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Original Article

Evaluation of systematic abdominal CT reading by radiology technologist as support in emergency settings

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Abstract: Background: To this date, there have been no studies evaluating the ability of radiology technologists to provide sufficient support in emergency situations. Therefore, we assessed the current status of human resources in CT reading support by radiology technologists in emergency care settings. Methods: We included healthcare providers working in the CT division. We performed this investigation from July 1 to September 31, 2019. We used CT images taken during emergencies in the Gifu University Hospital from June 2004 to March 2018. Using these images, we created a testing sheet for evaluation. The test sheet contained information on medical history as supportive information. We asked for a diagnosis based on the images, abnormal findings, and reasons for the diagnosis. Finally, we evaluated the score and the validation of each question. Results: We evaluated 97 general hospital medical staff. The average score was 75.46±20.38 points (range, 29-105 points). There was a weak correlation between test scores and years of work experience. However, scores depended not only on years of work experience; they also relied on career and reading experience. In the analysis of the validity of reading experience, the mean percentage of correct answers for identifying abnormalities was 77.8±15.5%. The mean percentage of correct answers in reading diagnosis was 52.2±24.4%. Conclusions: Establishing and improving educational strategies would allow clinical radiology technicians to consult doctors appropriately. This would optimize clinical radiology testing for patients with critical imaging abnormalities.

Keywords: Educational activities, diagnosis, diagnostic imaging, radiology

Introduction

In Japan, the government is promoting a "working style revolution", even in the medical profession [1]. As part of this trend, medical staff are asked to reduce work hours and workload. Thus, each hospital is required to change its working environment. This situation has put medical doctors working in emergency departments requiring computed tomography (CT) reading and diagnostic support in a difficult situation.

There are few facilities where medical doctors can get timely advice about CT readings. In addition, medical doctors working in emergency departments have a much heavier workload without these services, especially during the night shift.

The heavier workload is very concerning because potential life-threatening conditions might be missed, and there is a possibility of malpractice related to imaging diagnosis. Shifts and task-sharing are options to resolve the situation.

In April 2010, the Ministry of Health, Labour and Welfare amended the law so radiology technologists could be involved in supportive medical practice in the radiology department [2]. At that time, the Ministry of Health, Labour and Welfare asserted that hospitals must promote radiology practice that uses the technologists specialty

Subsequently, the Japan Association of Radiological Technologists performed a survey in which 90% of respondents reported that they

Table 1. Validation of each question

Question number	Case	Validity of Reading abnormality (%)	Validity of Reading diagnosis (%)
1	Normal	85.5	N/A
2	Upper gastrointestinal tract perforation case	84.5	32
3	Normal	64.9	N/A
4	Superior mesenteric artery embolism	35.1	35.1
5	Obturator hernia	75.3	75.3
6	Appendicitis	91.7	90.7
7	Strangulation ileus	84.5	84.5
8	Acute pancreatitis	80.4	70.1
9	Normal	77.3	N/A
10	Psoas abscess	63.9	62.9
11	Extrauterine pregnancy	95.9	21.9
12	Ischemic colitis	69.1	52.6
13	Diverticulitis of colon	92	55.7
14	Lower gastrointestinal tract perforation	69.1	34
15	Impending rupture of abdominal aortic aneurism	97.9	11.3

This table shows results for reading diagnosis and identification of abnormalities. Since Question 1, 3, and 9 are normal cases, the validity of the reading diagnosis is shown as N/A.

had been asked for advice on CT scanning and reading in after-hours settings. Thus, radiology technologists may play an important role in CT scanning and reading [3]. However, no studies have evaluated their ability to provide sufficient support.

Therefore, we evaluated the current status of human resources in CT reading support by radiology technologists in emergency settings.

Objective

A previous study evaluating CT reading skills of medical staff showed that reading skills depend on the individual staff person's work experience, tenure, and certifications [4]. Of note, the reading skills of staff with no experience in reporting, no certifications, and those not engaged in the CT division tend to be insufficient [4]. This result suggests that a lack of systematic reading skills and education in CT reading may affect these situations.

This study aimed to evaluate the current status of abdominal CT reading skills to establish a systematic reading strategy, evaluate a theory of abdominal CT reading in emergency settings, improve the reading skills of medical staff in the emergency department, and establish ideal reading support and training for radiology technologists.

Materials and methods

Research participants and timeframe

We included healthcare providers working in the CT division in this study. We performed an evaluation from July 1, 2019, to September 31, 2019. The institutional review board of Gifu University approved this research project (approval no. 30-089).

CT image selection for this research project and testing strategy

We used CT images taken during emergencies in the Gifu University Hospital advanced critical care center from June 2004 to March 2018 for our test. Using these CT images, we created and evaluated a testing sheet. The test sheet contained information on the medical history, such as the chief complaint, past medical history, and clinical examination findings as supportive information. We investigated the diagnosis based on the images, abnormal findings, and reasons for the diagnosis. In the question about the reasons for diagnosis, various choices were provided as outlined in **Table 1**.

Informed consent

We explained the project to prospective participants and obtained written informed consent from all study participants.

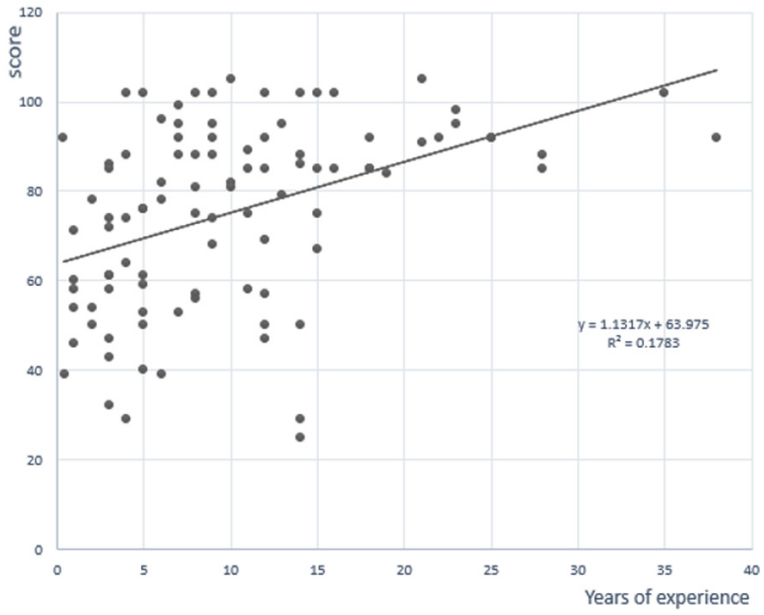

Figure 1. Distribution of test scores by years of work experience. The average score was 75.46±20.38 points (range, 29-105 points). The correlation coefficient was 0.178 (P=0.674), indicating a weak positive correlation.

Scoring and scoring guidelines

We provided DVD-ROM which recorded questions CT-images and a testing sheet to each participant, and then the participant answered on a paper-test. After that, we gathered the answer sheets, evaluatee, and scored their answers. We present a testing sheet as Supplementary Material. We assigned 7 points to each question. There were 15 questions on the test; 105 points was the maximum score. However, we scored partial points (4 points) in specific situations as follows:

-In the strangulation ileus case, the participant could not explain findings indicating strangulation despite a correct diagnosis.

-The participant cited only free air findings in the lower gastrointestinal tract perforation case. However, we scored the full points when the participant cited abnormal gastrointestinal tract findings that indicated lower gastrointestinal tract perforation.

-In the impending abdominal aortic aneurysm rupture case, the participant could not point out an abdominal aortic aneurysm.

-When there is a wide discrepancy in answers provided for abnormality and diagnosis reading in any question.

Evaluating rules identifying abnormal findings

We statistically analyzed answers on why a participant judged a finding as abnormal using the chi-square test or Fisher's exact test for 12 questions, with abnormal findings or a diagnosis requiring urgent care using Free JSTAT (provided by http://toukeijstat.web.fc2.com/index.html). We excluded three questions that had normal findings. In all statistical analyses, $P<0.05$ was considered statistically significant. In addition, we analyzed proportions for reasons for diagnoses. Furthermore, we analyzed statistically significant benchmarks, and when 60% of participants gave the correct answer.

Characteristics of study participants

Overall, 97 healthcare providers participated in this study, of whom 94 were radiology technologists, and 3 were medical doctors. On average, participants had 10.15±7.61 years of work experience.

Results

Test score distribution

The mean score was 75.46±20.38 points (range, 29-105 points). The distribution of test scores by years of work experience is shown in **Figure 1**. This distribution didn't follow a normal distribution. All participants with more than 20 years of work experience scored over 80 points. In detail, 50 participants scored 80 and over A total of 11 participants have more than 20 years of work experience. There was a weak correlation between years of work experience and test scores ($r=0.178$, $P=0.674$).

The mean score of participants usually involved in reading support or reading instruction was 89.61±13.99 points. The mean score of participants not usually engaged in reading support or education was 71.07±19.86 points; this was a statistically significant difference ($P<0.0001$).

Characteristics of answers by case

The percentage of correct answers for each case is shown in **Table 2**. This table shows results for reading diagnosis and identification of abnormalities. The mean percentage of correct answers for identifying abnormalities was 77.8±15.5% (range, 35.1-97.9%). The mean percentage of correct answers in reading diagnosis was 52.2±24.4% (range, 11.3-90.7%).

Questions for which the percentage of correct answers for identifying abnormalities was under 70% including ischemic colitis, superior mesenteric artery embolism, psoas abscess, and lower gastrointestinal tract perforation. Of note, the superior mesenteric artery embolism percentage was low, at 35.1%.

The questions for which the percentage of correct answers in the reading diagnosis was under 50% included upper gastrointestinal tract perforation, superior mesenteric artery embolism, lower gastrointestinal tract perforation, impending abdominal aortic aneurysm rupture, and extrauterine pregnancy. Notably, the percentages for impending abdominal aortic aneurysm rupture and extrauterine pregnancy were also quite low, between 10% and 20%.

When we analyzed normal cases, the percentage of correct answers ranged from 64% to 85%, which was in the same range as the percentage for all abnormal cases.

Analysis of diagnostic benchmarks

Table 2 shows each benchmark for recognizing abnormalities by participants on the reasons for diagnosis written testing sheet. The benchmarks shown in **Table 2** are benchmarks in which over 60% of participants gave correct answers. Therefore, the percentage value placed under each benchmark is the percentage in which participants gave correct answers. In addition, if this percentage was significantly higher than the percentage in which participants did not provide correct answers, we described *p*-values.

Discussion

In this section, we discuss scoring trends of study participants, systemic CT reading strategy and theory of abdominal emergency diseases, and CT reading support by radiology technologists based on three points.

Trends in scoring among participants

When we evaluated the relationship between test scores and years of work experience, there was a weak correlation, but the difference between groups was not statistically significant. However, we found high scorers (above 100/105 points) with less than 10 years of work experience. We also found low scorers with over 10 years of work experience. These results suggest that there is not always a strict relationship between test scores and years of work experience. This result was consistent with previous studies [4] showing that CT reading skills may depend on radiology specialty, reporting duty, and certification in CT specialty, not years of work experience. In addition, many participants who provide education on CT reading or have reporting duties scored much higher. Thus, education may affect CT's reading skills.

The average score for reading abnormalities was approximately 75/105 points, meaning participants had good reading ability. However, the validity of reading abnormalities and diagnosis for life-threatening diseases [5] was quite low for some questions. For example, the validity in the superior mesenteric artery embolism case (**Figure 2**) was 35.1%, and the upper gastrointestinal tract perforation case (**Figure 3**) was 34%. This result suggests that CT readers have to pay attention to some cases in which it is difficult to identify the abnormality without careful reading.

CT reading support by radiology technicians: Previous studies showed that the clinical cases for which clinical radiologists were asked for advice are similar to those for which the medical doctor fails to find an abnormality. Often these cases are critical and life-threatening [6].

Thus, it is important for radiology technologists to find abnormalities when they are engaged in CT reading support. We have to consider setting up an educational strategy so that they can make a temporal diagnosis using some clinical and CT reading benchmarks. This means that clinical radiology technologists engaged in CT reading support need basic clinical reasoning skills using medical information such as the chief complaint, medical history,

Table 2. Reading benchmarks of each question

	Cases	Reading Benchmarks							
Luminal organs	Upper gastrointestinal tract perforation	Medical History	Serial findings in a different image slice	CT-window optimization					
		75%	72%	76%					
	Lower gastrointestinal tract perforation	Medical History	Abnormal structure	Serial findings in a different image slice	CT-window optimization				
		81%	55% (P<0.01)	78%	67% (P<0.01)				
	Appendicitis	Medical History	Laboratory findings	Abnormal findings in a normal structure	Abnormal structure	Hounsfield unit value changes around the target	Serial findings in a different image slice	Laterality	coronal and enhanced images
		84%	76%	83%	85%	75%	84%	7% (P<0.05)	74%
	Ischemic colitis	Medical History	Laboratory findings	Abnormal structure	Hounsfield unit value changes around the target	Serial findings in a different image slice	CT-window optimization		
		80% (P<0.01)	56% (P<0.05)	84% (P<0.001)	67% (P<0.01)	70% (P<0.01)	24% (P<0.05)		
	Diverticulitis of colon	Abnormal structure	Hounsfield unit value changes around the target	Serial findings in a different image slice					
		84%	80%	72%					
	Obturator hernia	Medical History	Abnormal structure	Serial findings in a different image slice	Laterality				
		86%	77%	88%	68%				
	Strangulation ileus	Medical History	Abnormal structure	Hounsfield unit value changes around the target	Serial findings in a different image slice				
		78%	91%	75%	93%				
Solid organs	Acute pancreatitis	Medical History	Hounsfield unit value changes around the target	Serial findings in a different image slice					
		86%	86%	62%					
	Psoas abscess	Abnormal findings in a normal structure	Abnormal structure	Hounsfield unit value changes around the targe	Serial findings in a different image slice	Laterality	coronal and enhanced images		
		40% (P<0.05)	73%	62%	71%	75% (P<0.01)	65%		
	Extrauterine pregnancy	Medical History	Abnormal structure	Hounsfield unit value changes around the target	Laterality	enhanced images			
		82%	68%	60%	61%	61%			
Vascular diseases	superior mesenteric artery embolism	Medical History	Laboratory findings	Serial findings in a different image slice	enhanced images	Careful reading			
		80%	77% (P<0.05)	83%	80%	71% (P<0.01)			
	Impending abdominal aortic aneurysm rupture	Abnormal structure	Serial findings in a different image slice						
		81%	65%						

This table explains the benchmarks for the reading in each question. These percentages are the proportion of correct answers selected as the benchmark. If we found a significant difference between the proportion of the person giving correct and incorrect answers, we presented the *p*-value with the percentage.

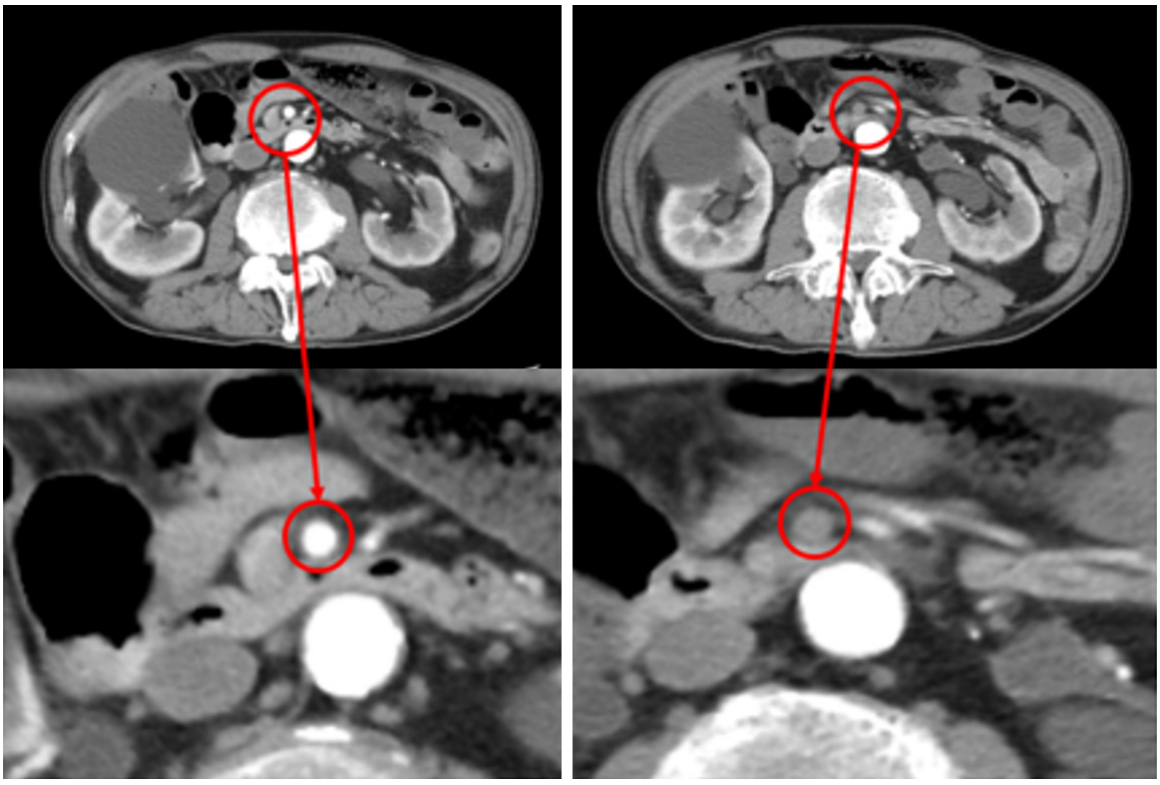

Figure 2. Superior mesenteric artery occlusion. The left figure shows blood flow in the superior mesenteric artery. The right figure is a slice distal to the left figure, where the blood flow is impaired. This finding suggests thrombotic occlusion of the superior mesenteric artery.

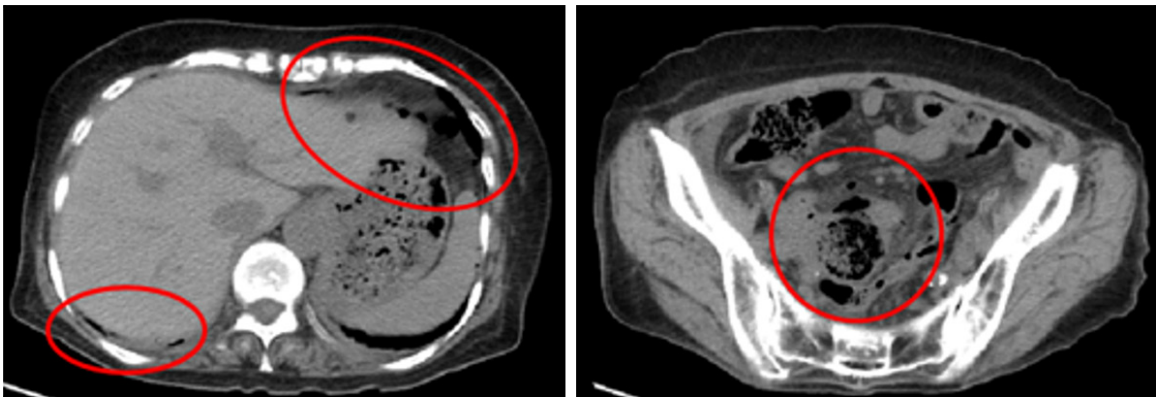

Figure 3. Lower gastrointestinal tract perforation. The left figure shows an image at the level of the liver with free air observed on the liver surface and in the left abdominal cavity behind the diaphragm. The figure on the right shows an image at the level of the pelvis. Perforation of the ileum is suspected because the residue is confined to the ileum, and free air is found around the ileum. A slight increase in peripheral fat tissue is also observed.

and laboratory findings available on the order sheet.

In addition, we should establish and improve educational strategies so that clinical radiology technicians can consult appropriate doctors to optimally perform clinical radiology examinations for patients if they find a critical abnormality. It would be a good "alarm" for medical staff and patients.

Finally, a Japanese organization for emergency radiology technicians provided some elements in a certification program [7]. This program

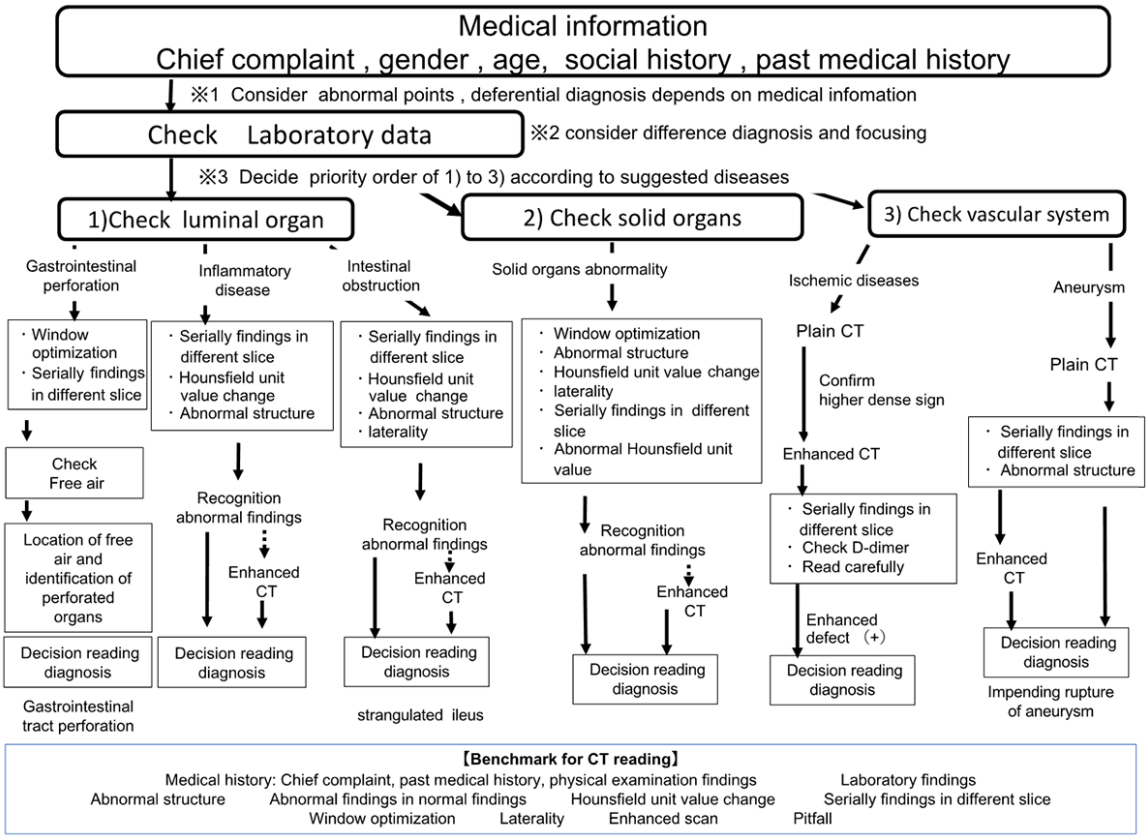

Figure 4. CT interpretation strategy for emergency abdominal diseases. Based on the findings from our study, we suggest an interpretation strategy for major emergency abdominal diseases based on three areas: luminal organs, solid organs and tissues, and vascular.

requires that a certified person behave instructively in a clinical situation. The certification program will help ensure the ability of radiology technicians to take an examination such as the one used in our study because our findings suggest that length of work experience does not always correlate with CT reading abilities.

Systematic CT reading strategy and theory of emergent abdominal diseases: We found trends in reading and attention points when reading CT images. We suggest the following reading strategies based on the results of our study and considering and referring to previous studies.

When healthcare providers read CT images for life-threatening abdominal diseases, they need to identify the most likely diagnosis using additional medical information stated on the order sheet as a first step, such as the chief complaint, gender, age, social history, and past medical history. A suggested strategy is shown in **Figure 4**. In particular, when a CT reader evaluates a case of localized stomachache, checking each component is necessary.

Healthcare providers should refer to laboratory findings as the next step (**Figure 4**). Healthcare providers should focus on findings reflecting inflammation because life-threatening abdominal diseases include many inflammatory disorders.

For systematic reading, we suggest the following theories of reading. First, healthcare providers should read three times in one direction (from head to toe). The first reading is for luminal organs, the second is for solid organs, and the third is for vessels. This process would allow systematic screening of the abdomen.

Study limitations

There are several limitations to our study. First, we only focused on 12 common, risky, and life-threatening acute abdominal acute diseases.

Therefore, data for other parts of the body remain unclear. In addition, it is unclear whether healthcare providers can improve their CT reading ability using the strategies and theories we suggest in this manuscript. Thus, further research using the suggested CT reading strategies is needed.

Conclusion

This study found no relationship between test scores and years of work experience. In addition, scores depended on experience in the CT division and education at each facility.

These results suggest the importance of education and work experience in the CT division and reading support. Therefore, creating an educational strategy for radiology technicians, especially certified emergency radiology technologists, is important.

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We explained the project to prospective participants and obtained written informed consent from all study participants. In Using CT images in Gifu University Hospital, informed consent was obtained through opt-out on the website.

Disclosure of conflict of interest

None.

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