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ORIGINAL ARTICLE

CME

Appendicitis Computed Tomography Score: a Useful Tool for Predicting Perforation and Surgical Course of Acute Appendicitis

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ABSTRACT

Objective: *To investigate the utility of the Appendicitis Computed Tomography (ACT) scoring system in the diagnosis of perforated appendicitis and prediction of surgical outcome.*

Methods: *A retrospective study was conducted on 102 subjects who underwent computed tomography (CT) scan and appendectomy for acute appendicitis between May 2011 and January 2012. Images were reviewed for five individual CT signs (appendiceal wall defect, phlegmon, abscess, extraluminal gas, and extraluminal appendicolith) and a score (ACT score) was assigned for each patient based on the number of detectable findings. Correlation of ACT score and individual CT signs with appendiceal perforation and surgical outcome was evaluated statistically. Diagnostic power was assessed using receiving operating characteristic (ROC) curve.*

Results: *A total of 84 subjects were included in the final study after exclusion. ACT score was significantly higher for the perforated group compared with the non-perforated group (2.52 vs. 0.40, p < 0.001) and also higher for the open surgery group than the laparoscopic surgery group (2.78 vs. 0.93, p < 0.001). ACT score was an independent predictor of perforation (odds ratio [OR] = 7.05, p < 0.001), need for open surgery (OR = 2.99, p = 0.002), and operating time (increase of 12.93 minutes, p < 0.001). On ROC curves, ACT score showed a higher discriminating power for both appendiceal perforation (area under the curve [AUC] = 0.939) and need for open surgery (AUC = 0.858) than individual CT signs. An ACT score of 0 was 100% sensitive for excluding appendiceal perforation and open surgery in our study, whereas an ACT score of >3 was diagnostic for perforated appendix.*

Conclusions: *The ACT score is a practical and accurate tool for diagnosis of appendiceal perforation and prediction of surgical outcome.*

中文摘要

闌尾炎CT評分：一個能預測急性闌尾炎穿孔和手術結果的有用工具

賴銘曦、朱志揚、梁肇庭、馮啓邦、李騰飛、宋咸東、邱麗珊

目的：探討闌尾炎電腦斷層掃描（ACT）評分系統對於診斷闌尾炎穿孔和預測手術結果的效用。

方法：回顧研究於2011年5月至2012年1月期間因急性闌尾炎而接受闌尾切除術，並接受電腦斷層掃描（CT）的102名患者。找出他們的CT影像是否有以下五項獨立特徵：闌尾壁缺損、蜂窩織炎、膿腫、闌尾腔外集氣和闌尾腔外結石；並按其出現特徵的數目給予評分（即ACT分數）。把ACT分數

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和獨立的闌尾穿孔CT特徵和手術結果的相關性進行了統計學評估。利用ROC曲線為評估其診斷功能。

結果：共84名病人被納入最後研究。闌尾穿孔患者的ACT分數顯著高於沒有穿孔的患者（2.52比0.40，p<0.001）；接受開腹手術患者的ACT分數顯著高於接受腹腔鏡手術的患者（2.78比0.93，p<0.001）。ACT分數是以下幾項的獨立預測因子：穿孔（比數比=7.05，p<0.001）、需進行開腹手術（比數比=2.99，p=0.002）和手術時間（增加了12.93分鐘，p<0.001）。經ROC曲線分析，ACT分數在闌尾穿孔（曲線下之區域=0.939）和需進行開腹手術（曲線下之區域=0.858）方面比獨立CT特徵有較高的辨識能力。本研究發現ACT分數為「零」時即可完全排除闌尾穿孔和開腹手術的可能性，而ACT分數高於3時可被診斷為闌尾穿孔。

結論：ACT分數是診斷闌尾穿孔和預測手術結果的一個既實用又準確的工具。

INTRODUCTION

Acute appendicitis is one of the most common reasons for admission for acute abdomen with a reported lifetime incidence of 7%.[1] Today, preoperative imaging for confirmation of clinically suspected acute appendicitis is an increasingly frequent request for urgent cross-sectional imaging and at some centres, it is almost a uniform prerequisite. Computed tomography (CT) scan is the most frequently used imaging modality for diagnosing or excluding acute appendicitis because of its high sensitivity and specificity, which is reported to be 94% and 95%, respectively.[2] In addition to confirmation of diagnosis, there are many ancillary findings on the images within the same CT scan that may have value in the prediction of clinical and surgical outcome.

Like Ranson's score for acute pancreatitis, development of a simple scoring system for acute appendicitis would be ideal to help gauge the severity of disease and to facilitate communication between surgeon and radiologist as to the urgency of the patient's condition. Information that can aid the surgeon in estimating the level of difficulty of the operation and expected duration of surgery would allow optimisation of use of operating theatre and surgical planning. Laparoscopy is currently the standard surgical method for appendicectomy. In most centres, conversion to open surgery is reserved for complicated cases where laparoscopic surgery has failed. It would be ideal if the preoperative CT findings could help identify high-risk groups who are likely to require open surgery. This would enhance communication between the surgeon and the patient, and improve the mutual understanding of the expected prognosis and surgical outcome. Such prognostic information may also aid surgeons in their choice of surgical approach or timing allowed for trial of laparoscopic surgery, and thus minimise unnecessary operating time and use of laparoscopic equipment in cases where a laparoscopic approach is unlikely to be successful. Based on the findings published by Horrow et al,[3] we have established a scoring system for acute appendicitis — the Appendicitis Computed Tomography score (ACT score), and assessed its correlation with prevalence of appendiceal perforation, surgical outcome, and prognosis, in terms of operating time and surgical approach, for patients with acute appendicitis.

METHODS

Subjects

This retrospective study comprised 102 consecutive subjects who underwent contrast-enhanced CT scan of the abdomen and pelvis, and surgical appendectomy within the same hospital stay during the period from May 2011 to January 2012. Patient medical records, operative findings, pathological reports, and CT findings were reviewed. Subjects were excluded if: (a) the contrast-enhanced CT scan was performed after appendectomy with no preoperative CT available, (b) subjects had incidental appendectomy unrelated to acute appendicitis, or (c) the appendectomy was performed more than 24 hours after CT. The study was conducted with approval from the hospital's institutional review board and was compliant with Health Insurance Portability and Accountability Act.

Clinical and Operative Outcome

Confirmation of acute appendicitis and the presence or absence of perforation were determined from operative records and anatomical pathology records.

Initial surgical approach (laparoscopic versus open), need for conversion to open surgery, and duration of surgery were determined from the patient's medical and operative records.

Imaging Acquisition Parameters

All CT scans consisted of plain and contrast-enhanced scans of the abdomen and pelvis with scanning range starting from the dome of the diaphragm and extending to the pubic symphysis. The scans were performed on either a 16-detector row multi-detector CT (Aquilion 16; Toshiba, Tokyo, Japan) or a 64-detector row multi-detector CT (Aquilion Cx; Toshiba, Tokyo, Japan) with 3D reformatting capability. After plain CT scan, contrast-enhanced CT scan was obtained with 80 ml of contrast material containing 370 mg of iodine per ml (Iopamidol; Iopamiro 370, Bracco) being injected at a rate of 2-3 ml/sec. The scan delay time was 85 seconds after contrast injection. The volume of contrast was adjusted for patients younger than 12 years, with injected volume being 2 ml/kg body weight. No oral contrast was given for the CT scans.

Image Evaluation and ACT Score Calculation

All CT images were retrospectively and independently reviewed at a stand-alone workstation (Vitrea, Toshiba, Tokyo, Japan) by two fellow radiologists (CYC with 6 years of experience and VKPF with 5 years of experience), who were blinded to the patients' clinical, surgical, and pathological records. The radiologists assessed the presence of five CT findings, in accordance with the study by Horrow et al.[3] These included: (a) defect in enhancing appendiceal wall, (b) phlegmon, (c) abscess, (d) extraluminal gas, and (e) extraluminal appendicolith (Figure 1). In cases of disagreement, consensus was achieved through mutual discussion.

Defect in enhancing appendiceal wall was defined as an interruption in the enhancement of the appendiceal wall. This sign was not assessed in patients in whom the appendix could not be identified. Phlegmon was defined as diffuse and substantial inflammation of the peri-appendiceal fat with ill-defined but not rim-enhancing fluid collections. Abscess was defined as a discrete

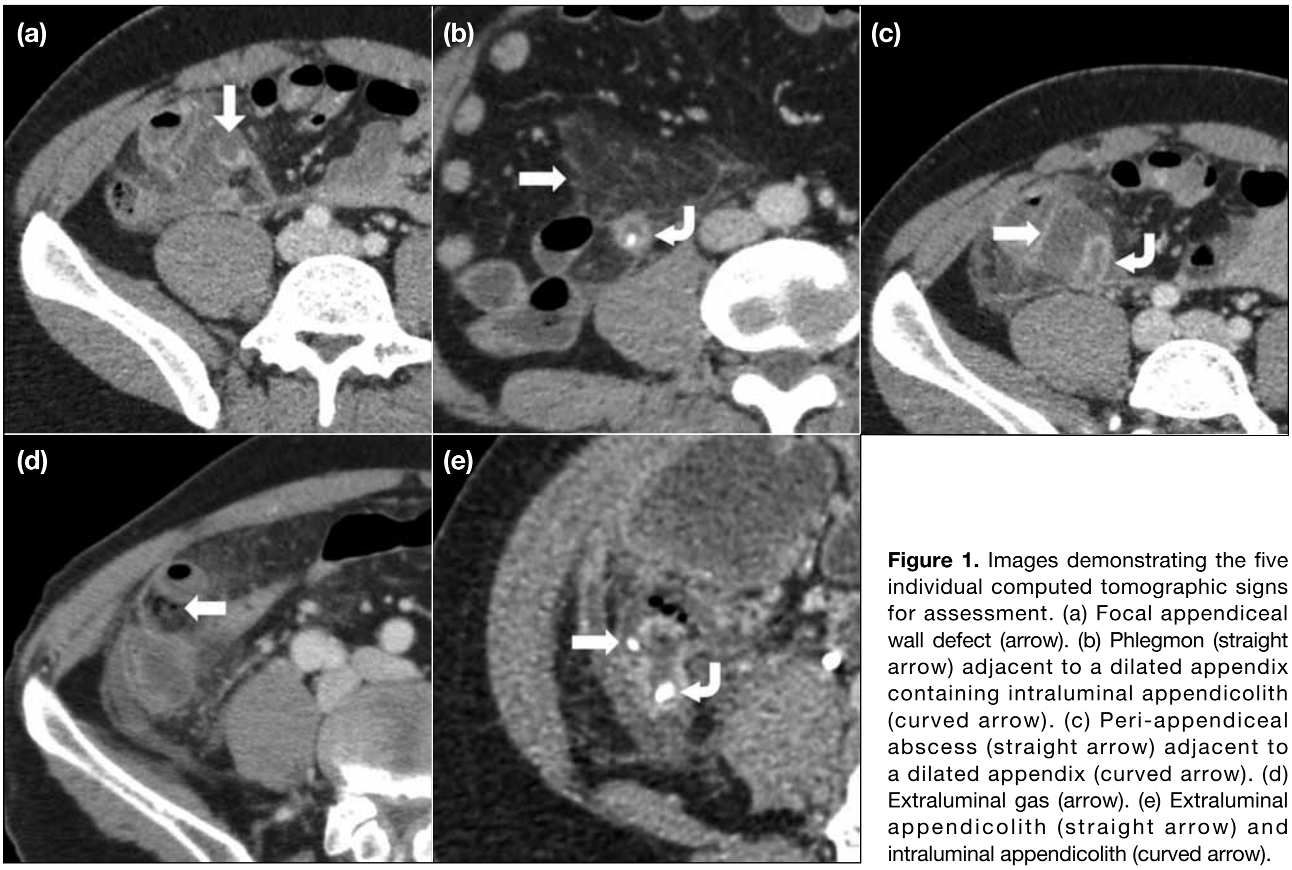


Figure 1. Images demonstrating the five individual computed tomographic signs for assessment. (a) Focal appendiceal wall defect (arrow). (b) Phlegmon (straight arrow) adjacent to a dilated appendix containing intraluminal appendicolith (curved arrow). (c) Peri-appendiceal abscess (straight arrow) adjacent to a dilated appendix (curved arrow). (d) Extraluminal gas (arrow). (e) Extraluminal appendicolith (straight arrow) and intraluminal appendicolith (curved arrow).

collection with rim enhancement. Extraluminal gas was defined as focal areas of free gas outside of the bowel lumen. Appendicolith was regarded as a well-defined, hyperdense non-enhancing structure and also had to be determined as intraluminal or extraluminal.

The ACT score was the total number of positive findings as listed above. The maximum score was therefore 5 and the minimal score was 0.

Statistical Analyses

Statistical analyses were performed using the Statistical Package for the Social Sciences (Windows version 15.0; SPSS Inc, Chicago [IL], US). Test for normality was performed using Shapiro-Wilk test. Mann-Whitney *U* test, Chi-square test, and Fisher's exact test were also performed. A significance level of 0.05 was used. Sensitivity, specificity, and accuracy of individual CT findings and the ACT score in determining the presence of perforation were evaluated. Interobserver agreement of the specific findings was presented as Kappa score, using the following scale: fair agreement, 0.21-0.40; moderate agreement, 0.41-0.60; substantial agreement, 0.61-0.80; and almost perfect agreement, 0.81-1.00.[4] Receiver operating characteristic (ROC) curves were analysed for individual CT findings and the ACT score in terms of diagnostic power for determining appendiceal perforation and need for conversion to open surgery. Association of the ACT score with perforation, conversion to open surgery, and operating time was evaluated using univariate and multivariate regression analyses.

RESULTS

Subject Characteristics

Of the 102 consecutive subjects initially entered into the study, 18 were excluded. The final study population consisted of 84 patients (Figure 2). Detailed demographics of the final study population are listed in Table 1.

Perforated appendix was noted on surgery / pathological examination in 34.5% (n = 29) of subjects. All appendectomies were performed with a laparoscopic approach as the initial attempt. The mean rate of conversion to open surgery was 10.7%. No peri-operative mortality was noted.

The distribution of the five individual CT signs and ACT score for the study population is listed in Tables 1 and 2. Interobserver agreement for the five individual signs ranged from moderate agreement (Kappa score: 0.41-0.60) to almost perfect agreement (Kappa score: 0.81-1.00), depending on the individual sign. Almost

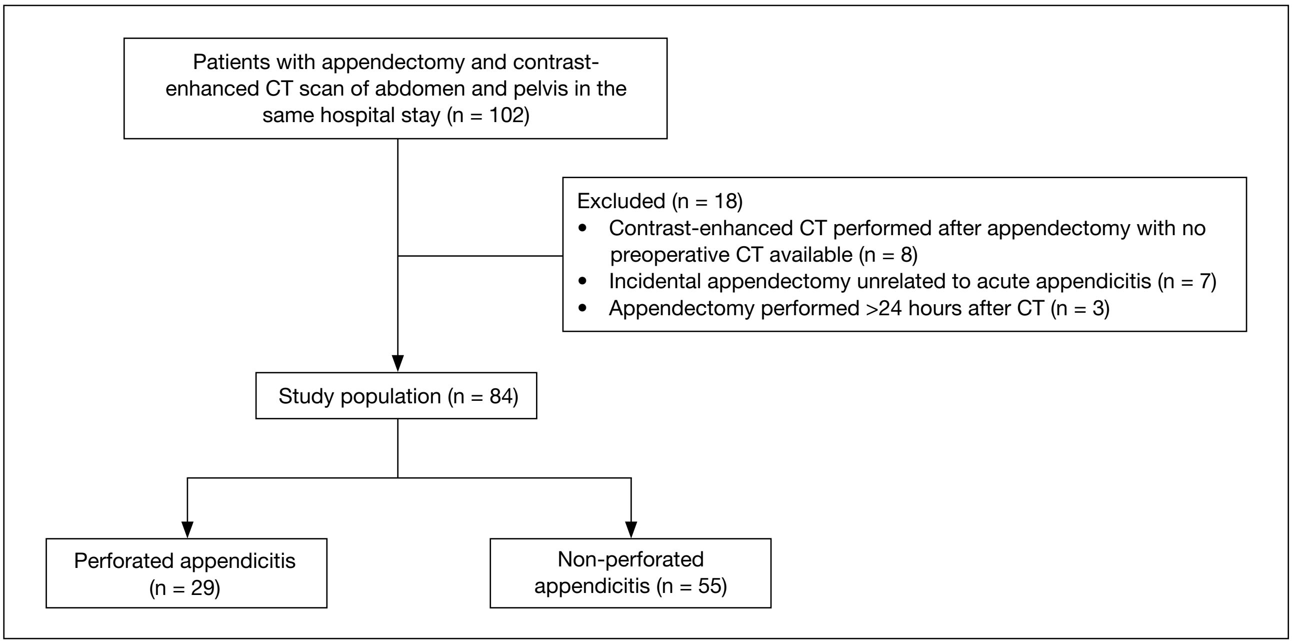


Figure 2. Flowchart of study protocol.
Abbreviation: CT = computed tomography.

Table 1. Subject characteristics, ACT scores, individual CT findings with perforated versus non-perforated appendix.

	Data			p Value
	All (n = 84)	Perforated (n = 29)	Non-perforated (n = 55)	
Male:female ratio	0.68:1	1.42:1	0.48:1	0.019
Age (years)*	48.8 ± 20.3	43.1 ± 23.2	51.8 ± 18.2	0.075
Operating time (mins)*	58.9 ± 26.6	79.3 ± 24.5	48.1 ± 20.0	<0.001
Conversion to open surgery	10.7%	24.1%	3.6%	0.008
Mean ACT score	1.13	2.52	0.40	<0.001
ACT score 0	50.0%	0%	76.4%	-
ACT score 1	11.9%	13.8%	10.9%	-
ACT score 2	17.9%	34.5%	9.1%	-
ACT score 3	16.7%	41.4%	3.6%	-
ACT score 4	2.4%	6.9%	0%	-
ACT score 5	1.2%	3.4%	0%	-
Focal wall defect	40.5%	82.8%	18.2%	<0.001
Phlegmon	17.9%	31.0%	10.9%	0.035
Abscess	23.8%	65.5%	1.8%	<0.001
Pneumoperitoneum	11.9%	52.6%	0%	<0.001
Extraluminal appendicolith	2.4%	6.9%	0%	1.116

Abbreviations: ACT score = Appendicitis Computed Tomography score; CT = computed tomography.
* Means ± standard deviations are shown.

Table 2. Subject characteristics, ACT scores, individual CT findings in subjects undergoing open versus laparoscopic surgery.

	Data			p Value
	All (n = 84)	Open surgery (n = 9)	Laparoscopic surgery (n = 75)	
Male:female ratio	0.68:1	1.25:1	0.71:1	0.475
Age (years)*	48.8 ± 20.3	43.1 ± 23.2	51.8 ± 18.2	0.235
Operating time (mins)*	58.9 ± 26.6	94.1 ± 26.5	53.9 ± 23.6	0.004
Perforation	34.5%	77.8%	29.3%	0.008
Mean ACT score	1.20	2.78	0.93	<0.001
ACT score 0	50.0%	0%	56.0%	-
ACT score 1	11.9%	11.1%	12.0%	-
ACT score 2	17.9%	22.2%	17.3%	-
ACT score 3	16.7%	55.6%	12.0%	-
ACT score 4	2.4%	0%	2.7%	-
ACT score 5	1.2%	11.1%	0%	-
Focal wall defect	41.0%	88.9%	35.1%	0.003
Phlegmon	18.1%	33.3%	16.2%	0.353
Abscess	24.1%	77.8%	17.6%	<0.001
Pneumoperitoneum	12.0%	55.6%	6.8%	0.001
Extraluminal appendicolith	2.4%	11.1%	1.4%	0.206

Abbreviations: ACT score = Appendicitis Computed Tomography score; CT = computed tomography.
* Means ± standard deviations are shown.

perfect agreement was noted for focal wall defect (κ = 0.894), pneumoperitoneum (κ = 1.00), and extraluminal appendicolith (κ = 0.971). There was slightly lower interobserver agreement for abscess (κ = 0.657) and for phlegmon (κ = 0.481).

Effects of Appendiceal Perforation on Surgical and Clinical Outcomes

The mean operating time was significantly longer in the perforated appendix group than the non-perforated group (79.3 minutes vs. 48.1 minutes, $p < 0.001$). The rate of conversion to open surgery (24.1% vs. 3.6%, $p = 0.008$) was also significantly higher in the perforated group (Table 1).

Correlation of Appendiceal Perforation with ACT Score and Individual Computed Tomography Findings

The mean ACT score was significantly higher for the perforated group than the non-perforated group (2.52

vs. 0.40, p < 0.001; Table 1).

There was a higher prevalence of focal wall defect (p < 0.001), pneumoperitoneum (p < 0.001), abscess (p < 0.001), and phlegmon (p = 0.035) in subjects with perforated appendix (Table 1). No statistically significant result was seen for extraluminal appendicolith, despite a higher numerical prevalence being observed in the perforated group (6.9% vs. 0%). This was probably due to the small number of cases of extraluminal appendicolith (n = 2), leading to the results being statistically insignificant despite a higher numerical prevalence.

Correlation of Need for Open Surgery with ACT Score, Individual Computed Tomography Findings, and Operating Time

Subjects who required open surgery had a higher mean ACT score than those who underwent laparoscopic appendicectomy (2.78 vs. 0.93, p < 0.001). CT findings of focal wall defect (p = 0.003), pneumoperitoneum (p = 0.001), and abscess (p < 0.001) were more prevalent in those who required open surgery (Table 2). As expected, there was an increase in operating time in subjects who required conversion to open surgery compared with those who underwent successful laparoscopic surgery (94.1 minutes vs. 53.9 minutes, p = 0.004).

Univariate and Multivariate Regression Analyses of ACT Score

Results for univariate and multivariate regression are shown in Tables 3 and 4. Univariate regression showed that increased ACT score was significantly associated with the increased odds of appendiceal perforation (p < 0.001), conversion to open surgery (p = 0.002), and increased operating time (p < 0.001).

When adjusted for other potential factors using multivariate regression, ACT score was an independent predictor of perforation (odds ratio [OR] = 7.05, p < 0.001). ACT score was also noted to be an independent predictor of the need for open surgery (OR = 2.99, p = 0.002), even after adjusting for the presence of appendiceal perforation. As for the operating time, ACT score was also an independent predictor (mean increase of 12.93 minutes, p < 0.001) after adjusting for conversion to open surgery and perforation. Understandably, open surgery was also a predictor of operating time (mean increase of 16.10 minutes, p = 0.025), independent of ACT score and perforation.

Table 3. Univariate regression of ACT score with surgical outcome.

Independent variable	Odds ratio	p Value	95% CI
Perforation			
ACT score	7.05	<0.001	3.31-15.01
Conversion to open surgery			
ACT score	2.99	0.002	1.51-5.93
Increased operating time			
ACT score	-*	<0.001	11.56-17.71

Abbreviations: ACT score = Appendicitis Computed Tomography score; CI = confidence interval.
* Mean increase of operating time was 14.34 minutes.

Table 4. Multivariate regression of ACT score with surgical outcome.

Independent variable	Odds ratio	p Value	95% CI
Perforation*			
ACT score	7.05	<0.001	3.31-15.01
Conversion to open surgery†			
ACT score	2.99	0.002	1.51-5.93
Increased operating time†			
ACT score	-‡	<0.001	9.69-16.28
Conversion to open surgery	-§	0.025	2.03-30.17

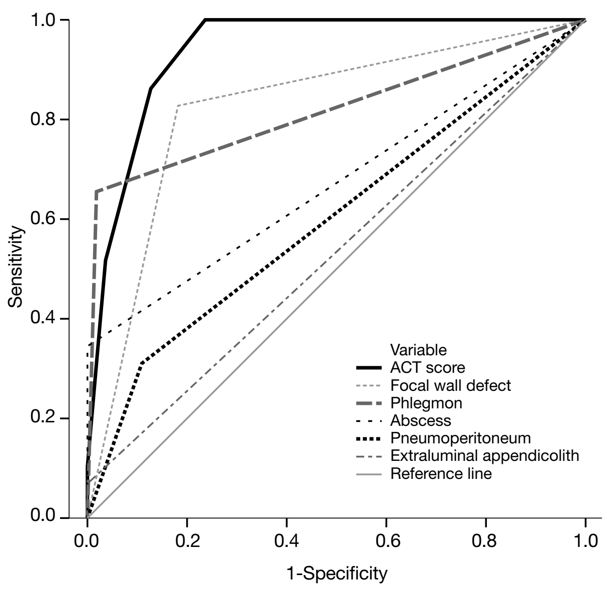
Abbreviations: ACT score = Appendicitis Computed Tomography score; CI = confidence interval.
* Results were also adjusted for subject's gender.
† Results were also adjusted for perforation and subject's gender.
‡ Mean increase of operating time was 12.93 minutes.
§ Mean increase of operating time was 16.10 minutes.

Diagnostic Power of ACT Score and Individual Computed Tomography Signs for Appendiceal Perforation and Need for Conversion to Open Surgery

The ROC curves and area under the curve (AUC) of ACT score and individual CT signs for discriminating appendiceal perforation and need for open surgery are shown in Figures 3 and 4, respectively. Compared with use of CT signs individually, ACT score showed a higher discriminating power for both appendiceal perforation (ACT score ROC AUC = 0.939, 95% confidence interval [CI], 0.892-0.987) and need for open surgery (ACT score ROC AUC = 0.858, 95% CI, 0.763-0.953) on the ROC curves.

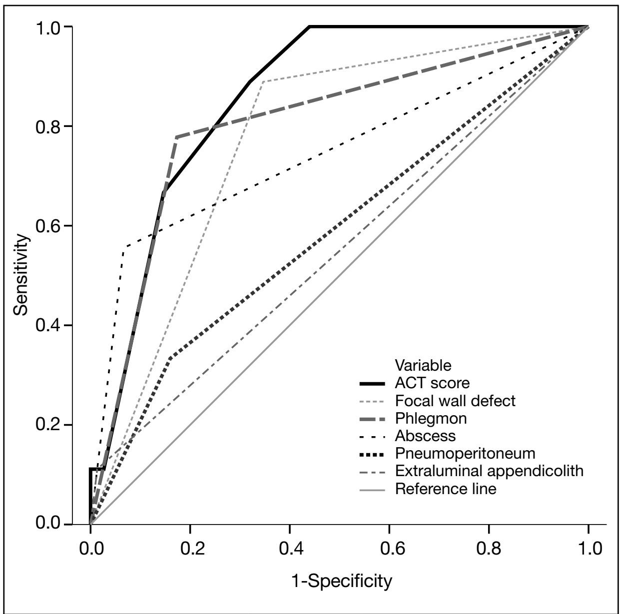
Sensitivity, Specificity, and Accuracy of ACT Score and Individual Computed Tomography Signs in Discriminating Perforated Appendix and Need for Open Surgery

Subgroup analysis was performed by stratifying subjects into groups depending on whether their ACT score was



Variable	Area under the curve	95% Confidence interval	
		Lower bound	Upper bound
ACT score	0.939	0.892	0.987
Focal wall defect	0.823	0.723	0.922
Phlegmon	0.601	0.468	0.733
Abscess	0.818	0.708	0.929
Pneumoperitoneum	0.672	0.541	0.804
Extraluminal appendicolith	0.534	0.402	0.667

Figure 3. Receiver operating characteristic curves of ACT score and individual CT signs with perforation at surgery. Diagonal segments are produced by ties.
Abbreviations: ACT score = Appendicitis Computed Tomography score; CT = computed tomography.



Variable	Area under the curve	95% Confidence interval	
		Lower bound	Upper bound
ACT score	0.858	0.763	0.953
Focal wall defect	0.771	0.628	0.914
Phlegmon	0.587	0.375	0.798
Abscess	0.802	0.637	0.968
Pneumoperitoneum	0.744	0.539	0.950
Extraluminal appendicolith	0.549	0.336	0.762

Figure 4. Receiver operating characteristic curves of ACT score and individual CT signs with conversion to open surgery. Diagonal segments are produced by ties.
Abbreviations: ACT score = Appendicitis Computed Tomography score; CT = computed tomography.

above a certain specified level. Tests for sensitivity, specificity and accuracy were determined. Results are shown in Tables 5 and 6. In brief, all subjects who had a perforated appendix had ACT score of >0, i.e. an ACT score of 0 implied no appendiceal perforation within our study population (100% sensitive). All subjects with ACT score of >3 had perforated appendix (100% specific). With regard to the need for conversion to an open procedure, none of the subjects with ACT score of 0 required open surgery (100% sensitive). An ACT score of 5 (i.e. ACT score >4) implied the need for open surgery within our study.

DISCUSSION

Association of ACT Score with Perforation, Operating Time, and Conversion to Open Surgery

Perforation of the appendix in acute appendicitis is associated with increased morbidity and mortality,[5] and longer hospital stay,[6,7] and thus increased hospital costs. Preoperative information on the likelihood of perforation can allow the surgeon to better estimate the complexity of the surgery and aid in the management of patients. A number of authors have investigated the use of CT in differentiating perforated and non-perforated appendicitis, because clinical and laboratory findings are inaccurate in differentiating the two.[3,6,8-11] A prior study by Horrow et al[3] identified five CT signs that are useful in predicting appendiceal perforation. Based on this, we developed the ACT score as a means to convey prognostic information to the surgeon and to help direct patient management. Our study showed that the ACT score was an independent predictor of appendiceal perforation at surgery. For every point of increase in ACT score, the odds of appendiceal perforation increased 7-fold. This information may help facilitate

Table 5. Diagnostic accuracy of ACT score and individual CT signs with perforation at surgery.

Perforation	Sensitivity	Specificity	Accuracy
ACT score			
>0	100.0	74.5	83.3
>1	86.2	87.3	86.9
>2	51.7	96.4	81.0
>3	10.3	100.0	69.0
>4	3.4	100.0	66.7
CT sign			
Focal wall defect	82.8	81.8	82.1
Phlegmon	31.0	89.1	69.0
Abscess	65.5	98.2	86.9
Pneumoperitoneum	34.5	100	77.4
Extraluminal appendicolith	6.9	100	67.9

Abbreviations: ACT score = Appendicitis Computed Tomography score; CT = computed tomography.

Table 6. Diagnostic accuracy of ACT score and individual CT signs with the need for conversion to open surgery.

Conversion to open surgery	Sensitivity	Specificity	Accuracy
ACT score			
>0	100.0	54.7	59.5
>1	88.9	68.0	70.2
>2	66.7	85.3	83.3
>3	11.1	97.3	88.1
>4	11.1	100.0	90.5
CT sign			
Focal wall defect	88.9	64.9	67.5
Phlegmon	33.3	83.8	78.3
Abscess	77.8	82.4	81.9
Pneumoperitoneum	55.6	93.2	89.2
Extraluminal appendicolith	11.1	98.6	89.2

Abbreviations: ACT score = Appendicitis Computed Tomography score; CT = computed tomography.

the surgeon in deciding the urgency of the patient's condition and appropriate surgical approach.

In addition to being a predictor of appendiceal perforation, the ACT score also showed significant association with operating time and odds of conversion to open surgery. Laparoscopic appendectomy is currently the standard initial operative method for acute appendicitis. Nonetheless, it may not be suitable for all cases and some will require conversion to open surgery. Conversion from a laparoscopic to an open procedure results in a larger abdominal wound, increased operating time, longer hospital stay, and a higher overall complication rate.[10,12] This results in higher hospital operational costs. Together with the additional resources required for the use and cleaning of laparoscopic equipment, the ability to prognosticate the odds of requiring open surgery and the duration of operating time may help the surgeon to decide the appropriate initial surgical approach and the time for conversion to open surgery. This, in turn, will allow better hospital resource allocation and operating theatre scheduling. It will also enhance communication between the clinician and patient and better manage preoperative expectations for prognosis and surgical outcome.

The rate of conversion to open surgery in our study was 10.7%, which is comparable to previous reported rates of 9.7% to 11%.[12-14] The mean operating time in our study was 59 minutes and this was significantly increased in cases of perforation (79 minutes) and open surgery (94 minutes) [Tables 1 and 2]. ACT score was a predictor of open surgery and was independent of the presence of perforation, with a higher ACT score being associated with increased odds of requiring conversion to open surgery. Increased ACT score was also an independent predictor of operating time and this was independent of both perforation and conversion to open surgery (Table 4). Hence patients with a high ACT score are at risk of needing open surgery and a longer operating time due to both the ACT score factor itself and the time required for an open procedure. Comparing subjects with ACT score of 5 with subjects with ACT score of 0, the subject with a higher ACT score would have a 35-fold increased risk of appendiceal perforation, 15-fold increased risk of requiring open surgery, and a mean addition of 65 minutes of operating time.

Utility of ACT Score as a Potential Clinical Tool

The aim of developing the ACT score is to provide a simple tool, which is easy to use, easy to interpret, and can convey prognostic information to aid clinical decisions in patient management. Scoring systems are increasingly being used in radiology (e.g. PI-RADs [Prostate Imaging Reporting and Data System] for prostate imaging) and provide a platform and a common language to facilitate communication between the radiologist and clinician, and enhance patient management. The ACT score is a simple summation of the number of positive CT signs based on Horrow et al's study.[3] It is easy to calculate and uses ancillary information already available from the diagnostic CT scan and requires no additional image post-processing. This would be advantageous in the setting of urgent conditions such as acute appendicitis, where rapid communication of information to the clinician is crucial. Being a linear 6-point scale score, the ACT score is easy for the surgeon to understand and use for optimal patient management.

The ROC curve provided a basis for comparison of the diagnostic power of ACT score with that of individual CT signs. The ACT score showed greater AUC, and therefore higher discriminating power, for both need for conversion to open surgery and presence of appendiceal perforation than the five individual CT signs used alone (Figures 3 and 4). Subgroup analysis further showed that an ACT score of 0 was 100% sensitive for excluding appendiceal perforation and also excluded the need for open surgery within our study population (Tables 5 and 6). Conversely, an ACT score of >3 was diagnostic for appendiceal perforation within our study subjects. Thus, the ACT score allows for easy and rapid stratification of subjects, operative risks, and surgical outcome; all of which aid in surgical planning and clinical decision-making.

Interobserver agreement on individual CT findings, which comprised the ACT score, was fairly high in our study. Interobserver agreement on the individual CT findings has seldom been reported in previous studies.[3,6,8,15] Although our CT images were assessed by less experienced radiologists, our study showed a higher interobserver agreement when compared with the study by Foley et al.[6] We believe that this was mainly due to the use of thinner CT sections. The use of thinner collimation can improve visualisation of the appendix, appendicolith, and in appendiceal wall defects.[8,16] In our centre, the use of thin CT sections is routine practice for evaluation of contrast-enhanced CT scan. With the widespread use of multidetector CT scanners and the advancement of the PACS (picture archiving and communication system), we believe thinner CT sections will be increasingly used and, hence, improved interobserver agreement can be achieved. We did notice that there was only moderate interobserver agreement for the finding of phlegmon ($\kappa = 0.481$), which was less than that of the other four CT parameters used for assessment of the ACT score. This is concurrent with the findings from the initial study by Horrow et al[3]; this also suggested that phlegmon was more subjective.

Limitations of Study

There were a few limitations of our study. First, this was a retrospective study, which was highly dependent on the completeness of both the surgical and pathological reports. We tried our best to ensure data completeness during the study process. Second, the sample size of this study was limited. Hence, although the calculated specificity for conversion to open surgery was 100% for ACT score of >4 (as shown in Table 6), as there was only one case in this group; we did not consider this to be of sufficient supporting evidence. Further research with a prospective study and larger sample size would be helpful to confirm the findings of this study. Third, there was potential review bias because our assessors knew all patients had undergone appendectomy for acute appendicitis. Nonetheless the assessors were blinded to the presence or absence of perforation and all the surgical and clinical reports, and this might reduce the review bias. Fourth, it was not possible to entirely exclude the chance that appendiceal perforation occurred during the time between the CT scan and the surgery, leading to erroneous interpretation of associations between CT signs or ACT scores with perforation. Also, theoretically, minor injury to the appendix during surgery could have resulted in erroneous pathological findings of perforation. In our centre, appendectomy was performed promptly for all cases and performed either directly by or under the supervision of an experienced surgeon, hence the chance of occurrence of these events was low. Fifth, there was a lack of evaluation of surgeon experience in assessing the risk of conversion to open surgery. This factor has been shown to be related to successful laparoscopic appendectomy.[14] Ours is a major laparoscopic surgery centre in Hong Kong and this may help to minimise the bias, although it would be helpful to include this factor for investigation in future studies. In addition, surveys for assessment of the user-friendliness should be included in future studies to evaluate the clinical applicability of the ACT score.

CONCLUSION

This study showed that the ACT score is an accurate and practical tool for the diagnosis of perforation in acute appendicitis and is also an important independent predictor of surgical outcome, including conversion to open surgery and operating time. The ACT score has a role in providing a quick and easily understandable figure that can enhance communication between the radiologist and surgeon and help the surgical team prioritise their patients in terms of clinical urgency. The ACT score can also aid in surgical planning and facilitate communication between the clinician and patient in terms of preoperative expectations for prognosis and clinical outcome.

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