

Picture archiving and communication systems lead to sustained improvements in reporting times and productivity: results of a 5-year audit

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AIM: To evaluate the impact of picture archiving and communications systems (PACS) on reporting times and productivity in a large teaching hospital.

MATERIALS AND METHODS: Reporting time, defined as the time taken from patient registration to report availability, and productivity, defined as the number of reports issued per whole time equivalent (WTE) radiologist per month, were studied for 2 years pre- and 3 years post-PACS installation. Mean reporting time was calculated for plain radiographs and specialist radiology techniques [computed tomography (CT), magnetic resonance imaging (MRI), ultrasound, and nuclear medicine]. Productivity, total department workload, and unreported film rates were also assessed. Pre- and post-PACS findings were compared.

RESULTS: Between 2002–2006 the number of radiological patient episodes increased by 30% from 11,531/month to 15,057/month. This was accompanied by a smaller increase in WTE reporting radiologists, from 32 to 37 (15%). Mean reporting times have improved substantially post-PACS, plain radiograph reporting time decreased by 26% (from 6.8 to 5 days; $p = 0.002$) and specialty modalities by 24% (4.1 to 3.1 days; $p < 0.001$). Radiologist productivity has increased by 18% (337 films to 407 films/WTE radiologist/month). Unreported films have decreased from 5 to 4% for plain radiographs and are steady for specialty modalities (< 1%). In most areas improvements have been sustained over a 3-year period.

CONCLUSION: Since the introduction of PACS, reporting times have decreased by 25% and the productivity improved by 18%. Sustained improvements are felt to reflect the efficiencies and cultural change that accompanied the introduction of PACS and digital dictation.

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Introduction

Picture archiving and communication systems (PACS) are being installed throughout UK hospitals under the National Health Service (NHS) *Connecting for health* scheme national PACS programme. It is anticipated that PACS should be both cost-effective and contribute to improved patient care through more rapid reporting turnover. This will become ever more important with the NHS 18-week waiting list targets. The importance of prompt reporting times has been addressed by

The Royal College of Radiologists (RCR). In 2000, the RCR commissioned a national audit of radiological examination reporting¹ and concluded that the standards proposed were not being met. The two main factors that could improve the process were identified as appropriate information technology systems, such as PACS and reporting support.

There is some evidence for the economic efficacy of PACS compared with conventional film, particularly if PACS implementation is coupled with a change in the departmental work flow.^{2,3} Previous studies have assessed the effect of PACS installation on radiologists' reporting time⁴ and dictation turn-around times.^{5,6} The results have been mixed, for example, Bryan *et al.*⁴ observed that reporting time was not lengthened post-PACS, whereas Lepanto and co-workers reported improvements with magnetic resonance imaging (MRI) and plain

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radiography but not computed tomography (CT) and only for the first year post-PACS.⁶ The few studies that have assessed global report turnaround times have been limited to subgroups, such as accident and emergency plain radiographs⁷ or abdominal and pelvic CT⁸; although the latter was merely a projected improvement in report turnaround time. In a more recent study, there was no change in "reading time" post-PACS.⁹ Furthermore, most studies have assessed just parts of the global radiological process that begins with image production and culminates in the report being available for the referring clinician.

If the implementation of PACS and digital dictation does indeed improve workflow, it should shorten this global radiological process throughout the department with better availability of the end-product (i.e. the radiological report). The primary aim of the present study was to evaluate the impact of PACS on all reporting times and productivity within the department. The secondary aim was to investigate whether any improvement was sustained and to identify reasons for discrepant trends.

Methods

The Radiology Department provides services within a 1055-bed teaching hospital. The hospital has local catchment population of 330,000, as well as being a tertiary referral centre. Films are reported by consultant radiologists and radiologists in training. PACS was installed in June 2003,¹⁰ and set up to support all modalities, including plain radiographs, CT, MRI, ultrasound, and nuclear medicine images. Digital dictation, a method of recording the spoken word in real-time within a digital audio format, was introduced a year later. The workflow (or the "patient/imaging study journey") before and after implementation of PACS at our institution is illustrated in Figs. 1 and 2. The Radiology Information System (RIS) predates PACS and has been operational since 1989.

For study purposes rather than merely dictation times or the time taken over film interpretation, reporting time was more broadly defined as the time elapsed (in days) from performing the imaging examination to issuing a typed report,

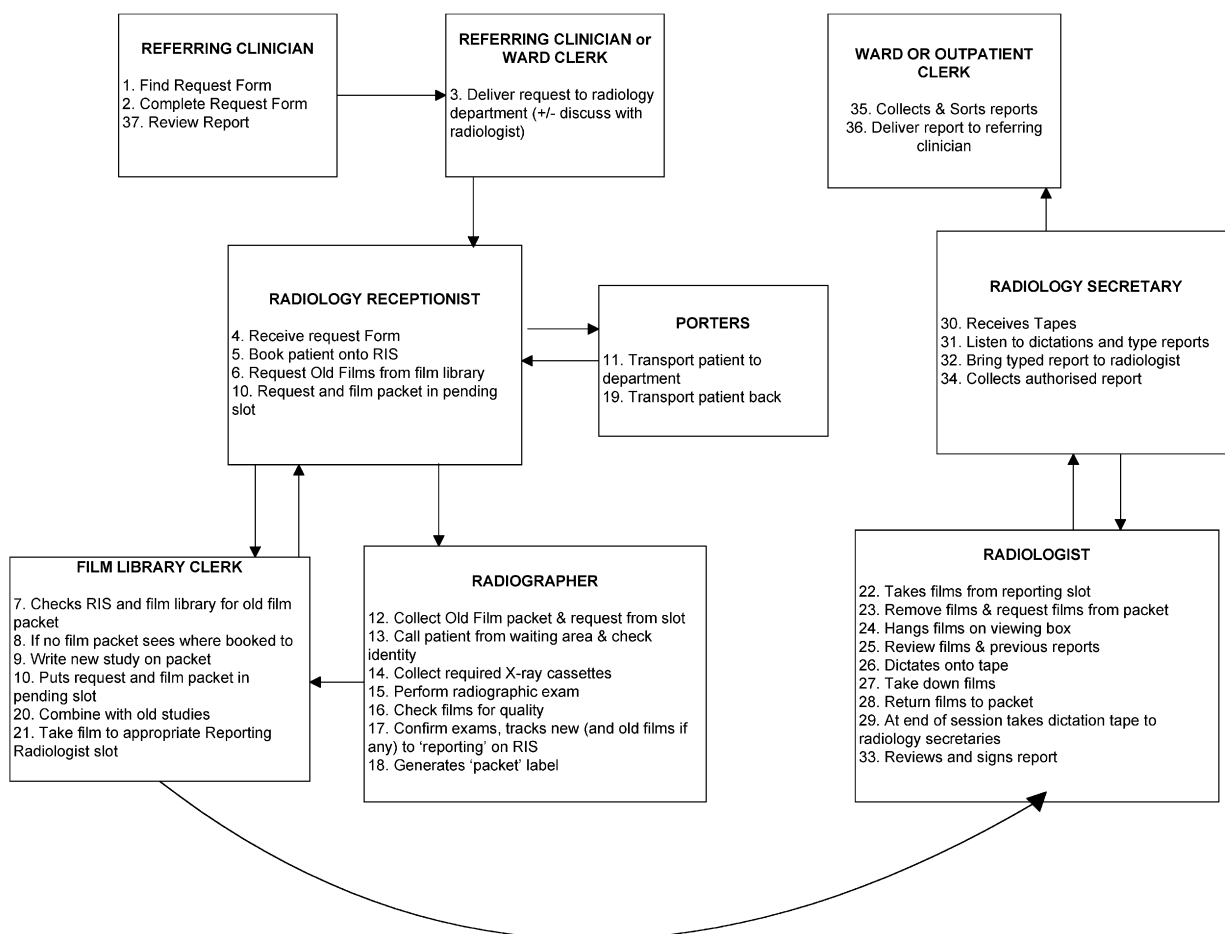


Figure 1 Pre-PACS: Workflow in the radiology department for inpatient plain radiograph request. Report turnaround consists of 33 steps (Steps 5–37).

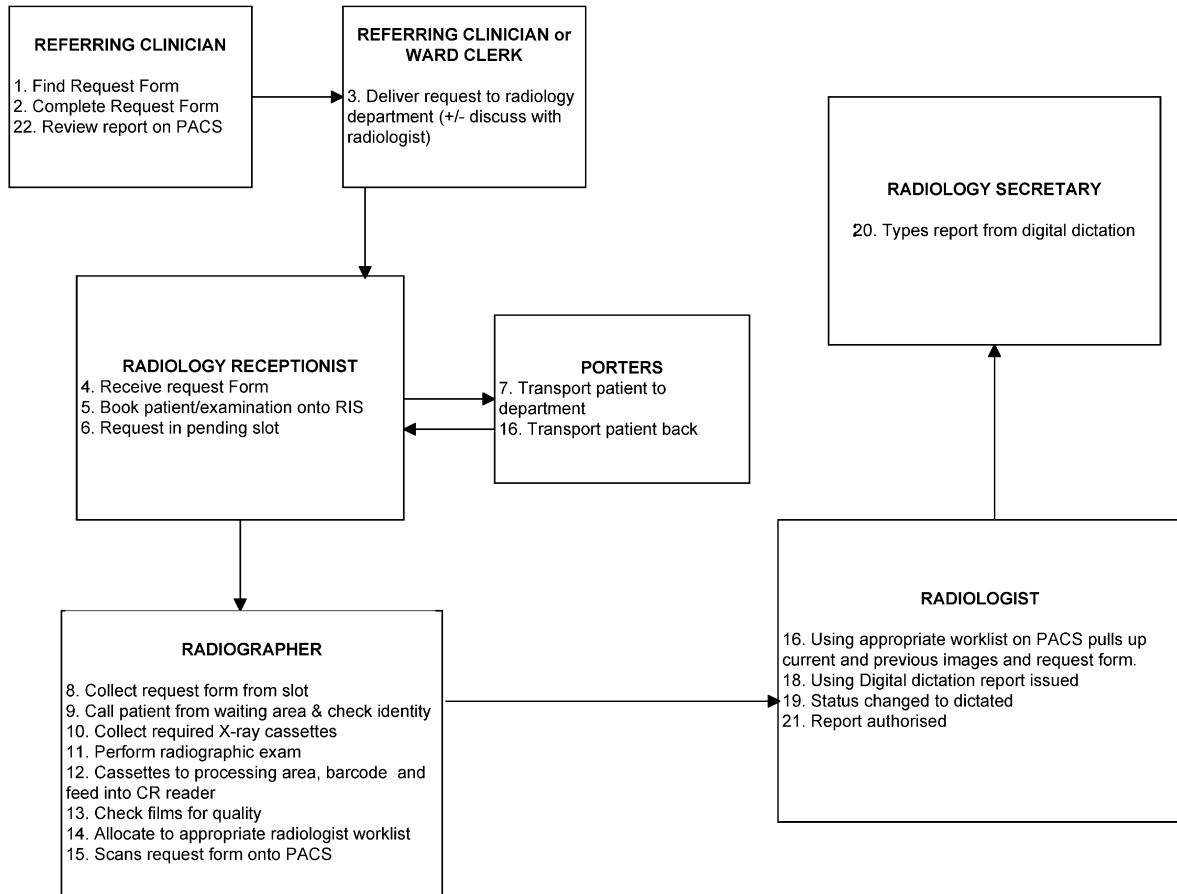


Figure 2 Post-PACS and digital dictation: Workflow in the radiology department for inpatient plain radiograph request. Report turn-around consists of 18 steps (Steps 5–22).

authorized or unauthorized, both of which are available for viewing by our referring clinicians. Prior to PACS, availability was either as an electronic patient record (EPR) or as a typed report. Post-PACS the report is available on PACS alongside the corresponding image.

Period of data collection

PACS (Philips Easy Access Enterprise Release 10.1 PACS) was installed at our institution in June 2003.¹⁰ In order to compare reporting times pre- and post-PACS the same quarter (1 February–30 April) was studied for the 2 years preceding PACS and the 3 subsequent years. These months were chosen to allow for the initial transition period from hard-copy films to PACS, when reporting times were likely to be artificially raised in the first 6 months, as reported elsewhere.⁶ February to April was also chosen to avoid the Christmas–New Year period, which may have shown wide variations due to variance in number of staff at this period.

Data collection

All data, including times, were obtained from the RIS (RadCentre Version 4.5 supplied by iSOFT), which is a prospective permanent record. RIS has an internal clock that is synchronized to the local computer terminals, which, in turn, are synchronized to the hospital main servers and calibrated to the nearest second. To maintain accuracy of the RIS clock local users are denied access to the local computer terminal clock and hence the RIS internal clock. When a patient attends for any radiological investigation their attendance is booked in on the RIS and the attendance date and time (h:min:s) are registered. Similarly, when a report is typed onto RIS the time is automatically registered as “Section Type Date”. A separate ongoing monthly audit of radiological department activity assesses for “black holes” or missing data and ensures that all activity is captured.

RIS was interrogated in the following way. The whole RIS database was searched by selecting “all categories”. For each year under investigation

a start date (1 February) and end date (30 April) was entered. For plain radiographs there are four main referral areas: inpatients, outpatient clinics, general practitioners (GP), and accident and emergency (A&E). These four patient groups were selected one at a time and the following data imported into a spreadsheet: attendance number, attendance source, attendance booked in date and time, and section typed date and time. For each of these categories mean time (days) to issue a typed report was determined by calculating the time difference between section typed date and attendance booked date. The procedure was repeated for the main specialist imaging techniques: MRI, CT, ultrasound, and nuclear medicine.

The absolute number of examinations performed was also calculated, together with number and percentage of unreported films. An unreported film was designated any film still unreported on the 25th of the following month, i.e., the date of the regular monthly audit. To compare global productivity the number of films reported per radiologist, per month was calculated for each of the study years and compared pre- and post-PACS.

Statistical analysis

SPSS Version 14.0 was used for all statistical analysis. The distribution of reporting times was non-normal and so comparisons of reporting times pre- and post-PACS were made using the Wilcoxon Rank Test. Comparisons were made for 2002 versus

2006 to assess the change over time. The mean of the pre-PACS years (2002–2003) versus the mean of the post-PACS years (2004–2006) were also compared to allow a more direct assessment of the effect of PACS.

Results

Over the 5 years studied, the number of studies performed per month increased by about 30% (see Table 1). In the same time period productivity, defined as number of films reported per whole time equivalent (WTE) radiologist, increased by 18%.

Plain radiographs

Numbers performed. Plain radiograph studies increased by 27.8% (Table 1; Fig. 3). Although the number of plain radiographs performed for GPs and A&E remained stable over the study period (Fig. 3), with approximately 1350 and 3000 per month, respectively; there was an almost two-fold increase in the number of inpatient radiographs (from 2254 to 3879) and a 39% increase in outpatients ($n = 2069$ to $n = 2885$).

Reporting times. Fig. 4 shows the trends in plain radiograph reporting times, the arrows demonstrating implementation of PACS in June 2003 and digital dictation 1 year later. Despite the increases in the number of plain radiographs performed, there was an overall reduction in reporting times. For outpatients, reporting times were rising (see

Table 1 Workforce numbers, workload, productivity and reporting times pre- and post-PACS implementation

	Pre-PACS		Post-PACS		
	Feb–Apr 2002	Feb–Apr 2003	Feb–Apr 2004	Feb–Apr 2005	Feb–Apr 2006
Staff (WTE)					
Consultants	16	17	18	18	19
Registrars	16	18	18	18	18
Total	32	35	36	36	37
Workload per month ^a					
Plain films	8669	8678	9789	11185	10,835
Specialist modality	2862	3103	3914	3749	4222
Total (per month)	11531	11781	13703	14934	15057
Number of films per WTE per month (productivity)	360.3	336.6	380.6	414.8	406.9
Mean reporting time ^b (days)					
Plain films	6.23	7.38	6.38	4.68	3.96
Specialist modality	3.80	4.64	2.92	3.26	3.31

WTE, whole time equivalent.

^a Numbers given for workload are mean per month for the 3 month period of assessment.

^b The mean reporting times pre-PACS (2002 and 2003) versus post-PACS (2004–2006) were 6.8 versus 5 days and 4.2 versus 3.1 days, for plain radiographic and specialist modality studies, respectively. See text (under methods) for definition of reporting time.

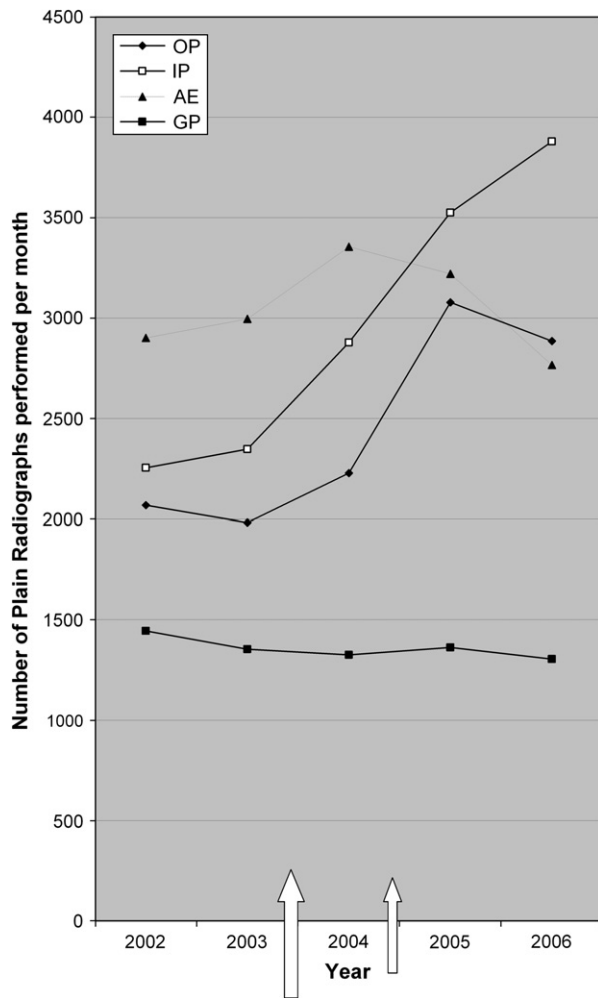


Figure 3 Number of plain radiographs performed per month 2002–2006. Large arrow: introduction of PACS; small arrow: introduction of digital dictation; OP, outpatients; IP, inpatients; AE, accident & emergency; GP, general practice.

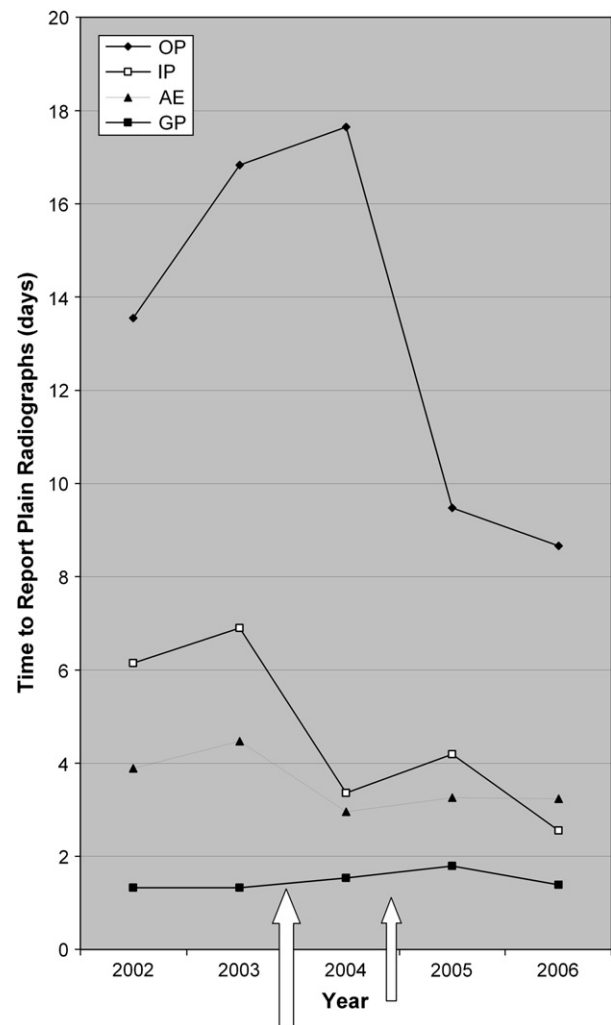


Figure 4 Plain radiograph reporting times (days) 2002–2006.

Fig. 4) before the implementation of PACS; mean 13.6 days (median 12, range 0–52 days) in 2002, mean 16.8 days (median 16, range 0–52 days) in 2003 and were still rising 6 months after PACS; mean 17.7 days (median 17, range 1–51 days) in 2004. Post-PACS times have now almost halved and the mean reporting time in 2005–6 was 9.1 days (median 7, range 0–53 days). For A&E patients the improvement is less marked from a pre-PACS mean of 4.2 (median 2.5, range 0–51 days) days to mean 3.2 (median 2, range 0–50 days) post-PACS. Reporting times for GP radiographs have increased slightly since the introduction of PACS; mean 1.3 (median 1, range 0–31 days) to mean 1.6 (median 1, range 48 days). All these changes in reporting times were statistically significant ($p = 0.001$ for all comparisons; Wilcoxon rank test).

Global comparison showed that since the implementation of PACS there has been a 36% improvement in reporting times of all plain radiographs from a mean of 6.8 to 5 days ($p < 0.001$; see Table 1 and footnote).

Unreported radiographs. The percentage plain radiographs unreported are summarized in Fig. 5. There has been an improvement in the number of unreported plain radiographs, from 5% pre-PACS (2002–2003) to 4% post-PACS (2004–2006).

Specialist radiology modalities

Numbers performed. The number of specialist modality films showed a much larger increase when compared with plain radiographs, increasing by 47% between 2002 to 2006 (Table 1, Fig. 6). This is mostly accounted for by the increased US and CT examinations, which have increased by almost 30 and 100%, respectively.

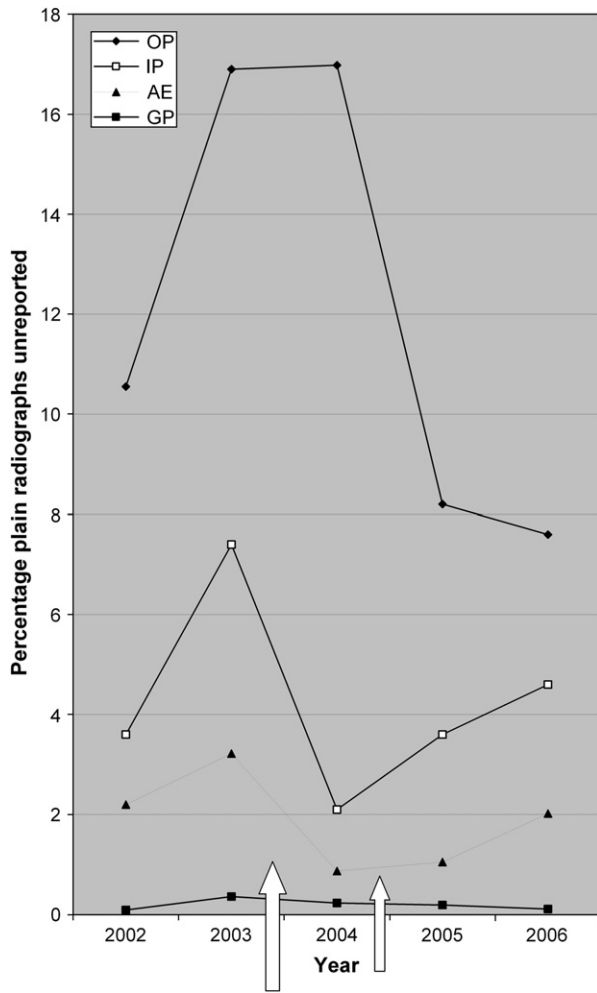


Figure 5 Percentage plain radiographs unreported per month 2002–2006.

Reporting times. The reporting times for each of the four specialist modalities (CT, MRI, ultrasound, and nuclear medicine) are shown in Fig. 7. The time trends show a mixed pattern. CT reporting times remained stable at 2 days, MRI reporting times increased (4.6 to 7.5 days, $p < 0.001$ Wilcoxon Rank) and both ultrasound and nuclear medicine significantly decreased (2.2 to 1.3 days and 6.4 to 2.6 days, respectively; $p < 0.001$). However, global comparison showed a 27% improvement in specialist reporting times from pre-PACS mean of 4.2 to 3.1 days post-PACS ($p < 0.001$, see Table 1 and footnotes).

Unreported films. These are illustrated in Fig. 8. Throughout the study period, fewer specialist films were left unreported compared with plain radiographs. Although overall, the percentage specialist unreported films decreased from an already low baseline, from a mean 1.11 to 0.97% post PACS, the time trends show that the data are skewed by a substantial improvement in nuclear medicine

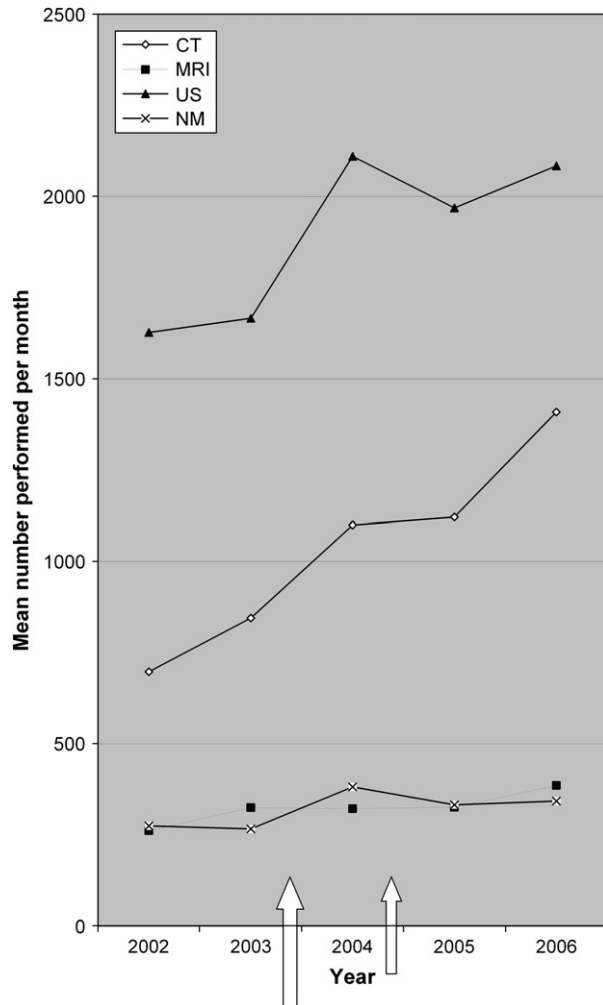


Figure 6 Number of specialist modality films performed per month 2002–2006.

reporting, (from 4.6% down to 1.5%), which masks an increase in MRI and US departments. Much of this improvement occurred before PACS implementation with the appointment of a new consultant specializing in nuclear medicine. However, even if nuclear medicine is excluded, the percentage unreported specialist modality films (CT, MRI, and US) films is still very acceptable with only 0.94% studies unreported post-PACS.

Manpower versus workload pre- and post-PACS

Naturally there have been changes in manpower over the 5-year span. This is summarized in Table 1 (more subtle and temporary changes due to illness or maternity leave are not included). The number of WTE reporting radiologists in February–April 2003 was 35 (18 specialist registrars (SpRs) and 17 consultants). Since PACS installation in June 2003,

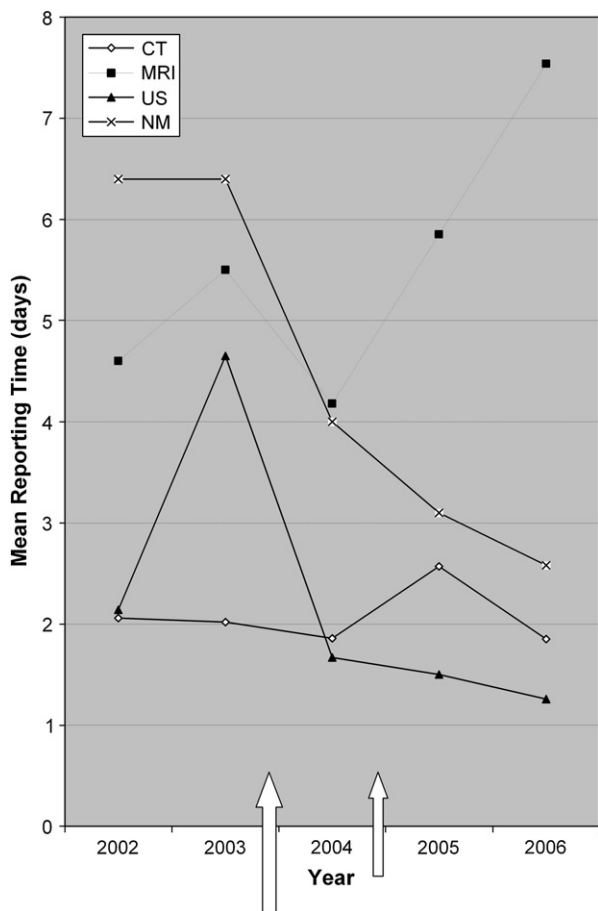


Figure 7 Specialist modality reporting times (days) 2002–2006.

two WTE consultants have been appointed, but the number of SpRs has remained stable. During this same period the number of films to report (plain and specialist modality) rose by 27.8% (11,781 to 15,057 per month). However, as the reporting times and unreported film rates show, the disproportionate rise in department activity was accommodated by the efficiencies introduced by PACS. Productivity, defined as the number of films reported per WTE radiologist, increased from 336.6 per month to 406.9 per month (i.e., by 18%). Between March 2002 and March 2006 there was a reduction in the numbers of radiographers (74.5 to 71.9 WTE) and clerical staff (35 to 27.1 WTE).

Discussion

Within the radiology department a key area of clinical governance is prompt reporting. The expense of PACS is justified on the promise of improved productivity and reduced film reporting times. Faster delivery of images, no lost or misplaced images, and multilocation viewing, allowing

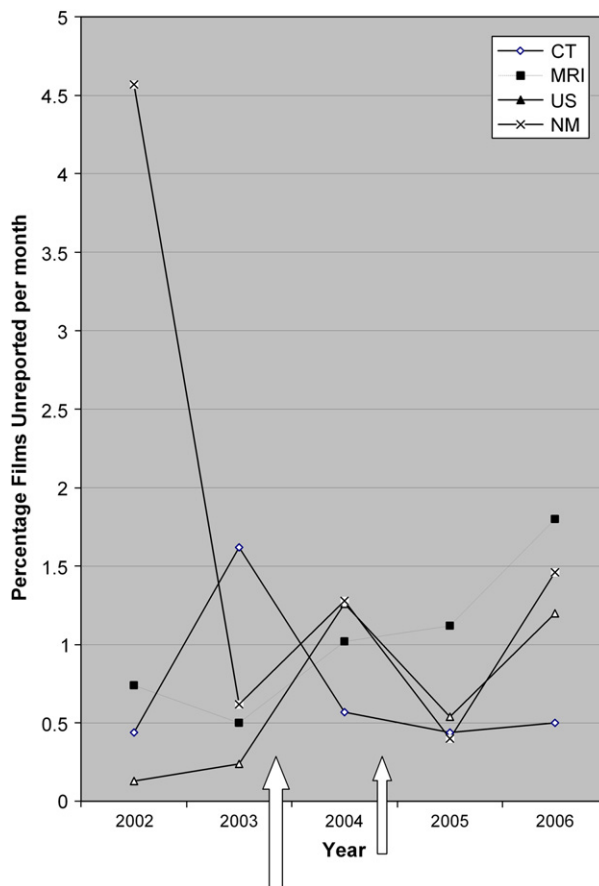


Figure 8 Percentage specialist modality films unreported per month 2002–2006.

one to “dip in” and report, whilst waiting for another radiological examination to be performed, should improve efficiency. This cultural change in the working of the radiology department is illustrated in Figs. 1 and 2, with an abbreviated “film journey”. Using the reporting time definition as described above (time from performing the examination to availability of report to referring clinician), in our department the number of steps in the film journey has reduced by 45% (from 33 to 18). Furthermore, digital dictation means more immediate availability of the dictated reports, improving secretarial efficiency. It was found that since the introduction of PACS and digital dictation, the reporting times have decreased by between 27–36% (depending on the modality) and our productivity (measured as number of films reported per WTE radiologist) has increased by 18%. Both these benefits have been broadly sustained over a 3 year period.

These improvements were in spite of a 30% increase in patient episodes. The total number of plain film and specialist modality films (CT, MRI, nuclear medicine, and ultrasound) performed annually increased from 138,000 in 2002 to just over

180,000 in 2006. The expansion of radiology staff was more modest, and prior to PACS productivity was decreasing and reporting times were stable or increasing (Table 1). Both these deteriorating trends have reversed post-PACS.

However, there are two areas of discrepancy: GP-requested plain radiographs and MRI. One of the key areas addressed in the RCR audit¹ was aiming for a 24 h report turnaround for GP films. This is particularly important as GPs do not have access to the actual images. Over the 5-year period of study, the number of radiographs requested by GPs remained stable (Fig. 2), yet reporting times increased, albeit only slightly (Fig. 3). The explanation, may lie with PACS rather than extraneous factors. Pre-PACS, GP reporting was the most efficient service of the department, because many of the steps illustrated in Fig. 1 were circumvented. Before PACS both the radiograph and the request form were placed immediately in a special "hot reporting" box for GP films. Since PACS, although the radiograph is immediately available for viewing, there is often a delay in the scanning in of the request form. Thus, although PACS has improved most reporting to a higher baseline, GP reporting has slipped down. Although the change is numerically small, it is an example of how PACS may sometimes reduce the performance of an otherwise efficient service. Currently, the GP reporting service is being reviewed, and by prioritising the scanning of these request forms the deterioration may be rectified.

With MRI the situation is more complex. Although the machine was upgraded in 2005 the workload has been steady. The explanation for worsened reporting times may lie with the highly specialized nature of these studies. For example, plain radiographs or body CT examinations will be reported by a much larger pool of radiologists. Any increase in workload or change in workforce, e.g., maternity or sick leave, can be easily accommodated. In comparison, fewer radiologists would feel confident when faced with a specialized investigation, such as MRI of the pelvis for local rectal cancer staging. This reflects the negative impact of increased subspecialization on department efficiency and the solution is not clear. The findings of the present study are not in line with those of Lepanto et al. who found an improvement in both reporting times and productivity 1-year post-PACS, but they only assessed spinal MRI.⁶ Encouragingly, a recent re-audit showed that MRI reporting times were at about a similar level to 2002 (mean reporting time 5.4 days on spot monthly audit in January 2007).

It is often stated that once PACS is installed there will be no more "lost" films and so fewer

unreported films. In this audit the percentage unreported plain radiographs has decreased, but still remains too high at 4% unreported on the 25th day of the following month. A large proportion of these were outpatients. Currently, outpatient films are allocated to individual radiologists on a weekly basis, but this will change to daily allocation, which will hopefully improve the unreported rate. The percentage unreported specialist modality films has remained at approximately 1% pre- and post-PACS (Fig. 8).

The present study has several potential limitations. First, the figures generated for reporting times rely on the integrity of the RIS. Although the "booked in" and "section typed" times are accurate (see methods), the true reporting times are likely to be slightly shorter than calculated because of the delay from booking a patient in to performing the investigation. However, this would be partly counterbalanced by the slight delay (minutes) in transferring the typed report from RIS to the EPR or PACS. Reporting times pre-PACS may also be underestimated for those clinicians who preferred typed (paper) rather than electronic reports. Second, the 3 study months chosen may not be representative of the whole year. Despite this, the present study is the largest of its kind, addressing global reporting performance and over a 5-year period. However, contrast fluoroscopy or interventional studies were not included in the analysis. These are often performed by trainee radiologists or trained radiographers and then reported with a senior radiologist. It was felt that as specialist examinations reporting times on these should be addressed in a separate audit. However, as a result the authors can not comment on shifting trends of utilization, such as more CT being performed to replace barium studies.¹¹ It is also not clear what the relative contribution of digital dictation is in the overall efficiency gains demonstrated here. This would probably require a continuous dataset from the inception of digital dictation and raises an interesting possibility for future studies.

The definition of reporting time used in the present study was the availability of an authorized or unauthorized report, and might be seen as a limitation. Ideally, the clinician would like to obtain the fully authorized report. With voice recognition this is becoming possible for the majority of plain radiographs and those specialist techniques that do not require further discussion. However, with more complex imaging, further discussions are often needed at clinical-radiological-pathological multidisciplinary meetings before the final authorized report (amended if

necessary) is issued. A recent study found that the immediate authorization of a report with speech recognition can be a disadvantage from this point of view.¹² Finally, it is assumed that all the relevant radiological activity applicable for this study was captured, as the separate regular monthly audit is designed to identify such "lost" data or "black holes".

In conclusion, when PACS is coupled with a change in departmental workflow, there can be a substantial and sustained improvement in reporting times and productivity: 27–36 and 18%, respectively; with no deterioration in the unreported film rate. Also any assessment of the effect of PACS on reporting times should be across the board. This enables identification of subsets of films where reporting times may actually increase after PACS implementation, such as GP and MRI reporting as in the present study. This, in turn, enables scrutiny of the individual workflow pathways. Reasons for increased times can be identified and the necessary remedies effected. With the introduction of voice recognition further reduction in the number of steps can be anticipated, although caution is needed as there are reports that voice recognition may reduce an individual radiologist's productivity.¹² A re-audit is planned in 2008 after voice recognition has been implemented.

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