Title

Optimizing patient care in radiology through team-working: a case study from the United Kingdom

Objectives: To investigate how changes in service delivery within the radiology department of an acute district general hospital optimized imaging services for patients and referrers through a strong emphasis on team-working.

Methods: Data related to service delivery was collected for three consecutive years and interrogated by imaging modality and reporting practitioner (radiologist, reporting radiographer, sonographer) to explore how workload had changed over the cycle.

Results: Departmental activity demonstrated consistent increases, both overall (13.3%) and for most modalities (MRI 43.7%, CT 22.8%) for the study period (March 2010 – March 2013). Overall trend suggested significantly shorter waiting times (CT 0.7 weeks, MRI 1.3 weeks, non-obstetric ultrasound one week; all modalities p=0.001). Some modality variation in reporting times was apparent, with CT (p=0.06) and MRI (p=0.01) decreasing but there was an increase in x-ray reporting times (p=0.001). Reporting radiographers and sonographers reported the majority of x-ray and non-obstetric ultrasound interpretations (59% and 52%, respectively). A radiographer-led neonatal reporting service was implemented and the urology patient pathway redesigned. Effective team-working produced savings of three full-time consultant radiologist posts.

Conclusion: Radiologists and radiographers, working together, can deliver an effective service. Innovation, staff development and redesign of patient pathways, have produced significant improvements. [197 words]

Introduction

Person-centred care, an aging population, government targets and new technology have resulted in an unprecedented growth in imaging workload (1-4). In response to these rising demands an increasing number of radiographers who have completed a relevant postgraduate qualification now undertake clinical reporting (5-7). The current political and economic climate in the United Kingdom has resulted in renewed focus being placed on the efficient use of NHS resources in the drive to deliver savings while improving patient care and outcomes (8). Team-working has been highlighted in a recent joint publication by the Royal College of Radiologists and the College of Radiographers as fundamental and essential to ensure that modern radiology services meet current and future demand in an effective, efficient and patient focused manner (9).

The introduction of radiographer reporting and implementation of the four tiered job structure, from assistant practitioners to consultant radiographers, has aided radiology departments to meet these ever increasing demands in a patient focused and efficient manner through the appropriate use of skill mix (10). Radiographer practice and their contribution to patient care are often driven by local service demands, with many varied and excellent examples occurring across the United Kingdom (11-13). Presented here, as a case study, is the model of service delivery implemented in the radiology department of an acute district hospital.

The Homerton University Hospital serves a diverse population of 246,000, with 51,500 in-patient, 272,300 out-patient, and 119,800 emergency attendances and 13,990 neonatal intensive care bed days in 2012/13 (14). Radiology provides general x-ray, ultrasound (US), fluoroscopy, computed tomography (CT), magnetic resonance imaging (MRI) and mammography services to hospital and community patients with a combined workforce of 91 full time equivalent (FTE) staff.

The aim of this study was to explore the role that multidisciplinary team working can have on patient care; how service delivery responds to increasing demands, trends in waiting and report turnaround times, to identify novel examples of best practice, while ensuring that a safe service is provided.

Methods

The structure and characteristics of the department were outlined. Departmental staff numbers and profile (profession and grade) was determined through workforce analysis. Significant landmark events; installation of new equipment, patient pathway redesigns and introduction of novel services, were highlighted at service review conducted at the end of the audit cycle. Key measures of department performance were identified and agreed at the commencement of the audit cycle, with changes implemented in response to clinician and patient need.

Monthly departmental activity data was collated from the radiology information system for three consecutive years (April 2010 – March 2013) from regular service evaluation reports generated by the Information Management department. Data was collected using Microsoft Excel 2013 (Microsoft Corporation), with pivot tables used to perform the analysis. Data was stratified by modality, referral source and

examination type (x-ray and ultrasound) using the filter functions. Statistical analysis performed using SPSS (IBM version 19).

Waiting time for radiology investigations was highlighted as an important indicator, both for the delivery of a patient focused service and to ensure compliance with national standards(15, 16). Waiting times for modalities not providing a walk in service (CT, MRI, US) were calculated in weeks, taken from the date of examination request to completion date. Report turn-around time, calculated in hours from examination completion time to the provisional of a final report, has been emphasized as a key factor in radiology performance, from the perspective of patients(17) and referring clinicians(9). Stratified by imaging modality (and examination where appropriate), average RTAT was determined using Microsoft Excel. Multidisciplinary team-working was been suggested as one method to provide prompt and accurate diagnoses in the context of increasing radiology workloads(9). To assess the contribution of each professional group to department activity, the proportion of examinations performed and/or interpreted by different professional groups was determined using Microsoft Excel by filtering the data by reporting practitioner. To examine for trends in the waiting time and RTAT data, one-way multivariate analysis of variance (MANOVA) was performed. Results with $p<0.05$ were deemed significant.

Ultrasound and plain imaging cases from the monthly radiology discrepancy meeting were analysed for reporting practitioner, type of discrepancy and discrepancy grade and examined with chi-squared or Fisher's exact test as appropriate.

Local Research & Development indicated that NHS ethical approval was not required for this service evaluation. The project was registered with the local Clinical Audit department in line with good practice and local requirements.

Results

Activity

Departmental activity demonstrated consecutive year on year increases (117,520 – 133,149 examinations) over the study period, most pronounced in the cross-sectional areas with MRI and CT producing the largest percentage increase in workload (Table 1).

Workload by Professional Group

The proportion of examinations performed/interpreted by each professional group were identified (Table 2). The radiology department employs advanced radiographer practitioners who provide definitive reports (9) for CT head and MRI lumbar spine examinations. However, the vast majority (>99%) of these examinations were interpreted by radiologists. Sonographers and a consultant musculoskeletal (MSK) physiotherapist reported just over half of all non-obstetric ultrasound examinations for each of the three years. There was a steady increase in the proportion of x-ray examinations interpreted by reporting radiographers, increasing from 49% in year 1 to 59% in year 3. Analysis of x-ray examination type revealed that this rise was

driven largely by an increase in the number of chest and abdominal x-rays interpreted by reporting radiographers, especially in-patient examinations (Table 3 and Figure 1 and 2).

Waiting times

Data analysis on modality waiting times and report turnaround times was conducted with one-way multivariate analysis of variance (MANOVA). The waiting time data for all modalities (CT, MRI, US) show a highly significant (p=0.0001) reduction. The majority of the improvement occurs between years 1-2 and although there has been a further reduction in mean waiting time between years 2-3 it was not significant (p=0.91[CT], p=0.87[MRI] and p=0.88[US] respectively). This is most likely accounted for by a 'floor' effect (18), whereby the average time is so low it is unlikely to reduce further due to underlying practical constraints; for example, the average wait time for CT in March 2012 was five days (Figure 3).

Report turnaround times

There are mixed results in the analysis of the report turnaround time (RTAT) data (Figure 4). Computed tomography examinations demonstrated an improvement (15 to 10 hours) which approached statistical significance (p=0.06) for reporting time between years 1 and 3, but without significant decrease in any one year, suggesting a progressive service improvement. These results were mirrored in MRI: no year showed a statistical significant decrease, but the overall trend (years 1-3) demonstrated a significant reduction in RTAT (71 to 47 hours, p=0.01). Conversely, the RTAT data for x-rays demonstrated a reverse trend when compared to the overall improvement for the department. The average x-ray RTAT for the study

period showed a highly significant increase (p=0.001) overall (years 1-3), driven by an increase between years 2 and 3 (average time 41 to 71 hours, p=0.001).

Radiology Discrepancies

Analysis of the ultrasound and plain imaging cases from the departmental monthly discrepancy meeting was performed, in line with best practice recommendations (7, 9, 19), to ensure that patient safety has been maintained with radiographer image interpretation. Data was available for two of the three study years (Years 2 and 3, 2011/12 & 2012/13) and was interrogated for reporting practitioner, examination type, discrepancy type (cognitive or perceptual) and discrepancy grade. The discrepancies were graded by consensus at the monthly meetings (20) and followed Royal College of Radiologists guidance (19).

Ultrasound produced four total discrepancies in the study period; one registrar (grade 4), two consultant (grades 4 and 5) and one sonographer (grade 3). No further analysis was performed due to the small number of cases.

Statistical analysis was conducted for plain imaging discrepancies using a chi-squared or Fisher's exact test where appropriate and weighted by the proportion of examinations interpreted by each professional group. Chest x-rays were the most common source of discordant reports (31 of 51 differences, 61%). When analysed by professional group, consultant radiologists produced the majority of the discrepant chest x-ray interpretations (22 of 31, 71%). After adjustment for the number of cases reported, chest x-ray reports by consultant radiologists gave rise to the most departmental discrepancies (Fisher's exact test, p=0.001). The proportion of perceptual (43 of 51, 84%) and cognitive (8 of 51, 16%) discrepancies did not demonstrate any statistically apparent difference between radiologists and

radiographers (Fisher's exact test, p=0.37). No significant difference between reporting practitioners was demonstrated when the grade of discrepancy was examined (chi-squared test, p=0.23).

Service and pathway redesign

Retrospective review identified several pathway re-designs and novel initiatives which improved the service delivered by radiology. In response to increased activity and in order to reduce waiting and RTAT, the work pattern of the consultant radiologists was altered. Previously, when a consultant had been on leave, the allocated CT or US list was cancelled with only emergency/urgent cover provided. In order to maximise the use of high value in demand technologies a rolling rota was implemented with consultants' cross-covering lists. The system of assigning cross-sectional reporting was also changed at this time; instead of all cases from a session being assigned to the supervising radiologist the cases were allocated throughout the week according to their individual job plans. Each radiologist has a monthly allocation based on individual job plan (number of MRI professional activity sessions) and days in attendance. This system has meant that MRI lists are booked by clinical priority not consultant availability and has also contributed to the decrease in report turnaround time as cases were assigned continuously rather than 'en masse' several times a week. Increased capacity for CT, MRI and US was also gained by extending the routine hours provided. The continuously high demand for US had meant that evening lists had been a regular feature for several years. An alteration in non-medical employment contracts provided the flexibility for both CT and MRI to offer an extended service. This initiative, offered on a flexible basis, has enabled waiting

times to be kept to a minimum while offering appointment times that are convenient to patients with Saturday (MRI) and Sunday (CT) appointments available.

In July 2011 a novel, radiographer-led neonatal image interpretation service was introduced. One of the radiographers, already an established advanced radiographer practitioner reporting a wide range of plain film examinations, completed an intensive, bespoke education and training programme to enable safe and accurate reporting of neonatal x-rays from the neonatal intensive care and special care baby units. This development led to an additional 3,500 examinations a year receiving a formal, definitive report, and improved the service provided to this vulnerable patient group and the clinicians caring for them. This now ensures all imaging investigations receive a radiological report, in line with legislative requirements (21) and best practice guidance (22).

As demonstrated in the activity figures there has been a marked reduction in the number of intravenous urograms (IVU) performed; only three in the final year of the study (2012-13). Consultation between radiology and urology departments resulted in a redesigned haematuria pathway; renal US and IVU were replaced with direct Urology referral and patients were investigated with a either a CT IVU or a renal US and CT KUB (Kidney Ureter Bladder) depending on age and degree of haematuria.

Other developments which have improved service delivery include fixed, additional timetabled radiologist plain imaging reporting, and a reporting radiographer (07:30-17:30) Monday to Friday. Plain imaging queries from radiology and A&E are now directed to the reporting radiographers which allows the acute radiologist, whose responsibilities also include co-ordination of the CT & MRI work lists, to perform urgent interventions and prompt interpretation of A&E and in-patient cross-sectional

imaging, to focus on these key and vital roles, maximising efficiency and effectiveness.

Role development within radiology was not limited to the radiographic workforce. A highly specialised consultant musculoskeletal physiotherapist performs ultrasound and ultrasound guided interventions and complements the service provided by the MSK radiologists. An assistant practitioner and a team of radiology department assistants (RDAs) have been integrated with the radiology team for a considerable period. The assistant practitioner supports the GP and outpatient x-ray service, producing high quality images and increased their contribution from 15.6% to 22.4% of the plain imaging workload over the study period. RDAs support the cross-sectional imaging areas by preparing the patients for their examinations, including cannulation where required, and assist the radiologists and consultant physiotherapist with interventional procedures. The RDAs also liaise with the Day Stay Unit to book and co-ordinate ultrasound guided liver biopsies.

Comparison of local workload with Royal College of Radiologists guidance on radiologist workload

Guidance on consultant radiologist workload was recently published by the Royal College of Radiologists to aid in workforce and job planning (23). Following the suggested framework, workload was determined by using the central suggested values (Table 4) and an estimated 20% of CT and MRI falling into the ‘complex’ category. The recommended time spent for clinical multidisciplinary team meetings, both preparation and participation, is 20% of clinical time and this was included in the assessment. For year three of the study (2012-13), 11,834 consultant hours were

required based on departmental activity utilizing a multidisciplinary team approach. Projected activity for an exclusive consultant service was 15,595 consultant hours for the same departmental workload, the equivalent of three full-time consultant radiologist posts.

Discussion

Report turnaround times

A critical review of the literature on report turnaround times was conducted to place the results of this study into national and international context. Much of the literature arises from the United States, which makes direct comparison with the results of this study difficult. There are fewer radiologists per capita in the UK(24) and the financial model of United States healthcare often links RTAT with remuneration and bonus payment (25, 26). The United States system of work, with consultant radiologist authorization of preliminary registrar reports (27), often remotely (28), also differs from typical practice in the UK. The few studies from the United Kingdom demonstrate that the performance of the department featured in this study is comparable to the literature. House & Williams (29) found that after introducing a telemedicine reporting service the average RTAT was three days for CT, four days for MRI and two days for x-ray examinations and a one day turnaround for GP x-ray cases. Hart et al reported average RTAT times of 1.76 days for A&E, 1.84 for general practitioner referrals, 2.9 for in-patient and 2.5 days for out-patient examinations (30). Comparison with the national Diagnostic Imaging Dataset (England)(31), a national system for reporting key radiology performance indicators, demonstrates the department is matching or outperforming the England average for

RTAT for the investigations highlighted as fundamental to early cancer diagnosis. Data from the latest available month (October 2012), indicates that this department of radiology performs as well as or outperforms the average for England in all key areas. Median reporting time for chest and abdominal CT (same day) and chest x-rays (same day for GP, next day for all other referrals) is in contrast with the average performance across England; average reporting performance is next day for CT chest & abdomen and GP chest x-ray examinations and 2 days for all other chest x-ray referrals (31).

The targets set by the National Diagnostic Imaging Board in 2008 (32) for report turnaround have been reinforced in a recent joint publication by the Royal College of General Practitioners, the Royal College of Radiologists and the Society and College of Radiographers (33). These standards for report turnaround are same day for A&E and inpatient examinations and next day for all other investigations, with 90% compliance to account for second opinions, additional clinical history and subspecialist advice. These targets, measured in same and next day, are less precise than the number of hours which is usually used in the literature. Another limitation is the 90% compliance; is it possible to measure objectively the 10% tolerance level is truly being used for difficult cases and not those that have simply been overlooked? Changes in practitioner working patterns may have contributed to the increase in x-ray RTAT during the audit cycle, and this was identified during the continuous service review. To counter the increase in x-ray RTAT and reduce clinical risk the number of radiographer reporting sessions was increased and a new Sunday radiographer reporting service introduced.

Comparison of local workload with RCR guidance on radiologist workload

The workforce census conducted by the Royal College of Radiologists in 2011 highlighted a vacancy rate of 9% in consultant posts, framed against an ever increasing imaging workload, both in volume and complexity (34). The use of a diverse multidisciplinary team has assisted in maintaining an efficient, effective patient focused radiology service in lieu of three full time consultant radiologist posts.

Discrepancy rate

It is vital that any health service places patient safety at the centre of all service redesigns; in a drive for efficiency there must never be a compromise on quality (35, 36). The Royal College of Radiologists and College of Radiographers have always maintained that any radiographer that wishes to extend their practice must perform at a level comparable to a consultant radiologist (9). Image interpretation is a subjective task (6), with significant variation reported in the literature (37-40). The discrepancy data, available for two of the three years, suggests that there has been no impact on quality or patient safety by utilising trained and qualified reporting radiographers within a supportive clinical department, although the small sample size prevents firm conclusions from being drawn. The results confirm the findings of Donald & Barnard (41), who found 447 of the 558 (80%) discrepancies were perceptual (Homerton 43 of 51, 84%), with no significant differences between radiologists and radiographers. The severity of the radiographer and radiologists discrepancies did not demonstrate any statistical difference, although the most frequent source of discordant interpretations were chest x-ray reports produced by radiologists after the number of cases interpreted had been taken into account

(radiologists 22 of 31, 71%). An important limitation in the discrepancy analysis is the self-reported nature of the discrepancy referrals, with cases identified either at subsequent imaging or by the relevant clinical team. This bias is recognised within the literature (19, 41, 42) and needs to be considered when comparing performance to more structured assessments of diagnostic accuracy (1, 43).

Waiting Times

The recent joint guidance produced by the Royal College of General Practitioners, Royal College of Radiologists and the Society and College of Radiographers outlined ambitious targets for waiting times for primary care imaging referrals (33). Through excellent team-work, use of skill-mix and extended hours, the radiology department is currently well within the maximum recommended waiting time for routine appointments; ultrasound currently one week, MRI 1.3 weeks and CT less than a week. The aim of zero waiting times should be a goal of any department, and radiology will continue to strive to meet this ambitious objective. The government has mandated performance targets for hospitals for suspected cancer referrals, cancer treatment and non-urgent care (15, 44, 45). Imaging services are pivotal to diagnosis and assessment of treatment and lie at the heart of streamlined patient care and service delivery. The short waiting times provided for imaging investigations helps the hospital to meet these targets (14). An extended day (12 hour) seven day CT and MRI service will be introduced, in line with national best practice (46). This service will help to maintain short patient waiting times, deal with anticipated increase in demand and offer patients' increased choice in an efficient and effective manner.

Radiology Education and Professional Development

All members of the radiology department, medical and allied health, are supported in on-going professional development and training. A comprehensive programme of in-house training provided by radiologists, reporting radiographers, sonographers, podiatrists and physiotherapists improves the knowledge base of all staff, provides information on leading edge developments and ensures that all practice is evidence based. This is coupled with support, both financial and through protected study time, which enables, for example, attendance at short courses, training days, conferences and formal post-graduate education. A restructured multidisciplinary clinical audit group has been formed within radiology to identify areas for improved patient care and service delivery. Research plays an important role in practice and professional development, and the department actively supports a part-time PhD student.

Multidisciplinary team meetings (MDTs) are an important component of modern patient care, in which radiology plays a key role (47). The reporting radiographers and sonographers are active participants in several MDTs which include rheumatology, paediatrics, neonatology and respiratory (reporting radiographers) and fetal medicine and gynaecology (sonographers). Involvement with the clinical team who provide direct patient care encourages multi-professional communication, and integrates the Radiology department into the patient care pathway.

Executive Support

In the complex environment of an acute hospital change management cannot be implemented in isolation(48). Support of the Trust executive has enabled continued

investment in radiology, both capital and personnel, which has been crucial in enabling continued service development and improvement.

Conclusion

Multiple drivers for continued increases in imaging workload exist; an improved awareness of the importance of person-centred care as a result of the Francis report (49) and the on-going focus on government waiting time targets for emergency (44) and cancer care(15) and elective treatment (45). These pressures, coupled with the drive for efficiency mandated by the current economic and political climate have resulted in renewed focus on streamlined service delivery and appropriate use of skill-mix and resources in the NHS (3, 4, 10). Use of advanced radiographic practitioners, both sonographers and reporting radiographers can assist in maintaining a high quality imaging service (9).

Highlighted in this case study are examples of best practice which can be used to meet current and future demand without a compromise on quality. The use of an integrated multidisciplinary team, which incorporates radiologists, reporting radiographers, sonographers, assistant practitioners and radiology department assistants, ensures that that the appropriate task is performed by the appropriate person. The hospital continues to keep activity and targets under close monitoring, with anticipated and unexpected changes in workload to be met by innovation, restructuring and alteration in skill mix. Future plans include the introduction of advanced practice mammographer breast ultrasound and biopsy service.

Acknowledgements

The authors wish to thank Kate Grayson for providing statistical advice, Dr Emma Goldstraw for assistance in collating the discrepancy data and Prof. Graham Bohamley for help preparing the manuscript.

Conflicts of interest

The authors declare no conflicts of interest.

Funding

Nil

Modality	2010-11	2011-12	2012-13	% change 10-11/ 11-12	% change 11-12/ 12-13	% change 10-11/ 12-13
CT	11636	12631	14289	8.6	13.1	22.8
DEXA	384	344	382	-10.4	11.0	-0.5
Fluoroscopy	1228	1043	936	-15.1	-10.2	-23.8
Interventional	730	434	745	-40.5	71.7	2.1
MRI	5814	6456	8357	11.0	29.4	43.7
Mammography	1339	1460	1403	9.0	-3.9	4.8
Non Obstetric US	23057	26199	27642	13.6	5.5	19.9
Nuclear Medicine	542	502	453	-7.4	-9.9	-16.5
Urogram	237	91	3	-61.6	-96.7	-98.7
X-Ray	72546	74802	78843	3.1	5.4	8.7
Grand Total	**117520**	**123974**	**133149**	**5.5**	**7.4**	**13.3**

Table 1. Annual departmental activity stratified by modality.
CT = Computed Tomography, DEXA = Dual Energy X-ray Absorptiometry, MRI = Magnetic Resonance Imaging, US = Ultrasound

Modality	% Total RR/Son		
	2010-11	2011-12	2012-13
CT	<1	<1	<1
MRI	<1	<1	<1
US	52	51	52
X-Ray	49	58	59

Table 2. Proportion of reports produced by reporting radiographers and sonographers.
CT = computed tomography, MRI = magnetic resonance imaging, US = non-obstetric ultrasound, RR = reporting radiographer, Son = sonographer

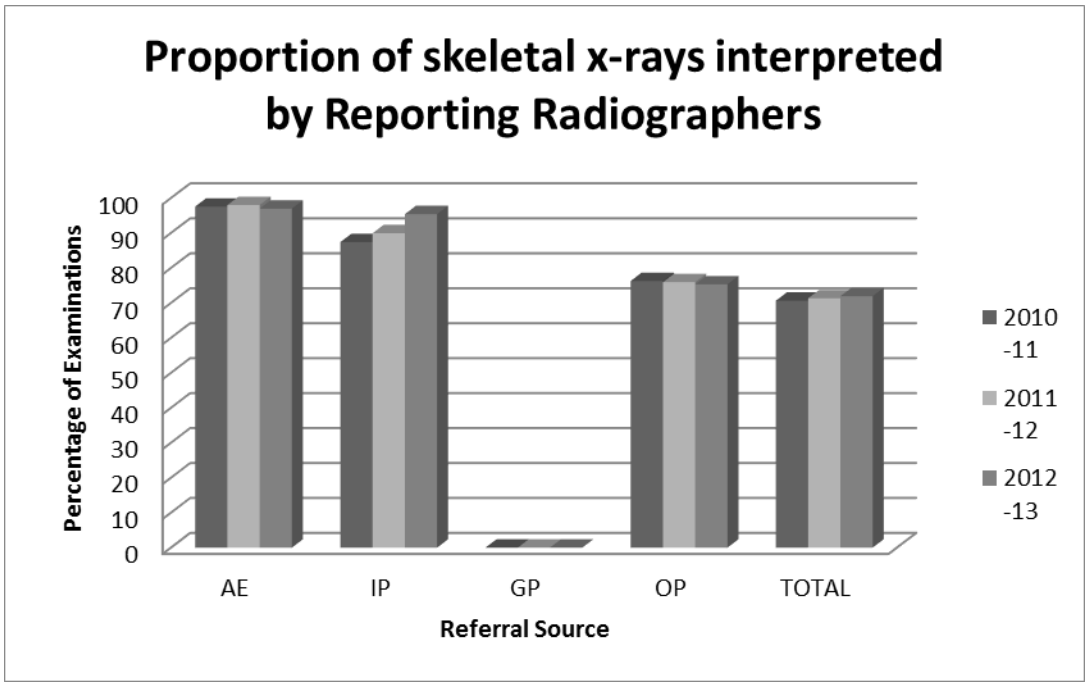

Figure 1. Proportion of skeletal x-rays reported by radiographers stratified by referral source.
AE = Accident & Emergency, IP = In-patient, GP = General Practice, OP = Out-patient

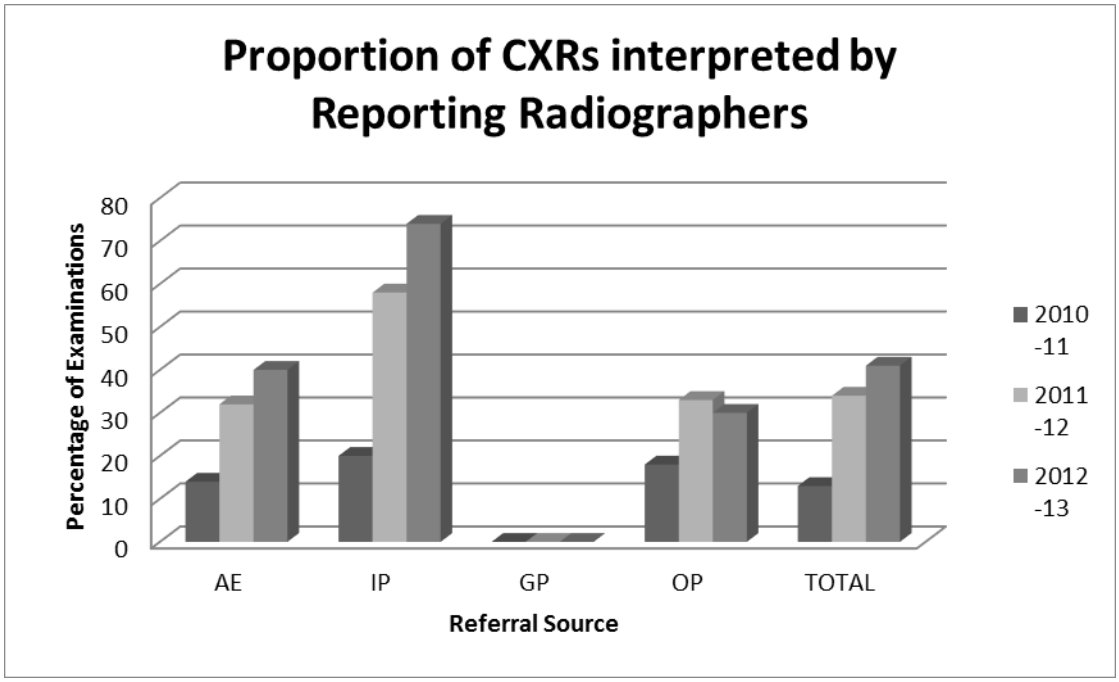

Figure 2. Proportion of chest x-rays reported by radiographers stratified by referral source.
AE = Accident & Emergency, IP = In-patient, GP = General Practice, OP = Out-patient

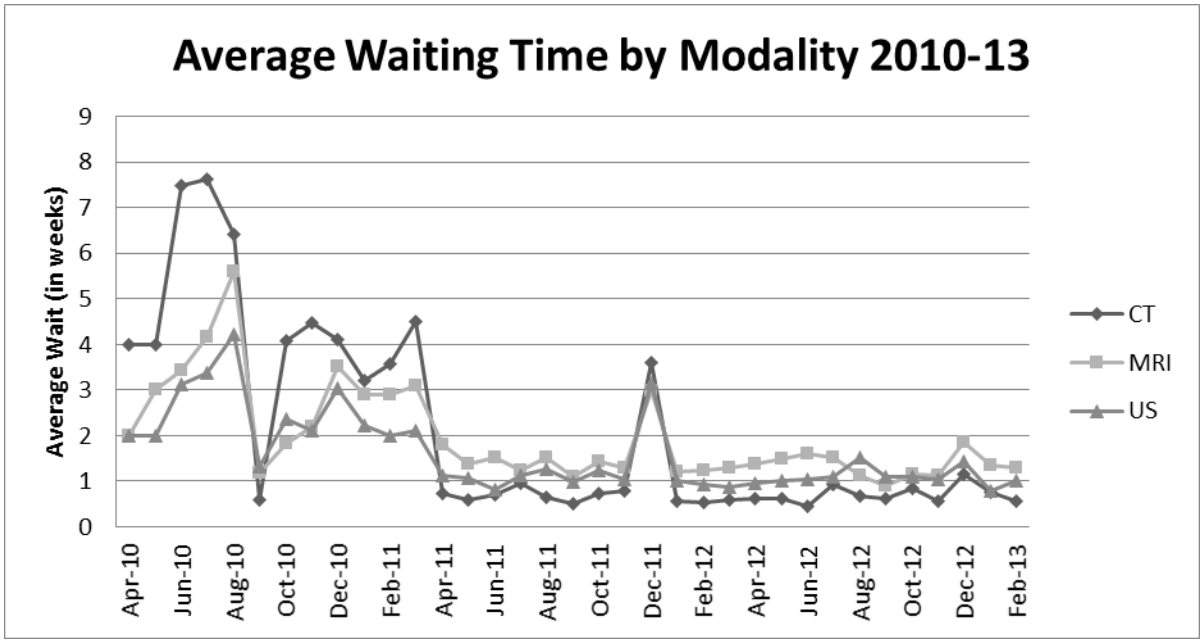

Figure 3. Average waiting times for cross-sectional imaging.
CT = computed tomography, MRI = magnetic resonance imaging, US = Non-obstetric ultrasound

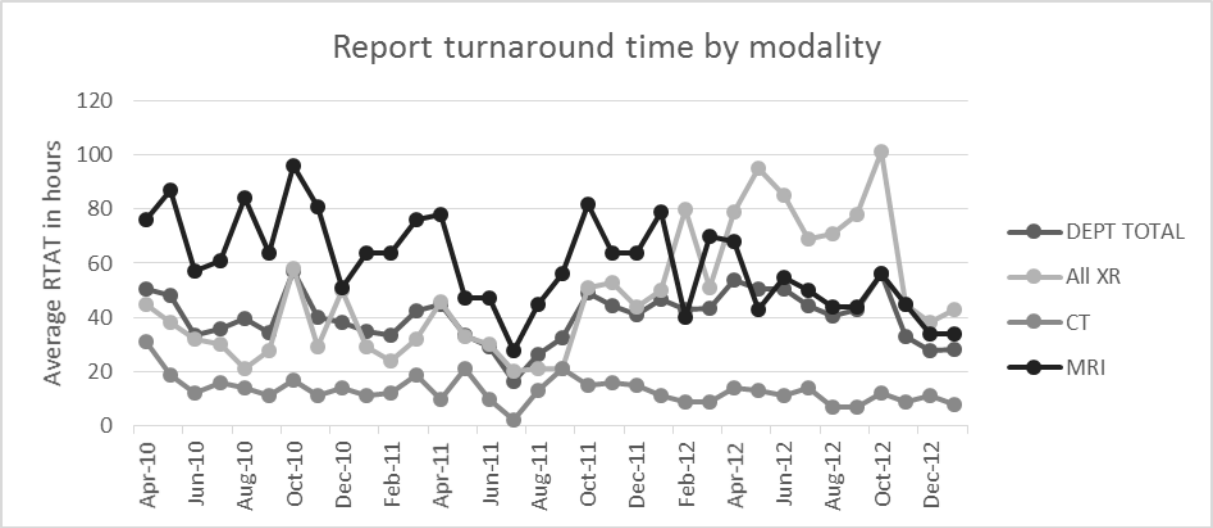

Figure 4. Average report turnaround time by modality.
RTAT = report turnaround time, XR = x-ray, CT = computed tomography, MRI = magnetic resonance imaging

Examination	Cases per hour
CT/MRI	4
complex CT/MRI	1.5
Fluoroscopy	3
CT/MR Interventional	3
Mammography	5
US	5
US Interventional	3
X-ray	45

Table 4. Royal College of Radiologists suggested consultant workload in cases per hour (median values) [15](23)

References

1. Brealey S, Scally A, Hahn S, Thomas N, Godfrey C, Coomarasamy A. Accuracy of radiographer plain radiograph reporting in clinical practice: a meta-analysis. *Clin Radiol*. 2005;60(2):232-41.
2. Secretary of State for Health. Equity and excellence: Liberating the NHS. Department of Health Do. UK: Crown Stationary Office; 2010.
3. NHS Improvements. The best of clinical pathway redesign: Practical examples delivering benefits to patients. UK: Department of Health, 2011.
4. NHS Improvements. First steps towards quality improvement: A simple guide to impoving services. UK: Department of Health, 2011.
5. Paterson A, Price RC, Thomas A, Nuttall L. Reporting by radiographers: a policy and practice guide. *Radiography*. 2004;10(3):205-12.
6. Brealey S. Measuring the effects of image interpretation: an evaluative framework. *Clin Radiol*. 2001;56(5):341-7.
7. College of Radiographers. Preliminary Clinical Evaluation and Clinical Reporting by Radiographers: Policy and Practice Guidance. London: College of Radiographers, 2013.
8. HM Treasury. Spending Review 2010. HM Treasury. London: HMSO; 2010.
9. Royal College of Radiologists, Society & College of Radiographers. Team working in clinical imaging. London: Royal College of Radiologists and the Society and College of Radiographers, 2012.
10. Department of Health. Radiography Skills Mix: A report on the four-tier service delivery model. UK: Department of Health, 2003.
11. Sumkin JH, Klaman HM, Graham M, Ruskauff T, Gennari RC, King JL, et al. Prescreening mammography by technologists: a preliminary assessment. *Am J Roentgenol*. 2003;180(1):253-6.
12. Leslie A, Lockyer H, Virgee JP. Who should be performing routine abdominal ultrasound? A prospective double blind study comparing the accuracy of radiologist and radiographer. *Clin Radiol*. 2000;55(8):606-9.
13. Hogg P, Holmes K. The interpretation of nuclear medicine data by non-medical health care professionals: Developments in the United Kingdom. *J Radiography Diag Imaging*. 2000;3:77-85.
14. Homerton University Hospital. Annual Report and Accounts 2012/13. London: Homerton University Hospital, 2013.
15. Cancer, Cardiovascular, End of Life Care and Dermatology Programme. Cancer Waiting Times - A Guide (Version 8.0). London: Department of Health, 2011 19 October 2011.
16. National Radiology Service Improvement Team. Service improvement for radiologists: A signposting document summarising service improvement methodology and benefits. UK: Department for Health, 2007.
17. National Clinical Imaging Group. Implementing 7 Day working in Imaging Departments: Good Practice Guidance. UK: Department of Health, 2011.
18. Habbema JDF, Eijkemans R, Krijnen P, Knottnerus JA. Analysis of data on the accuracy of diagnostic tests. In: Knottnerus JA, Buntinx F, editors. The Evidence Base of Clinical Diagnosis: Theory and Methods of Diagnostic Research. Singapore: Blackwell Publishing; 2009. p. 118-45.
19. Royal College of Radiologists. Standards for Radiology Discrepency Meetings. London: Royal College of Radiologists, 2007 Contract No.: BFCR(07)8.

20. Jolly BC, Ayers B, Macdonald MM, Armstrong P, Chalmers AH, Roberts G, et al. The reproducibility of assessing radiological reporting: studies from the development of the General Medical Council's Performance Procedures. *Med Educ*. 2001;35 Suppl 1(Suppl 1):36-44.
21. The Ionising Radiation (Medical Exposure) Regulations 2000, (2000).
22. Royal College of Radiologists. Standards for the Reporting and Interpretation of Imaging Investigations. London: Royal College of Radiologists, 2006.
23. Royal College of Radiologsts. Clinical radiology workload: guidance on on radiologists' reporting figures. London: Royal College of Radiologists, 2012.
24. Fowler R. The bigger picture on diagnostic imaging. *Health Service Journal*. 2013.
25. Boland GW, Halpern EF, Gazelle GS. Radiologist report turnaround time: impact of pay-for-performance measures. *Am J Roentgenol*. 2010;195(3):707-11.
26. Lahiri A, Seidmann A. Analyzing the differential impact of radiology information systems across radiology modalities. *J Am College Radiol*. 2009;6(10):705-14.
27. Andriole KP, Prevedello LM, Dufault A, Pezeshk P, Bransfield R, Hanson R, et al. Augmenting the impact of technology adoption with financial incentive to improve radiology report signature times. *J Am College Radiol*. 2010;7(3):198-204.
28. Deitte LA, Moser PP, Geller BS, Sistrom CL. Email notification combined with off site signing substantially reduces resident approval to faculty verification time. *Acad Radiol*. 2011;18(6):774-81.
29. House C, Williams R. How trusts can make radiology reporting world class. *Health Service Journal*. 2012(22 March).
30. Hart JL, McBride A, Blunt D, Gishen P, Strickland N. Immediate and sustained benefits of a "total" implementation of speech recognition reporting. *Brit J Radiol* 2010;83(989):424-7.
31. Department of Health. Diagnostic Imaging Dataset Statistical Release. London: Department of Health; 2013.
32. National Diagnostic Imaging Board. Radiology Reporting Best Practice Guidance. London: Department of Health, 2008.
33. Royal College of General Practitioners, Society & College of Radiographers, Royal College of Radiologists. Quality imaging services for primary care: a good practice guide. London: Royal College of Radiologists, 2013 Contract No.: BFCR(13)2.
34. Royal College of Radiologists. Clinical Radiology UK Workforce Report 2011. London: Royal College of Radiologists, 2012 Contract No.: BFCR(12)14.
35. Care & Quality Commission. Essential standards of quality and safety. Care & Quality Commission; 2010.
36. College of Radiographers. Code of Conduct and Ethics. London: College of Radiographers, 2008.
37. Robinson P, Wilson D, Coral A, Murphy A, Verow P. Variation between experienced observers in the interpretation of accident and emergency radiographs. *Brit J Radiol*. 1999;72(856):323-30.
38. Goddard P, Leslie A, Jones A, Wakeley C, Kabala J. Error in radiology. *Brit J Radiol*. 2001;74(886):949-51.
39. Potchen EJ, Cooper TG, Sierra AE, Aben GR, Potchen MJ, Potter MG, et al. Measuring performance in chest radiography. *Radiology*. 2000;217(2):456-9.
40. Eng J, Mysko WK, Weller GE, Renard R, Gitlin JN, Bluemke DA, et al. Interpretation of Emergency Department radiographs: a comparison of emergency medicine physicians with radiologists, residents with faculty, and film with digital display. *Am J Roentgenol*. 2000;175(5):1233-8.
41. Donald JJ, Barnard SA. Common patterns in 558 diagnostic radiology errors. *J Med Imaging Radiat Oncol*. 2012;56(2):173-8.
42. Brealey S, Scally AJ. Bias in plain film reading performance studies. *Brit J Radiol*. 2001;74(880):307-16.

43. Piper K, Cox S, Paterson A, Thomas A, Thomas N, Jeyagopal, N, Woznitza, N. Chest reporting by radiographers: Findings of an accredited postgraduate programme. *Radiography* [IN PRESS] doi: 10.1016/j.radi.2014.01.003

44. Department of Health. The Operating Framework for the NHS in England 2012/13. London: Department of Health, 2011 24 November 2011.

45. Department of Health. The Handbook to the NHS Constitution for England. London: Department of Health; 2012.

46. National Clinical Imaging Advisory Group. Implementing 7 Day working inImaging Departments: GoodPractice Guidance. Department of Health, 2012.

47. Royal College of Radiologists. Cancer Multidisciplinary Team Meeting – Standards for Clinical Radiologists. London: Royal College of Radiologists, 2005 Contract No.: BFCR(05)9.

48. Radiology Service Improvement Team. Radiology: A National Framework for Service Improvement. Department of Health, 2003.

49. Francis R. Report of the Mid Staffordshire NHS Foundation Trust Public Inquiry Executive Summary. London: 2013.