Concordance between a gastrointestinal consultant radiologist, a consultant radiologist and qualified reporting radiographers interpreting abdominal radiographs

Moth, A., Benning, J., Glover, J, Brown, V., Pittock, L., Woznitza, N. and Piper, K.

A. Moth, J. Benning, J. Glover, V. Brown, L. Pittock, N. Woznitza, K. Piper,

Concordance between a gastrointestinal consultant radiologist, a consultant radiologist and qualified reporting radiographers interpreting abdominal radiographs,

Radiography,

Volume 29, Issue 2,

2023,

Pages 408-415,

ISSN 1078-8174,

https://doi.org/10.1016/j.radi.2022.12.008.

(https://www.sciencedirect.com/science/article/pii/S1078817422002164)

Anonymised manuscript:

Introduction:

Radiographer reporting of radiographs is well established in the United Kingdom. Although preliminary image interpretation by radiographers was recognised in the 1980's[1], the Society and College of Radiographer's position was that radiographers should be extending their skills in providing written reports.[2] By 2012 it was acknowledged that reporting radiographers (RRs) add real value to reporting services in the UK.[3] Today there is an ever growing radiographer reporting establishment and more are required to report imaging studies.[4,5] This has no doubt been accelerated by the severe shortage of radiologists[6] but with major reform of diagnostic services planned for the next 5 years, working across traditional boundaries is in the NHS long-term plan. The recommendations are for radiographers to report at least 50% of plain x-rays.[7]

A number of studies have evaluated radiographer reporting accuracy of skeletal radiographs.[8,9] Radiographers demonstrated a high level of accuracy, sensitivity and specificity for skeletal trauma reports in a large UK based study.[10] A meta-analysis of 12 studies found that radiographers accurately report radiographs in clinical practice with no significant difference between radiographers and radiologists[11].

The abdomen x-ray (AXR) has been reported to be overused and unhelpful.[12] Many studies have questioned its continued use in clinical practice given the low diagnostic yield.[13-17] Smith *et al*.[18] state it should be reserved for specific conditions. Others advocate its continued use for bowel obstruction, identification of foreign bodies,

location of catheters and follow up urinary stones[19] and the Royal College of Radiologists (RCR) guidelines also continue to justify the AXR for certain pathological conditions.[20] Despite CT scanning being widely available and stated limited value of the AXR, it remains a commonly requested examination and is likely to remain so for specific conditions well into the future.

The AXR can be difficult to interpret [21] and the chest x-ray is considered a complex imaging investigation[22]. Therefore, it could be assumed studies comparing consultant radiologists with reporting radiographers in chest and abdomen reporting may yield similar results. Woznitza *et al*.[22] compared the diagnostic accuracy of radiographer chest x-ray interpretation to consultant radiologists. This incorporated a range of pathologies, and although it did not take place in the clinical setting, it showed that reporting radiographer accuracy was similar to that of consultant radiologists. One study specifically analysed AXR interpretation by radiographers compared to a radiologist. However, the scope of this study was limited in several ways: the sample size of AXRs, training of radiographers (not reporting radiographers) and range of pathologies included.[23]

Studies have shown that radiographers can accurately report musculoskeletal and chest x-rays but there is paucity of research exploring the performance of radiographers reporting AXRs in the clinical setting. The aim of this study was to explore the performance of radiographers in a District General Hospital reporting AXRs.

Objectives:

The principal objective of this research was to assess the interobserver agreement in AXR reports for a non-gastrointestinal consultant radiologist and reporting radiographers compared to an index gastrointestinal consultant radiologist. As this research was intended to reflect clinical practice, it also aimed to determine the effect of discordant reports on patient management and outcome.

Methods:

Participants:

Convenience sampling was used in this study. An independent gatekeeper approached the participants to ascertain an expression of interest in taking part. Three reporting radiographers, one consultant radiologist, one index gastrointestinal consultant radiologist and one colorectal consultant surgeon agreed to participate in the study. The three radiographers in this study had between 27 and 31 years experience in general radiography and all had completed a post graduate programme in AXR reporting. Years of experience independently reporting AXRs ranged from 1 to 3 years. The consultant radiologist had over 30 years experience as a radiology consultant and regularly undertakes radiographic reporting sessions. The index radiologist had 6 years experience as a specialist consultant. The surgeon had 2.5 years experience as a consultant actively participating in multidisciplinary team meetings.

Sample size:

This study is based on a standard superiority test with values of 0.05 and 0.2 for type 1 and type 2 errors and a standard 5% inferiority difference which is acceptable in clinical

practice.[25] 126 AXR's were required to be reported by the radiographers and the consultant radiologist to adequately power the study.[25]

Data collection:

As the study was intended to reflect clinical practice, existing AXR reports made by the radiographers were randomly collected. Data was collected over a 10 month period. Only examinations that had no previous abdominal imaging (radiographs, ultrasound and cross sectional imaging) were included in the study because the consultant radiologist and index radiologist did not have access to previous imaging when rereporting the AXRs. Using Microsoft Excel, a random sample of 42 AXR reports for each radiographer was included to avoid limited selection bias.

All 126 AXRs were pseudonymised by removing patient identifying data in a specially created work folder on a Philips Picture Archiving Communications System (PACS). The gender, age and clinical history of the patient for each AXR was provided in a separate workbook. The index and consultant radiologists were asked to report the AXRs blinded to the original report. The index radiologist reports were then compared against the consultant radiologist and radiographer reports for observer agreement.

A surgeon was asked to assess all the reports made by the index radiologist compared to the radiographers (group 1) and index radiologist compared to the consultant radiologist (group 2). 30 reports from group 1 were included in group 2 for comparison and vice versa so that terminology differences between the radiographers and the consultant radiologist could not influence the surgeon's decision. It was decided to include all reports, including those that were in apparent agreement so as not to bias

the surgeon's decision on scoring.[29] When comparing the reports, the surgeon was provided with the gender, age and clinical history of the patient, the index and observer reports. The surgeon was aware of which report the index radiologist had made but blinded to the author of the comparative report. The scoring system was adapted from a similar study [27] and scored as follows:

1 The index radiologist and observer reports agree.

2 Minor disagreement between the index radiologist and observer reports but no change in patient management.

3 Major disagreement between the index report and observer reports which would have resulted in a change in patient management.

Following scoring, all major disagreements were highlighted to the referrer of the AXR for appropriate patient management.

Statistical analysis:

Percentages with 95% confidence intervals applying the Wilson procedure [30] were used to compare the radiographers and consultant radiologist with the index radiologist. The difference in proportions test (z score) was used and is appropriate for larger sample sizes with a normal distribution.[31] This was calculated using the Vassar Stats package applying the two tailed probability value.[32] It highlighted any significant difference in overall, minor and major disagreement between the radiographers and consultant radiologist compared to the index radiologist. [25]

Ethics:

Ethical approval was obtained from Canterbury Christ Church University prior to study commencement. Participant consent and information was provided but patient consent was not required. The Research and Development Department at Ashford and St Peter's Hospitals NHS Trust considered the study met the definition of service evaluation and did not require formal NHS Research Ethics Committee or Health Research Authority approvals. Local confirmation of capacity and capability was not applicable.

Results:

A total of 991 AXRs were reported by the radiographers between January and October 2021 (Figure 1). After excluding examinations with previous abdominal imaging, 259 AXRs were eligible for inclusion in the study. To obtain the sample size for each radiographer, 133 AXR reports were randomly excluded so that 42 AXR reports were included for each radiographer. A total of 126 AXRs were included in the final study which were rereported by the index radiologist and consultant radiologist. Interobserver agreement was then assessed by the consultant surgeon.

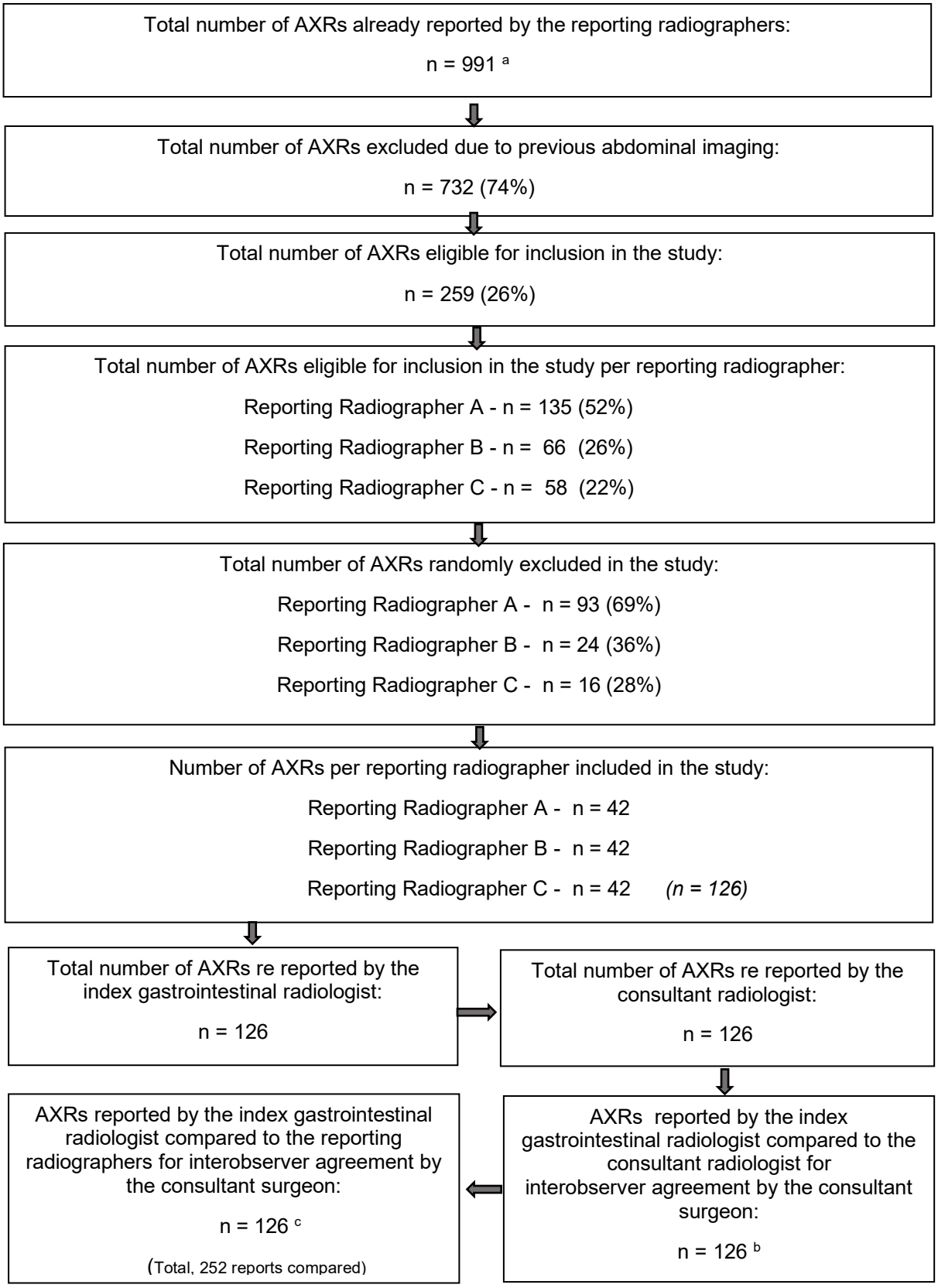
An equal number of male and female patients were included in the study with a mean age of 57 years. The referral source for those AXRs included in the study are shown in Table 1. The majority were from the emergency department (n=112/126) followed by in-patients (n=9/126) and general practice (n=5/126). No outpatients were included. There are few indications for requesting an AXR in the outpatient setting [20, 33] and thus it is unsurprising that none were randomly selected. The reasons for referral are shown in Table 1. The most common referral was to investigate suspected bowel obstruction

(41%), followed by abdominal pain (9.5%). These are common reasons for requesting an AXR in clinical practice [20, 33-35]

The overall agreement for the consultant radiologist compared to index radiologist was 71.4% (95% CI, 62.6 - 79) and for the radiographers compared to the index radiologist was 74.6% (95% CI, 66 - 81.7). Major disagreements, where the report would have resulted in change in patient management, was 18.3% (95% CI, 12.2 - 26.3) for the consultant radiologist compared to the index radiologist and 13.5% (95% CI, 8.3 - 21) for the radiographers compared to the index radiologist (Table 2; figures 2a and 2b). There was no significant difference between the consultant radiologist and radiographers in identifying a normal examination ($z = -1.21$ and $p = 0.23$). Overall agreement between the consultant radiologist and radiographers was similar ($z = -0.57$ and $p = 0.57$). No significant difference was found for major or minor disagreements between the consultant radiologist and radiographers (Figures 2a and 2b). Figures 3a and 3b show no significant difference in major disagreement between the radiographers compared to the consultant radiologist.

Reasons for the major disagreements between the reports made by the radiographers and consultant radiologist are shown in table 3. Faecal loading was the most common error with a higher tendency to overcall across both groups (3.6% compared to 2.4%); the radiographers tended to overcall faecal loading. Excluding faecal loading in the major disagreements did not significantly influence performance between both groups ($z = -1.05$ and $p = 0.29$).

Figure 1: AXRs included in the study:



[a] Data collected over a period of 10 months.

[b,c] 30 reports moved to the other group when being assessed for agreement by the consultant surgeon.

Table 1: Referral source and clinical details of patients included:

Referral source	*Value*	*(%)*
Outpatient / n (%)	0/0	(0)
In Patient / n (%)	9/126	(7)
GP / n (%)	5/126	(4)
Emergency Department / n (%)	112/126	(89)
Reasons for referral	***Value***	*(%)*
? Bowel obstruction, n (%)	52	(41)
? Small bowel obstruction, n (%)	2	(1.6)
? Colitis / inflammation, n (%)	1	(0.8)
? Constipation, n (%)	4	(3.2)
? Obstruction and perforation, n (%)	10	(8)
? Gastroenteritis, n (%)	1	(0.8)
? Foreign body, n (%)	6	(4.7)
? Toxic megacolon, n (%)	1	(0.8)
? Pseudo-obstruction, n (%)	1	(0.8)
? Faecal impaction, n (%)	2	(1.6)
? Perforated ulcer, n (%)	1	(0.8)
? Volvulus, n (%)	2	(1.6)
? Abdominal infection / abscess, n (%)	1	(0.8)
? Distended loops of bowel, n (%)	3	(2.4)
? Perforation, n (%)	4	(3.2)
? Renal tract stone, n (%)	3	(2.4)
? Bowel wall thickening, n (%)	1	(0.8)
? Faecal loading, n (%)	5	(4)
Umbilical pain and vomiting, n (%)	1	(0.8)
Right upper quadrant pain, n (%)	1	(0.8)
Right Iliac fossa pain, n (%)	1	(0.8)
Rule out an acute abdomen, n (%)	1	(0.8)
Left lower quadrant pain, n (%)	1	(0.8)
Generalised abdominal tenderness, n (%)	1	(0.8)
Abdominal pain, n (%)	12	(9.5)

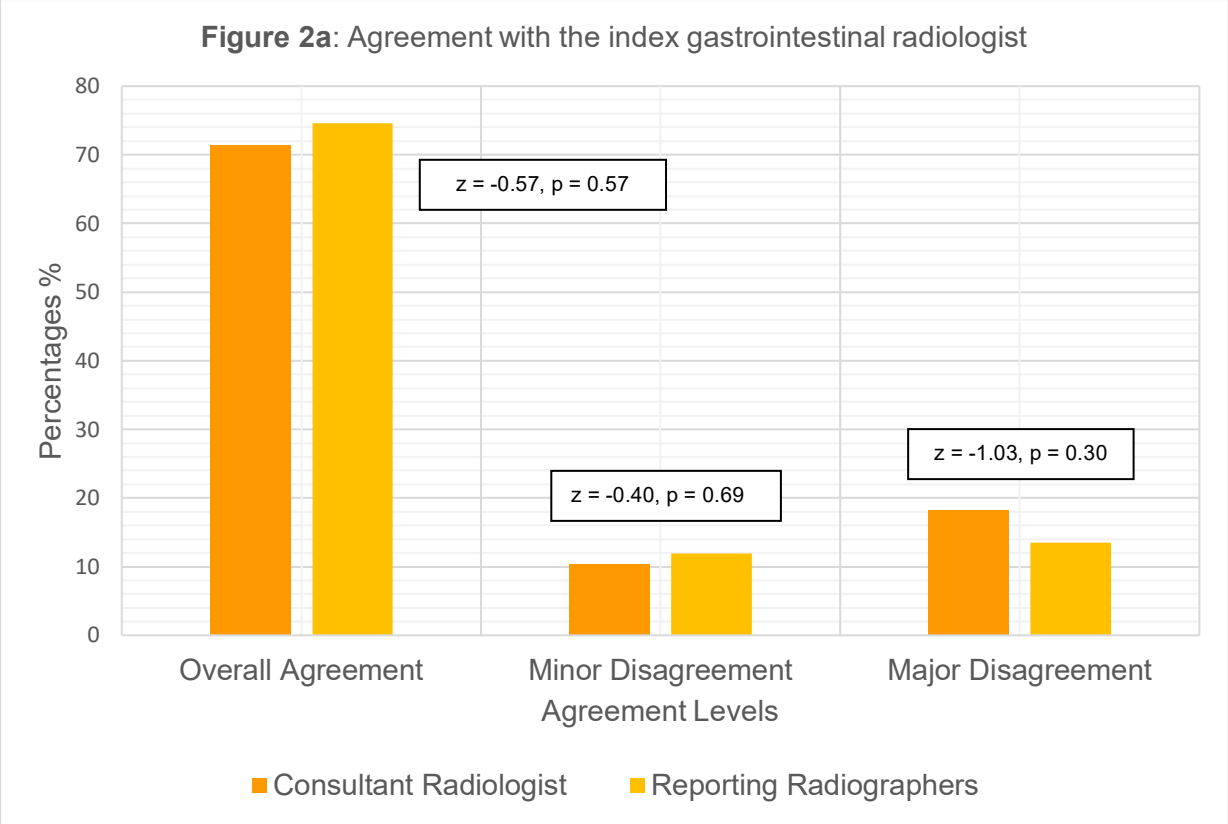
Table 1: continued:

Reasons for referral	*Value*	*(%)*
Abdominal pain and guarding, n (%)	1	(0.8)
Nausea and vomiting, n (%)	5	(4)
Diarrhoea, n (%)	2	(1.6)

Table 2: Observer agreement for reporting AXRs between the index gastrointestinal radiologist, consultant radiologist and reporting radiographers:

Agreement with the Index Radiologist	**CR[a]**	**RRs[b]**
Normal examination		
Yes, n (%)	89 (70.6)	80 (63.5)
No, n (%)	37 (29.4)	46 (36.5)
Overall agreement, n (%) (95% CI)[c]	90 (71.4) (62.6 - 79)	94 (74.6) (66 - 81.7)
Minor disagreement, n (%) (95% CI)[c]	13 (10.3) (5.8 - 17.3)	15 (11.9) (7 - 19.2)
Major disagreement, n (%) (95% CI)[c]	23 (18.3) (12.2 - 26.3)	17 (13.5) (8.3 - 21)
Major disagreement RR1, n (%) (95% CI)[c]		6 (14) (6 - 29)
Major disagreement RR2, n (%) (95% CI)[c]		6 (14) (6 - 29)
Major disagreement RR3, n (%) (95% CI)[c]		5 (12) (4.5 - 26)

a Consultant Radiologist. b All three Reporting Radiographers. c 95% CI's including continuity correction.



p value - applying the two tail probability.

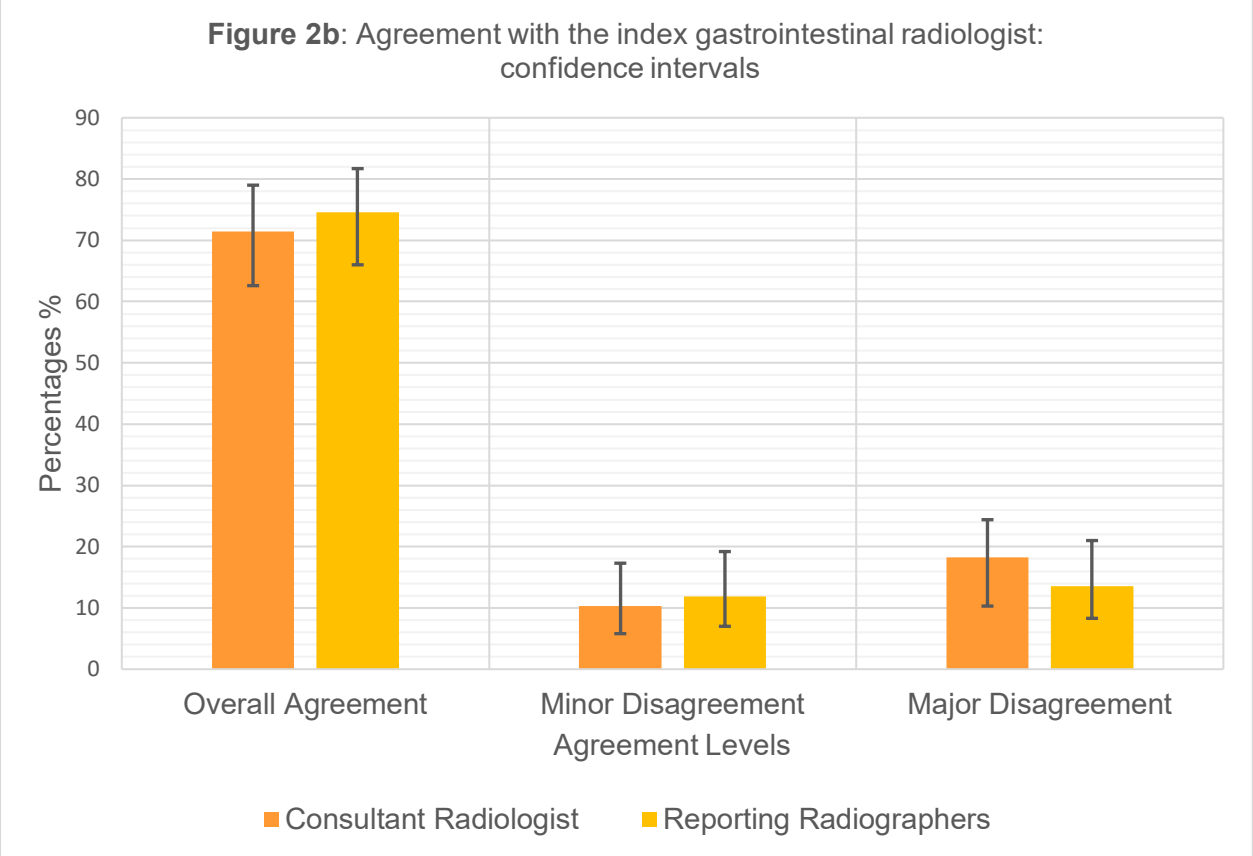
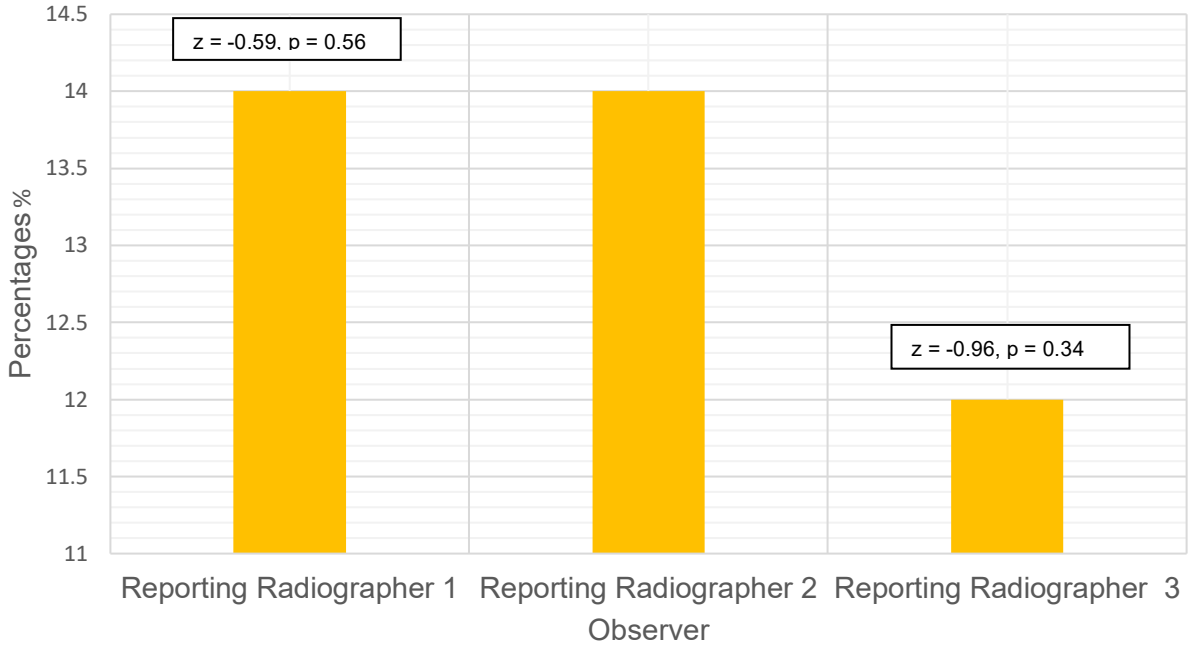


Figure 3a: Major disagreement between the 3 reporting radiographers compared to the consultant radiologist



p value - applying the two tail probability

Figure 3b: Major disagreement between the 3 reporting radiographers compared to the consultant radiologist: confidence intervals

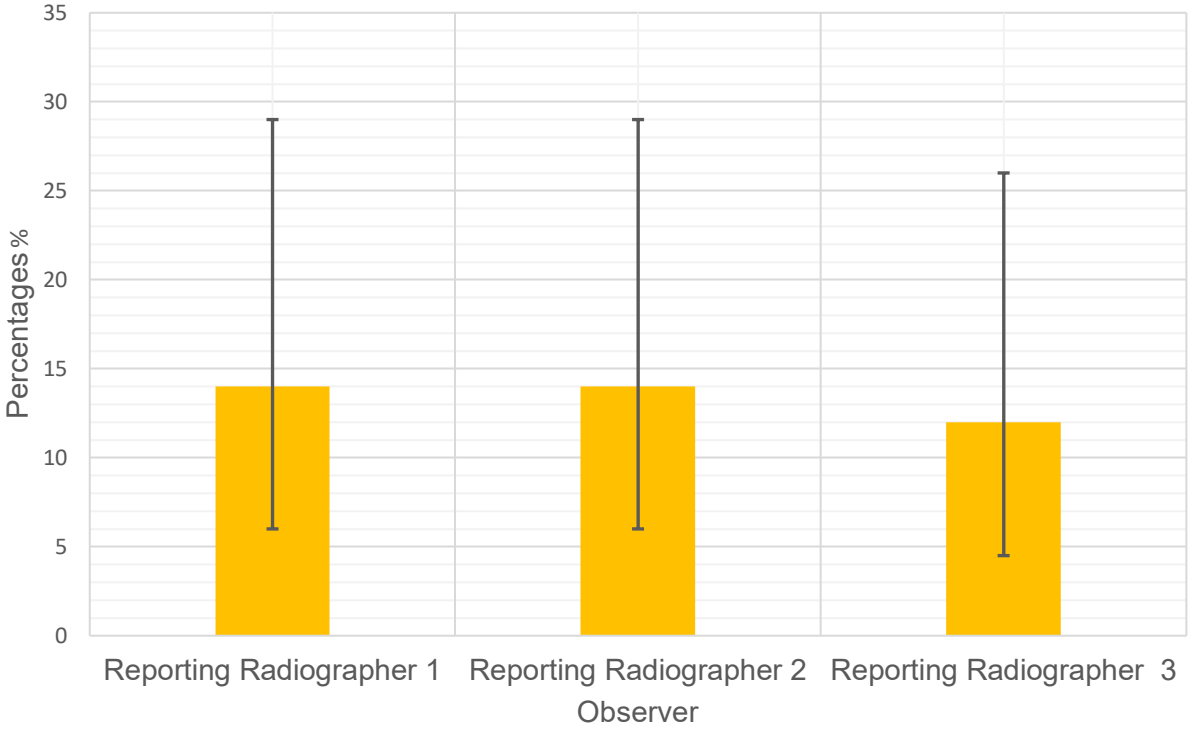


Table 3: Breakdown of major disagreements by the consultant radiologist and reporting radiographers:

Discrepancy	CR[a]	RRs[b]	%
<u>Reported by the gastrointestinal radiologist but not the observers:</u>			
PR (rectal) examination suggested in the report.	**2**		(0.8)
Thumb printing of the large bowel.	1	1	(0.8)
Possible stone reported overlying the right side of the pelvis.	1	1	(0.8)
Significant faecal loading.	**4**	**2**	(2.4)
Misplaced urinary catheter.	1	1	(0.8)
Stone in the ureterovesical junction.	1	1	(0.8)
CT examination suggested to further evaluate prominent loops of bowel.	1	1	(0.8)
CT examination suggested to further evaluate significant faecal loading.	1	1	(0.8)
CT examination suggested to further evaluate a moderately dilated stomach.	1		(0.4)
CT examination suggested for possible bony sclerotic lesions.	1		(0.4)
Kidney stone in the left kidney.	**2**		(0.8)
Possible pelvic mass.	1		(0.4)
<u>Reported by the observers but not the gastrointestinal radiologist:</u>			
Mucosal oedema suggestive of Crohn's disease.	1		(0.4)
Faecal loading.	**4**	**5**	(3.6)
Gallstones.		1	(0.4)
Appearances suggestive of large bowel obstruction.		1	(0.4)
Appearances suggestive of small bowel obstruction.		1	(0.4)
Pancreatic calcification.		1	(0.4)
Volvulus suspected.	1		(0.4)
Total	**23**	**17**	**16%**

a Consultant Radiologist b All three Reporting Radiographers

% CR + RRs (n = 252 reported by the observers)

Discussion:

Research comparing reporting radiographer AXR reports with a consultant radiologist is very limited. Although one study reported a 100% accuracy rate [23], variation between experienced consultant radiologists has been reported as considerable with concordance at 51%.[24] Chest x-ray reporting by reporting radiographers compares favourably with consultant radiologists [22] and therefore it is possible that the accuracy of reporting radiographer reports compared to consultant radiologists would not be significantly different for AXRs. 126 AXRs were therefore required to power the study.

Previous comparative studies have recognised interobserver variation between radiologists and that validity of research could be limited if a report is assumed to be accurate by measuring sensitivity and specificity.[26,27] Interobserver variation is considerable for AXRs [24] and therefore observer agreement was adopted in this research.

Measuring the effects of image interpretation is important.[28] Previous studies have evaluated the radiographer academic performance in reporting radiographic examinations. As this research aimed to assess reporting radiographers in the clinical setting, it was important to establish how any discordant reports were interpreted by a clinician which could affect patient management. A surgeon was therefore asked to assess all the reports made by the index radiologist compared to the radiographers and consultant radiologist.

This study found comparable agreement between the radiographers and a consultant radiologist (71.4% CR and 74.6% RRs) with no statistically significantly difference (z = -

0.57, p = 0.57). Interobserver agreement may seem low but a previous study found three experienced radiologists independently reported 97 AXRs with concordance between readers of 51%.[24] In this previous study, major disagreements accounted for 8-18% which is similar to that found in the current study but major discrepancies were classified differently. An important part of this study was to identify if any of the discordant reports made by the radiographers would have resulted in a change in patient management. There was no statistically significant difference between the radiographers and consultant radiologist (18.3% CR and 13.5% RRs, z = -1.03, p = 0.30). Suh *et al*[21] compared major discordant reports between emergency physicians and gastrointestinal radiologists and a 16% discrepancy rate was found, similar to the results found in this research.

Major disagreement rates between the radiographers were comparable despite post qualification experience (12-14%). In the current study, experience of the reporting radiographer did not appear to influence report concordance. Minor disagreements between the consultant radiologist and index radiologist and radiographers and index radiologist were found. Minor disagreements would not have changed patient management however, no statistically significant difference was found between the consultant radiologist and radiographers (10.3% CR and 11.9% RRs, z = -0.40, p = 0.69). As with major disagreements, the majority of minor discordant reports were due to under calling and overcalling minor faecal loading. The consultant surgeon evaluating the reports considered faecal loading important in patient management, however, both Bertin *et al.*[36] and Driver *et al*.[37] contend that the degree of faecal loading does not correlate well with symptoms of constipation and aid diagnosis. Importantly, faecal loading is difficult to determine on the AXR [33] which may explain the level of discordant reports between the groups in this study. Excluding faecal loading in

the major disagreements did not significantly change the relative performance. Previous studies do not emphasise faecal loading in discordant reports.[21]

Limitations:

There are limitations to this study.[38,39] The data was collected from a single NHS hospital site which could have implications on the reproducibility of the results. Future larger studies should increase radiographer and radiologist participation from differing organisations and interobserver assessment from more than one consultant surgeon would increase the validity of the results by eliminating individual bias. Random selection of AXR reports was used in this study. Stratified randomisation was not employed due to the limited number of AXR reports made by the radiographers. Justification for the AXR continues to be debated and future larger studies could compare reports for specific indications such as foreign bodies, catheter location, follow up urinary stones and obstruction.[19]

It is possible that the radiographers asked for a second opinion from a consultant radiologist before finalising their AXR report. However, this is unlikely to have affected the results as radiographers are required to state in the report if an opinion was sought and there was no evidence of a second opinion being recorded in the reports included in the current sample. The consultant radiologist was aware of the study and the Hawthorne effect impacting on behaviour could have affected the results.[40] The consultant radiologist rereported AXRs and was aware that all their reports were being compared to the radiographers which may have changed their normal reporting behaviour in clinical practice. In future studies increasing the sample size and informing the radiologist that not every reported examination will be included in the final data analysis may help to address this.

When comparing interobserver agreement of AXR reports, it was possible that the consultant surgeon recognised reporting phrases employed by reporters which could have influenced their decision making. To reduce this possibility 30 reports from each group were placed in the other group when scoring took place and the surgeon was not aware of the observer's profession apart from the index radiologist. A qualitative analysis of AXR reports was not undertaken as part of this study but differences between radiologist and radiographer reporting terminology could have influenced the scoring of reports. Future studies may use a qualitative approach to elaborate on quantitative data.

Conclusion:

This study suggests that reporting radiographers are able to report AXRs in clinical practice to the same level of agreement as a consultant radiologist with no significant difference in overall, minor or major disagreements. This study addresses the paucity of research in AXR reporting by radiographers. It provides reassurance that the radiographer reporting service at a local District General Hospital is comparable to a consultant radiologist and provides evidence more widely that adequately trained radiographers can report AXRs equal to that of a general consultant radiologist.

Word count 2637

References:

1. Berman L, Delacey G, Twomey E., Twomey B, Welch T, Raphael E. Reducing errors in the accident department: A simple method using radiographers. *Br Med J (Clinical Research Edition)* 1985;**290**(6466): 421-22.

2. The College of Radiographers. *Medical Image Interpretation and Clinical Reporting by Non-Radiologists: The Role of the Radiographer*. 2nd edn. London: The College of Radiographers. 2006.

3. RCR and SCoR. *Team working in clinical imaging*. London: The Royal College of Radiologists and the Society and College of Radiographers; 2012.

4. Stevens, B.J. A survey assessment of reporting radiographers scope of practice in the West Midlands region of the United Kingdom. *Radiography* 2019;**25**(3):214-9.

5. CoR. *Diagnostic Radiography Workforce UK Census 2020. 2020.* www.sor.org/learning-advice/professional-body-guidance-and-publications/documents-and-publications/diagnostic-workforce-census-reports/or-diagnostic-radiography-workforce-uk-census-2020. [Accessed: 4th January 2022].

6. The Royal College of Radiologists. *Clinical radiology UK workforce census 2020 report*. London: The Royal College of Radiologists; 2021.

7. NHS England. *Diagnostics: Recovery and Renewal – Report of the Independent Review of Diagnostic Services for NHS England.* 2020. https://www.england.nhs.uk/publication/diagnostics-recovery-and-renewal-report-of-the-independent-review-of-diagnostic-services-for-nhs-england. [Accessed: 1st November 2021].

8. Brealey S, King, DG., Crowe MTI, Crawshaw I, Ford L, Warnock NG, et al. Accident and Emergency and General Practitioner plain radiograph reporting by radiographers and radiologists: a quasi-randomised controlled trial. *Br J Radiolo* 2003; **76**(2003):57-61.

9. Piper K, Paterson A, Godfrey R. Accuracy of radiographers reports in the interpretation of radiographic examinations of the skeletal system: a review of 6796 cases. *Radiography* 2005;**11**(1):27-34.

10. Piper K, Paterson A, Ryan C. The implementation of a radiographic reporting service for trauma examinations of the skeletal system in 4 NHS trusts. NHS Executive South Thames funded research project. Canterbury Christ Church University; 1999.

11. Brealey S, Scally AJ, Hann S, Thomas N, Godfrey C, Coomarasamy A. Radiographer plain film reporting performance during clinical practice: a meta-analysis. *Clin Radiol* 2005**;60**(2): 232-41.

12. Fernandez M, Craig S. Appropriateness of adult plain abdominal radiograph requesting in a regional Emergency Department. *J Med Imaging Radiat Oncol* 2019***;63***(2019):175-82.

13. Hampson F A, Shaw A. Assessment of the acute abdomen: role of the plain abdominal radiograph. *Reports in Medical Imaging* 2010;(3):93-105.

14. Gans SL, Stoker J, Boermeester M. Plain abdominal radiography in acute abdominal pain; past, present and future. *Int J of Gen Med* 2012;(5):525-33.

15. Pate A, Baltazar G, Chasin C, Chendrasekhar A. Have Plain Abdominal Radiographs Outlived Their Usefulness?. *Am Surg* 2014;**11**(80):304-6.

16. Denham G, Smith T, James D, McKiernan, S, Evans T. Exploring the evidence-practice gap in the use of plain radiography for acute abdominal pain and intestinal obstruction: a systematic review and meta-analysis. *Int J Evid Based Healthc* 2020 Jun;**18**(2):159-69.

17. Paolillo C. Is there still a role for abdominal plain X-ray in acute abdomen?. *Emergency Care Journal* 2015;**11**(2):50-1.

18. Smith JE, Hall EJ. The use of plain abdominal x-rays in the emergency department. *Emerg Med J* 2009; Mar **26**(3):160-3.

19. Artigas Martin JM, Marti de Gracia M, Rodriguez T, Marquina Martinez D, Parrilla Herranz P. Routine abdominal X-rays in the emergency department: A thing of the past?. *Radiologia* 2015; **57**(5):380-90.

20. RCR. *iRefer Guidelines: Making the best use of clinical radiology*. 2019. www.irefer.org.uk. [Accessed: 15th December 2021].

21. Suh R, Maglinte D, Lavonas E, Kelvin F. Emergency Abdominal Radiography: Discrepancies of preliminary and Final Interpretation and Management Relevance. *American Society of Emergency Radiology* 1995; **2**(6):315-1818.

22. Woznitza N, Piper K, Burke S, Ellis S, Bothamley G. Agreement between expert thoracic radiologists and the chest radiograph reports provided by consultant radiologists and reporting radiographers in clinical practice: review of a single clinical site. *Radiography* 2018; **24**(3):234-39.

23. Brown C, Neep M, Pozzias E, McPhail S. Reducing risk in the emergency department: a 12 month prospective longitudinal study of radiographer preliminary image evaluations. *J Med Radiat Sci* 2019; **66**(3):154-62.

24. Robinson PJA, Wilson D, Coral A, Murphy A, Verow P. Variation between experienced observers in the interpretation of accident and emergency radiographs. *Br J Radiol* 1999 Apr;**72**(856):323-30.

25. Scally AJ, Brealey S. Confidence Intervals and Sample Size Calculations for Studies of Film-reading Performance. *Clin Radiol* 2003 Mar;**58**(3):238-46.

26. Brealey SD, Piper K, King D, Bland M, Caddick J, Campbell P et al. Observer agreement in the reporting of knee and lumbar spine magnetic resonance (MR) imaging examinations: Selectively trained MR radiographers and consultant radiologists compared with an index radiologist. *European journal of radiology* 2013 Oct;**82**(10):e597-e605.

27. Piper K, Mitchell M, Griffin K, Morgan T, Roy A, Thomas A et al. Concordance between a neuroradiologist, a consultant radiologist and trained reporting radiographers interpreting MRI head examinations: An empirical study. *Radiography* 2021 May;**27**(2):475-82.

28. Brealey S. Measuring the Effects of Image Interpretation: An Evaluative Framework. *Clin Radiol* 2001; **56**(5):341-47.

29. Sackett DL, Haynes, RB, Tugwell P. Clinical epidemiology; a basic science for clinical medicine. Boston: Little Brown & Co; 1985.

30. Wilson EB. Probable inference, the law of succession, and statistical inference. *J American Stat Assoc 1927;***22**:209-12.

31. Hicks CM. Research Methods for Clinical Therapists: Applied Project Design and Analysis. Edinburgh: Churchill Livingstone; 2009.

32. Lowry R. *VassarStats: Website for Statistical Computation*. [cited 7th February 2022]. Available from: www.vassarstats.net.

33. Chowdhury D, Pulis N. Review of the need for abdominal x-rays in the diagnosis of acute abdominal pain – an emergency department perspective. Have we changed practice?.*Int J Med Rev Case Rep* 2020; **4**(5):156-62.

34. Ismail H, Malik A. Will Plain Abdominal Radiographs become Obsolete?. *Radiology 2017;* **2**(2):32-7.

35. Chawla A., Peh W. Abdominal radiographs in the emergency department: current status and controversies. *J Med Radiat Sci 2018;* **65**(4):250-1.

36. Bertin C, Ponthus S, Vivekanantham H, Poletti P, Kherad, O, Rutschmann O. Overuse of plain abdominal radiography in emergency departments: a retrospective cohort study. *BMC Health Serv. Res 2019;* **19**(1):1 - 7.

37. Driver BE, Chaitanya CBS, Kartha G, Cole JB, Klein, LR, Rischall M. Utility of plain abdominal radiography in adult ED patients with suspected constipation. *Am. J.Emerg.Med* 2020; **38**(6):1092-96.

38. Kukull WA, Ganguli M. Generalizability. The trees, the forest, and the low-hanging fruit. *Neurology* 2012; **78**(23):1886-91.

39. Creswell JW, Creswell DJ. Research Design. 5th edn. London: SAGE Publications; 2018.

40. McCambridge J, Witton J, Elbourne DR. Systematic review of the Hawthorne effect: new concepts are needed to study research participation effects. Journal of Clinical Epidemiology. 2014 Mar;**67**(3):267-77.