J R Coll Physicians Edinb 2014; 44:14–9
http://dx.doi.org/10.4997/JRCPE.2014.104
© 2014 Royal College of Physicians of Edinburgh

CLINICAL

Optimising neuroimaging effectiveness in a district general hospital

[1]MO McCarron, [2]C Wade, [3]P McCarron
[1]Consultant Neurologist, Department of Neurology, Altnagelvin Hospital, Derry; [2]Medical Secretary, Department of Neurology, Altnagelvin Hospital, Derry; [3]Professor, Department of Public Health Medicine and Epidemiology, Queen's University, Belfast, UK

ABSTRACT

Background: Diagnostic accuracy in neurology frequently depends on clinical assessment and neuroimaging interpretation. We assessed neuroimaging discrepancy rates in reported findings between general radiologists and neuroradiologists among patients from a district general hospital (DGH).

Methods: A neuroradiologist's report was sought on selected DGH patients over 28 months. Pre-planned outcomes included comparisons of primary findings (main diagnosis or abnormality), secondary findings (differential diagnoses and incidental findings) and advice from neuroradiologists for further investigations.

Results: A total of 233 patients (119 men and 114 women), mean age 47.2 (SD 17.8) years were studied: 43 had a computed tomography (CT) brain scan only, 37 had CT and magnetic resonance imaging (MRI) scans and 153 had only MRI scans. Discrepancies in the primary diagnosis/abnormality were identified in 33 patients (14.2%). This included 7 of 43 patients (16.3%) who had a CT brain scan as their only neuroimaging. Secondary outcomes differed in 50 patients (21.5%). Neuroradiologists recommended further neuroimaging for 29 patients (12.4%). The most common discrepancies in the primary diagnosis/abnormality were misinterpreting normal for hippocampal sclerosis and missed posterior fossa lesions. There was no evidence of temporal changes in discrepancy rates.

Conclusions: Selecting CT and MR neuroimaging studies from general hospitals for reviewing by neuroradiologists is an important and effective way of optimising management of neurological patients.

Correspondence to ***M McCarron***
Department of Neurology
Altnagelvin Hospital
Derry BT47 6SB
N Ireland

tel. ***+44 (0)287 134 5171***
e-mail
markmccarron@doctors.org.uk

KEYWORDS Neuroimaging, district general hospital, neurology, effectiveness

DECLARATION OF INTERESTS No conflicts of interest declared.

INTRODUCTION

As neuroimaging technology advances, improvements in patient diagnosis and management with quality-assured reporting of findings should follow. However, human error is inevitable in medicine, including radiology; discrepancies occur in 2–20% of reports.[1] Unlike many physical signs, radiology scans remain unchanged and can be retrieved and reviewed to provide second opinions and assess discrepancy rates.[2,3] With increasing emphasis on patient safety and processes of care,[4–8] frameworks for addressing radiological discrepancies in a formative process with educational feedback are emerging.[9,10]

BACKGROUND

Changes in different aspects of healthcare can have numerous consequences, which initially may not be anticipated. For example, in the UK one result of the European working time directive and modernising medical careers on NHS resources was the introduction of the role of physician assistant, as currently exists in the USA.[11] In the same way, increasing numbers of magnetic resonance imaging (MRI) scanners and the rise in the number of neurologists working in district general hospitals (DGH) in the UK have triggered an evaluation of the role of neurologists[12] and the assessment of the quality of neuroimaging reports provided by general radiologists.[2] The appointment of a neurologist in our DGH (along with informal opinions of other neuroradiologists in our organisation) prompted a systematic examination of the quality assurance processes related to local neuroimaging reports and the potential usefulness of a second reporting system from neuroradiologists. We consider this an important issue as many neurological inpatients in the UK are managed in DGHs.

Measuring the effectiveness of a service is a recognised aspect of assessing service quality.[13] We previously measured neuroimaging discrepancies in a DGH and completed an audit cycle.[14,15] In the current update, we report: (i) neuroimaging discrepancy rates for 2007–9;

(ii) trends in discrepancy rates to measure the ongoing impact of a second reporting service; and (iii) identify recurrent areas of discrepancies and features of the service amenable to development.

METHODS

Neurological patients with any neuroimaging (computed tomography [CT] of brain or MRI of brain or spine) and attending one neurologist from 1 January 2007 until 30 April 2009 were eligible for involvement in this study if a second report on the neuroimaging was requested. The initial report came from general radiologists in the DGH and the second report from neuroradiologists working at a tertiary referral hospital. Selection criteria for an opinion from a neuroradiologist remained constant between the studies[14,15] and included the following: (i) a report from a general radiologist recommending a neuroradiologist's opinion; (ii) after personally reviewing the neuroimaging there was concern on the part of the neurologist about the presence or nature of a structural abnormality; (iii) doubt from the neurologist of the reported differential diagnosis or lack of diagnosis from the report provided by general radiologists. This last indication included reports from general radiologists in which refinement of the differential diagnosis was deemed desirable.

Four neuroradiologists provided written second opinion reports. They had worked between two and 24 years as consultant neuroradiologists. The 20 general radiologists had worked between three and 21 years as consultant radiologists. Two general radiologists performed double-reporting. They provided a report consensus after both had individually studied the neuroimaging. The neurologist's workload remained stable.

OUTCOME MEASURES

Primary outcome

The primary outcome measure was the frequency of disagreement between neuroradiologists and general radiologists in the primary diagnosis/abnormality of each report.

Secondary outcomes

Incidental findings such as brain atrophy, pineal or arachnoid cysts and differences in differential diagnoses were all categorised as secondary findings. Other secondary outcomes included the frequency of combined disagreements in primary and secondary findings, the proportion of patients in whom neuroradiologists recommended additional neuroimaging investigations, which had not been mentioned by general radiologists, and the frequency of disagreement in the primary diagnosis/abnormality in patients with CT brain-only imaging. As we were aware of anecdotal evidence that discrepancies in reporting CT brain scans had occurred, we were prompted to perform this subgroup analysis. Discrepancies were itemised and classified as: missed abnormality, normal misinterpreted as abnormal, or misinterpreted lesions (e.g. perivascular space misinterpreted as an infarct). Location of discrepancies (hemisphere, posterior fossa, or spinal) was recorded. Details of abnormal vessels were also recorded.

The results were then compared with two previous studies[14,15] and with an independent study from neuroradiologists working in Northern Ireland.[2]

STATISTICAL ANALYSES

The number and proportion of patients in whom neuroimaging discrepancies were identified by neuroradiologists were calculated with 95% confidence intervals (CI) for the proportions, using the Wilson procedure with a correction for continuity. The Fisher exact test was used for comparing categorical values.

RESULTS

Of 233 patients there were 119 men and 114 women, mean age 47.2 (SD 17.8) years; 43 patients had CT brain scans only, 153 had MRI brain and/or spine scans only and 37 had both CT and MRI scans. Primary diagnosis/abnormality discrepancies were identified in 33 patients (14.2%). Secondary outcomes including secondary findings or differential diagnosis discrepancies, CT-only primary diagnosis/abnormality discrepancies and the frequency of further recommended neuroradiological investigations are listed in Table 1. The individual itemised primary diagnosis/abnormality discrepancies

TABLE 1 Discrepancy outcomes in neuroimaging

	2007–9 n=233	
Outcomes	**% (number)**	**95% confidence intervals**
Differences in primary diagnosis/ abnormality	14.2 (33)	10.1–19.5
Secondary finding/ differential diagnosis	21.5 (50)	16.5–27.4
Primary or secondary finding differences	33.5 (78)	27.5–40.0
Further investigation recommended	12.4 (29)	8.6–17.6
Computed tomography-only patients primary finding differences	16.3 (7 of 43)	7.3–31.3

© 2014 RCPE

TABLE 2 Itemised discrepancies between the general radiologist's diagnosis and that of the neuroradiologists

General radiologist finding	Neuroradiologist finding
Magnetic resonance imaging	
Cerebrovascular	
Strongly suggests multiple sclerosis	Cystic infarcts in basal ganglia and pons
Arteriovenous malformation	Chronic left transverse sinus thrombosis
Haemorrhage due to an angioma	Right frontal infarct and ischaemia
Normal	Left superior and middle temporal gyri cystic infarcts
Normal magnetic resonance imaging (MRI) brain and MR venography	Abnormal left internal jugular vein
No pontine lesions mentioned	Cystic pontine infarcts
Normal	Right internal carotid artery dissection
Right thalamic gliosis	Bilateral cerebellar, right thalamic and acute vermian infarctions
Inflammatory	
Small localized syrinx	Long-standing cervical lesion probably inflammatory
Mid-brain glioma	Left medial longitudinal fasciculus inflammatory demyelination
Normal	
Right temporal postictal oedema	Normal
Bilateral uncus/hippocampus postictal oedema	Normal
Possible right hippocampal sclerosis	Normal
Right postictal oedema or mesial sclerosis	Normal
Mesial temporal sclerosis	Normal medial temporal lobes
Hyperintense conus – transverse myelitis	Normal cauda equina
Infection	
Infarctions with high probability of frontal abscess	Infarctions secondary to meningitis
New lesions not related to meningitis	Old brain changes from bacterial meningitis
Tumour	
No skull vault metastases mentioned	Skull vault metastases
Miscellaneous	
Mild tonsillar herniation	Retroflexed odontoid peg. No tonsillar herniation
Normal	Right cerebral destructive lesion
No intracranial enhancement	Features of intracranial hypotension
Non-obstructive hydrocephalus	Obstructive hydrocephalus with colloid cyst
Hippocampal sclerosis	Cyst at lateral end of hippocampal sulcus
Multiple sclerosis lesions periventricularly perpendicular to ventricle, corpus callosum, right mid brain	Thalamic change suspicious for Wernicke encephalopathy and non-specific nodular lesions
Normal	Acute hypoxic ischaemic encephalopathy or carbon monoxide poisoning
Computed tomography-only	
Cerebrovascular	
No focal brain lesion	Subcortical white matter lesions
Haemorrhagic infarct	Left frontal intracerebral haemorrhage, probably cerebral amyloid angiopathy
Normal	Left posterior parietal ischaemia or trauma
Right basal ganglia infarct	Right inferior basal ganglia perivascular space
No focal lesion	Middle cerebral artery dot sign
Normal	Ischaemic pons and focus in right occipital lobe
Normal	
Ischaemic left basal ganglia, external capsule and insula	Normal

are listed in Table 2. Illustrative examples of discrepancies in the primary diagnosis/abnormality category are shown in Figure 1A–C.

The location and type of discrepancies among primary diagnoses/abnormalities are listed in Table 3. One-third of discrepancies occurred from vascular, spinal or posterior fossa lesions. Missed lesions, misinterpretation of abnormalities and misinterpretation of normal structures as abnormal were distributed in similar proportions. Recurring disagreements included misinterpretation of hippocampal architecture or cysts as hippocampal sclerosis or postictal oedema (n=6) and missed posterior fossa lesions (n=3). Double reporting by some general radiologists reduced but did not eliminate primary finding discrepancies (9%, 95% CI, 2%–30% versus 15%, 95% CI, 10%–20%, p=0.55). The neurologist had requested a neuroradiologist's report in 31 of the identified 33 primary discrepancies while general radiologists had suggested a neuroradiologist's report in the other two patients.

© 2014 RCPE

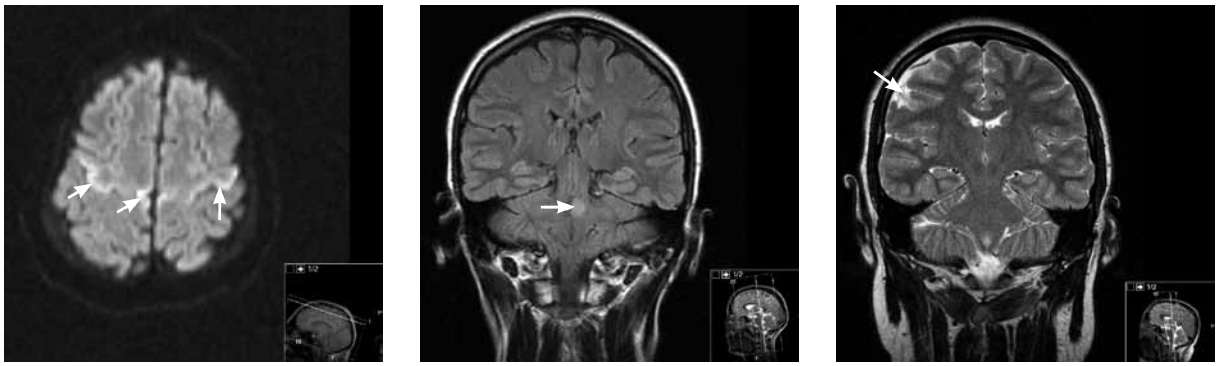


FIGURE 1A–C **(A)** Missed hypoxic ischaemic change bilaterally demonstrated on axial diffusion weighted imaging magnetic resonance imaging (MRI) scan of brain (arrows). **(B)** Demyelination in left pons – misinterpreted as possible glioma on coronal T2-FLAIR image (arrow). **(C)** Missed destructive right cortical lesion demonstrated on coronal T2 MRI scan (arrow).

TABLE 3 Reporting and neuroradiological characteristics among 33 primary finding discrepancies

Characteristic	Number (%)
Category of discrepancy	
Supratentorial	22 (67)
Posterior fossa	5 (15)
Spine	2 (6)
Vascular (vessel only)	4 (12)
Type of discrepancy	
Missed abnormality	12 (36)
Misinterpreted abnormality	11 (33)
Normal misinterpreted as abnormal	10 (30)
Primary discrepancies and number of reporting general radiologists	
Single reporter	31 of 210 (15)
Double general radiologist	2 of 23 (9)*
Radiology personnel	
Total number of reporting general radiologists	20
Total number of neuroradiologists	4
*χ^2 test p=0.55	

The findings of this study and two previous studies are summarised in Figure 2. Overlapping confidence intervals demonstrate little change in the discrepancy rate of primary and secondary findings with time. Additional investigations were consistently recommended by neuroradiologists in more than 10% of patients. The results of these studies are comparable to an independent study of second opinions performed independently by neuroradiologists working in Northern Ireland.[2]

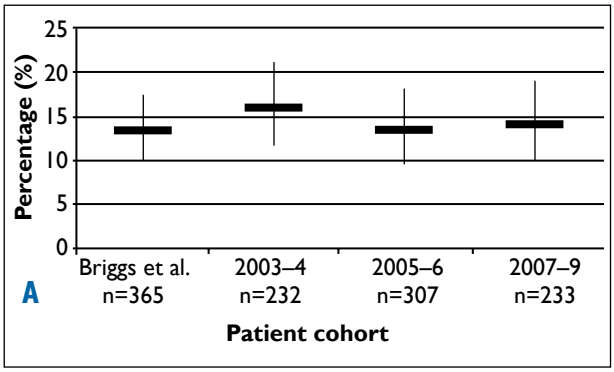
DISCUSSION

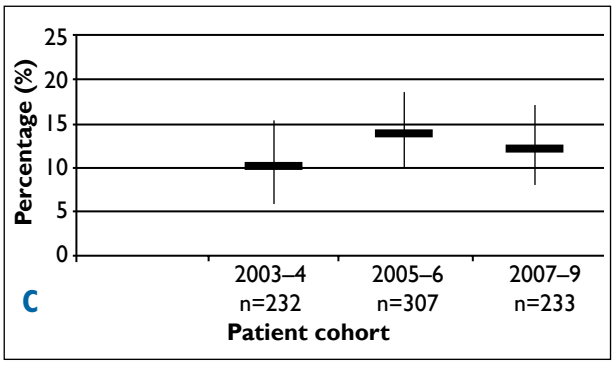
This study demonstrated that selected second reporting from neuroradiologists can improve diagnostic accuracy and optimise management of neurological patients in a DGH. Multidisciplinary involvement as recorded in previous studies[2,14,15] continues to yield similar efficacy in revising reports and justifies the local neurology/radiology investment in this exercise. The effectiveness of a service is a recognised feature of quality.

The published literature has many reports of very low discrepancy rates between general or trainee radiologists and neuroradiologists.[16] In a large study in the US of over 2,000 scans, clinically relevant discrepancies were reported in just 1.8% among faculty neuroradiologists.[17] Clinically relevant discrepancies have a similarly low frequency rate of less than 2% in many radiology subspecialties.[18] In addition, in a stroke study double-reading of CT brain scans was not thought to be an efficient method to substantially improve imaging health quality outcomes.[19] However, these studies used unselected patients. Our higher rates of discrepancy from both MRI (brain and spine) and CT (brain) scans result from the selection of patients, mainly by neurology, for a neuroradiologist's report. This process appears to yield proportionately better diagnostic accuracy than unselected studies. A report from a Canadian tertiary referral centre for head and neck cancer found that management changed in more than one-third of patients following a neuroradiologist's second opinion review.[20] This study and our study support the need for appropriate selection of patients for a second opinion service to be worthwhile.

Our DGH has a tradition of learning from feedback.[21] The neuroimaging discrepancies are continuously fed back to the local radiology department and multi-disciplinary meetings involving neurologists, neuroradiologists and general radiologists have evolved in an iterative process. The apparent lack of any improvement may have a number of contributing factors such as too many general radiologists reporting on too few patients with neuroimaging. Although somewhat speculative, this may cause spectrum bias, which is the performance of a diagnostic test according to the casemix of the population tested.[22] Casemix is a mixture

© 2014 RCPE





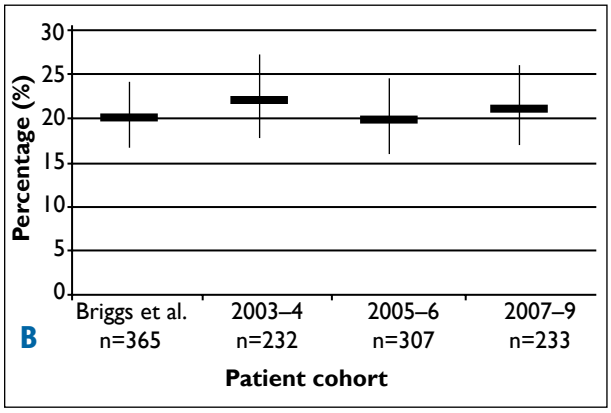


FIGURE 2A–C **(A)** Summary of primary diagnosis/abnormality discrepancy rates, **(B)** secondary finding discrepancy rates, and **(C)** frequency of recommendations for further neuroradiological investigations in current and previous studies with 95% confidence intervals.

of disease severity and prevalence. In addition, our current real practice study was performed over 28 months, four months longer than our second study[15] but had fewer patients. This may reflect improvement in that there was apparently less need to seek second reports from neuroradiologists. These issues highlight some of the complexities in demonstrating quality improvement in a neurological service; similar discrepancy rates may in fact hide increasing effectiveness of our developing service. The working experiences of the general radiologists and neuroradiologists were similar; all were NHS consultants. In addition, we previously demonstrated that rates of discrepancy reports were not significantly different among neuroradiologists at our tertiary centre or among general radiologists in our hospital.[15]

Previous reports have encouraged research into opportunities for improving healthcare other than focusing on death as an outcome.[23] Others have recognised that internally-driven efforts may be required to demonstrate quality improvement.[8] An improvement-focused culture is emerging[4] and many radiologists believe that system improvements offer greatest quality benefits.[1]

Neurologists have to adapt to a changing work environment by contributing to robust audit measures with formative feedback to their multidisciplinary colleagues to improve service development. Neurologists can assist in clinical diagnostic accuracy[12,24] and can shorten length of stay in a teaching hospital.[25] A neurologist's effectiveness in this team approach requires further examination and refinement.

Limitations in our study include the lack of a gold standard in radiology. It is however accepted that the best available quality standard for neuroimaging is usually derived from neuroradiologists. Although a single centre study, our results have been validated in an independent study performed by neuroradiologists working in Northern Ireland using similar methodology.[2] The high discrepancy rates in our studies may not only reflect our selection methods, but also previous under reporting of discrepancies within general radiology. Independent assessments are required to avoid bias, as previously demonstrated in carotid endartectomy surgery in which neurologists detected a higher rate of surgical complications than vascular surgeons.[26] Our team approach is proving helpful in identifying not only reports of misinterpreted abnormal findings and reports of normal anatomy misinterpreted as abnormal, but has been particularly helpful for identifying missed lesions, which may not have been realised if selection for neuroradiologists' opinions had been restricted to general radiologists.

While double reading of mammography increases cancer detection rates,[27] debate over second opinions in neuroradiology continues. In our neuroimaging study double reading by general radiologists may still incur discrepancy, although this was based on a sample that was too small to permit any further interpretation. Double reading of all neuroimaging scans by neuroradiologists has been deemed by some to be inefficient.[19] However, Zan et al.[3] argue that a neuroradiologist's review of outside studies benefits patients. They reported a 7.7% 'clinically important' discrepancy rate, most of which were discrepancies in detecting abnormalities rather than interpreting identified findings. Had our work involved consecutive unselected patients, we previously estimated a discrepancy rate in the primary diagnosis/abnormality to be around 6%.[14] A

© 2014 RCPE

formal specialist second opinion has been recommended by neuroradiologists in Northern Ireland, but the selection criteria have not been clearly described.[2] Both these studies represent a view from tertiary centres; development of local DGH services are required to maximise the diagnostic accuracy. Our studies of selective clinical audit at DGH level[14,15] demand input from neurologists working with general radiologists and neuroradiologists to offer neurological patients better quality in the process of their overall local care. Quality control assessments among university-based neuroradiologists suggest a clinically significant discrepancy rate in both CT and MR imaging of 2%.[10]

Future areas of research and development should examine the effectiveness of double reporting of neuroimaging among general radiologists, efforts to minimise spectrum bias and the impact of local general radiologists with a special interest in neuroimaging. In this way robust local neuroimaging services can be further developed.

Acknowledgements

The authors are grateful to the many patients and colleagues in neuroradiology and general radiology, who assisted with this study.

REFERENCES

1 Goddard P, Leslie A, Jones A et al. Error in radiology. *Br J Radiol* 2001; 74:949–51.

2 Briggs GM, Flynn PA, Worthington M et al. The role of specialist neuroradiology second opinion reporting: is there added value? *Clin Radiol* 2008; 63:791–5. http://dx.doi.org/10.1016/j.crad.2007.12.002

3 Zan E, Yousem DM, Carone M et al. Second-opinion consultations in neuroradiology. *Radiology* 2010; 255:135–41. http://dx.doi.org/10.1148/radiol.09090831

4 Kaminski GM, Britto MT, Schoettker PJ et al. Developing capable quality improvement leaders. *BMJ Qual Saf* 2012; 21:903–11. http://dx.doi.org/10.1136/bmjqs-2012-000890

5 Lilford RJ, Brown CA, Nicholl J. Use of process measures to monitor the quality of clinical practice. *BMJ* 2007; 335:648–50. http://dx.doi.org/10.1136/bmj.39317.641296.AD

6 Bever CT, Holloway RG, Iverson DJ et al. Invited article. Neurology and quality improvement: an introduction. *Neurology* 2008; 70:1636–40. http://dx.doi.org/10.1212/01.wnl.0000310989.84987.88

7 Nicholl DJ, Yap CP, Cahill V et al. The TOS study: can we use our patients to help improve clinical assessment? *J R Coll Physicians Edinb* 2012; 42:306–10. http://dx.doi.org/10.4997/JRCPE.2012.405

8 Pronovost PJ, Hudson DW. Improving healthcare quality through organisational peer-to-peer assessment: lessons from the nuclear power industry. *BMJ Qual Saf* 2012; 21:872–5. http://dx.doi.org/10.1136/bmjqs-2011-000470

9 Brady A, Laoide RO, McCarthy P et al. Discrepancy and error in radiology: concepts, causes and consequences. *Ulster Med J* 2012; 81:3–9.

10 Babiarz LS, Yousem DM. Quality control in neuroradiology: discrepancies in image interpretation among academic neuroradiologists. *AJNR Am J Neuroradiol* 2012; 33:37–42. http://dx.doi.org/10.3174/ajnr.A2704

11 Ross N, Parle J, Begg P et al. The case for the physician assistant. *Clin Med* 2012; 12:200–6. http://dx.doi.org/10.7861/clinmedicine.12-3-200

12 McColgan P, Carr AS, McCarron MO. The value of a liaison neurology service in a district general hospital. *Postgrad Med J* 2011; 87:166–9. http://dx.doi.org/10.1136/pgmj.2010.106971

13 Black N. Time for a new approach to assessing the quality of hospitals in England. *BMJ* 2013; 347:f4421. http://dx.doi.org/10.1136/bmj.f4421

14 McCarron MO, Sands C, McCarron P. Quality assurance of neuroradiology in a District General Hospital. *QJM* 2006; 99:171–5. http://dx.doi.org/10.1093/qjmed/hcl012

15 McCarron MO, Sands C, McCarron P. Neuroimaging reports in a general hospital: results from a quality-improvement program. *Clin Neurol Neurosurg* 2010; 112:54–8. http://dx.doi.org/10.1016/j.clineuro.2009.10.009

16 Cooper VF, Goodhartz LA, Nemcek AA Jr et al. Radiology resident interpretations of on-call imaging studies: the incidence of major discrepancies. *Acad Radiol* 2008; 15:1198–204. http://dx.doi.org/10.1016/j.acra.2008.02.011

17 Viertel VG, Babiarz LS, Carone M et al. Quality control in neuroradiology: impact of trainees on discrepancy rates. *AJNR Am J Neuroradiol* 2012; 33:1032–6. http://dx.doi.org/10.3174/ajnr.A2933

18 Ruma J, Klein KA, Chong S et al. Cross-sectional examination interpretation discrepancies between on-call diagnostic radiology residents and subspecialty faculty radiologists: analysis by imaging modality and subspecialty. *J Am Coll Radiol* 2011; 8:409–14. http://dx.doi.org/10.1016/j.jacr.2011.01.012

19 Jordan YJ, Jordan JE, Lightfoote JB et al. Quality outcomes of reinterpretation of brain CT studies by subspecialty experts in stroke imaging. *AJR Am J Roentgenol* 2012; 199:1365–70. http://dx.doi.org/10.2214/AJR.11.8358

20 Lysack JT, Hoy M, Hudon ME et al. Impact of neuroradiologist second opinion on staging and management of head and neck cancer. *J Otolaryngol Head Neck Surg* 2013; 42:39. http://dx.doi.org/10.1186/1916-0216-42-39

21 O'Kane MJ, McManus P, McGowan N et al. Quality error rates in point-of-care testing. *Clin Chem* 2011; 57:1267–71. http://dx.doi.org/10.1373/clinchem.2011.164517

22 Ransohoff DF, Feinstein AR. Problems of spectrum and bias in evaluating the efficacy of diagnostic tests. *N Engl J Med* 1978; 299:926–30. http://dx.doi.org/10.1056/NEJM197810262991705

23 Hogan H, Healey F, Neale G et al. Preventable deaths due to problems in care in English acute hospitals: a retrospective case record review study. *BMJ Qual Saf* 2012; 21:737–45. http://dx.doi.org/10.1136/bmjqs-2011-001159

24 Douglas MR, Peake D, Sturman SG et al. The inpatient neurology consultation service: value and cost. *Clin Med* 2011; 11:215–7. http://dx.doi.org/10.7861/clinmedicine.11-3-215

25 Forbes R, Craig J, Callender M et al. Liaison neurology for acute medical admissions. *Clin Med* 2004; 4:290. http://dx.doi.org/10.7861/clinmedicine.4-3-290

26 Rothwell PM, Slattery J, Warlow CP. A systematic review of the risks of stroke and death due to endarterectomy for symptomatic carotid stenosis. *Stroke* 1996; 27:260–5. http://dx.doi.org/10.1161/01.STR.27.2.260

27 Helvie M. Improving mammographic interpretation: double reading and computer-aided diagnosis. *Radiol Clin North Am* 2007; 45:801–11. http://dx.doi.org/10.1016/j.rcl.2007.06.004

© 2014 RCPE