Received:
21 May 2015

Revised:
15 January 2016

Accepted:
19 January 2016

doi: 10.1259/bjr.20150416

Cite this article as:

Perry H, Foley KG, Witherspoon J, Powell-Chandler A, Abdelrahman T, Roberts A, et al. Relative accuracy of emergency CT in adults with non-traumatic abdominal pain. *Br J Radiol* 2016; **89**: 20150416.

FULL PAPER

Relative accuracy of emergency CT in adults with non-traumatic abdominal pain

¹HELEN PERRY, MBChB, ²KIERAN GEORGE FOLEY, FRCR, ¹JOLENE WITHERSPOON, FRCS, ¹ANNA POWELL-CHANDLER, MRCS, ¹TARIG ABDELRAHMAN, BM, MRCS, ²ASHLEY ROBERTS, MD, FRCR and ¹WYN G LEWIS, MD, FRCS

¹Department of General Surgery, University Hospital of Wales, Cardiff, UK

²Department of Radiology, University Hospital of Wales, Cardiff, UK

Address correspondence to: Prof. Wyn G Lewis

E-mail: wyn.lewis@wales.nhs.uk

Objective: CT examination prior to emergency laparotomy has become ubiquitous in contemporary clinical practice, but the relative accuracy of CT in this context has not been widely reported. The aim of this study was to determine the accuracy and strength of agreement between the perceived pre-operative CT diagnosis and operative findings.

Methods: Data from patients undergoing pre-operative CT prior to emergency laparotomy from January 2013 to June 2014 in a large teaching hospital were analysed. The CT diagnosis was compared with operative findings using the χ^2 test and weighted kappa statistic (Kw). Results were further analysed related to the time of day the CT was reported, anatomical location and grade of the reporting radiologist.

Results: 361 patients [median age 67 years (18–98 years); 180 males] underwent CT prior to emergency laparotomy. CT reports were deemed accurate in 318 (88.1%) cases and inaccurate in 43 (11.9%) cases, which resulted in 5 negative laparotomies in this latter cohort (11.6%, χ^2 37.50, df 1; $p < 0.0001$). Accuracy and strength of agreement varied with anatomical location of the pathology; upper

gastrointestinal (UGI) 75.5%, Kw 0.673 (0.531–0.815; $p < 0.001$); small bowel 89.9%, Kw 0.781 (0.687–0.875, $p < 0.001$); lower gastrointestinal (LGI) 90.4%, Kw 0.821 (0.749–0.893; $p < 0.001$). CT examinations reported within normal working hours had higher strength of agreement [Kw 0.832 (0.768–0.896), $p < 0.001$] than CTs reported out of hours [Kw 0.789 (0.721–0.857), $p < 0.001$], but there was no significant difference in overall accuracy (89.9 vs 86.0%; χ^2 1.306, df 1, $p = 0.253$). Reporter seniority was not associated with improved diagnostic accuracy (χ^2 1.825, df 1; $p = 0.177$).

Conclusion: CT agreement with emergency operative pathology was good to excellent, but the strength of agreement varied in relation to anatomical location of pathology.

Advances in knowledge: Overall accuracy was 88.1% with good to excellent agreement between pre-operative CT and emergency laparotomy findings in adult patients with non-traumatic abdominal pain in the acute setting. Diagnostic accuracy of CT reporting varies with anatomical location of pathology.

INTRODUCTION

Patients requiring emergency surgery are amongst the most sick patients managed by the National Health Service (NHS), and the delivery of emergency general surgery care is currently suboptimal.^{1–3} For elderly, patients who are frail with significant comorbidities, the risk of death or serious complications is high. In general surgery alone, emergency cases account for 14,000 admissions to intensive care unit (ICU) in England and Wales annually, carrying a mortality rate of over 25% and associated costs of at least £88 million.^{1,2,4} It is a key hospital service, which has seen significant and ongoing change over the last 15 years and requires further substantial development to meet the needs of contemporary NHS and society.

Assessment protocols for patients with abdominal pain vary, not only from hospital to hospital but internationally based on healthcare resource. The historical radiological assessment by plain abdominal and chest films is often superseded by CT.⁵ While possessing self-evident advantages over plain-film radiology and ultrasonography in many instances, the modality still has limitations including expense, high radiation dose, limited availability compared with plain films and the potential for misinterpretation.^{6,7}

The NHS faces a significant reconfiguration of regional services and in many hospitals out-of-hours (OOH) radiology reporting is outsourced to external reporting services to meet increasing demand. This reduces the opportunity for initial ultrasound evaluation and face-to-face discussion

with image review between the operating surgeon and the reporting radiologist.

Whether CTs are reported in-house or outsourced, the quality of radiology reporting must be high to ensure patient safety and help to facilitate optimal surgical outcomes.

The aim of this study was to determine the accuracy and strength of agreement between the pre-operative CT and emergency laparotomy findings in adult patients with non-traumatic abdominal pain, in the setting of unscheduled care in a UK teaching hospital serving a tertiary population of 1.4 million. Differences in CT findings between the timing of the examination, various anatomical locations and reporter seniority were assessed.

METHODS AND MATERIALS

Evaluation of a surgical database containing details of the emergency laparotomy findings and review of the corresponding radiology CT report was carried out by a senior surgical trainee. Data were extracted from the running theatre database that records all operations performed within the large tertiary teaching hospital.

Consecutive patients were identified who underwent both pre-operative CT (within 24 h of operation) and operative assessment between 1 January 2013 and 30 June 2014. Data from the first 12 months of the study period were collected prospectively and subsequently analysed. However, to increase sample size and study power, a further 6 months of data were collected retrospectively and added to the original data set. The combined data set was then analysed retrospectively.

All adult patients undergoing their first emergency laparotomy over the 18-month period were included. Exclusion criteria were patients who underwent laparotomy without prior CT, primary procedures of the appendix or biliary tree, repeat laparotomies and patients in whom the CT findings led to laparoscopic investigation rather than emergency laparotomy. Appendix and biliary pathologies were excluded in line with the current National Emergency Laparotomy Audit methodology.⁸

All CT examinations were reported by radiologists working within the same NHS trust (in-house) rather than being outsourced to external reporting services.

CT examinations were performed with a GE HD 750 Discovery 64-slice scanner (GE Healthcare, Pollards Wood, Buckinghamshire, UK). A collimation of 40 mm, pitch of 0.984: 1 and tube rotation speed of 0.4 s were used. Tube output was 120 kVp with smart milliampere dose modulation between 60 and 600 mA. Slice thickness was 0.625 mm with acquisition of images in coronal and sagittal planes using soft tissue and bone algorithms in 3-mm reconstructions. At this institution, standard protocols were used depending on the clinical indication for CT.

A standard CT of the abdomen and pelvis was performed in the portal venous (PV) phase (timing 70 s) with positive oral contrast. 100 ml of Niopam 300 was given intravenously at 3–4 ml s⁻¹, followed by 20 ml of saline. 20 ml of Omnipaque 350 in 500 ml of water was used as oral contrast, 250 ml given 1 h

prior to CT, 250 ml given 30 min prior to CT and 10–50 ml given immediately before scanning. i.v. contrast was withheld according to local guidelines in patients with impaired renal function or previous adverse reaction and where the clinical indication was for renal tract stones.

Alternative CT protocols include investigation of small-bowel obstruction, performed with i.v. contrast in the PV phase without oral contrast. Suspicion of bowel ischaemia was investigated with i.v. contrast in the arterial (timing 20–30 s) and PV phases without oral contrast. Investigation of gastrointestinal (GI) bleeding was performed in three phases: pre-contrast, arterial and PV phases without oral contrast.

Laparotomies were performed in the emergency setting by senior surgical registrars or the on-call consultant surgeon within an appropriate timeframe, depending on clinical priority and following assessment by an on-call anaesthetist to assess pre-operative risk and comorbidities.

The comparison between CT report and laparotomy was performed by a higher surgical trainee. However, any “grey” cases were discussed with a consultant surgeon before being marked accurate or inaccurate. No specific rules were applied in this process. The decision was based on surgical opinion.

The patient cohort was subclassified based on the location of their pathology, *i.e.* upper gastrointestinal (UGI), small bowel, lower gastrointestinal (LGI), vascular and other (including gynaecological and anterior abdominal wall pathology) (Table 2). UGI pathology was defined as acute conditions involving the oesophagus, stomach and duodenum. Small-bowel pathology included those of the jejunum and ileum, and LGI pathology included the colon and rectum.

The patients were also subdivided into groups separated by the grade of CT reporter, either a training grade or consultant radiologist. CT reports were evaluated to assess whether or not the CT had been reviewed by a consultant radiologist and those reviewed were further subdivided into absolute agreement, addendums or amendments.

Addendums were defined as CT reports in which the reviewing radiologist essentially agreed with the original report, but added supplementary comments that were not clinically significant, *e.g.* incidental findings of cysts.

Amendments were defined as supplementary reports which contained findings regarded as clinically significant by the reviewing radiologist. However, initial clinical management was based on the first report. Definitions of addendums and amendments were pre-specified during the design of the study, prior to data collection.

This study was deemed to be service evaluation rather than original research; therefore, ethical approval was not required.

Statistical analysis

The pre-operative CT diagnosis and the intraoperative surgical findings were compared, and overall accuracy was calculated.

Table 1. Diagnoses identified at laparotomy

Diagnosis	Upper GI	Small bowel	Large bowel	Vascular	Other	Total
NAD	2	1	3	–	–	6
Inflammation	3	2	16	–	–	21
Perforation	19	9	37	–	–	65
Obstruction	2	105	52	–	–	159
Sepsis/collection	13	10	17	–	7	47
Ischaemia	1	17	8	–	–	24
Tumour	1	–	10	–	–	11
Haemorrhage	4	–	1	6	3	14
Ileus	–	1	1	–	–	2
Other	4	4	3	–	1	12

GI, gastrointestinal; NAD, no abnormality detected.

The weighted kappa statistic (Kw)^{9,10} was used as a novel method to provide a robust measure of strength of agreement, by taking into account the degree to which the report was inaccurate, when compared with the “gold-standard” operative pathological findings.

To facilitate calculation of Kw, a virtual mathematical matrix was constructed so that different levels of agreement were classified related to the pathological findings found at operation. When UGI pathology was found at operation, and the CT reported small-bowel pathology, this was classified as 1 degree of error, and if colonic pathology was reported on CT, this was classified as 2 degrees of error. Similarly, addendums to reports were classified as 1 degree of error; amendments were classified as 2 degrees of error.

The maximum value of Kw is 1.00 when agreement is perfect; a value of 0 indicates no agreement better than chance, and negative values show worse than chance agreement. The hypothesis of Kw = 0 was tested, and the value of Kw was assessed for strength of agreement and categorized according to the method of Landis and Koch.⁹

Intergroup comparison of overall accuracy between reporter seniority, timing of CT and anatomical location was made using

the χ^2 test.¹¹ A *p*-value of <0.05 was considered statistically significant. All statistical tests were pre-specified at the outset of the study prior to data collection and analysis. Data analysis was carried out with the SPSS® v. 13 (IBM Corp., New York, NY; formerly SPSS Inc., Chicago, IL).

RESULTS

A consecutive series of 519 patients undergoing emergency laparotomy were examined. 361 (69.6%) patients out of 519 patients underwent laparotomy following CT and were included in the study. The median age was 67 years (range 18–98 years); 177 patients were male and 184 patients were female. Table 1 details the diagnoses identified at laparotomy.

Of the 361 cases included, 318 cases were found to have a correct diagnosis at CT, giving an overall CT accuracy of 88.1% (Table 2) and Kw of 0.812 [95% confidence interval (CI) 0.766–0.858, *p* < 0.001]. In contrast, 43 cases were found to have incorrect diagnoses, which was associated with an incidence of 5 negative laparotomies (11.6%, χ^2 37.50, df 1; *p* < 0.0001).

189 (52.4%) CTs were performed in normal working hours from 8 AM to 5 PM, from Monday to Friday (excluding bank holidays). CTs performed and reported OOH accounted for the remaining 172 (47.6%) CTs. OOH CTs were further subdivided (Table 3)

Table 2. Relative accuracy of CT reports

Anatomy	Total CTs performed	CT correct	CT incorrect	Accuracy %
All sites	361	318	43	88.1
Upper GI	49	37	12	75.5
Small bowel	149	134	15	89.9
Lower GI	146	132	14	90.4
Vascular	6	6	0	100
Other	11	9	2	81.8
All sites excluding vascular	355	312	43	87.9

GI, gastrointestinal.

Table 3. Details of CT examinations related to time performed and grade of radiologist

Time CT performed	Total number	Consultant CT reports	Training radiologist CT reports	Reports changed	Amendments	Addendums	Overall correct
Weekday	189 (52.4)	180 (95.2)	9 (4.8)	4 (2.1)	1 (0.5)	3 (1.6)	170 (89.9)
Weekend day	63 (17.5)	2 (3.2)	61 (96.8)	22 (35.0)	3 (4.8)	19 (30.2)	53 (84.1)
Weekday evening	35 (9.7)	2 (5.7)	33 (94.3)	18 (51.5)	1 (2.9)	17 (48.6)	31 (88.6)
Nights	74 (20.5)	2 (2.7)	72 (97.3)	38 (51.4)	13 (17.6)	25 (33.8)	64 (86.5)
All out-of-hours reports	172 (47.6)	6 (3.5)	166 (96.5)	78 (45.4)	17 (9.9)	61 (35.5)	148 (86.0)
Total	361	186 (51.5)	175 (48.5)	82 (22.7)	18 (5.0)	64 (17.7)	318 (88.1)

Data are number of CTs (%).

Weekend, Friday 5 PM–8.30 PM, Saturday, Sunday and bank holidays, 8–8.30; weekday, 8 AM–5 PM excluding bank holidays; weekday evenings, Monday–Thursday 17.00–20.30; nights, 8.30 PM–8 AM.

with 74 (20.5%) CTs of the overall scans performed at night (8.30 PM–8 AM), 63 (17.5%) CTs performed on a weekend day or bank holiday [from 5 PM Friday to 8.30 PM on Sunday (excluding nights)] and 35 (9.7%) CTs performed on weekday evenings (5 PM–8.30 PM).

343 (95.0%) CT protocols were contrast enhanced. 169 (46.8%) patients had i.v. contrast in PV phase only with 150 (41.6%) patients receiving oral contrast in addition. 18 (5.0%) patients had non-contrast scans owing to either clinical suspicion of calculi or contraindication to contrast media and 9 (2.5%) patients had oral contrast only. 9 (2.5%) patients had i.v. contrast in arterial and PV phases and 6 (1.6%) patients underwent pre-contrast arterial and PV phases.

186 (51.5%) CTs were reported by consultant radiologists and 175 (48.5%) CTs by training radiologists. 180 (95.2%) CTs performed in normal working hours were reported by consultant radiologists compared with 9 (4.8%) CTs reported by radiologists in training. Overall, CTs performed in normal working hours reported the highest overall accuracy (89.9%) (Table 3).

OOH CTs were largely reported by training radiologists (96.5%), with consultant reports accounting for 3.5% CTs (Table 3). The difference in reporting seniority grade within hours *vs* OOH was highly significant (χ^2 303.498, 1 df; $p < 0.001$). The overall accuracy of consultant reports was 90.3% compared with the training radiologist accuracy of 85.7%, but this difference was not statistically significant (χ^2 1.825, df 1; $p = 0.177$).

The number of CTs reviewed by a consultant radiologist was assessed. 6 out of 184 (3.3%) of consultant-reported CTs were reviewed. Four reports were not changed and two (1.1%) reports were given an addendum. There were no amendments. All of the 175 training radiologist reports were reviewed by consultants. There was absolute agreement in 95 (54.3%) reports. 80 (45.7%) reports were changed (18 amendments, 62 addendums). Training radiologist CT reports were more likely to

have an amendment or addendum than consultant reports (χ^2 102.346, df 1; $p < 0.001$); however, this may reflect the system of checking OOH CT scans by the on-call consultant the following morning.

The timing of the CTs, when reports were reviewed by a consultant, was also evaluated. Four (2.1%) in-hours reports were subsequently changed (one amendment, three addendums). In contrast, 78 (45.4%) of OOH CT reports were changed (17 amendments, 61 addendums), following consultant review (χ^2 95.874, df 1; $p < 0.001$). The true significance, and in particular accuracy, of any changes made following consultant review is unknown, as the initial clinical management was based on the first report and will be the subject of a subsequent study.

There was no significant difference between the overall accuracy of normal working hours and OOH reports (89.9 *vs* 86.0%; χ^2 1.306, df 1, $p = 0.253$). Similarly, Kw for normal working-hour reports and OOH reports were 0.832 (95% CI 0.768–0.896, df 1; $p < 0.001$) and 0.789 (95% CI 0.721–0.857; $p < 0.001$), respectively. Although categorized by Landis and Koch⁹ as excellent and good strength of agreement, respectively, the CIs for each Kw overlap, which implies no difference between in-hours and OOH agreement.

The commonest pathology was small bowel related in 149 (41.3%) patients, LGI in 146 (40.4%) patients, UGI in 49 (13.6%) patients, vascular in 6 (1.7%) patients and other pathology in 11 (3%) patients.

Amongst the GI subdivisions, overall accuracy was highest in the LGI pathology group with 90.4% (in 132/146 patients), followed by small-bowel pathology, with an overall accuracy of 89.9% (in 134/149 patients). UGI pathology was least accurately reported (75.5%; in 37/49 patients). Presentations with vascular disease showed a CT accuracy of 100%. Pathologies determined as “other” had an accuracy of 81.8% (in 9/11 patients). The accuracy of UGI reports was significantly

lower than that of small-bowel (χ^2 6.513, df 1, $p = 0.011$) and LGI reports (χ^2 7.259, df 1, $p = 0.007$). There was no significant difference between the accuracy of small-bowel and LGI reports (χ^2 0.019, df 1; $p = 0.890$).

In addition, the strength of agreement varied with anatomical location of the pathology. UGI agreement was good (Kw 0.673, 95% CI 0.531–0.815, $p < 0.001$), small-bowel agreement was good (Kw 0.781, 95% CI 0.687–0.875, $p < 0.001$) and LGI agreement was excellent (Kw 0.821, 95% CI 0.749–0.893, $p < 0.001$).

Table 4 contains the Kw values relating to anatomical location of pathology and timing of CT reporting.

DISCUSSION

This large observational cohort study examines the accuracy and strength of agreement between emergency abdominal CT examination and operative pathology in adult patients undergoing emergency non-traumatic laparotomy. The principal findings were that variations in diagnostic accuracy exist between anatomical pathological locations, with UGI pathology least accurately reported.

Inaccurate CT diagnoses occurred in 11.9% of cases and were associated with a significant rate (11.6%) of avoidable negative laparotomy. Arguably, this may reflect reduced exposure of radiologists to acute UGI pathology, as there were approximately three times as many CTs performed for small- and large-bowel pathologies when compared with UGI. This is also reflected in the lower Kw values (Table 4).

Approximately half of CT reporting was performed OOH, predominantly by training radiologists, and later checked by a consultant radiologist. All reports by trainees were later reviewed by a consultant radiologist, which reflects a robust on-call review process within the department. However, the timing of review, accuracy of amendments and influence on surgical outcomes has not been assessed.

The need for high-quality CT reporting relating to improved management of patients undergoing surgery has already been recognized by the Royal College of Radiologists, with their forthcoming audit of the “Accuracy of Interpretation of Emergency Abdominal CT in Adult Patients Who Present with Non-Traumatic Abdominal Pain 2014”, the data from which is currently undergoing statistical analysis.

The relative importance of various statistical analyses regarding accuracy of diagnostic tests varies according to the clinical situation. An emergency laparotomy is a high-risk operation, one defined as having an operative mortality of $>5\%$ by the National Emergency Laparotomy Audit.⁸ Obtaining a correct diagnosis prior to emergency laparotomy is vital, especially in patients who are elderly or have significant comorbidities, where the risk of complication or death is high.

Ideally, the best diagnostic test available would have 100% accuracy, sensitivity and specificity. A reduction in sensitivity will result in fewer “true-positive” CTs, meaning more patients will have a delay in treatment/laparotomy owing to a missed diagnosis. This increases the subsequent risk of morbidity and mortality associated with delayed surgery. A reduction in specificity results in more patients undergoing an emergency laparotomy owing to more “false positives” from “overcalls”. This exposes the patient to the risks associated with unnecessary surgery.

The study has several strengths. Data were collected on a large cohort of patients in a UK teaching hospital. Evaluation of the reports by a senior surgical trainee, as described above, is pragmatic and reflects the “real world”, which could be regarded as a further strength of this study. All emergency CTs were reported by in-house radiologists and not outsourced. Even with increasing use of outsourcing, this study remains relevant to emergency CT reporting.

The results of this study are comparable with those reported in similar studies with accuracies of 82–87%.^{12–14} The results are also in keeping with reports of specific acute abdominal diagnoses such as appendicitis with an accuracy of 80.6–99%,^{15–17} gastrointestinal perforation with an accuracy of 86%,¹⁸ bowel ischaemia with an accuracy of 79.17–81%,^{19,20} diverticulitis with an accuracy of 98%²¹ and bowel obstruction with an accuracy of 65–97%.^{22–26} However, the variable accuracy related to anatomical location of the pathology has not been described.

Stoker et al conducted a large study including over 1000 patients investigating the diagnostic accuracy of different imaging strategies in acute abdominal pain.²⁷ The sensitivity of CT was found to be superior to ultrasound (89 vs 70%, $p < 0.001$) and the study concluded that the best conditional strategy was initial ultrasound examination followed

Table 4. Weighted kappa statistic (Kw) related to the time the CT was performed

Anatomical location	Total	In hours	All out of hours
UGI Kw	0.67 (0.53–0.82)	0.68 (0.49–0.88)	0.66 (0.45–0.87)
Small-bowel Kw	0.78 (0.687–0.875)	0.78 (0.626–0.926)	0.78 (0.652–0.90)
Large-bowel Kw	0.82 (0.75–0.89)	0.86 (0.77–0.95)	0.78 (0.67–0.90)

UGI, upper gastrointestinal.

95% confidence intervals are in parentheses.

Figure 1. The clinical question was “renal colic”; therefore, a stone protocol was performed without oral or i.v. contrast. Pneumoperitoneum was reported, but the final diagnosis of the perforated duodenal ulcer was not mentioned and this report was judged as incorrect.

by CT in negative or inconclusive cases, which provided the highest sensitivity with the lowest overall radiation exposure. The diagnostic accuracy of ultrasound has not been investigated in this study, but the overall accuracy of CT reporting is in keeping with that reported by Stoker (88.0% vs 89%).

Weir-McCall *et al* reported a trend towards improved accuracy of consultant radiologist CT reports when compared with radiologists in training, with the duty registrar reports associated with a 78% diagnostic accuracy.¹² The overall accuracy of the initial CT report by either registrar or consultant was 81%, which improved to 93% following review by a second consultant, although this difference was not significant ($p = 0.15$). These findings are therefore consistent, and indeed again, no significant difference was found to be related to radiologist grade. Relative report accuracy following consultant radiologist review was not assessed in this study.

This raises the question of what constitutes a clinically significant difference in overall CT accuracy between groups. Arguably, from statistical principles, since equivalence may be interpreted as outcomes in numerical terms that approach each other to within a degree of 15%, then differences larger than this might be considered relevant. A figure in keeping with this could also be derived from a combination of this study's results (overall accuracy between training radiologists and consultants of 85.7–90.3%) and the report of Weir-McCall (range 78–93%), neither of which demonstrated a statistically significant difference related to overall accuracy.

This study has several potential limitations. No power calculation was performed prior to the study because of the relative lack of relevant literature available. Only patients who underwent laparotomy following CT were studied, *i.e.* patients who underwent surgical intervention during their hospital stay. This excludes assessment of the accuracy and benefit of CT in the group of patients with non-traumatic abdominal symptoms who

are managed conservatively and do not proceed to emergency laparotomy.

It was assumed that the CT report was correct in this cohort, but patients were reviewed and managed appropriately on an individual basis according to clinical symptoms and signs. Moreover, patients who underwent diagnostic laparoscopy as a result of their CT findings were not included. No specific rules were used to determine whether a “grey” case was deemed accurate or inaccurate. This decision was subjective, as the opinion of a consultant surgeon was used.

The discrepancies were identified by the surgical authors and may arguably be judged to be too harsh from a radiological perspective. For example, the CT protocol varied, according to the clinical indication at the time of the referral, and no account for this was taken in the evaluation of the radiological report (Figure 1).

This suggests the need for further education of surgeons regarding the limitations of certain CT protocols and may also reflect the need for reporting radiologists to clarify such limitations.

CONCLUSION

In conclusion, this study has shown that diagnostic accuracy varies with anatomical location and the strength of agreement between CT diagnosis, and operative pathology varied from good to excellent. The reason for the significantly lower accuracy of UGI pathology reporting is uncertain and may be related to exposure to caseload effect. Reassuringly, no significant difference was apparent in the diagnostic accuracy of CTs reported by consultant radiologists when compared with training radiologists. The overall high accuracy facilitates appropriate management decisions, aids pre-operative decision-making regarding surgical access and the choice of a surgeon of appropriate general surgical speciality and seniority, to perform the inherently high-risk procedure of emergency laparotomy, thus optimizing patient safety and minimizing risk.

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