Solutions for Diagnostic Imaging Using Digital Technology

Many countries and regions around the world are currently facing either an actual or projected shortage of medical practitioners. The shortage of radiologists who specialize in diagnostic imaging has become a severe problem in Japan and China in particular, leading to wider problems that include heavier workloads for these people and both a lower overall level and regional variability in the quality of diagnostic imaging. Hitachi, meanwhile, is seeking to improve the efficiency and quality of medical examination in general, and image diagnosis in particular, through the use of digital technologies such as AI, big data, and the IoT to support diagnostic imaging. Rather than past practices that have focused on the equipment used, this involves working on developments that are expected to deliver value to a wide variety of users through solutions that improve imaging efficiency and support the quantification and interpretation of the images acquired.

Takashi Shirahata
Yoshitaka Bito, Ph.D.
Hiroyuki Itagaki
Osamu Miyazaki
Tetsuhiko Takahashi, Ph.D.
Yoshihiro Iwata

1. Introduction

Although Japan, relative to its population, has very high numbers of computed tomography (CT), magnetic resonance imaging (MRI), and other diagnostic imaging systems compared to other nations, the number of radiologists is low. China is also suffering from a shortage of diagnostic imaging specialists, with even fewer radiologists than Japan despite a rapidly rising number of diagnostic imaging systems. These shortages are placing heavier workloads on radiologists and giving rise to both regional variability and falls in the quality of diagnostic imaging. Hitachi is working on the development of solutions that improve the efficiency and quality of diagnostic imaging through the use of such digital technologies as artificial intelligence (AI), big data, and the Internet of Things (IoT). This article describes examples of this work.

2. Government Policy, Markets, and Technologies

2. 1 Medical Devices and their Regulation

Medical devices are regulated on the basis of categories determined by the risks they pose. Computer-aided detection and diagnosis (CAD) was first approved for use in mammography in the USA in 1998. Although a number of other CAD systems have also been approved over the two decades since then, including for chest X-rays and lung CT scans, it is only the use of CAD for mammography that has entered widespread use, insurance cover having been extended to the practice in the USA in 2001[1].

In Japan, the subject has been discussed at the Round-table Conference for the Utilization of AI in Healthcare hosted by the Ministry of Health, Labour and Welfare and support for diagnostic imaging has been named as one of the six key areas where further AI development is needed to allow practical implementation[2]. Furthermore, with diagnostic imaging systems that use AI being seen as having the best prospects for early practical application, an investigation into these has been launched as part of a project for the preparation of product evaluation criteria for next-generation medical devices, regenerative medicine, and similar, and also at a project for developing a set of guidelines for medical devices. Work is also underway aimed at speeding up and otherwise facilitating the development and approval processes in preparation for the FY2020 revisions to the medical payment system, as indicated in the second Growth Strategy Council – Investing for the Future.

2. 2 Developments in Technology for Diagnostic Imaging

In the case of diagnostic imaging, CAD (the use of computers to assist with medical examinations) can be further divided into computer-aided detection (CADe) for identifying signs of potential lesions and computer-aided diagnosis (CADx), which also includes tasks that involve classification such as grading tumor severity.

The tasks of object recognition and classification, for which deep learning has achieved very high levels of performance in recent years, are very much the same tasks as those posed by support for the interpretation of diagnostic images (CADe/CADx). Furthermore, the automatic captioning of images is reminiscent of interpretation report generation. While neither of these constitute automatic diagnosis, as the final interpretation is still made by the radiologist with reference to the information provided by CAD, hopes are rising that the use of AI will allow CAD systems that enhance the quality and workflow of diagnostic imaging to enter practical use.

3. Overview of Diagnostic Imaging Support

To reduce mortality rates due to malignant neoplasms, the number of patients institutionalized due to cerebrovascular disease, and the numbers suffering from metabolic syndrome or reduced mobility (locomotive syndrome), what is needed is the early identification and diagnosis of these conditions to enable early treatment and lifestyle changes. Hitachi is establishing a variety of solutions that use digital technologies such as AI, big data, and the IoT to improve the efficiency and quality of all steps in the radiography workflow, including scanning and imaging as well as interpretation, in order to achieve the early identification and diagnosis of disease (see **Figure 1**). The following sections describe applications for, respectively, improving scanning efficiency by helping to achieve the correct

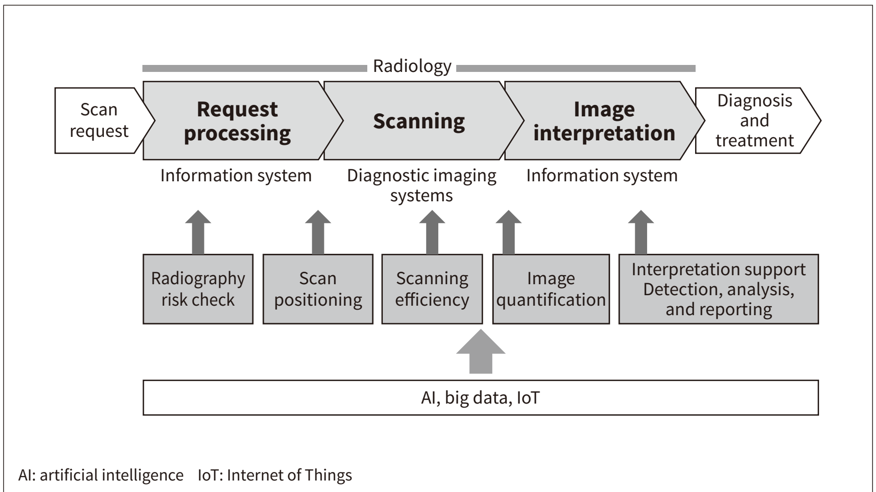
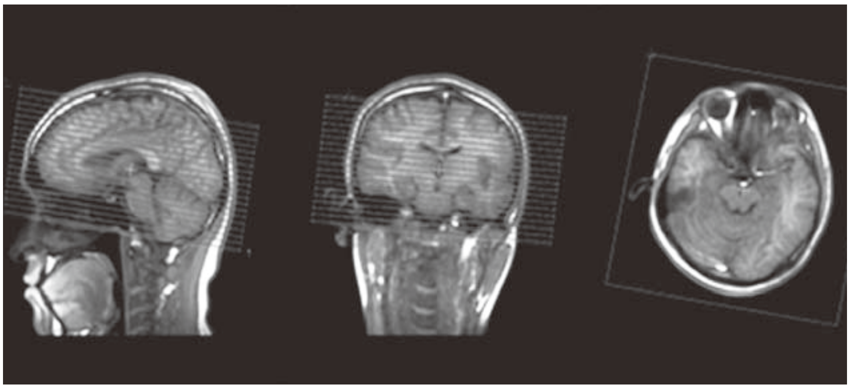


Figure 1 — Improvements to Efficiency of Radiographic Examination Process Provided by Diagnosis Support System

Hitachi supplies diagnostic support tools that use digital technologies for a variety of applications, including scanning, image quantification, and diagnosis.

Figure 2 — Support Function for Achieving Correct Scanning Position

As the scanning positions are displayed automatically after the scanogram is taken, the overall scan time can be shortened and positioning repeatability can be achieved when a patient undergoes a series of scans over a period of time.



scanning position, improving efficiency and quality by quantifying images, and improving the efficiency and quality of interpretation by supporting the associated work.

4. Scanning Efficiency Improvement and Quantification of Diagnostic Imaging

4. 1 Improving Scanning Efficiency by Helping Achieve Correct Scanning Position

The workflow for medical imaging (radiology) involves: (1) Scan preparation, (2) Positioning and scanning the patient, (3) Identification and classification of lesions (such as their malignancy or benignity), and (4) Reporting. Digital technologies, including image processing, are used in the second and third of these, with a high degree of commonality in terms of technology. Depending on the purpose of the scan, however, quality of identification (of any lesion) is a key requirement in the case of (3), whereas the requirement in (2) is to achieve a level of quality in the identification of tissue morphology within the time available.

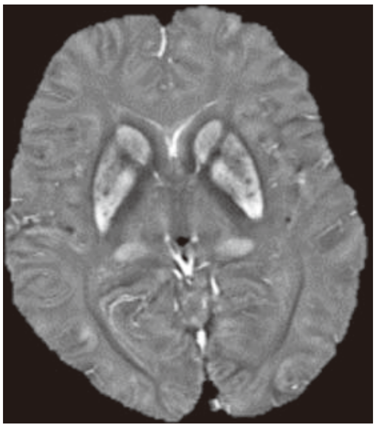
In the case of medical scanning, reducing the time taken is more important than might be expected, both in terms of hospital operations (number of scans able to be conducted each day) and diagnostic capability (to prevent loss of image quality due to the patient's body moving during the scan). Considered in terms of the constraints on automatic operation (the automatic determination of scan location), the time constraints referred to above are as follows.

- Acquiring the inputs for automatic operation should not require any additional scans
- The processing associated with automatic operation should not cause any delays

To satisfy these constraints, scanogram images were used as the input for automatic operation. As scanogram images are always taken first to check that the patient is positioned correctly, their use does not lengthen the scan time. A scanogram, however, which takes only about 15 seconds to acquire, has low spatial resolution and therefore is not well suited to providing a detailed picture of tissue morphology. Hitachi succeeded in resolving this technical issue by modifying the algorithm used for automatic operation with regard to tissue contrast and representative structures. Furthermore, automatic operation was able to complete at roughly the same time as scanogram acquisition by executing it in parallel. This means that the radiographer is able to proceed with the scan without delay.

A support function for MRI scan positioning was implemented. Thanks to the modifications to the algorithm and by performing machine learning on numerous scans of people's heads, the function succeeded in achieving both real-time performance and reliable operation when using scanogram images. The slice lines recommended for use in the scan are displayed on the scanogram image immediately after scanogram acquisition completes (see **Figure 2**). The scanner operator only needs to check the displayed slice lines and make any small adjustments considered necessary before starting the scan. The benefits include faster scan times, even in the case of experienced operators. The function also helps ensure the repeatability of scan position when a patient is undergoing a series of scans over a period of time.

Figure 3 — QSM
Quantitative susceptibility mapping (QSM) is a way to visualize differences in the magnetic susceptibility of tissue, with potential applications in the early diagnosis of neurodegenerative disease and measurement of oxygen extraction fraction.



4. 2
Quantification of Diagnostic Imaging

Used in MRI, quantitative susceptibility mapping (QSM) is a technique for visualizing the differences in the magnetic susceptibility of different tissues (see **Figure 3**). Neurodegenerative disease is accompanied by changes at the microscopic level, such as the deposition of iron in tissues or loss of the myelin sheaths around nerve cells, and these in turn cause changes in the magnetic susceptibility of the tissue. QSM has the potential to help with the early diagnosis of neurodegenerative disease through its ability to identify these changes in susceptibility. As differences in blood oxygenation level also influence magnetic susceptibility, another potential use for QSM is as a non-invasive technique for measuring regional oxygen extraction fraction in the brain.

5. Use of AI to Support Image Interpretation

5. 1
Reduction in Mortality Rates from Use of Lung Cancer CT Scanning, and Associated Challenges

With lung cancer being the leading cause of death due to cancer internationally, its early detection and diagnosis are crucial to reducing mortality rates. The National Lung Screening Trial in the USA reported in 2011 that low-dose CT chest scans for lung cancer are effective for reducing mortality rates for the disease in heavy smokers(3). In response, the US Preventive Services Task Force (USPSTF)(4) has made CT scanning for lung cancer a recommended practice, and the American College of Radiology (ACR)*1 has established the Lung Imaging Reporting and Data System (Lung-RADS)*2 to serve as a quality management system for the reporting and management of these scans(5).

In Japan, simple chest X-rays are used for population based screening examinations and both simple chest X-rays and CT scanning are used for opportunistic screening examinations. The Hitachi area of Ibaraki prefecture has been running an ongoing program of CT scanning for lung cancer, with a longitudinal study of residents of Hitachi City having found a statistically significant reduction in mortality rates(6).

When CT imaging is used for examination, the radiologist needs to review more than 100 scans for each positive finding of lung cancer. Scan interpretation includes comparing images with past scans to study how lesions change over time, and presenting the results of interpretation in the form of a report. It is work that radiologists find both mentally and physically draining. Moreover, having scans reviewed by two radiologists to ensure the quality of interpretation only adds to this workload, not to mention the additional costs it imposes on the hospital.

5. 2
Interpretation Support System

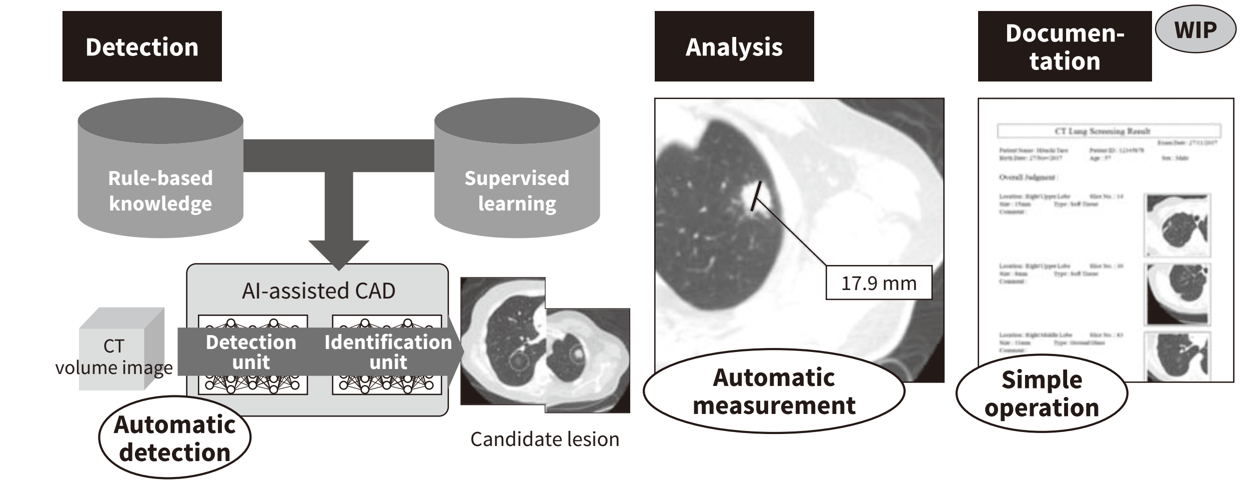
Hitachi has since the late 1990s been working on research into interpretation support systems that use a computer to identify potential lesions and present these to radiologists so as to help improve interpretation efficiency and enhance accuracy by reducing misdetection(7). Unfortunately, these systems have not entered practical use due to problems that include a high rate of false positives (in which healthy tissue is misidentified as a lesion).

The most recent research, however, has achieved a step up in the accuracy of lesion identification through the use of deep learning, reducing false positives to a very low level even when the detection sensitivity is raised. Unfortunately, this has also raised new problems, including the large amounts of data required for

*1, 2 ACR and Lung-RADS are registered trademarks of the American College of Radiology.

Figure 4 — Overview of Lung Cancer Diagnosis Support System

Hitachi is developing a system that supports all aspects of image interpretation, including the analysis and reporting of candidate lesions as well as their automatic detection and presentation to the radiologist.



CAD: computer-aided detection/diagnosis CT: computed tomography WIP: work in progress

deep learning and that it results in what, in effect, is a black box. This latter problem makes it difficult to express things like the logic that led to a conclusion, or which features of the image caused the lesion to be identified.

To resolve these problems, development work by Hitachi has been based on the concept of hybrid learning in which machine learning is combined with pre-existing knowledge. That is, the technology being developed for interpretation support is a combination of the latest deep learning methods with the rule-based image processing techniques that Hitachi has established through its experience as a manufacturer of diagnostic imaging equipment. This improves learning efficiency by incorporating quantitative features of lesions that are based on the knowledge of medical practitioners into a learning model that uses a convolutional neural network to detect lesions automatically. This provides better learning convergence than when the detection of lesion sites is performed by conventional deep learning, also achieving a high lesion detection accuracy using a comparatively smaller set of image data. The inclusion of known quantitative features of lesions derived from the knowledge of medical practitioners means that the technology can also be applied to rare lesions where it is difficult to collect enough training data, and that it can indicate what it was about an area that led to detection. By running the lesion detection process prior to the radiologist commencing image interpretation and then suggesting candidate lesions as they work, the potential benefits include more efficient interpretation and higher accuracy by reducing the number of lesions that are overlooked. Preparations are currently underway for clinical trials that will assess the utility of the technology quantitatively with regard to interpretation accuracy and efficiency. Hitachi is also developing a system to support the broader aspects of interpretation, including automatic report generation and automating the measurement of lesion size and comparison with past data (see **Figure 4**). The system works with images acquired by CT scanners supplied by other vendors, not just those made by Hitachi.

While this section has described an interpretation support system for lung cancer, Hitachi is also developing similar technology for various different imaging modalities and the diagnosis of other diseases, including the use of MRI for the diagnosis of brain disease.

6. Conclusions

This article has described what Hitachi is doing to support radiology examination so as to enhance its efficiency and quality. These initiatives are intended not only to reduce radiologist workloads through higher efficiency and quality, but also to extend healthy life spans and reduce mortality rates and the number of people needing care through the early detection and diagnosis of disease.

In the future, Hitachi intends to continue supplying solutions that utilize digital technologies to assist medical practitioners with diagnosis.

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Authors

Takashi Shirahata
Diagnosis Support Solution Department, Solution Business Division, Diagnostic Systems Division, Healthcare Business Unit, Hitachi, Ltd. *Current work and research:* Development of diagnostic support solutions. *Society memberships*: The Japan Society of Medical Physics (JSMP).

Yoshitaka Bito, Ph.D.
Healthcare Business Unit, Hitachi, Ltd. *Current work and research:* Development of diagnostic support solutions. *Society memberships*: The International Society for Magnetic Resonance in Medicine (ISMRM), the Alzheimer's Association International Society to Advance Alzheimer's Research and Treatment (ISTAART), the Japanese Society for Magnetic Resonance in Medicine (JSMRM), and the Japanese Society for Medical and Biological Engineering (JSMBE).

Hiroyuki Itagaki
Strategy Planning Department, Strategy Planning Division, Strategy Planning & Development Office, Healthcare Business Unit, Hitachi, Ltd. *Current work and research:* Planning to globalize diagnostic support solutions. *Society memberships*: The Japanese Society of Radiological Technology (JSRT), and the JSMRM.

Osamu Miyazaki
Solution Business Division, Diagnostic Systems Division, Healthcare Business Unit, Hitachi, Ltd. *Current work and research:* Development of diagnostic support solutions. *Society memberships*: The Japanese Society for Artificial Intelligence (JSAI).

Tetsuhiko Takahashi, Ph.D.
Solution Business Division, Diagnostic Systems Division, Healthcare Business Unit, Hitachi, Ltd. *Current work and research:* Development of diagnostic support solutions. *Society memberships*: ISMRM, JSMRM, and the Japanese Society of Medical Imaging Technology (JAMIT).

Yoshihiro Iwata
Diagnosis Support Solution Department, Solution Business Division, Diagnostic Systems Division, Healthcare Business Unit, Hitachi, Ltd. *Current work and research:* Development of diagnostic support solutions.