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Original Article

Preoperative imaging lowers the negative appendectomy rate in acute appendicitis

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ABSTRACT

INTRODUCTION. Acute appendicitis is a common surgical emergency, but accurate diagnosis remains challenging. Despite the 2020 World Society of Emergency Surgery Jerusalem guidelines recommending structured imaging pathways, including ultrasound and selective computed tomography, clinical assessment remains the primary diagnostic tool in Denmark. Contemporary practice emphasises rapid assessment, with imaging reserved for older or borderline cases. We hypothesised that reliance on clinical assessment alone contributes to a high number of negative appendectomies, particularly in young adults.

METHODS. We conducted a single-centre retrospective cohort study of adults (>18 years) undergoing surgery for suspected appendicitis at a tertiary university hospital in Denmark between January 2021 and December 2023. Data were extracted from electronic medical records and analysed in Stata 19.5.

RESULTS. Among 613 patients, 522 had histologically confirmed appendicitis, yielding an overall negative appendectomy rate (NAR) of 14.9%. Patients without preoperative imaging (n = 279) had a NAR of 24.4%, compared with 6.9% among those who underwent preoperative imaging (n = 334).

CONCLUSIONS. Reliance on clinical assessment alone results in a substantial number of unnecessary operations. Preoperative imaging significantly reduces NAR ($p < 0.001$), supporting broader adoption of guideline-based diagnostic strategies to improve diagnostic accuracy and optimise resource utilisation.

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Acute appendicitis (AA) remains one of the most common surgical emergencies worldwide, with an estimated 17.7 million cases in 2019 [1]. Accurate diagnosis is challenging as multiple conditions can mimic appendicitis, and clinical evaluation combined with routine blood tests is often insufficient to reliably distinguish AA from other causes of abdominal pain [2].

Several clinical scoring systems, including the Alvarado score [3] and the Appendicitis Inflammatory Response (AIR) score [4], have been developed to aid decision-making, but their diagnostic performance varies: the Alvarado score shows heterogeneous accuracy, with high sensitivity at lower cutoffs but limited specificity at higher thresholds [5], whereas the AIR score generally demonstrates a high sensitivity but only moderate specificity [6]. Preoperative imaging – primarily CT and ultrasound – improves diagnostic accuracy and reduces the negative appendectomy rate (NAR) [7-9]. The 2020 World Society of Emergency Surgery (WSES) Jerusalem guidelines emphasise structured diagnostic algorithms incorporating imaging, particularly ultrasound, to support clinical assessment [2].

In Denmark, the diagnosis of AA still largely relies on clinical assessment, with supplementary imaging, often based on non-standardised criteria, performed at the discretion of individual clinicians. Historically, patients suspected of appendicitis were admitted for observation, allowing clinicians to detect evolving disease without routine imaging. Contemporary practice emphasises rapid assessment and decision-making within a few hours in the emergency department due to reduced inpatient capacity and increased demand for efficient patient flow. Consequently, decisions regarding surgery, discharge or imaging are made within hours.

Despite strong evidence supporting standardised imaging pathways, Danish clinical practice still varies considerably across hospitals and among individual clinicians. Only limited Danish data exist on the effects of preoperative imaging on diagnostic accuracy and negative appendectomy rates. We aimed to describe current diagnostic practice and evaluate how preoperative imaging influences the negative appendectomy rate in a large Danish university hospital.

Methods

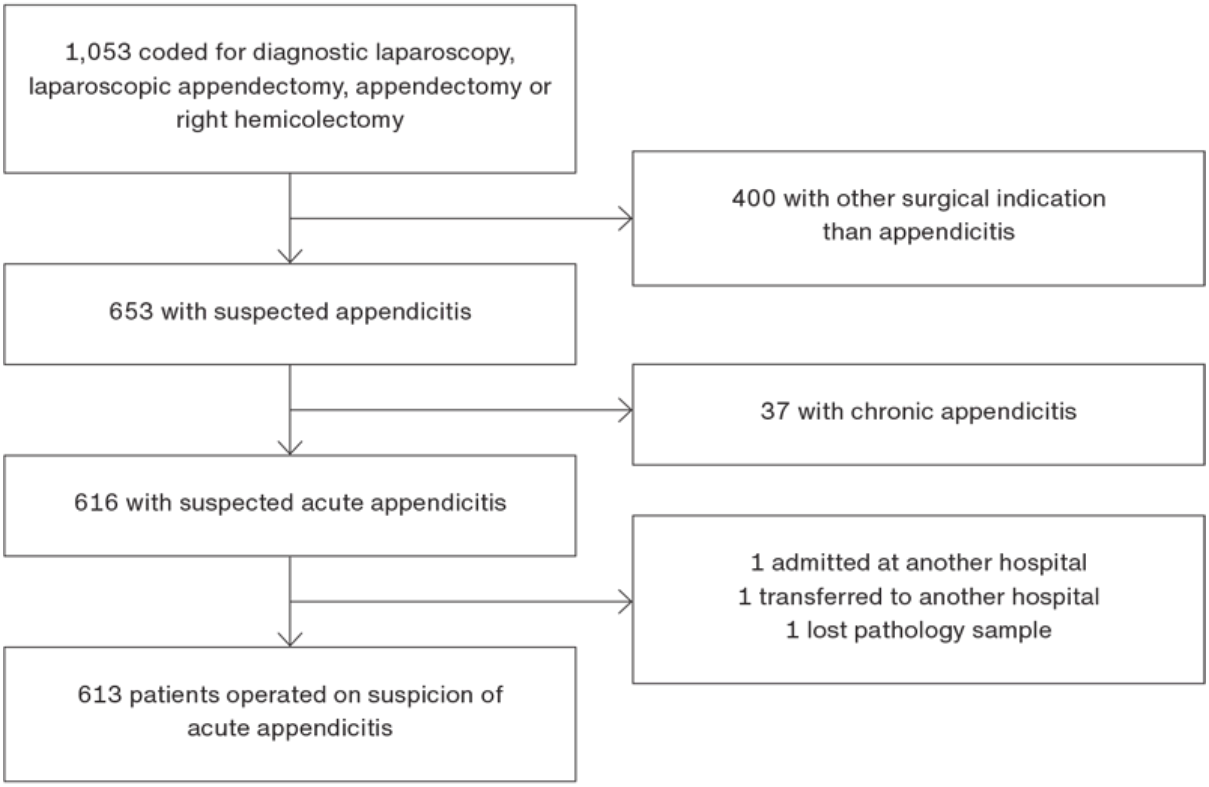
Study design and setting

This retrospective cohort study included adult patients (≥ 18 years) undergoing appendectomy or diagnostic laparoscopy at a tertiary university hospital in Denmark from 1 January 2021 to 31 December 2023. The study was approved by the local institutional review board. Patients under 18 years of age were excluded, as paediatric patients have different differential diagnoses and diagnostic pathways, including infrequent use of CT and more frequent surgery without imaging. Outcomes in children have been assessed separately in a previous, unpublished study.

Data collection

Electronic records were screened for procedure codes corresponding to laparoscopic appendectomy, open appendectomy or diagnostic laparoscopy. Detailed review confirmed eligibility and allowed collection of demographics, clinical presentation, laboratory values, data necessary to calculate the Alvarado score (see Supplementary material - Appendix 1), imaging, intraoperative findings, histopathology and post-operative course. After exclusions (surgery performed on suspicion of non-AA diagnosis), 613 patients were included (**Figure 1**). Data were managed using Research Electronic Data Capture (REDCap) [10].

FIGURE 1 Patient inclusion and exclusion flow chart.



Outcome measures

The primary outcome was NAR, defined as intraoperative or histological absence of appendicitis. Secondary outcomes included the sensitivity of CT, the sensitivity and positive predictive value of Alvarado score ≥ 7, and subgroup analyses by imaging status.

Statistical analysis

Descriptive statistics were performed in Stata 19.5. Median and IQR are reported for non-normally distributed variables. Differences in NAR between groups were assessed using Fisher's exact test, and relative risk (RR) with 95% CI were calculated. In subgroup analyses, between-group differences were assessed using the Mann–Whitney U test for non-parametric continuous variables and the χ^2 or Fisher's exact test for categorical variables, as appropriate.

Trial registration: not relevant.

Results

Cohort characteristics

A total of 613 patients were included in the study (**Table 1**). The median age was 36 years (IQR: 26-57 years), and 52.5% were female. Most patients underwent laparoscopic appendectomy (n = 537, 87.6%), followed by diagnostic laparoscopy (n = 60, 9.8%) and open appendectomy (n = 13, 2.1%). Preoperative imaging was performed in 334 patients (54.5%), predominantly CT (n = 300, 89.8%) and, less frequently, ultrasound (n = 34, 10.2%) – performed by a trained radiologist. The median Alvarado score was 7 (IQR: 6-8).

TABLE 1 Baseline characteristics of the study cohort (N = 613).

Age, median (IQR), yrs	36 (26-57)
Females, n (%)	322 (52.5)
Alvarado score, median (IQR)	7 (6-8)
Type of surgery, n (%)	
Laparoscopic appendectomy	537 (87.6)
Diagnostic laparoscopy	60 (9.8)
Open appendectomy	13 (2.1)
Right-sided hemicolectomy	3 (0.5)
Preoperative imaging	
Computed tompgraphy, n (% of imaged)	300 (89.8)
Ultrasound, n (% of imaged)	34 (10.2)
Subtotal, n (% of N)	334 (54.5)

Outcome measures

Overall, 91 patients (14.9%) did not have appendicitis on intraoperative or histological examination. In most of these cases, the appendix was not removed because its intraoperative appearance was macroscopically normal. Thirty-one appendices were excised and subsequently found to be histologically normal (5.6% of all appendectomies). The NAR was significantly lower among patients who underwent preoperative imaging than among those without imaging (6.9% versus 24.4%; RR = 0.28, 95% CI: 0.18-0.45, $p < 0.001$).

Abdominal CT demonstrated a sensitivity of 92.2% (95% CI: 88.4-95.0%) and a positive predictive value of 98.1% (95% CI: 95.7-99.4%), whereas ultrasound sensitivity could not be reliably calculated due to the small number of cases (n = 34). An Alvarado score ≥ 7 had a sensitivity of 70.7% (95% CI: 66.7-74.6%) and a positive predictive value of 87.6%; specificity and negative predictive value could not be calculated because patients with low scores who were not operated on or did not undergo imaging were not included in the cohort.

Intraoperative findings

Among patients with confirmed appendicitis (n = 522), 61.9% had phlegmonous, 13.2% gangrenous and 24.9% perforated appendicitis. In patients with normal appendices, the most common findings were mesenteric adenitis and gynaecological conditions (e.g., endometriosis, salpingitis and ovarian cysts). Less frequent findings included an inflamed Meckel's diverticulum, terminal ileum inflammation and one case of carcinomatosis.

Subgroup analysis

Scanned versus non-scanned

Patients undergoing preoperative imaging were older (median 52.5 (IQR: 33-67) versus 28 (IQR: 21-36) years; p <

0.001), had higher CRP levels (67 (IQR: 23-165) vs. 35 (IQR: 15.5-75.5) mg/l; p < 0.001) and lower Alvarado scores (7 (IQR: 6-8) vs. 8 (IQR: 7-9); p < 0.001) than patients who did not undergo imaging (**Table 2**).

TABLE 2 Patient characteristics and negative appendectomy rates stratified by preoperative imaging.

	Preoperative imaging (N_p = 334)	No preoperative imaging (N_n = 279)	p value[a]
Age, median (IQR), yrs	52.5 (33-67)	28 (21-36)	< 0.001
Females, n (%)	179 (53.6)	143 (51.3)	0.564
CRP concentration, median (IQR), mg/ml	67 (23-165)	35 (15.5-75.5)	< 0.001
Leukocyte concentration, median (IQR), × 10^9/l	12.7 (9.7-15.7)	13.2 (10.6-16.0)	0.175
Alvarado score[b], median (IQR)	7 (6-8)	8 (7-9)	< 0.001
Time from admission to operation, median (IQR), h	10 (7-16)	8 (5-13)	< 0.001
Negative appendectomy, n (%)	23 (6.9)	68 (24.4)	< 0.001

a) Calculated using the Mann-Whitney U test for continuous variables and the χ^2- or Fisher's exact test for categorical variables, as appropriate.
b) Scale 0-10.

Three main reasons for imaging were identified: age over 50 years, suspicion of more acute or severe pathology, and clinically borderline cases where discharge was considered despite weak clinical characteristics for appendicitis.

Appendicitis versus non-appendicitis

Patients with negative appendectomy were younger (median 28 (IQR: 22-34) versus 39 (IQR: 27-60) years; p < 0.001) and more frequently female (73.6% versus 48.9%; p < 0.001) than those with confirmed appendicitis. Leukocyte count was significantly lower among patients without appendicitis (10.6 (IQR: 8.0-13.5) vs. 13.2 (IQR: 10.9-16.1) × 10&;/l; p < 0.001), whereas CRP levels did not differ significantly between groups (p = 0.54). The median Alvarado score was slightly higher among patients with appendicitis than among those without (8 (IQR: 6-8) versus 7 (IQR: 6-8); p = 0.001), although the difference was small and the IQRs overlapped (**Table 3**).

TABLE 3 Patient characteristics stratified by appendicitis status.

	Appendicitis (N_a = 522)	No appendicitis (N_n = 91)	p value[a]
Age, median (IQR), yrs	39 (27-60)	28 (22-34.5)	< 0.001
Females, n (%)	255 (48.9)	67 (73.6)	< 0.001
CRP concentration, median (IQR), mg/ml	47 (21-120)	47 (21.5-96.5)	0.540
Leukocyte concentration, median (IQR), × 10^9/l	13.2 (10.9-16.1)	10.6 (8-13.5)	< 0.001
Alvarado score[b], median (IQR)	8 (6-8)	7 (6-8)	0.001

a) Calculated using the Mann-Whitney U test for continuous variables and the χ^2- or Fisher's exact test for categorical variables, as appropriate.
b) Scale 0-10.

Discussion

Our study shows a very high NAR among patients undergoing surgery without preoperative imaging. Patients who did not receive imaging had n NAR of 24.4%, compared with 6.9% among those who underwent CT or ultrasound, demonstrating that reliance on clinical assessment alone increases unnecessary surgeries.

Subgroup analyses showed that patients selected for imaging were generally older and had higher CRP levels, reflecting clinicians' tendency to image cases with potentially complex or atypical presentations. Among negative appendectomies, younger patients and females were overrepresented. Although the median Alvarado score was slightly lower in patients without appendicitis than in those with appendicitis, the interquartile ranges largely overlapped, indicating that clinical scoring alone may not reliably distinguish appendicitis from mimicking conditions in these populations.

Limitations of this study include its retrospective design and potential selection bias among imaged patients. The small number of patients undergoing ultrasound limits our ability to draw conclusions about its impact on the negative appendectomy rate; therefore, our findings primarily reflect those from CT-based imaging. Alvarado scores were calculated retrospectively, and specificity and negative predictive value could not be assessed because patients with low scores who were not operated on were excluded. Despite these limitations, our findings align with those of prior studies, which demonstrate that preoperative imaging improves diagnostic accuracy and reduces unnecessary operations [7-9, 11]. Our findings apply only to adults and cannot be extrapolated to children, who follow different diagnostic pathways and have different risks of negative appendectomy.

Historically, a NAR of 20-25% was accepted to avoid missed complicated appendicitis, whereas contemporary studies report substantial variation, 0-46%, with an overall estimated rate of 13% [12]. Clinical scoring systems such as the Alvarado [3] and AIR [4] scores may aid decision-making, but their diagnostic performance is inconsistent: the Alvarado score shows variable sensitivity and specificity [5], whereas the AIR score generally demonstrates high sensitivity but only moderate specificity [6].

Diagnostic laparoscopy for suspected appendicitis is generally considered safe and is associated with low complication rates [13, 14]. Although preoperative imaging incurs direct costs and resource use, it substantially reduces NAR, avoiding unnecessary anaesthesia, operative time and hospital stay. Routine imaging is therefore cost-effective, particularly when ultrasound is used as the first-line modality [11, 15], and preoperative CT has also been shown to reduce costs [7]. Potential downsides include diagnostic delays and radiation exposure [16-18], although low-dose CT protocols have been shown to maintain diagnostic accuracy while minimising radiation exposure [19, 20].

Our results highlight the gap between Danish clinical practice and international guidelines. The 2020 World Society of Emergency Surgery Jerusalem guidelines recommend structured imaging protocols to support rapid, accurate diagnosis [2]. Implementing such protocols could reduce NAR, improve resource utilisation and enhance patient safety, particularly in young adults and women, who are at a higher risk for negative appendectomies. Future studies could evaluate the prospective implementation of low-dose CT and expanded use of ultrasound to further reduce unnecessary imaging and optimise diagnostic workflows.

Conclusions

Reliance on clinical assessment alone results in a substantial number of negative appendectomies. Preoperative imaging significantly reduces unnecessary operations (NAR: 24.4% versus 6.9%; $p < 0.001$). In modern emergency workflows, where rapid assessment and short observation periods are required, structured,

guideline-based imaging protocols –incorporating selective CT and ultrasound – may particularly reduce unnecessary diagnostic laparoscopies in young adults while potentially optimising resource utilisation.

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