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Medical Image Intelligent Access Integrated with Electronic Medical Records System for Brain Degenerative Disease

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Introduction

As the computer data storage capacity increases and technology of digital imaging progresses rapidly, today we can access and manipulate massive image database on the Internet. How to search and access intelligently on content based image database become a prominent focus in the field of multimedia research. In this chapter, to support the diagnostic decision making, a new idea of grid-distributed, contextual, representation, use of specific visual medical knowledge, intelligent information access framework for medical images database was integrated with radiology reports and clinical department information. It will assist reducing the human, legal and financing consequences of these medical errors. A report by the American Hospital Association suggests that US hospitals use only 1.5%~2.5% of their Hospital Medical budgets on data information systems, which is less than the 5-10% of similar funds dedicated to such systems found in the budgets of other industries. Moreover, as computer data storage capacity increases and the technology involving digital imaging progresses rapidly, the traditional image has been replaced by Computer Radiography (CR) or Digital Radiography (DR) derived imagery, Computed Tomography (CT), Magnetic Resonance Imaging (MRI), and Digital Subtraction

Angiography (DSA). This advance reduces the space and the cost associated with X-ray films, speeds up hospital management procedures improving also the quality of the medical imagery-based diagnosis quality. American hospitals, in particular, often consult image diagnostic professionals from India via Internet due to budget consideration. The clinical information gathered by this study will alleviate the budget issue because the tele-consultation regarding image diagnostics will then be feasible.

For the current medical image database system, image retrieval can be performed by using keywords for searching in pre-interpreted reports. However, the characteristics of free-text reports may compromise with the effort for clarification from low level features such as color, shape, texture, to medium level features describing by collection and spatial relationships, or highest abstract features which are semantic or contextual. In 1990s, the content-based image retrieval (CBIR) started [1] and grew steadily over the last ten years. [2] There is growing interest in CBIR because of the limitations inherent in metadata-based systems. Textual information about images can be easily searched using existing technology, but requires humans to personally describe every image in the database. However, CBIR query uses a lot of computer power to process, and it can economize a large manpower. Therefore, the content-based retrieval of the medical image also becomes a significant field for medical assistance, medical education and medical research. At clinics, when a physician diagnoses a patient through the patient's medical images, he has to entry the PACS and RIS. And he makes a diagnosis in another system, EMR (Electronic Medical Records). [3]

In Taiwan, the National Taiwan University Hospital (NTUH), which is traditionally the leading medical center, has recently adopted a complete health recording system, including an Electronic Medical Record (EMR) system linked to Hospital Information System (HIS), Research and Information System (RIS), Picture Archiving and Communication System (PACS), and other clinical information systems. National Taiwan University (NTU), one of the research partners of ONtology and COntext related MEDical image Distributed Intelligent Access (ONCO-MEDIA) project¹ is leading a study of the integration between the Content-Based Medical Image Retrieval (CBIR) and EMR systems as well as on its implications in providing improved clinical diagnostic and therapeutic decision support.

Dementia is the loss of mental functions -- such as thinking, memory, and reasoning -- that is severe enough to interfere with a person's daily functioning. Dementia is not a disease itself, but rather a group of symptoms that are caused by various diseases or conditions. Symptoms can also include changes in personality, mood, and behavior. In some cases, the dementia can be treated and cured because the cause is treatable. Dementia develops when the parts of the brain that are involved with learning, memory, decision-making, and language are affected by one or more of a variety of infections or diseases. The most common cause of dementia is Alzheimer's disease, but there are as many as 50 other known causes. Most of these causes are very rare. [5] Dementia is a word for a group of symptoms caused by disorders that affect the brain. People with dementia may not be able to think well enough to do normal activities, such as getting dressed or eating. They may lose their ability to solve problems or control their emotions. Their personalities may change. They may become agitated or see things that are not there. [6] Dementia has become more and more prevalent in recent years. In the United States, there are approximately 5 million people suffering from dementia and that number is projected to rise above 16 million by the

year of 2050. Presently, Americans pay US\$5000 per patient per year for dementia medication and associated nursing care costs [9] [10].

In Taiwan, there were approximately 140 thousand people suffering from dementia in 2005 and there will be 650 thousand dementia cases by the year of 2050. MMSE (mini-mental state examination) is commonly used in medicine to screen for dementia. The MMSE test is a brief 30-point questionnaire test that is used to screen for cognitive impairment. It is also used to estimate the severity of cognitive impairment at a given point in time and to follow the course of cognitive changes in an individual over time, thus making it an effective way to document an individual's response to treatment.

Since Dementia, as a disease, is an important and long term problem that causes significant burdens for families and societies, this study has endeavored to find a viable procedure to ameliorate the treatment of dementia patients and to enhance the early diagnosis and monitoring of its progression. [11]

In this chapter, we chose Dementia to establish a system for CBIR with EMR. Dementia is a neurological disease, usually the clinical course is long, and it represents a variety of characteristics in brain image such as CT (computed tomography), MRI (magnetic resonance imaging) or PET (Positron Emission Tomography). If the doctor wants to diagnosis a symptom, he needs a series of images to diagnose or decide for therapeutic strategies. Therefore, the image database correlated with clinical information would be crucial in care of a dementia patient. In addition, usually it is an intensive collaboration among neurologists, radiologists and other clinical specialties. This study focused on Dementia as a pathology model, in order to elaborate a prototyping system for CBIR with EMR. Dementia is a neurological disease, usually characterized by a slow histopathology, and presents itself with a variety of characteristic abnormalities in brain imagery such as CT, MRI, or PET. In the course of the treatment, a doctor may need a series of images to make the proper diagnosis or to make critical decision for therapeutic strategies. Therefore, an image database infused with clinical information could become a major component for the improvement of the dementia patient care. The chapter will describe a novel concept of Medical Image Distributed Intelligent Access Integrated with Electronic Medical Records is expected to enhance the early diagnosis and monitoring of disease progress.

2. Methods

Integration of RIS, EMR, PACS and Clinics to Support Diagnosis

At present, most hospitals store the medical images from CT, MRI, DSA and X-ray film in PACS. The clinicians make differential diagnosis of a patient in EMR system with references to laboratory results and image reports. Therefore, we have to provide the essential information from EMR, PACS and RIS to clinicians, such as neurologists, to support their decision. On the other hand, in the department of medical imaging, the radiologists also need to refer to medical information recorded by other specialties to interpret medical image for their reports on the RIS [7]. The image report by the radiologists could assist the clinicians to make correct diagnoses; however, the correct image interpretation also depends on the crucial medical information that clinical doctors must input. This co-dependence demonstrates the need for two-way communications between imaging professionals such as radiologists and their clinical counterparts that are treating the patients. Therefore, in this study, the integration of EMR, RIS and PACS and clinics input was implemented to

establish a prototype model for intelligent access of medical image database, and retrieve clinical information automatically. (Fig.1.) The integrated user interface used the ICD-9 (International Classification of Disease, Ninth Revision) 331.0 code to identify and query its relative medical information and medical images from HIS, PACS or RIS. Therefore, the important thing is to define what the essential clinical information is.

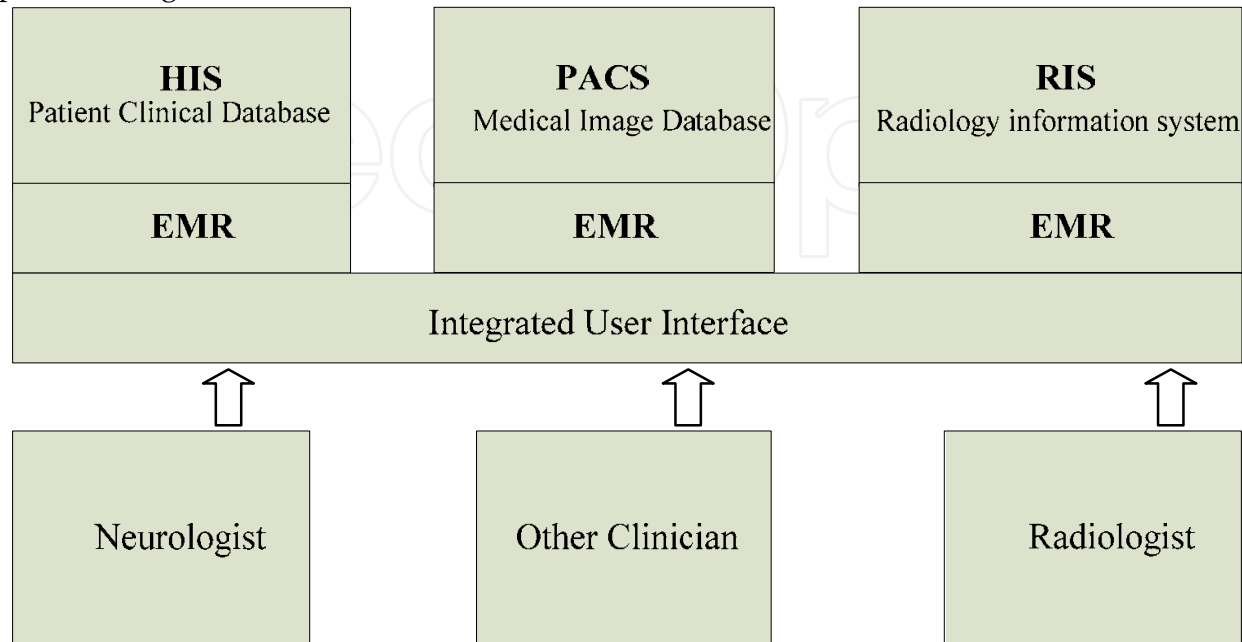


Fig. 1. System Structure of Prototype Model

Inter-disciplinary collaboration

This important process was the collaboration of the interdisciplinary among neurology, medical informatics and radiology experts. In this study, a prototype model was designed to assist the procedure involving the physician-in-the-loop approach [4].In this prototype model, a group of neurologists and radiologists collaborated to establish a common language involving the image diagnosis. In the EMR integration with RIS and PACS, we based on the diagnostic criteria and practical guideline to satisfy the diagnosis procedure and requirement. Moreover, the establishment of the ontology of dementia was in accordance with the essential clinical information of dementia. The process flow chart was as follow:

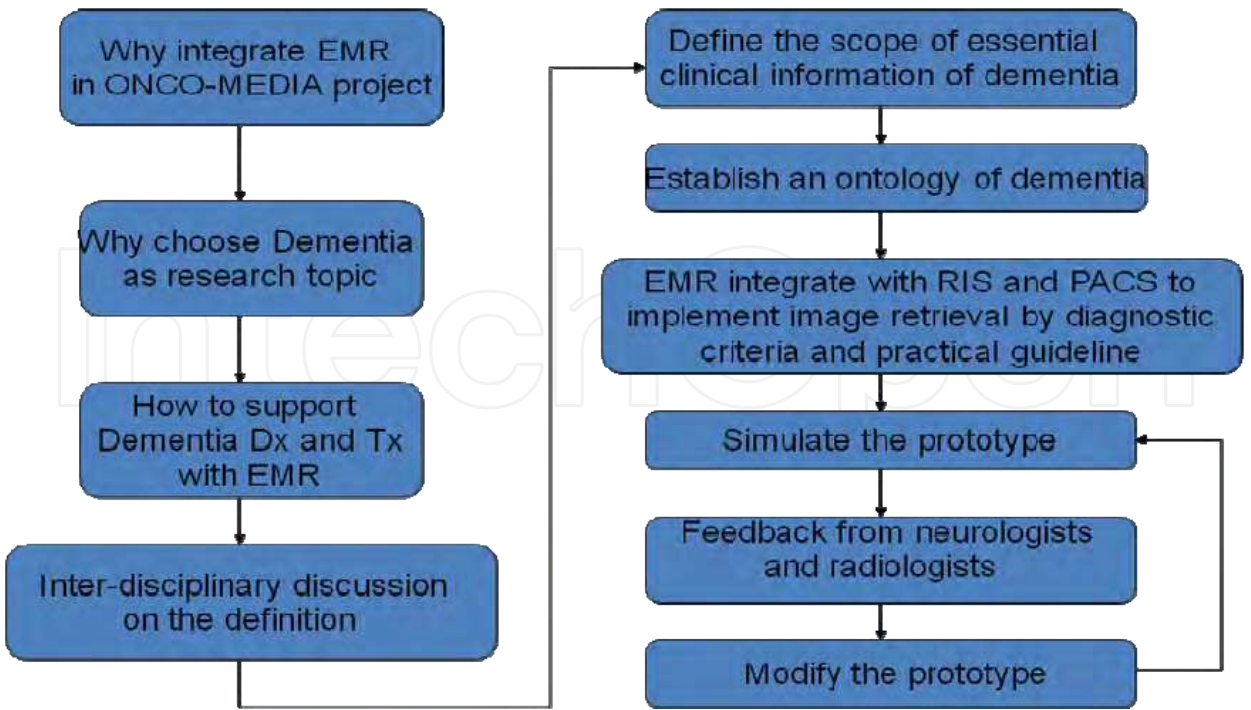


Fig. 2. Research flow chart

Establishing a Definition of Essential Clinical Information in Dementia

The Literature review is essential course before experts to define the essential clinical information. Therefore, journals, textbooks and clinical reports will be our guidelines. The UMLS [12] is a long-term project realized from 1986 by Library National of Medicine (LNM), the largest world's library in the biomedical domain of Maryland. This system is the result of the combination of 140 multilingual terminology databases, knowledge sources as well as tools in order to facilitate the tasks of accessing, researching, integrating and aggregating of biomedical and health information. The technical purpose of this system is to combine into a unified structure of different knowledge sources in the biomedical domain.[13] The purpose of NLM's Unified Medical Language System (UMLS) is to facilitate the development of computer systems that behave as if they "understand" the meaning of the language of biomedicine and health. Bio-medical information as a result of a large number of constantly increasing and are scattered in various database systems, so you want to search complete and no new information for easy, UMLS Thus came into being for the purpose of enhancing the capacity of the system, allowing the system to understand the readers biomedical aspects of meaning, and thus help readers information retrieval and integration. Therefore, we also have to depend on UMLS to support us to develop the dementia model. And the methods and steps, the experts discussed as follow:

- Literature review from journals, textbooks and clinical reports
- Selecting relevant medical image reports from department of medical imaging
- Using representative cases to simulate medical image distributed intelligent access integrated with EMR to select crucial clinical information
- Finalizing structure and items of essential clinical information regarding dementia
- Dependence on the Unified Medical Language System (UMLS) to facilitate the development of a prototype model that follows the international language of biomedicine and health.

3. Results

Essential Clinical information

After the inter-disciplinary collaboration, we got the final definition of essential clinical information in dementia when the neurologist diagnoses in a clinic. In the model, the essential clinical information of dementia included is summarized as follows:

- A. Base information
 - a. Sex
 - b. Age
 - c. Country
 - d. Residency
 - e. Education (yr)
 - f. Occupation (pre-retired work)
 - g. Language (dialect)
- B. Clinical history
 - a. Handedness
 - b. Age of onset
 - c. Initial symptom sequence (multi-choice):i. memory, ii. personality, iii .language, iv. gait and v. bradykinesia
 - d. Course: i. rapid progression (< 1 year), ii. chronic progression, iii. stepwise and iv. fluctuated
 - e. Risk factors (multi-choice): i.CVA, ii.HTN, iii.DM, iv. cardiac disease, v. hyperlipidemia, vi. obesity, vii. physical inactivity, viii. vegetarian, ix. parkinsonism and x. family history
- C. Clinical diagnosis
 - a. Normal
 - b. MCI (Mild Cognitive Impairment)
 - c. AD (Alzeimer Disease)
 - d. VaD (Vascular Dementia)
 - e. Mixed type
 - f. FTD (Frontotemporal Dementia)
 - g. DLB (Dementia with Lewy Bodies)
 - h. Dementia, other types
- D. Lab
 - a. CBC
 - b. Electrolyte
 - c. BUN/Cre
 - d. GOT/GPT
 - e. T4/TSH
 - f. B12/folate
 - g. Lipid profile
 - h. VDRL
 - i. Hachinski ischemic score
 - j. MMSE
 - k. CDR

The prototype system is designed to recognize a positive dementia diagnosis and reconfigure its patient information presentation accordingly. International Statistical Classification of Diseases and Related Health Problems (ICD) provides codes to classify diseases and a wide variety of signs, symptoms, abnormal findings, complaints, social circumstances and external causes of injury or disease.[14] The ICD-9(International

Classification of Disease, Ninth Revision) was published by the WHO in 1977.[15] In EMR of National Taiwan University, we use ICD-9. Each code of ICD-9 codes has a precise meaning, and as a whole it covers practically all known symptoms. ICD-9 codes 290-319 are mental disorders. And ICD-9 of dementia is 290. ICD-9 codes 320-359 are Diseases of the nervous system and code 331.0 is Alzheimer’s disease. In diagnosis flow with the model of the research, an input of the ICD-9 331.0 code for Alzheimer’s disease will alter and display the patient information, such as: base information, clinical history, lab results and medical images. (Fig. 3.)

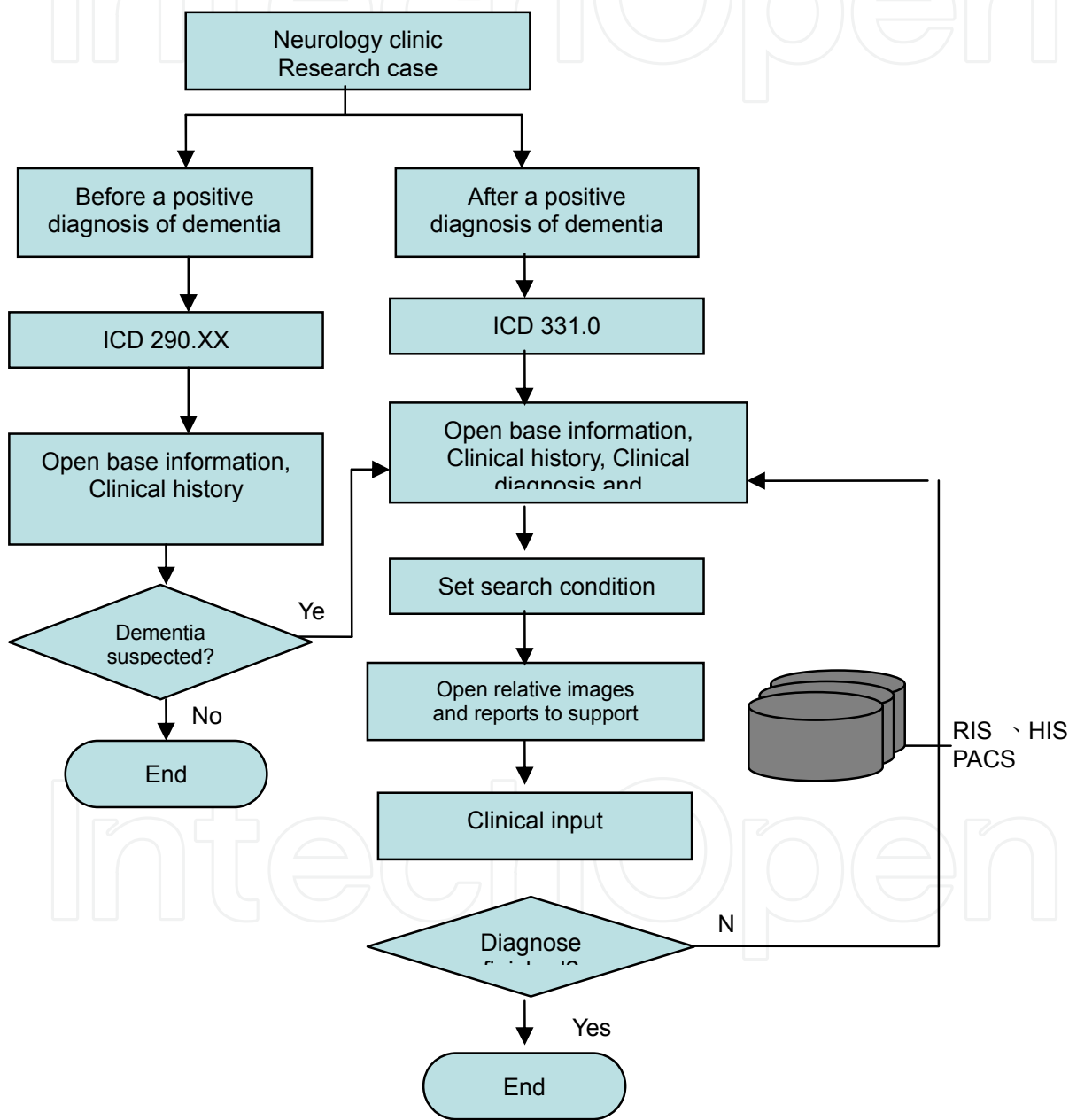


Fig. 3. Flow Diagram

On the other hand, if dementia has not been yet, the neurologists would still like to know the patient’s base information, clinical history, and lab results. Using this clinical history, the

neurologists may make a choice reflecting the initial symptom sequence, course, and risk factors, which will also support him to make an early diagnosis in the future. (Fig. 3.)

With the established prototype model, the data schema of the essential clinical information of dementia will be integrated into the EMR user interface in the clinical department in the EMR system of NTUH. Clinical doctors can input the essential clinical information, such as base information, clinical history, clinical diagnosis, upon initiation of dementia diagnoses and the system will present a prompt with a pop-up menu for easy data entry. At the same time, the prototype model will automatically retrieve the relative medical images and image reports by the radiologists in order to support the diagnosis. (Fig.4)

Moreover, the radiologists get images from PACS with differential diagnosis of dementia and the RIS can simultaneously automatically retrieve the essential clinical information related to specific image characteristics defined by a consensus of the neurology and radiology experts (Fig.5.). In this way, both user interfaces are designed to open a pop-up window with the pull down bar when the clinician or radiologist is ready to input data into the system. (Figs 4-5) [8]



Fig. 4. Prototype Model: Clinical History

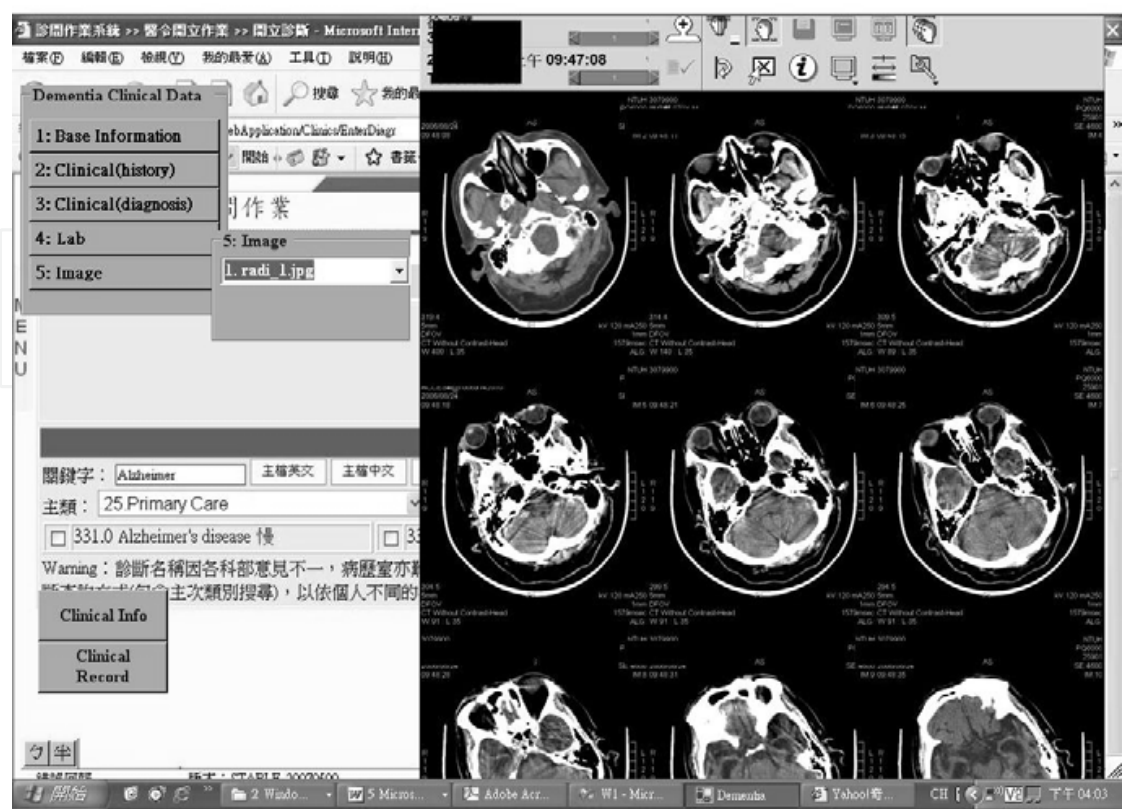


Fig. 5. Prototype Model: CT Image

4. Discussion

In this study, the intelligent information access framework for medical image databases was designed to integrate radiological reports and clinical information. The most important concern in this approach is the interdisciplinary collaboration among neurology, medical informatics and radiology experts. The second important concern would be the implementation with the critical and service-oriented hospital information system. Therefore, we will test the system by the physician-in-the-loop approach to enhance diagnosis practically and revise the system.

Moreover, we focused on decision support for dementia diagnosis, teaching and research. Therefore, we would retrieve images of similar patients via a medical grid by querying keywords of the base information, clinical History, clinical diagnose, Lab. we get the new retrieved image database for the patients. Therefore, we will analysis their medical image correlation by image processing and the relevance of the clinical data and images in order to assist diagnosis, research and teaching.

Security and privacy is also a very important issue in this field of research. First, we build trusted electronic relationships between healthcare customers, employees, businesses, trading partners and stakeholders. Therefore, when we use the patient’s anamnesis, examination data, or medical images, whether we have the patient’s permission or not, there must be a set of procedures to follow accordingly. We plan to consider the security and privacy function in the system, in the future.

The implementation of this prototyping system must be well organized and the initial testing done on an offline system. The clinical data could be backed-up and copied to a

separate system for the purposes of the trial. When the first prototype model becomes fully implemented, the system could be expanded by adding other neurodegenerative diseases one by one to enhance the power and comprehensiveness of the intelligent retrieval for clinical practice.

In the future, the system will be continuously developed to extend its spectrum of diseases and clinical specialties.

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