number of FTE staff increasing across the study period) and was complicated by changes in the nomenclature between the pre- and post-implementation data, which required categorical alignment (e.g., body part data) in order to ensure data integrity and consistency.

5. Conclusions

The introduction of new health IT systems can be a "double edged sword", offering improvements in Medical Imaging Department efficiency but at the same time bringing change, disruption, and unintended consequences. Such consequences may be particularly prevalent where a newly-implemented IT system does not replicate or improve on the functionality of the system being replaced. Potential hazards however, may also be related to unintended change involving workflows and processes within the department and across the hospital [9]. These types of anomalies are not easy to detect or predict [27]. Evaluations of health IT changeover can benefit from the adoption of mixed methods, which can generate a range of data sources to facilitate the identification of potential integration and work process problems and help pinpoint their causes.

Clinical Relevance Statement

This paper provides evidence about the impact of health IT changeover on Medical Imaging Department work practices and efficiency. The use of multiple data sources (quantitative and qualitative) facilitated the identification of issues related to the design, implementation, integration and sustainability of IT systems. These problems can affect the quality of Medical Imaging Department work and their contribution to safe patient care.

Conflicts of Interest

The authors declare that they have no conflicts of interest in the research.

Human Subjects Protection

The study was performed in compliance with the World Medical Association Declaration of Helsinki on Ethical Principles for Medical Research Involving Human Subjects, and was reviewed and received authorization from the relevant Local Health District Health Service Human Research Ethics Committee (HREC/09/CRGH/53;SSA/09/CRGH/177).

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Authorship

All authors have made substantial contributions to: (1) the conception and design of the study, acquisition of data, and/or analysis/interpretation of data; and (2) drafting and/or critical revision of the article for important intellectual content.

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Table 1 List of questions for semi-structured interviews

1) How do you use PACS/RIS in your work?
2) How do you feel the introduction of PACS/RIS has changed the way you work?
3) Sometimes there are challenges associated with integrating old and new systems – what are your thoughts on this?
4) If PACS/RIS were implemented again what could be done differently?
5) Do you communicate with other Departments and has this changed with the new system?

Table 2 *Processing* and *Reporting* TAT for x-ray and CT scan orders placed in the Emergency Department (March-April 2010–2012)

	ED Discharged Patients			ED Admitted Patients		
Processing TAT	**2010 Old System**	**2011 New PACS/RIS**	**2012 New PACS/RIS**	**2010 Old System**	**2011 New PACS/RIS**	**2012 New PACS/RIS**
X-ray						
Median processing TAT	39 min (37–40)	40 min (38–41)	33 min (31–34)*	46 min (45–48)	49 min (47–51)	44 min (42–46)*
% within 4 hours of order	100 (99.7–100)	99.9 (99.6–100)	99.6 (99.2–99.8)*	98.5 (97.9–99.0)	98.8 (98.2–99.2)	99.0 (98.4–99.4)
% within 2 days of order	100 (99.7–100)	100 (99.7–100)	100 (99.8–100)	99.9 (99.5–99.9)	99.8 (99.4–99.9)	99.8 (99.5–100)
Number of orders	1892	1805	1942	1982	1913	1806
CT scan						
Median processing TAT	81 min (74–90)	78 min (69–89)	70 min (57–78)*	102 min (93–113)	95 min (88–105)	84 min (77–96)*
% within 4 hours of order	89.5 (82.8–93.9)	96.5 (91.0–98.9)	97.5 (92.7–99.5)	85.5 (82.0–88.4)	88.1 (84.7–90.8)	89.1 (85.9–91.6)
% within 2 days of order	100 (96.3–100)	100 (96.1–100)	100 (96.3–100)	98.5 (96.9–99.3)	98.9 (97.3–99.6)	99.2 (97.9–99.8)
Number of orders	124	114	122	468	444	484
Reporting TAT						
X-ray						
Median reporting TAT	76 hrs (73–82)	44 hrs (42–46)†	38 hrs (35–40)†	84 hrs (79–87)	36 hrs (27–40)†	35 hrs (28–39)†
% within 4 hours of exam	1.8 (1.3–2.5)	9.1 (7.8–10.5)†	10.6 (9.3–12.0)†	1.1 (0.7–1.7)	11.2 (9.9–12.7)†	9.1 (7.9–10.6)
% within 2 days of exam	27.0 (25.1–29.1)	54.1 (51.8–56.4)†	60.0 (57.8–62.2)†	27.9 (26.0–29.9)	56.5 (54.3–58.7)†	60.7 (58.4–62.9)†
% within 7 days of exam	92.4 (91.2–93.6)	95.6 (94.5–96.4)†	97.2 (96.3–97.8)†	90.8 (89.4–92.0)	96.5 (95.6–97.3)†	97.3 (96.4–98.0)†
Number of orders	1892	1805	1942	1982	1913	1806
CT scan						
Median reporting TAT	19 hrs (18–22)	16 hrs (13–19)	19 hrs (16–21)	19 hrs (18–21)	17 hrs (15–19)	16 hrs (15–17)*
% within 4 hours of exam	17.7 (12.0–25.5)	24.6 (17.5–33.3)	22.1 (15.6–30.3)	22.4 (18.9–26.4)	23.6 (19.9–27.8)	30.4 (26.4–34.6)
% within 2 days of exam	73.4 (65.0–80.4)	79.8 (71.5–86.2)	69.7 (61.0–77.2)	69.7 (65.3–73.7)	77.7 (73.6–81.3)*	79.5 (75.7–82.9)*
% within 7 days of exam	95.2 (89.6–98.0)	99.1 (94.7–100)	93.4 (87.4–96.8)	94.9 (92.4–96.6)	99.3 (97.9–99.9)*	97.7 (95.7–98.8)
Number of orders	124	114	122	468	444	484

95% Confidence Intervals provided in parentheses. Note: medians are not additive, thus the TAT cannot be summed to approximate overall TAT.
† indicates significant difference of p<.0001 when compared with 2010.* indicates significant difference of p<.005 when compared with 2010.

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