The Role of Key Image Notes in CT Imaging Study Interpretation

Shu-Feng Fan,^{1,2} Zhe Xu,³ Hai-Qing He,¹ Jian-Rong Ding,¹ and Gao-Jun Teng²

The objective of the study was to investigate the clinical effects of CT key image notes (KIN) in the interpretation of a CT image study. All experiments were approved by the ethics committee of the local district. Six experienced radiologists were equally divided into routine reporting (RR) group and KIN reporting (KIN) group. CT scans of each 100 consecutive cases before and after using KIN technique were randomly selected, and the reports were made by group RR and KIN, respectively. All the reports were again reviewed 3 months later by both groups. All the results with using or not using KIN were interpreted and reinterpreted after 3 months by six clinicians, who were experienced in picture archiving and communication system (PACS) applications and were equally divided into the clinical routine report group and the clinical KIN report group, respectively. The results were statistically analyzed; the time used in making a report, the re-reading time 3 months later, and the consistency of imaging interpretation were determined and compared between groups. After using KIN technique, the time used in making a report was significantly increased (8.77 ± 5.27 vs. 10.53 ± 5.71 min, $P < 0.05$), the re-reading time was decreased (5.23 ± 2.54 vs. 4.99 ± 1.70 min, $P < 0.05$), the clinical interpretation and reinterpretation time after 3 months were decreased, and the consistency of the interpretation, reinterpretation between different doctors in different time was markedly improved ($P < 0.01$). CT report with KIN technique in PACS can significantly improve the consistency of the interpretation and efficiency in routine clinical work.

KEY WORDS: Key image, PACS, RIS, CT

Abbreviations

KIN	Key image notes
EMIF	Epub of medical imaging film
RR	Routine report
KINR	Key image notes report
CRR	Clinical routine report
CKINR	Clinical Key image notes report

In recent years, there were great progresses in spatial, temporal tissular, and structural resolutions of medical images, especially for advanced CT

studies. These changes are not only providing comprehensive and detailed imaging information for doctors using the excellent picture archiving and communication system (PACS) workstations but also bringing some challenges. It has become a common issue for many medical professionals as to how to quickly capture the key information from massive imaging data in a given circumstance.¹⁻³

The key images are the images that possess important clinical significance. In a special 3D or advanced PACS workstation, the radiologist can process, pick up key images, and make key image notes (KIN), such as displaying the images in a desired window width and level, magnification, orientation, and with a measurement, image reconstruction, and graphic annotation. The KIN technique in radiology information system (RIS) and PACS electronic process has been adopted in our hospital since 2008. This study aims to summarize our practical experience and to discuss the clinical value of KIN in CT imaging study interpretation.

¹From the Radiology Department, Taizhou Hospital affiliated to Wenzhou Medical College, #150 Ximen Road, Linhai 210009 Zhejiang Province, 317000, China.

²From the Jiangsu Key Laboratory of Molecular Imaging and Functional Imaging, College of Clinical Medicine, Southeast University, Nanjing, 210009, China.

³From the Hangzhou Dianzi University, Hangzhou, Zhejiang Province, 310018, China.

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Correspondence to: Shu-Feng Fan, Radiology Department, Taizhou Hospital affiliated to Wenzhou Medical College, #150 Ximen Road, Linhai 210009 Zhejiang Province, 317000, China; tel: +86-576-85199360; fax: +86-576-85199876; e-mail: shufengfan@163.com

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MATERIALS AND METHODS

One hundred consecutive 16-detector MSCT examinations both using KIN and not using KIN were enrolled in this study.

As shown in Figure 1, in Integrating the Healthcare Enterprise (IHE) technology framework, actors involved in the KIN integration profile include the acquisition modality, evidence creator, image manager, image archive, and image display.⁴ KIN were mainly created and displayed in the diagnostic workstation (Evidence Creator and Image Display). Storing, querying, and retrieving the KIN were accomplished through DICOM standard communications. The RIS/PACS software, offered by RADinfo Systems, completely supported IHE technology, which could generate KIN perfectly and associated KIN with relevant images accurately, realizing KIN objects, including associated grayscale softcopy presentation state objects, archived in RIS/PACS, and queried, retrieved, displayed, and managed with applications seamlessly throughout the hospital. Hence, doctors could easily consult and share the information with key images and key image notes.^{1,5}

All experiments were approved by the ethics committee of the local district. Two groups of consecutive 100 CT exams were selected in a prospective and randomized method: One was used for investigating the clinical effects of KIN mode and the other for routine mode. Diagnostic

doctors were randomly divided into the KIN report (KINR) group and the regular report (RR) group. Each group consisted of three radiologists who had similar experience in radiology and PACS applications. With the same equipments, under the same working condition and with the special RIS configuration settings just in the research data collecting period, three doctors completed all the reporting tasks independently. Three results, and their reporting and reviewing times were recorded automatically for every patient body location. According to the creating time, the last one of the three results was adopted as the default of the CT examination by RIS/PACS. The average time consumed in every report was considered as the report time for the location. After 3 months without follow-up information, three doctors of each group independently reviewed all the 100 CT cases in their idiomatic manner, and did not revise the KIN and report. The average time used in every location was called reinterpretation time, which was measured through the opening and closing PACS images time-recorded in RIS. When there was a discrepancy between the first interpretation and the reinterpretation, the final interpretation was established after discussion among three senior doctors.

Subsequently, six qualified clinicians who were experienced in PACS were randomly selected and divided into two interpreting group, the clinical regular report (CRR) group and clinical KIN report

Fig 1. KIN integrated model.

Fig 2. PACS/RIS key image note and selection (the right picture is the VOI display of the left image). After surveying, annotating, and using the other treatment, use the mouse to click the “Choose” button at the bottom left corner to complete the key image note selection.

Fig 3. Marked key image in PACS/RIS.

检查部位 胸部螺旋CT平扫+HRCT

影像所见:

胸廓对称, 所见肋骨未见异常。左下肺见分叶状块影, 大小约5.7cm左右, CT值约30-40HU, 邻肺见斑片状影, 局部胸膜略增厚; 余肺未见明显异常, 气管及支气管未见狭窄, 心脏大血管未见异常, 纵隔内未见增大的淋巴结, 两侧胸膜腔未见积液。

影像学诊断:

左下肺占位 考虑周围型肺Ca

Fig 4. Graphic diagnostic report.

(CKINR) group. Similarly, each group correspondingly interpreted and reinterpreted 3 months later the CT results with or without KIN, respectively. At clinical workstations of the full PACS, the opening and closing time of PACS images were

automatically recorded by RIS. The interpretation and reinterpretation time taken in the CT result of every patient body location were defined as the interval between the opening time and closing time, which was mentioned above. The consis-

Fig 5. Clinical workstation interface PACS image display has three display modes: Epub of film, key images, and original images. The doctors can choose any of them to view and set the default display mode by their habit.

Table 1. RR and KINR Time Comparison

	RR group (100 cases)			KINR group (100 cases)			$\chi^2/t, P$
Body part (count/all)	Head or spine (50/137)	Chest or extremity (41/137)	Abdomen or pelvic (46/137)	Head or spine (49/141)	Chest or extremity (45/141)	Abdomen or pelvic (47/141)	$\chi^2 = 0.149, P = 0.928$
Reporting time (min)	8.01 $\pm$ 3.91	9.91 $\pm$ 6.64	8.58 $\pm$ 5.13	9.47 $\pm$ 4.64	11.80 $\pm$ 6.49	10.41 $\pm$ 5.79	$t = 2.67, P = 0.008$
Reinterpreting time (min)	4.94 $\pm$ 2.33	6.01 $\pm$ 2.89	4.84 $\pm$ 2.31	3.29 $\pm$ 1.13	4.54 $\pm$ 1.88	4.21 $\pm$ 1.79	$t = -4.73, P = 0.000$

RR group regular report group, KINR group key image notes report group.

tency of interpretation made by clinicians and radiologists was compared, too.

The diagnostic consistency of the primary report (or interpretation) with the reinterpretation was classified into four levels: level I, inconsistent in both findings and conclusions; level II, partially different in findings and/or conclusions; level III, essentially consistent in findings and conclusions; level IV, fully consistent findings and conclusions.

Double-sample t test and the χ^2 test of numeration data were performed to examine the differences of the two groups in the CT reporting time, interpretation time, reinterpretation time, and diagnosis result consistency. Statistical significance was defined as $P < 0.05$. All tests were carried out with the software of SPSS (version 13.0) for Windows.

RESULTS

At the diagnostic workstation, a radiologist could easily select, handle, and mark key images (Fig. 2). The KIN was stored with an identical window width and center, constant measurements, and additional post-processed information. KIN also could be printed on the diagnostic report for convenience in the subsequent review (Figs. 3 and 4). During the review of the historical images in RIS/PACS, it was convenient to browse the KIN in order to reduce some unnecessary errors in key or subtle signs, and in measurement data between current and historical interpretation. At clinical workstations, a clinician

could observe the results offered through RIS/PACS in either the routine imaging display mode or the key image display mode by which the observer could be easily navigated to the key images that had been previously selected and marked. The default imaging display mode could be set according to the clinician habit (Fig. 5).

One hundred cases of CT exams in the RR group and KINR group, respectively, included 137 and 141 patient body locations examined, each one yielding one report (Table 1). The report time and reinterpretation time after 3 months of the RR group vs. KINR group were 8.77 ± 5.27 and 5.23 ± 2.54 min vs. 10.53 ± 5.71 and 4.99 ± 1.70 min, respectively. There was a significant difference in the mean report time and reinterpretation time between the two groups ($P < 0.01$). There were three (2.2%), four (2.9%), 17 (12.4%), and 113 (82.5%) locations getting level I–IV consistency, respectively, between the interpretation from the primary report and the review performed 3 months later in the RR group. In contrast, there were one (0.7%), two (1.4%), three (2.1%), and 135 (95.7%) locations getting level I–IV consistency, respectively, between the interpretation from the primary report and the review performed 3 months later in the KINR group. The difference between the two groups had a high statistical confidence ($P < 0.01$; Table 2).

The results of KINR were reviewed by the CKINR interpreting group, and the results of RR were reviewed by CRR interpreting group (Table 3). Clinical interpretation and reinterpreta-

Table 2. RR and KINR Consistency Comparison Table

	Level I	Level II	Level III	Level IV	χ^2, P
RR group	3 (2.2%)	4 (2.9%)	17 (12.4%)	113 (82.5%)	$\chi^2 = 11.77, P = 0.008$
KINR group	1 (0.7%)	2 (1.4%)	3 (2.1%)	135 (95.7%)	

Table 3. CRR and CKINR Time Comparison

	CRR group (100 cases)			CKINR group (100 cases)			$\chi^2/t, P$
Scan site (count/all)	Head or spine (50/137)	Chest or extremity (41/137)	Abdomen or pelvic (46/137)	Head or spine (49/141)	Chest or extremity (45/141)	Abdomen or pelvic (47/141)	$\chi^2 = 0.149,$ $P = 0.928$
Clinical interpreting (min)	5.60 $\pm$ 2.38	5.41 $\pm$ 2.36 5.45 $\pm$ 2.33	5.32 $\pm$ 2.28	4.56 $\pm$ 1.81	4.73 $\pm$ 2.00 4.69 $\pm$ 1.97	4.79 $\pm$ 2.14	$t = 2.92,$ $P = 0.004$
Clinical reinterpretation (min)	4.02 $\pm$ 1.56	3.85 $\pm$ 1.76 3.94 $\pm$ 1.60	3.93 $\pm$ 1.52	2.56 $\pm$ 0.92	2.94 $\pm$ 0.95 2.97 $\pm$ 1.45	3.44 $\pm$ 1.61	$t = 5.60,$ $P = 0.000$

CRR group clinic regular report group, CKINR group clinic KIN report group.

tion time after 3 months for CRR vs. CKINR groups were 5.45 $\pm$ 2.33 and 3.94 $\pm$ 1.60 min vs. 4.69 $\pm$ 1.97 and 2.97 $\pm$ 1.45 min, respectively. There was a significant difference in the clinical mean interpretation and reinterpretation time between the two groups ($P < 0.01$). The interpretation consistency between clinicians and radiologists for the same case was seven (5.1%, level I), seven (5.1%, level II), 20 (14.6%, level III), and 103 (75.2%, level IV) locations in the CRR group; and one (0.7%, level I), two (1.4%, level II), five (3.55%, level III), and 133 (94.3%, level IV) locations in the CKINR group, respectively. The CKINR group achieved higher scores than the CRR group. This result also was statistically significant ($P < 0.01$; Table 4).

Furthermore, the online storage and clinical application of KIN could provide an impersonal evidence to supervise and improve the quality of the image diagnosis, which may be favorable to the digital clinical radiology quality control in future.

DISCUSSION

With the rapid development of imaging equipment and its technology in recent years, a CT examination of one patient may yield over 1,000 images. Effectively viewing, processing the data, and quickly capturing the key information usually

needs excellent material and knowledge foundations, such as a high-resolution display monitor, an advanced workstation, and a doctor with enough training and experience. However, the conditions at different RIS/PACS terminals may vary from one to another. Large amount of images may be visited repeatedly in a low efficient routine, which often consumes more unnecessary time, increases the burden of the network, and easily creates some confusion or error among the results.^{1,2,6-8}

The preliminary results of this study indicate that KIN can help reduce the imaging review time for radiologists and reduce the imaging interpretation and reinterpretation time for clinicians, and improve the consistency of their interpretations for the same examination. Therefore, the application of KIN in RIS/PACS may help share important image information, and improve the efficiency in a later image reviewing, teaching, researching, and other related processing work. Otherwise, the related staff and the network would be repeatedly trapped in large number of images whether it is necessary or not. In addition, the application of KIN also offers a better foundation for graphic reports and digital clinical radiology quality control.

The radiologist has to take more time to create the KIN object during reporting, which maybe is the most disadvantageous in applying the KIN technique. Anyway, the additional time to make

Table 4. Interpretation Consistency of Clinicians with Radiologists

	Level I	Level II	Level III	Level IV	χ^2, P
CRR group	7 (5.1%)	7 (5.1%)	20 (14.6%)	103 (75.2%)	$\chi^2 = 20.04, P = 0.000$
CKINR group	1 (0.7%)	2 (1.4%)	5 (3.55%)	133 (94.3%)	

KIN objects is usually very limited in routine medicine practice. First, it is originally one necessary part of the reporting work to find and process key images. Second, one only needs to click the "Choose" button through the mouse to complete the selection of key images, and adding annotation is necessary only in a few key images with special signs or brief text. The radiologists may perform more efficient professional tasks to fulfill their technical accomplishment through the use of KIN in the RIS/PACS, provided with more professional interpretation skills and more excellent image displaying and handling tools.^{1,5-9}

On the other hand, the application of KIN may take more time and/or produce more confusion if key images and KIN are finished incompletely and/or incorrectly owing to the fact that the radiologists may lack the necessary knowledge and experience, or the clinical information is not enough. Moreover, during interpretation/reinterpretation or viewing/reviewing of PACS images, there are some unavoidable factors affecting the closing time recorded in RIS, such as unexpected interference (e.g., urgent call), insufficient disease information for evaluation, and discrepancy in conclusion. It is regretful that these factors had not been objectively investigated in this research. We think that it is necessary to establish a criterion guiding key image selection and notes as quickly as possible, and it may be very helpful to objectively evaluate the various related factors and effects of the KIN application in radiology and clinic workflow through further investigation.

On the whole, the implementation of the KIN in RIS/PACS has been proven to be effective in increasing the overall turn-around efficiency of a radiology department's routine work. The KIN helps the radiological professional better document and share key information in images. Although more and more hospitals are equipped with RIS/PACS, there is still a huge potential space for future functionality enrichments. The implementation of the KIN function in our RIS/PACS showed that this technique possesses great potentialities in clinical practice. Continuous improvement in the RIS/PACS and routine clinical workflow requires

tremendous efforts from all professional workers in the near future.¹⁰⁻¹²

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