Impact Surgery

Original Research

e-ISSN: 3033-4470

Evaluation of clinical examination and preoperative imaging in UK-patients with right iliac fossa pain and medium to high-risk appendicitis scores

RIFT Study Group on behalf of the West Midlands Research Collaborative

Correspondence: Dr Dmitri Nepogodiev, Institute of Applied Health Research, University of Birmingham, Birmingham B15 2TH, UK

Abstract

Introduction: Clinical risk models can be used to identify UK patients with right iliac fosa pain who are at low-risk of appendicitis and can be safely managed on ambulatory pathways, avoiding hospital admission and unnecessary surgery. This study examined the diagnostic pathways in patients with medium or high-risk scores.

Methods: This prospective cohort study included patients admitted with suspected appendicitis in the UK. Patients aged ≥16 years were included if they had a medium or high-risk score for appendicitis (Appendicitis Inflammatory Response Score (AIRS) >2 in men, Adult Appendicitis Score (AAS) >8 in women). The primary outcome measure was the normal appendicectomy rate (NAR). The AIRS and AAS risk prediction models were validated against pre-determined criteria.

Results: This UK study included 2,231 women and 1,958 men. Overall, 57.7% of patients underwent surgery. The NAR was 18.4% in women aged 16-45 years, 9.5% in men aged 16-45 years, 4.5% in women aged ≥46 years, and 2.1% in men aged ≥46 years. Risk prediction models did not achieve the pre-determined threshold to be used to identify patients with appendicitis. Ultrasound was the most common imaging modality in women aged 16-45 years, whereas CT was most common in the other subgroups. CT was performed in 12.8% of women aged 16-45 years, 21.1% in men aged 16-45 years, 69.3% in women aged ≥46 years, and 74.5% in men aged ≥46 years. The overall NAR in patients who had CT imaging alone (3.6%) was lower than in patients who had no imaging (12.4%) or ultrasound imaging alone (19.0%).

Conclusion: UK patients with a low-risk of appendicitis should be triaged to ambulatory management, whilst those with a medium/high-risk should mostly undergo a CT scan. Normal appendicectomy should become a specific therapeutic option rather than a chance finding.

Keywords: Appendicitis; appendicectomy; general surgery; emergency surgery; risk prediction models.

1. Collaborating authors are listed in the online suplement

Cite as: RIFT Study Group on behalf of the West Midlands Research Collaborative. Evaluation of clinical examination and preoperative imaging in UK-patients with right iliac fossa pain and medium to high-risk appendicitis scores. Impact Surgery. 2024;1(2):46-54. Doi: https://doi.org/10.62463/surgery.34

Introduction

Acute appendicitis remains the most common general surgery emergency in the world and surgery remains the mainstay of treatment[1]. Despite this, investigation and diagnosis remain largely unstandardised, with unclear guidance over when to use imaging and which modalities are best[2]. The UK has continued to struggle with high admission rates for patients with right iliac fossa pain and high normal appendicectomy rates (NAR), underpinned by variable cross-sectional imaging rates[3]. Although some countries have reported high preoperative imaging use, many countries have no national data and are likely to have similar variations in practice to the UK[4-7].

The RIFT-1 study validated existing appendicitis risk prediction models in UK patients with the aim of determining the optimum model and cut-offs to identify patients at low risk of appendicitis.[3] The Appendicitis Inflammatory Response Score (AIRS) was found to be the best performing model in men, with only 2.4% of men aged 16-45 years with AIRS ≤2 having appendicitis. The Adult Appendicitis Score (AAS) was found to be the best performing score in women, with only 3.7% of women aged 16-45 years with AAS ≤8 having appendicitis. These low rates of appendicitis suggest that most of patients with low-risk scores can be safely managed on ambulatory pathways. This could reduce not only hospital admissions but also unnecessary surgery; the NAR in men stratified as low-risk was 74% and the NAR in women stratified as low-risk was 58%.

There remains an evidence gap around diagnostic pathways for patients with medium or high-risk scores. An evidence-based approach to diagnosis would improve shared decision-making with patients, discussions around antibiotic-first therapy, and preoperative surgical planning for minimally invasive surgery. Such an approach could prevent unnecessary surgery and ensure that normal appendicectomy is performed as a deliberate, targeted therapy rather than a result of misdiagnosis. This study aimed to examine the diagnostic accuracy of clinical risk prediction models and imaging in diagnosing appendicitis in UK patients with right iliac fossa pain and medium or high-risk scores.

Methods

The Right Iliac Fossa Pain Treatment Study captured data on patients presenting to hospital with acute right iliac fossa pain across the UK, Italy, Portugal, Republic of Ireland, and Spain. Analyses of this dataset have previously found high levels of data completeness (99.1%) and data accuracy (98.3%)[3].

Study population

The UK has a higher NAR than the other countries that participated in RIFT, so this analysis was restricted to the UK where there is a specific need to explore strategies to reduce NAR. The RIFT-1 study found AIRS[8] ≤2 (men) and AAS[9] ≤8 (women) to be the optimal risk prediction models and cut-offs to identify patients at low risk of appendicitis. As this study aimed to focus on diagnostic strategies in medium and high-risk patients, it included men with AIRS >2 and women with AAS >8. As gynaecological causes of right iliac fossa pain are more common in younger women, analyses were pre-planned to be stratified by age group (≤45 years versus >45 years), consistent with the RIFT-1 study.

Data collection

The RIFT Study protocol has previously been published[10]. In short, all UK hospitals providing acute general surgery were invited to register for the study. Participating hospitals collected data on all consecutive patients presenting with suspected appendicitis during one or more of four pre-specified two-week study periods between 13 March 2017 and 18 June 2017. Patients were included if they were referred by either a general practitioner or an emergency physician to the on-call surgical team with either acute right iliac fossa pain or suspected acute appendicitis. Consecutive patients were identified at the point of admission to the surgical unit. Patients who had previously undergone appendicectomy were excluded. Pregnant women were excluded, due to the distinct clinical pathways that these patients follow. Patients with records missing the necessary variables to calculate the AIRS and AAS scores were excluded from this analysis. Patients treated for presumed appendicitis without available histopathology (appendicitis versus normal appendectomy) were excluded from the study due to the inability to ascertain the final diagnosis. This applied both to patients who underwent appendicectomy without subsequent available histology and to those who received non-operative treatment for acute appendicitis.

Teams of up to three investigators based on the acute surgical unit collected data over each two-week period. To ensure accurate contemporaneous bedside data collection, a case report form was designed to be completed at the point of initial surgical assessment. Data collection was supervised by a consultant surgeon at each hospital. Data items required to calculate the AIRS and AAS models were collected, along with data on ultrasound, CT, and MRI imaging results taken from formal radiology reports. In patients who underwent surgery, details of the procedure were recorded along with any subsequent histopathology results. Electronic and paper records were used to follow up patients at 30 days after their initial presentation, documenting any surgical procedures performed upon readmission.

Clinical outcomes

Patients were classified as having appendicitis if they underwent appendicectomy or right hemicolectomy for presumed acute appendicitis within 30 days of initial presentation, and histopathological examination of the appendix confirmed a diagnosis of acute appendicitis. Appendicitis was subcategorised based on histopathology reports as either simple or complex (gangrenous, perforated) appendicitis.

The numerator for the NAR was the number of patients with normal appendix histology, and the denominator was the total number of all patients who underwent appendicectomy. Patients with appendix pathology other than appendicitis (e.g. tumour) were included in the denominator but not the numerator.

Statistics and validation of risk prediction models

Baseline characteristics were described by presenting simple counts and percentages. This study evaluated the performance of AIRS in men and AAS in women for identifying patients at high risk of appendicitis. The reference standard was a histopathological diagnosis of acute appendicitis within 30 days of initial assessment.

The performance of the risk prediction models was evaluated by the positive predictive value (PPV, the proportion of patients stratified to the high-risk group who have appendicitis) and sensitivity (proportion of patients with appendicitis who were stratified to the high-risk group). For each patient sub-group, score cut-offs were systematically varied and PPV and sensitivity calculated at each cut-off. Through a consensus exercise with senior surgeons, it was established a priori that a PPV of ≥95% must be accompanied by a sensitivity of ≥30% to integrate risk scoring for identifying patients at high-risk of appendicitis in to routine practice.

The performance of imaging (ultrasound and CT) was assessed by calculation of area under the curve (AUC), sensitivity, specificity, NPV and PPV. In addition, 95% confidence intervals (95% CI) were calculated for all measures of diagnostic performance. Analyses were carried out in Stata (Version 15, Stata Corp., College Station, Texas).

Study approval and reporting

This observational study made no changes to clinical care pathways, with no additional follow-up required. Only anonymised data was collected. Therefore, the study was registered locally at each participating hospital as either a clinical audit or service evaluation. This study is reported according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines and the Standards for Reporting Diagnostic Accuracy (STARD) guidelines for diagnostic accuracy studies[11,12].

Results

This study was based on 4,189 medium and high-risk patients in the UK. This included 1,569 women aged 16-45 years and 662 women aged ≥46 years with an AAS >8, and 1,417 men aged 16-45 years and 541 men aged ≥46 years with an AIRS >2 (Figure 1). Women were less likely to be operated on than men in both age groups (Table 1): 16-45 years (51.9% versus 66.8%), and ≥46 years (50.6% versus 59.0%).

Amongst operated patients, women were more likely than men to undergo procedures other than appendicectomy, most frequently diagnostic laparoscopy (7.0% [80/1149] of all procedures in women of all ages) or gynaecological procedures (3.1% [36/1149]). Amongst patients who underwent appendicectomy, the NAR was higher in women than men in both age groups (Table 1): 16-45 years (18.4% versus 9.5%), and ≥46 years (4.5% versus 2.1%).

Women who did not undergo appendicectomy most frequently received a diagnosis of non-specific abdominal pain (40.0% [496/1241]) or gynaecological pathology (25.5% [317/1241], Table S1). Men who did not undergo appendicectomy most frequently received a diagnosis of non-specific abdominal pain (44.0% [334/759]) or non-appendix gastrointestinal pathology (32.9% [250/759]).

Table 1: Operative management

	Age 16-45 years		Age ≥46 years	
	Men	Women	Men	Women
Operated	66.8% (947/1417)	51.9% (814/1569)	59.0% (319/541)	50.6% (335/662)
Appendicectomy	95.7% (906/947)	86.0% (700/814)	91.9% (293/319)	86.6% (290/335)
Appendicitis	87.6% (794/906)	76.1% (533/700)	91.8% (269/293)	93.1% (270/290)
Simple appendicitis	63.1% (501/794)	66.2% (353/533)	36.8% (99/269)	47.0% (127/270)
Complex appendicitis	36.9% (293/794)	33.8% (180/533)	63.2% (170/269)	53.0% (143/270)
Adenocarcinoma	0% (0/906)	0.1% (1/700)	0.7% (2/293)	0.7% (2/290)
Carcinoid	0.3% (3/906)	1.0% (7/700)	1.0% (3/293)	0.3% (1/290)
Crohn's disease	0% (0/906)	0.1% (1/700)	0% (0/293)	0% (0/290)
Other abnormal histology	2.5% (23/906)	4.1% (29/700)	4.4% (13/293)	1.4% (4/290)
Normal appendix	9.5% (86/906)	18.4% (129/700)	2.0% (6/293)	4.5% (13/290)
Other operations	4.3% (41/947)	14.0% (114/814)	8.1% (26/319)	13.4% (45/335)
Diagnostic laparoscopy	20	71	4	9
Colonic resection	2	3	5	17
Other GI procedures	15	4	13	12
Urology procedures	1	1	2	1
Gynaecology procedures	-	32	-	4
Missing	3	3	2	2
Not operated	33.2% (470/1417)	48.1% (755/1569)	41.0% (222/541)	49.4% (327/662)

GI: Gastrointestinal.

Table 2: Real-world normal appendicectomy rates stratified by risk prediction model score

	Men 16-45 years		Men ≥46 years	
AIRS score	Total patients	Normal appendicectomy rate	Total patients	Normal appendicectomy rate
3	75	33.3%	12	8.3%
4	89	14.6%	23	0.0%
5	166	14.5%	49	2.0%
6	181	5.0%	62	3.2%
7	175	4.0%	51	3.9%
8	118	2.5%	45	0.0%
≥9	102	4.9%	51	0.0%
	Women 16-45 years		Women ≥46 years	
AAS score	Total patients	Normal appendicectomy rate	Total patients	Normal appendicectomy rate
9	72	27.8%	4	25.0%
10	92	27.2%	20	25.0%
11	95	21.1%	23	8.7%
12	117	20.5%	42	0.0%
13	91	12.1%	42	0.0%
14	76	15.8%	26	7.7%
15	65	12.3%	40	0.0%
16	42	11.9%	31	3.2%
≥17	50	8.0%	62	3.2%

AAS: Adult Appendicitis Score; AIRS: Appendicitis Inflammatory Response Score.

Table 3: Preoperative imaging rates				
	Age 16-45 years		Age ≥46 years	
	Men	Women	Men	Women
Imaging performed	35.8% (508/1417)	70.9% (1113/1569)	80.6% (436/541)	87.2% (577/662)
Ultrasound only	11.1% (158/1417)	50.0% (784/1569)	4.2% (23/541)	11.5% (76/662)
CT only	21.1% (299/1417)	12.8% (201/1569)	74.5% (403/541)	69.3% (459/662)
Ultrasound and CT	3.0% (42/1417)	7.0% (110/1569)	1.7% (9/541)	5.6% (37/662)
MRI*	0.6% (9/1417)	1.2% (18/1569)	0.2% (1/541)	0.8% (5/662)
No imaging performed	64.2% (909/1417)	29.1% (456/1569)	19.4% (105/541)	12.8% (85/662)

CT: Computed Tomography; MRI: Magnetic Resonance Imaging; *Includes all patients who had any combination of scans including a MRI scan.

Table 4: Overall diagnostic performance of ultrasound and CT imaging for diagnosis of appendicitis		
	Ultrasound	Computed tomography
Proportion of patients with final diagnosis of appendicitis	26.4% (333/1262)	45.2% (708/1567)
Imaging findings for appendicitis		
Positive	12.6% (158/1262)	46.7% (732/1567)
Equivocal	69.3% (875/1262)	11.7% (184/1567)
Negative	17.9% (226/1262)	41.2% (645/1567)
Missing	0.2% (3/1262)	0.4% (6/1567)
Performance for appendicitis		
AUC	0.68 (0.66-0.7)	0.94 (0.93-0.95)
Sensitivity	39.3% (34.1%-44.8%)	94.8% (92.9%-96.3%)
Specificity	97.1% (95.8%-98.1%)	92.8% (90.9%-94.5%)
PPV	82.9% (76.1%-88.4%)	91.7% (89.4%-93.6%)
NPV*	81.7% (79.2%-83.9%)	95.5% (93.9%-96.8%)

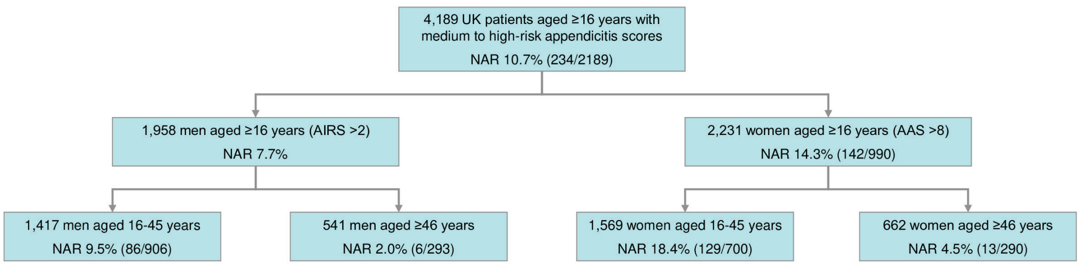
AUC: Area Under Curve; NPV: Negative Predictive Value; PPV: Positive Predictive Value. 95% confidence intervals are given in parentheses. *Main analysis based on imaging reported as either 'negative' (i.e. excluding appendicitis) or 'equivocal' (i.e. unable to either exclude or confirm appendicitis) both being classified as negative imaging; yielding NPV 81.7% for ultrasound, and 95.5% for CT. If analysis is restricted to imaging reported as 'negative', then the NPV for ultrasound was 96.9% (93.7%-98.7%), and the NPV for CT was 99.2% (98.2%-99.7%).

Table 5: Normal appendicectomy rates by preoperative imaging modality

	Age 16-45 years		Age ≥46 years		Overall
	Men	Women	Men	Women	
Imaging performed					
Ultrasound only	16.4% (11/67)	20.9% (58/277)	0% (0/9)	9.5% (2/21)	19.0% (71/374)
CT only	5.5% (9/164)	8.6% (8/93)	1.3% (3/224)	2.6% (6/234)	3.6% (26/715)
Ultrasound and CT	7.1% (1/14)	15.2% (5/33)	0% (0/4)	14.3% (1/7)	12.1% (7/58)
MRI*	20.0% (1/5)	20.0% (1/5)	n/a	n/a	20.0% (2/10)
No imaging performed	9.8% (64/656)	19.5% (57/292)	5.4% (3/56)	14.3% (4/28)	12.4% (128/1032)

CT: Computed Tomography; MRI: Magnetic Resonance Imaging; n/a: not applicable as no patients; * Includes all patients who had any combination of scans including a MRI scan.

Figure 1: Flowchart of included patients



AAS: Adult Appendicitis Score; AIRS: Appendicitis Inflammatory Response Score; NAR: Normal Appendicectomy Rate.

Figure 2a: Normal appendicectomy rates by preoperative imaging

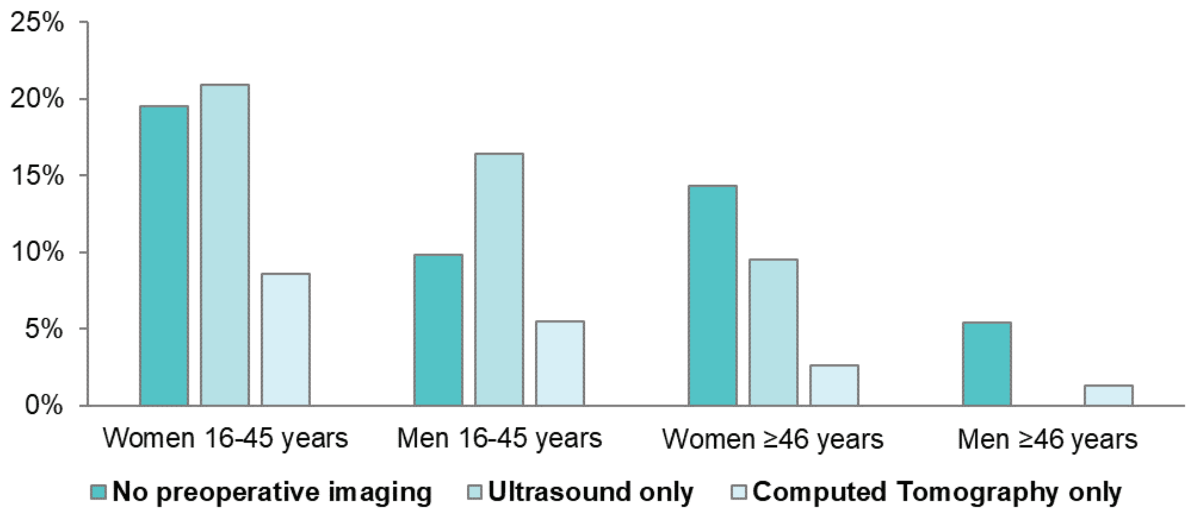
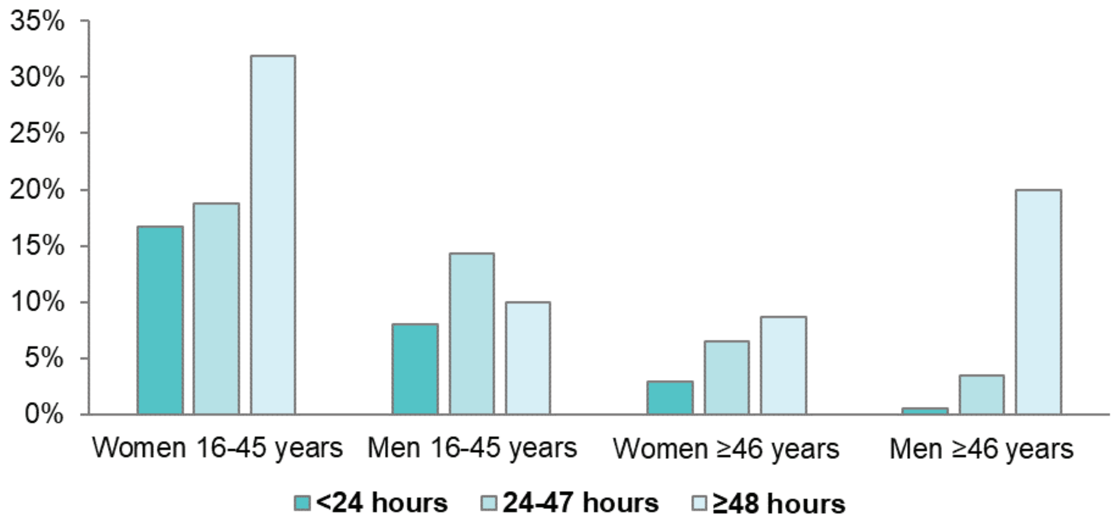


Figure 2b: Normal appendicectomy rates by duration of preoperative observation



Performance of risk prediction models

Risk prediction models failed to meet the pre-determined threshold for identifying patients with appendicitis across all four patient subgroups. (Tables S2-S5). Considerable NARs were recorded even for patients with high scores, especially in younger patients (Table 2, Figure S1).

Preoperative imaging

Women had higher rates of preoperative imaging than men in both age groups (Table 3), 16-45 years (70.9% versus 35.8%) and ≥46 years (87.2% versus 80.6%). Ultrasound predominated as the most common imaging modality for women aged 16-45 years, accounting for 80.3% [894/1113] of all imaging in this group. Conversely, CT was most common in women aged ≥46 years (86.0% [496/577]), men aged 16-45 years (67.1% [341/508]), and men aged ≥46 years (94.5% [412/436]). In total, MRI imaging was only performed for 33 patients (Table 3).

Among patients who underwent ultrasound, 30.4% (384/1262) yielded definitive results regarding appendicitis, while 69.3% (875/1262) returned equivocal findings, with three results missing (Table 4). Across all patients, gynaecological pathology was more commonly observed in ultrasound than appendicitis (210 versus 158 patients, Table S6).

The diagnostic performance of ultrasound was poor, with a PPV of 82.9% and an AUC of 0.68 (Table 4). In the subgroup of patients who had an ultrasound with findings other than appendicitis, the NPV was 89.1% and the AUC was 0.55 (Table S7). Findings of non-appendix pathology on ultrasound did not exclude appendicitis.

Amongst patients who underwent a CT imaging, 87.9% (1377/1567) of results were either positive or negative for appendicitis, 11.7% (184/1567) of results were equivocal, and 6 results were missing (Table 4). When pathology other than appendicitis was detected on CT imaging, gastrointestinal pathology emerged as the predominant finding across all groups, except for women aged 16-45 years, among whom gynaecological pathology was the most prevalent (Table S8). The diagnostic performance of CT was good with a PPV of 91.7%, a sensitivity of 94.8%, and an AUC of 0.94 (Table 4).

The overall NAR in patients who had CT imaging alone (3.6%) was lower than in patients who had no imaging (12.4%) or ultrasound imaging alone (19.0%). This pattern remained consistent across all age and gender subgroups (Table 5, Figure 2a), with the lowest NARs observed in men aged ≥46 years (1.3%) and women aged ≥46 years (2.6%) who underwent CT imaging alone.

Clinical observation

Across all age and gender subgroups, longer preoperative clinical observation was associated with higher NAR (Figure 2b, Table S9). Overall, NAR was 8.8% in patients observed for less than 24 hours, compared to 13.4% in patients observed for 24-47 hours, and 20.0% in patients observed for ≥48 hours. Patients with a normal appendicectomy showed the highest rates of postoperative readmission (10.2%, 23/226, Table S10).

Intraoperative diagnosis

When surgeons made the intraoperative diagnosis of appendicitis, this was correct on 95.4% (1889/1979, Table S11) of occasions. However, when the intraoperative diagnosis of a normal appendix was made, this was incorrect on 30.4% of occasions (63/207).

Discussion

This study shows that in UK patients presenting with right iliac fossa pain and a medium to high-risk appendicitis score, reliance on clinical evaluation, risk scoring, and ultrasound results in high NAR in both men and women. The predetermined thresholds for introducing risk scoring to identify appendicitis in this population were not met. The utilisation of CT imaging in this real-world population was associated with lower NAR.

Ultrasound did not correlate with lower NAR in this UK population. When ultrasound was combined with CT, NAR remained high, suggesting that dual imaging is a marker for a challenging diagnostic group. Similarly, longer preoperative observation was associated with higher NAR, likely also reflecting diagnostic complexity.

Improved diagnosis would allow better shared decision-making, enabling informed discussion about antibiotic therapy options in patients with early appendicitis, absence of faecolith, or a preference for avoiding surgery[13]. It would also support better surgical planning, including early stratification of perioperative antibiotics, reduction of preoperative delays[14], and optimised surgical bed management which would support improved elective surgery performance[15].

Limitations of this observational study include the inability to directly assess the influence of risk scoring on decision-making and the risk of selection bias introduced by imaging selection by surgeons, which may limit the generalisability of imaging performance.

There is extensive evidence regarding the management of suspected appendicitis and NAR from countries such as the United States[6]. However, robust NAR data are lacking in most countries, and a high-quality prospective global study is needed to establish NAR and imaging utilisation worldwide, particularly in lower-resource settings.

Primary antibiotic therapy became commonplace for appendicitis during the COVID-19 pandemic[17], but post-pandemic surgery has re-established itself as the gold-standard treatment. It is now time to embed evidence-based approaches to diagnosis. In the UK, patients with right iliac fossa pain should be risk scored, with low-risk patients triaged to ambulatory management and medium and high-risk patients routinely undergoing CT imaging. Patients who have been admitted for 24 hours should be prioritised for CT as further delay is unlikely to be beneficial. Ultrasound should be reserved for investigation of possible gynaecological pathology in women. Normal appendicectomy should transition from being a chance finding to a deliberate therapeutic option, reserved for carefully selected patients. This approach would improve informed consent, promote a more satisfactory surgical encounter from the patient's perspective, and lead to a more predictable postoperative course. Implementation studies are now needed to change clinical practice in the NHS; the post-pandemic period is a good opportunity for change whilst surgical systems are being re-developed[18].

Competing interests

The authors have declared that no competing interests exist.

Funding

The authors received no specific funding for this work.

Acknowledgements

None

References

1. GlobalSurg Collaborative. Mortality of emergency abdominal surgery in high-, middle- and low-income countries. *Br J Surg*. Jul 2016;103(8):971-988.

2. Di Saverio S, Podda M, De Simone B, et al. Diagnosis and treatment of acute appendicitis: 2020 update of the WSES Jerusalem guidelines. *World J Emerg Surg*. Apr 15 2020;15(1):27.

3. RIFT Study Group on behalf of the West Midlands Research Collaborative. Evaluation of appendicitis risk prediction models in adults with suspected appendicitis. *Br J Surg*. Jan 2020;107(1):73-86.

4. Kim K, Kim YH, Kim SY, et al. Low-dose abdominal CT for evaluating suspected appendicitis. *N Engl J Med*. Apr 26 2012;366(17):1596-605.

5. van Rossem CC, Bolmers MD, Schreinemacher MH, et al. Diagnosing acute appendicitis: surgery or imaging? *Colorectal Dis*. Dec 2016;18(12):1129-1132.

6. Mock K, Lu Y, Friedlander S, Kim DY, Lee SL. Misdiagnosing adult appendicitis: clinical, cost, and socioeconomic implications of negative appendectomy. *Am J Surg*. Dec 2016;212(6):1076-1082.

7. Bhangu A, Soreide K, Di Saverio S, Assarsson JH, Drake FT. Acute appendicitis: modern understanding of pathogenesis, diagnosis, and management. *Lancet*. Sep 26 2015;386(10000):1278-1287.

8. Andersson M, Andersson RE. The appendicitis inflammatory response score: a tool for the diagnosis of acute appendicitis that outperforms the Alvarado score. *World J Surg*. Aug 2008;32(8):1843-9.

9. Sammalkorpi HE, Mentula P, Leppaniemi A. A new adult appendicitis score improves diagnostic accuracy of acute appendicitis--a prospective study. *BMC Gastroenterol*. Jun 26 2014;14:114

10. RIFT Study Group on behalf of the West Midlands Research Collaborative. Right Iliac Fossa Pain Treatment (RIFT) Study: protocol for an international, multicentre, prospective observational study. *BMJ Open*. Jan 13 2018;8(1):e017574.

11. Cohen JF, Korevaar DA, Altman DG, et al. STARD 2015 guidelines for reporting diagnostic accuracy studies: explanation and elaboration. *BMJ Open*. Nov 14 2016;6(11):e012799. doi:10.1136/bmjopen-2016-012799

12. Cuschieri S. The STROBE guidelines. *Saudi J Anaesth*. Apr 2019;13(Suppl 1):S31-S34.

13. United Kingdom National Surgical Research Collaborative. Safety of short, in-hospital delays before surgery for acute appendicitis: multicentre cohort study, systematic review, and meta-analysis. *Ann Surg*. May 2014;259(5):894-903.

14. de Wijkerslooth EML, Boerma EG, van Rossem CC, et al. 2 days versus 5 days of postoperative antibiotics for complex appendicitis: a pragmatic, open-label, multicentre, non-inferiority randomised trial. *Lancet*. Feb 4 2023;401(10374):366-376.

15. NIHR Global Health Unit on Global Surgery, COVIDSurg Collaborative. Elective surgery system strengthening: development, measurement, and validation of the surgical preparedness index across 1632 hospitals in 119 countries. *Lancet*. Nov 5 2022;400(10363):1607-1617.

16. Ohmann C, Franke C, Yang Q. Clinical benefit of a diagnostic score for appendicitis: results of a prospective interventional study. German Study Group of Acute Abdominal Pain. *Arch Surg*. Sep 1999;134(9):993-6.

17. COVIDSurg Collaborative. Mortality and pulmonary complications in patients undergoing surgery with perioperative SARS-CoV-2 infection: an international cohort study. *Lancet*. Jul 4 2020;396(10243):27-38.

18. NIHR Global Health Research Unit on Global Surgery. Strategies to strengthen elective surgery systems during the SARS-CoV-2 pandemic: systematic review and framework development. *Br J Surg*. Jan 31 2024;111(2).