A real-time interactive pulmonary nodule analysis system

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Early diagnosis can dramatically improve the clinical outcome of cancer and other life-threatening diseases. Patients with lung cancer often die within one year after the onset of clinical symptoms, so screening and early detection can play a crucial role in saving a patient's life [1].

▶ CT screening and early detection can play a crucial role in saving a patient's life.

Low-dose CT scanning is an accepted diagnostic technique, but has relatively high false positive rates for small nodule detection. Even though a recent article suggests that low-dose CT lung screening could be cost-effective [2], it is not always sufficiently widely available for screening of large patient populations. A number of studies suggest that digital radiography, further enhanced by computer-aided detection and dose reduction refinements, could provide a more cost-effective tool [3-5].

This article presents initial experience with a real-time interactive diagnostic analysis system for digital chest radiography at the Carver College of Medicine/Iowa Hospitals and Clinics (Figure 1). The University of Iowa Hospitals and Clinics also houses the Holden

▲ Figure 1. Carver College of Medicine/Iowa Hospitals and Clinics.

Comprehensive Cancer Center and is affiliated with the Iowa City Veterans Affairs Medical Center and other local institutions and practitioners. It is the only public medical school in Iowa.

Located in Iowa City, a community of about 60,000, the University of Iowa health sciences campus includes the colleges of Medicine, Dentistry, Nursing, Pharmacy and Public Health, and University of Iowa Hospitals and Clinics, one of the nation's largest university-owned teaching hospitals.

Serving a catchment area with a population of over four million, the University of Iowa Hospitals and Clinics is the only tertiary healthcare facility in a radius of 200 miles, and is one of the few major trauma centers. It deals with some 800,000 outpatient visits and more than 41,000 admissions per year. In addition, the faculty and staff provide clinical services at 249 outreach clinics in 62 Iowa communities. These provide specialized services including care for children with special needs, high-risk infant follow-up, genetic counseling and prenatal health care.

The University of Iowa also has extensive telemedicine and teleradiology services, which provide outreach care via telecommunications technology. Affiliated regional medical education centers provide clinical care, community-based experience for medical students and coordinate residency programs.

Carver College

Carver College (officially the University of Iowa Roy J. and Lucille A. Carver College of Medicine) traces its origins back to 1850, when the Iowa State Legislature approved the affiliation of the College of Physicians and Surgeons with The University of Iowa. The College has four stated goals:

- Provide outstanding educational programs for students in the health professions and in the biomedical sciences in order that our graduates will have appropriate knowledge and skills for the needs of society
- Develop new knowledge about human biology, and conduct health services research related to the prevention, diagnosis and treatment of human disease
- Provide high-quality, cost-effective and comprehensive health care to patients of the University of Iowa Hospitals and Clinics, the Iowa City Veterans Affairs Medical Center, and their affiliated community programs
- Strengthen the faculty, facilities and management capacity of the College, its departments and programs, to achieve the collegiate mission.

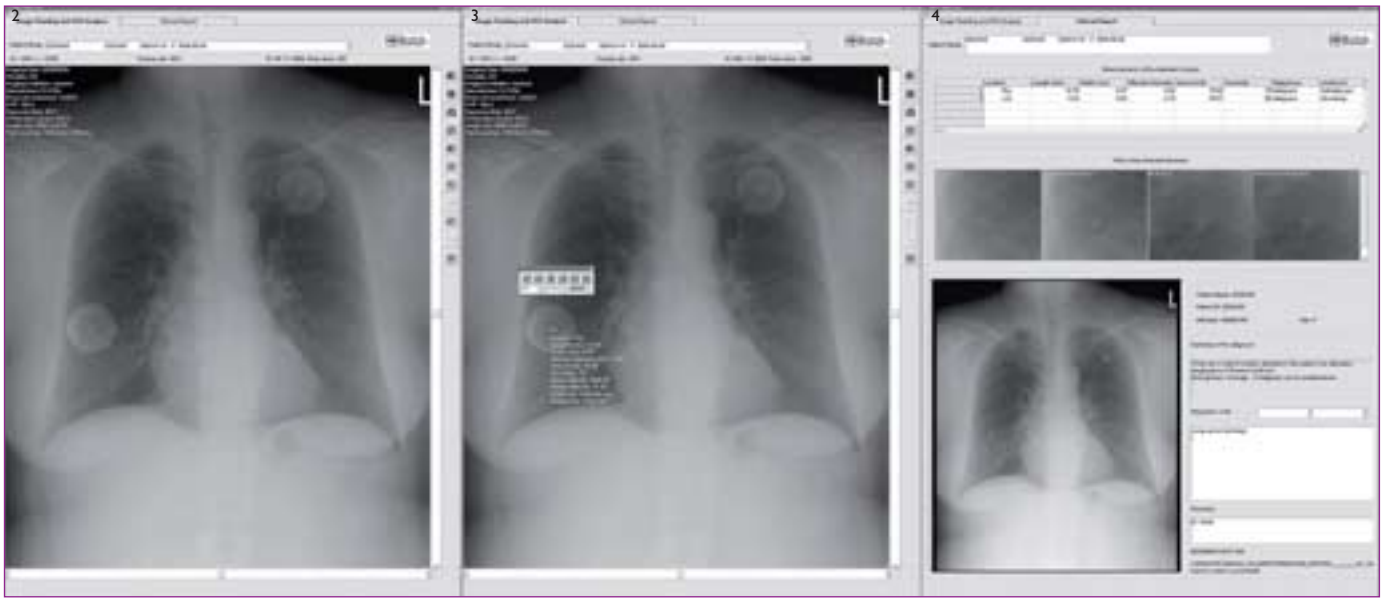

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Figure 2. Image reading. The system suggests candidate lesions and nodules.

Figure 3. ROI analysis. Quantitative measurements are computed and displayed automatically.

Figure 4. Reporting. Clinical reports confirmed by the reader are generated automatically.

The College's recently opened Medical Education and Research Facility (MERF) houses the Sahai Medical Education Center, Roy J. Carver Molecular Science Research Center and the Roland and Ruby Holden Cancer Research Laboratories. MERF-based research programs include the Center for Macular Degeneration, Interdisciplinary Research Program in Human Genetics, Center for Functional Genomics of Hypertension, labs for six biochemistry investigators, and cancer research programs in molecular mechanisms of metastasis, prostate cancer, neuro-oncology, stem cell biology, molecular epidemiology, radiation biology and experimental therapeutics.

Department of Radiology

The Department of Radiology provides diagnostic and therapeutic radiology services for University of Iowa Hospitals and Clinics patients as well as for patients further a-field through teleradiology. The department is well-equipped with imaging systems for conventional radiography/fluoroscopy, CT, MRI, PET/CT, Interventional Angiography and Ultrasound and is staffed by some 40 radiologists. The department is actively involved in research into new diagnostic and treatment modalities, including clinical research projects in most areas of imaging, and provides comprehensive training facilities. Of particular note are the advanced heart and lung imaging center, new and sophisticated techniques in cancer imaging, and innovative techniques for imaging and treating vascular disease.

Chest and Cardiovascular Radiology

The Chest Section of the Department of Radiology deals with all aspects of chest imaging as well as CT (and to a lesser extent MR) cardiovascular imaging. There is a close collaboration with cardiology (cardiac CT program), body and interventional radiology (cardiovascular imaging). Responsibilities include plain film and digital chest radiography of inpatients and outpatients as well as the provision of imaging facilities for the surgical, cardiac, and medical intensive care units. Additionally, as the online reading center, the section provides coverage for all aspects of outpatient plain film imaging.

Facilities in the Chest Section include conventional and digital radiography systems, three state-of-the-art spiral CT scanners (including 16-slice and 64-slice CT as well as a research 64-slice scanner within the division of physiologic imaging). All scanners are linked through a workstation network. The application of novel chest MR methods, such as hyperpolarized gas imaging, are being explored in a research environment. The section performs thoracic interventional procedures such as biopsies, drainages, and is exploring the use of CT-guided radiofrequency ablation in support of the cardio-thoracic surgery department.

Pulmonary nodule analysis

A number of studies [3-5] suggest that digital radiography in combination with computer-aided detection (CAD) could be a valuable adjunct to CT diagnosis and may have the potential to become a first-line screening tool.

The Carver College Department of Radiology worked in close cooperation with the Princeton-based company EDDA Technologies on the development of the IQQA-Chest real-time interactive diagnostic analysis system, providing clinical advice and testing, and confirmation of

▶ **Digital radiography with CAD may have the potential to become a first-line screening tool.**

Figure 5. Digital radiograph with noted lesions (sarcoma).

the findings with CT. The system was released and installed as a clinical package in the Department of Radiology in 2005.

IQQA-Chest is now marketed by Philips Medical Systems under the name xLNA (X-ray Lung Nodule Assessment). It will initially be available in the United States and China, and will become available in other countries from 2007. The new software has been integrated in the Philips digital radiography portfolio, including the state-of-the-art DigitalDiagnost for direct digital radiography, allowing clinicians to benefit from a powerful array of diagnostic tools, resulting in greater diagnostic confidence and better quality of care.

IQQA-Chest supports clinicians in identification, quantification, evaluation and reporting of pulmonary nodules.

IQQA-Chest supports clinicians in their identification, quantification, evaluation and reporting of pulmonary nodules. As a real-time interactive diagnostic analysis system, it integrates advanced computer analysis technology into the diagnostic process. Studies indicate that it could help clinicians increase their nodule discovery rate in a clinical environment[4,6,7].

Workflow

After acquisition of the digital radiographs, the images are analyzed in three steps:

- Image reading
- ROI analysis
- Reporting

Image reading

The patient studies are selected from a DICOM-compliant database. The large amount of data contained in the digital images makes it possible to view the images in adjustable viewing modes, including contrast-enhanced viewing and lesion-specific image enhancement viewing mode (Figure 2). The reader can select and mark the lesions/nodules for further analysis.

ROI analysis

Segmentation can be performed automatically or manually. Quantitative measurements from the segmentation results are computed and displayed automatically (Figure 3). The reader can then enter diagnosis and notes in the system, and confirm nodules to be reported.

Reporting

Clinical reports containing diagnostic information confirmed by the reader are generated automatically (Figure 4). The reader can enter additional notes and a digital signature. The report is then secured with a time stamp.

The report is then available for printing or storage in DICOM format for PACS archiving.

Deployment

IQQA-Chest was first deployed in the Chest Section for patients with known cancer who were being followed up with chest X-ray to assess for presence or development of metastases. It has been quite successful in offering "a second pair of eyes" to assist in nodule detection, in particular by junior radiologists. In addition, the confidence of radiologists was improved, in that they were less likely to suggest CT follow-up for a physician-identified suspicious area if the CAD software did not implicate the same area.

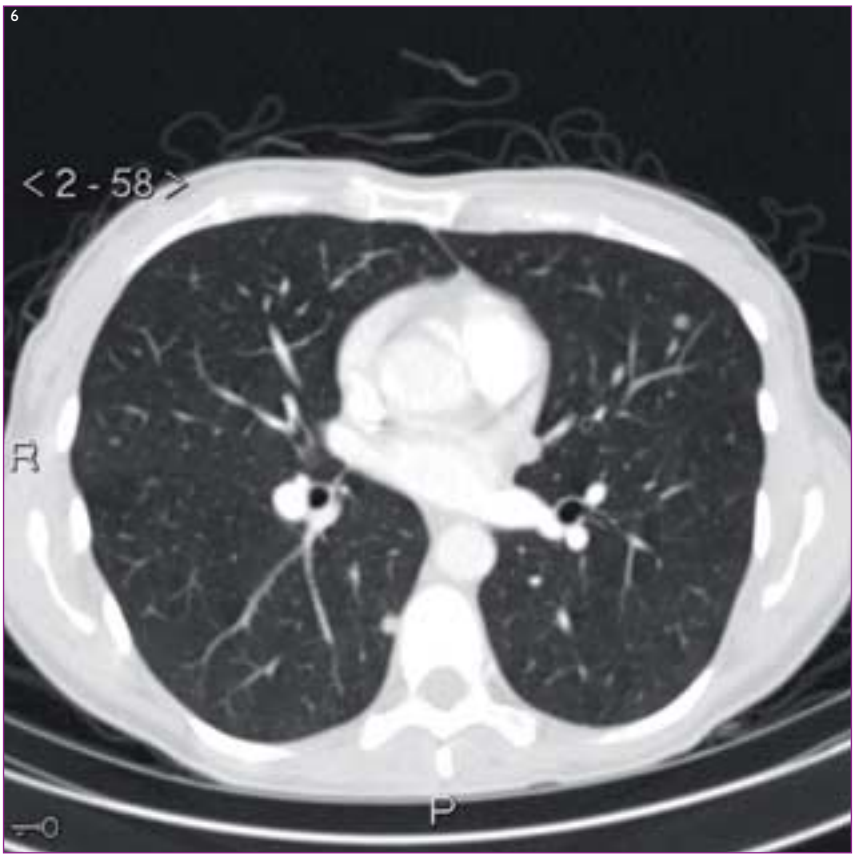
Initially, IQQA-Chest was configured on a separate server, because a new PACS was being installed at the time. It is now fully integrated and will automatically launch from the PACS working station and will generate a report that is added to the patient records. The reports incorporate key images, which include location, approximate size and radiologist's interpretation of chance for malignancy, confidence of presence of lesion and suggested management.

The IQQA system, which has a current installed base of 10 sites worldwide, is designed to assist physicians in the detection of lung nodules, including small ones (Figures 4,5). Multi-center clinical studies [4,6] suggest that IQQA-Chest could help physicians increase their nodule detection rate.

Evaluation

Li Fan, Ph.D. and colleagues at the Beijing Union Medical College, the Beijing Friendship Hospital, the Shanghai Zhejiang Hospital, and the Princeton-based corporation EDDA Technologies, gathered chest DR screening studies from a total of more than 500 patient studies [4,6]. The group evaluated the diagnostic performance of the IQQA-Chest pulmonary nodule analysis software using DR images generated on various types of DR imaging equipment. Their studies indicated that the IQQA-Chest technology reduced inter-observer variations in nodule detection rates and could increase detection rates overall.

In our own study [7], approximately 300 digital frontal chest radiographs were first read by resident radiologists using routine PACS viewing stations without CAD, and then re-read using IQQA-Chest. Changes of diagnosis following use of the software system were recorded. A final read was issued by faculty chest radiologists using the combined image analysis tools provided by IQQA-Chest and was archived in PACS.



▲ Figure 6. Follow-up CT directly after digital radiography.

A combination of follow-up using additional imaging as appropriate, and clinical findings, was used as reference method when available.

Preliminary results showed that the real-time interactive computer system could help participating residents detect more nodules, including small ones. In addition, the confidence of radiologists was improved, in that they were less likely to suggest CT follow-up for a physician-identified suspicious area if the CAD software did not implicate the same area.

Conclusion

The authors' own experience and reports in the literature indicate that a real-time interactive pulmonary nodule analysis and concurrent reading system can help radiologists increase their confidence level of diagnosis in a routine clinical teaching hospital reading environment, and reduce inter-observer variations in nodule detection. These systems may also be able to help clinicians improve their overall detection rate.

Chest X-ray computer aided detection can be incorporated into routine clinical workload, and should be particularly beneficial for solitary practitioners. These developments suggest that chest X-ray CAD will, in the future, offer an alternative to routine annual CT-based lung cancer screening at lower cost and with reduced X-ray exposure ■

▶ **The technology helped reduce inter-observer variations.**

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