

# A comparison between emergency physicians and radiologists on the interpretation of computed tomography in acute appendicitis

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## Ethics Committee Approval

This study was approved by IRB of Taipei Medical University and the approval number was listed as N201906023 (TMUH number N201909009). All procedures in this study involving human participants were performed in accordance with the 1964 Helsinki Declaration and its later amendments.

## Conflict of Interest

No conflict of interest was declared by the authors.

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## Abstract

**Background/Aim:** Appendicitis is a common acute abdominal disease seen in the emergency department (ED). Early diagnosis of appendicitis can reduce time to treatment and prevent complications. In this study, we aimed to compare the interpretation of computer tomography (CT) scans between emergency physicians and radiologists.

**Methods:** We conducted a retrospective cohort study that enrolled patients with CT scans for suspected acute appendicitis in an academic hospital from July 2019 to May 2020. Analysis of the accuracy of the diagnosis of appendicitis and time from completion of CT scan were compared between emergency physicians and radiologists.

**Results:** A total of 318 patients with appendicitis were included. Patients arriving at the hospital during off-hours were younger (mean difference: 5,  $P=0.016$ ) and more commonly had normal C-reactive protein (chi-square: 11.19,  $P<0.001$ ). Neither group's interpretation of appendicitis was affected by arrival time, and both groups performed differential diagnosis well (emergency physician area under curve [AUC]: 0.912 vs. radiologist AUC: 0.911). Time to CT interpretation by emergency physicians was significantly lower than by radiologists (mean difference: -217.37 min,  $P<0.001$ ).

**Conclusions:** The interpretation of abdominal CT scans for acute appendicitis by emergency physicians was more efficient and equally accurate compared to interpretation by radiologists.

**Keywords:** appendicitis, computed tomography, emergency physicians, radiologists

## Introduction

Appendicitis is a common acute abdominal disease seen in the emergency department (ED), and the estimated lifetime risk is around 7–8% [1]. Appendicitis can occur at any age, though it is most common in patients between 10 and 30 years old [2]. Obstruction of vermiform appendix, often by a fecalith, is the classic etiology of appendicitis. Other causes may include obstruction by tumor, gallstone, lymphoid hyperplasia, or parasitic infection [3]. Appendicitis is suspected in patients presenting with acute right lower quadrant pain and leukocytosis. The final diagnosis depends on histologic findings of the surgical specimen. There are several diagnostic image exams for appendicitis, including transabdominal ultrasonography, computed tomography (CT), and magnetic resonance imaging (MRI). CT with contrast is frequently used for diagnosis in the ED. CT is used in 86% of patients in the USA, and the sensitivity and positive predictive value of CT can reach 96% [4,5]. In many countries, the standard treatment for appendicitis is appendectomy, which requires immediate surgical consultation [6]. A meta-analysis of 11 non-randomized studies showed that delaying appendectomy for more than 48 hours was associated with increased surgical site infections and other adverse events, and that prompt appendectomy provided the fastest resolution of patients' pain [7]. Several studies have compared the CT time of interpretation of appendicitis between emergency physicians and radiologists [8,9]. The aim of this study was to compare the time to CT scan and the accuracy of CT scan interpretation between emergency physicians and radiologists.

## Materials and methods

This retrospective study was performed in the ED of a 750-bed tertiary referral and academic hospital in northern Taiwan, which handles approximately 52,000 ED visits annually. A preliminary report system for emergency physicians to document CT scan interpretations was established in June 2019. The reason for creating this system was to allow emergency physicians to receive a 20% bonus payment from the national health insurance if a preliminary report was documented within 2 hours of the completion of the CT scan. In the study, we reviewed all CT scans conducted from July 2019 to May 2020, and we recorded the report time for CT related to suspicion of appendicitis. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines were used during case enrolment. Report time was defined as the interval from the CT being ordered to the report being documented, and report times were recorded separately for the preliminary report system of emergency physicians and the final report of the radiologists. In the study's hospital setting, emergency physicians and radiologists read CT scans and make preliminary and final reports independently. Final diagnosis of appendicitis was determined by the pathologic report of the surgical procedure. We also collected clinical information such as sex, fever, white blood cell (WBC) count, and C-reactive protein (CRP). The definition of weekday hours was 08:00–17:00 from Monday to Friday, except for holidays; off-time hours were defined as weeknights (17:00–08:00 the next day) and weekend hours.

This study was approved by the IRB, approval number N201906023 (TMUH number N201909009).

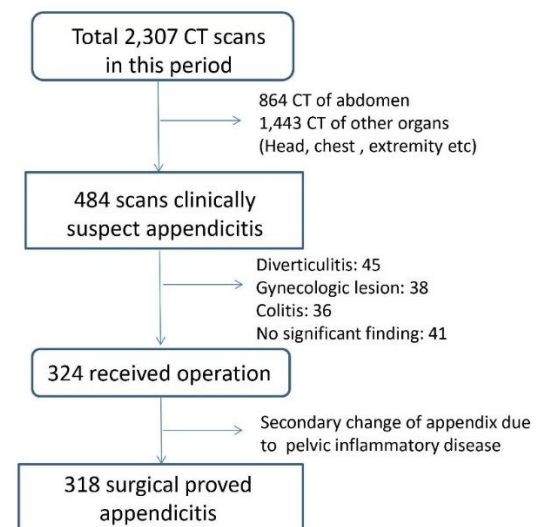
## Statistical analysis

All statistical analyses were conducted using SPSS Statistics version 24 for Windows (IBM Corp., Armonk, New York, USA). To analyze the association between ED arrival time (i.e., weekday hours vs. off-time hours) and characteristics, chi-square test was applied to dichotomous variables such as patient sex, fever, WBC count, and CRP level, as well as appendicitis judgment. Due to the imbalanced data on the interpretations of appendicitis (i.e., very few cases without appendicitis), precision-recall curves-based area under curve (AUC) were used to test the appropriateness of the interpretations of appendicitis by emergency physicians and radiologists. To examine the difference in review time and age between the two specialties, data were analyzed using the Wilcoxon test due to non-normal distribution. Medians with interquartile range (IQR) of review time were reported for each group, and between-group mean differences were also presented with the *P*-value of the Wilcoxon test.

## Results

A total of 2,307 abdominal CT scans were performed during the study period, including 484 cases with initial clinical suspicion of appendicitis. A total of 318 patients with appendicitis were enrolled according to surgical findings (Figure 1).

Figure 1: The algorithm for enrollment of the subjects.



With regard to patient characteristics, sex, fever, and abnormal WBC count did not vary in ED arrival time (Table 1). However, patients who presented to the ED during off-time hours were younger than those arriving during weekday hours (mean difference [MD]: 5;  $P=0.016$ ). Moreover, patients reporting to the ED during off-time hours more commonly had normal CRP than those who reported during weekday hours (chi-square: 11.19;  $P<0.001$ ). For both emergency physicians and radiologists, the accuracy of interpretation of appendicitis was not affected by arrival time. Based on surgical findings, both emergency physicians (AUC: 0.912) and radiologists (AUC: 0.911) were accurate in diagnosis of appendicitis.

On the other hand, report time of appendicitis was significantly different between emergency physicians and radiologists. On average, the report time among emergency

physicians was significantly lower than among radiologists (MD: -217.37 min;  $P < 0.001$ ) (Figure 2). This phenomenon did not vary by patient ED arrival time, fever, abnormal WBC count, or abnormal CRP (Table 2).

Table 1: Characteristics of patients with appendicitis (n=318)

Characteristic	Total <sup>a</sup>	Arrival time		Diff	P-value
		Off-time	Weekday hours		
<b>Sex (patient)</b>				2.50	0.114
Female	166 (52.2%)	110 (49.1%)	56 (59.6%)		
Male	152 (47.8%)	114 (50.9%)	38 (40.4%)		
<b>Age</b>	42.07±17.50	40.71±17.02	45.30±18.28	-5.00	0.016
<b>Fever</b>				0	1.000
Yes	42 (13.2%)	30 (13.4%)	12 (12.8%)		
No	276 (86.8%)	194 (86.6%)	82 (87.2%)		
<b>WBC</b>				2.75	0.097
Abnormal	238 (74.8%)	174 (77.7%)	64 (68.1%)		
Normal	80 (25.2%)	50 (22.3%)	30 (31.9%)		
<b>CRP</b>				11.19	<0.001
Abnormal	212 (66.6%)	136 (60.7%)	76 (80.9%)		
Normal	106 (33.3%)	88 (39.3%)	18 (19.1%)		
<b>Emergency</b>				--	--
Appendicitis	318 (100%)	224 (100%)	94 (100%)		
No appendicitis	0 (0%)	0 (0%)	0 (0%)		
<b>Radiology</b>				0.02	0.887
Appendicitis	316 (99.4%)	222 (99.1%)	94 (100%)		
No appendicitis	2 (0.6%)	2 (0.9%)	0 (0%)		

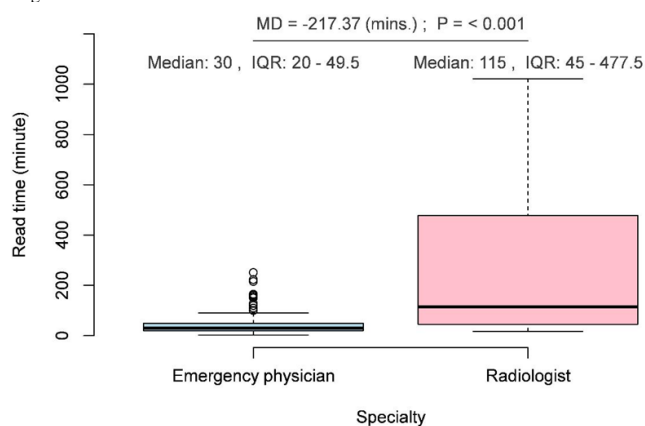
<sup>a</sup> number (percentage), Diff: Difference, CRP: C-Reactive protein, WBC: white blood cell. Chi-square was used to test categorical variable and student's t test for continuous variable.

Table 2: Subgroup analysis of review time (minutes) of appendicitis

Subgroup	Emergency physician		Radiologist		Diff	P-value
	Median	IQR	Median	IQR		
<b>Time of reporting</b>						
Weekday hours	33.00	20.00-76.50	70.00	41.50-142.50	-71.89	<0.001
Off-time	30.00	20.00-49.50	352.00	45.50-631.00	-313.07	<0.001
<b>Fever</b>						
Yes	23.00	20.00-33.00	89	36.00-390.00	-196.67	<0.001
No	31.00	20.00- 50.00	120.00	46.25-478.75	-220.52	<0.001
<b>WBC</b>						
Abnormal	32.00	20.00-50.00	138.00	45.00- 559.50	-235.50	<0.001
Normal	23.00	16.75- 47.5	91.00	44.50-350.50	-163.43	<0.001
<b>CRP</b>						
Abnormal	30.00	20.00-45.75	94.50	45.25-397.50	-194.45	<0.001
Normal	31.00	21.00- 60.00	150.00	45.00- 570.00	-263.21	<0.001

Wilcoxon test, CRP: C-Reactive protein, IQR: interquartile range, Diff: Difference, MD: mean difference, WBC: white blood cell

Figure 2: Boxplot of review time of appendicitis between emergency physician and radiologist.



## Discussion

Acute appendicitis is a common atraumatic surgical emergency in the ED [10]. Abdominal CT scan is a diagnostic tool to detect acute appendicitis, and timely and accurate interpretation of the CT scan can provide patients with optimal treatment. We investigated and compared the accuracy and the time of interpretation of abdominal CT scan for acute appendicitis between emergency physicians and radiologists in a Taiwanese cohort. Diagnosis with CT and surgical treatment is standard treatment for appendicitis in Taiwan [11]. We also analyzed the results of different admission times and patient characteristics. One of the most crucial findings in this study is

that the emergency physicians and radiologists showed similar accuracy but that the emergency physicians had shorter report times.

Several previous studies have compared the difference between radiologists and clinical physicians in CT scan results [8,9,12,13]. In our study of 318 cases, emergency physicians and radiologists showed similar accuracy results (AUC: 0.912 vs. 0.911). The slightly higher accuracy in emergency physicians may be due to the clinical approach with patients, involving history taking, physical examination, and real-time consultation with radiologists as needed. This result suggests that emergency physicians' interpretation of abdominal CT scan for acute appendicitis can be reliable. One study in the USA found that overcrowding in the ED is associated with an approximately 2-hour delay to CT interpretation by radiologists [14]. This delay may increase the length of stay for the patients, which can cause a vicious circle and increase the care burden for the staff. It can also delay the time to operation and ultimately increase morbidity or mortality. In our study, the overall mean deviation time between the two groups was 217 min from triage to CT interpretation. The overall median time for emergency physicians was 30 min, compared to 115 for radiologists. This difference may be due to the fact that radiologists have many reports that need to be documented at the same time, whereas emergency physicians are normally informed once the CT is done, allowing them to interpret the result in a timely fashion. The other reason is that patients' treatment and disposition depend on the CT result, so emergency physicians will have more motivation and time pressure to give an initial report. To differentiate the time difference in diagnosis, the mean deviation times during weekday hours and off-time hours were 72 min and 313 min, respectively. During weekday hours, the median times were 33 min for emergency physicians and 70 min for radiologists; during off-time hours, the times were 30 min for emergency physicians and 352 min for radiologists. We found no difference for emergency physicians between weekday hours and off-time hours because they are on duty and responsible throughout their 12-hour shifts. By contrast, the hospital where the study took place had six board-certified radiologists on duty during weekday hours for CT interpretations but only one radiologist on duty during off-time hours for emergency procedures and reports. This explains the significant increase in median times during off-time hours in the radiologists group. If emergency physicians can precisely and quickly interpret CT results for acute appendicitis and seek the opinions of radiologists as needed, it can decrease patients' wait times and observation times, thereby easing the care burden for staff and decreasing overcrowding in the ED.

## Limitations

One limitation of our study is the potential for selection bias due to its retrospective design and reliance on data from a single center. This may limit the generalizability of our findings to broader patient populations or healthcare settings. Additionally, the retrospective nature of the study may have introduced inherent biases in data collection and interpretation. Moreover, while efforts were made to control for various confounding variables, the possibility of residual confounding cannot be completely ruled out. Factors not accounted for in our

analysis may have influenced the observed associations between arrival time and diagnostic outcomes.

Finally, the analysis of report times was limited to appendicitis cases, and factors influencing report times for other conditions were not investigated. Understanding these factors could provide a more comprehensive perspective on the efficiency of radiological reporting in the ED.

### Future research

Further investigations are warranted to explore the factors contributing to the observed differences in report times and to develop strategies aimed at optimizing radiological reporting efficiency without compromising diagnostic accuracy.

### Conclusion

The accuracy of interpreting CT scans for appendicitis by both emergency physicians and radiologists remained consistent irrespective of arrival time, demonstrating consistently high diagnostic precision. Implementation of protocols or interventions aimed at reducing reporting disparities could lead to improved patient outcomes and resource utilization in the management of acute abdominal conditions.

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