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วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต

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PC-BASED MEDICAL IMAGE VIEWER/BROWSER FOR NUCLEAR MEDICINE IMAGING

Mr. Chumnarn Sangpha

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Medical Imaging

Department of Radiology
Faculty of Medicine
Chulalongkorn University

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เวชศาสตร์นิวเคลียร์เป็นหนึ่งในวิทยาการแรก ๆ ที่ใช้คอมพิวเตอร์ในการถ่ายภาพผู้ป่วย ประมวลผล จัดเก็บข้อมูลและแสดงภาพดิจิตอล เนื่องจากโปรแกรมแสดงภาพทางการแพทย์ที่มากับเครื่องถ่ายภาพรังสีแกมม่า ไม่สามารถที่จะปรับปรุงแก้ไขให้ตรงกับความต้องการของผู้ใช้ได้ จึงมีการพัฒนาโปรแกรม ChulaView เพื่อแสดงภาพเฉพาะในงานเวชศาสตร์นิวเคลียร์ โดยใช้ภาษาเดลไฟท์ในการพัฒนา โปรแกรมนี้มีความสามารถที่จะทำงานบนเครื่องคอมพิวเตอร์ส่วนบุคคล, สามารถปรับปรุงแก้ไขได้, สามารถแสดงภาพไดคอมและอินเตอร์ไฟล์ได้, มีเครื่องมือในการประมวลผลภาพ เช่น การขยายภาพ, การแสดงภาพต่อเนื่อง, การแสดงภาพหลาย ๆ ภาพพร้อมกัน และการเปลี่ยนค่าสีในการแสดงภาพ เป็นต้น ผู้ศึกษาได้ทำการทดสอบการแสดงภาพทางเวชศาสตร์นิวเคลียร์ด้วยโปรแกรม ChulaView เปรียบเทียบกับโปรแกรมการแสดงภาพจากเครื่องคอมพิวเตอร์ที่มากับเครื่องถ่ายภาพรังสีแกมมา โดยใช้ kappa test เพื่อศึกษาความเห็นพ้องระหว่างทั้งสองโปรแกรม จากการสุ่มตัวอย่างได้ภาพจากการตรวจผู้ป่วย 100 คน เป็นการตรวจกระดูก, ตรวจปอด และตรวจหลอดเลือดดำ อย่างละ 30 คน และเป็นการตรวจกล้ามเนื้อหัวใจ 10 คน โดยแบ่งการทดสอบเป็น 3 ส่วน ได้แก่ ด้านคุณภาพของภาพ, ด้านปริมาณของภาพ (จำนวนของพยาธิสภาพ) และด้านการวินิจฉัยโรค ได้ผลว่าด้าน คุณภาพของภาพ ได้ความเห็นพ้องยอดเยี่ยมในภาพการตรวจปอด, หลอดเลือดดำ และกล้ามเนื้อหัวใจ (kappa coefficient = 1.000) และได้ความเห็นพ้องดีในภาพการตรวจกระดูก (kappa coefficient = 0.709) ในด้านการวินิจฉัยโรค ได้ความเห็นพ้องยอดเยี่ยมในภาพการตรวจ กระดูก, ปอด และหลอดเลือดดำ (kappa coefficient = 1.000) และได้ความเห็นพ้องปานกลางในภาพการตรวจกล้ามเนื้อหัวใจ (kappa coefficient = 0.478) และในด้านปริมาณของภาพ ได้ความเห็นพ้องยอดเยี่ยมในภาพการตรวจ กระดูก, ปอด และหลอดเลือดดำ (kappa coefficient = 0.870 ถึง 1.000) และได้ความเห็นพ้องดีในภาพการตรวจกล้ามเนื้อหัวใจ (kappa coefficient = 0.211 ถึง 1.000) แสดงว่าโปรแกรมแสดงภาพ ChulaView มีความสามารถแสดงภาพเพื่อวินิจฉัยโรคทางด้านเวชศาสตร์นิวเคลียร์ โดยมีความสอดคล้องสูงกับโปรแกรมการแสดงภาพที่มากับเครื่องถ่ายภาพรังสีแกมมา

ภาควิชา รังสีวิทยา ลายมือชื่อนิสิต..

สาขาวิชา ฉายาเวชศาสตร์ ลายมือชื่ออาจารย์ที่ปรึกษา..

ปีการศึกษา 2546 ลายมือชื่ออาจารย์ที่ปรึกษาร่วม...

ลายมือชื่ออาจารย์ที่ปรึกษาร่วม...

4674719530 MAJOR DIAGNOSTIC IMAGING

KEYWORD: DICOM/ INTERFILE/ VIEWER/ NUCLEAR MEDICINE

CHUMNARN SANGPHA: PC-BASED MEDICAL IMAGE VIEWER/BROWSER FOR NUCLEAR MEDICINE IMAGING. THESIS ADVISOR: PANYA PASAWANG, M.Sc., THESIS CO-ADVISOR: ASSOCIATE PROFESSOR TAWATCHAI CHAIWATANARAT, M.D., TARATIP NARAWONG, M.Sc.,

Nuclear Medicine is one of the earliest imaging modalities using computers for acquisition, processing, storage and display of digital images. Generally, computer software used to view the nuclear medicine images will be supported by gamma camera vendor and cannot be modified. **ChulaView** program is a medical image viewer software that developed for nuclear medicine images using Delphi computer language. The capabilities of this software are PC-based, modifiable, support the standard medical image formats-Interfile and DICOM formats, and many processing tools such as zoom, change colour table, cine display, rotate and etc. ChulaView program was evaluated by agreement test -Kappa test- that compared with commercial computer program. The samples were 100 nuclear medicine studies: 30 bone studies, 30 lung studies, 30 vascular studies, and 10 myocardial perfusion studies. There were 3 parts of agreement: image quality, image quantity (number of lesion) and clinical diagnostic results. The results show that firstly, image quality was excellent for lung studies, vascular studies and myocardium perfusion studies (kappa coefficient = 1.000) and good agreement for bone studies (kappa coefficient = 0.709). Secondary, image quantitative was excellent agreement for bone studies, lung studies and vascular studies (kappa coefficient = 0.870 to 1.000), and fair to good agreement for myocardial perfusion studies (kappa coefficient = 0.211 to 1.000). And thirdly, clinical diagnostic results were excellent agreement for bone studies, lung studies and vascular studies (kappa coefficient = 1.000), and moderate agreement for myocardium perfusion studies (kappa coefficient = 0.478). In conclusion, ChulaView is a computer program to use as a tool for facilitating the interpretation, picture archiving and communication in nuclear medicine. It is comparable to a commercial software.

Department Radiology Student's signature……………………………..

Field of study Medical Imaging Advisor's signature…………………………….

Academic year 2004 Co-advisor's signature…………………………

Co-advisor's signature…………………………

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CHAPTER I

BACKGROUND AND RATIONALE

Digital medical images are commonly used in hospitals today, even outside the radiology department. Because of the interrelation of the radiology department and other departments, the transmission of medical images has become a critical issue.

The use of World Wide Web technologies in radiology is not new. These technologies have been used in radiology teaching files, to access information in multimedia integrated picture archiving and communication system, and for tele-radiology purposes.

These applications have recently become commercially available. A variety of products are being offered by different vendors, including Impax Web 1000 (Agfa, Gevaert Medical Imaging Group, Mortsel, Belgium), MediSurf (Algotec Systems , Duluth, Ga), WebLink 2.0 (GE Medical Systems , Waukesha, Wis), Exhibit (Mitra Imaging, Waterloo, Ontario, Canada), and MagicWeb (Siemens Medical Systems, Iselin, NJ).

There are a lot of Free Medical Imaging Viewer that user can download from internet and use in various radiology departments, that supports most common Medical Imaging file type (Interfile and DICOM).

However, most of such programs are meant to be used for a wide variety of image types, most of them are for MRI, CT or CR images and not specific for nuclear medicine images. As a result there may be lag of some important features needed to view nuclear medicine images such as dynamic image display, simultaneous multiple image-orientation display or different color map display.

Internet technology makes file transfer across the network easy. It may help solving the problem of the fact that there are short of nuclear medicine physician in Thailand. Once nuclear medicine studies have been performed, the studied images will be stored in digital files ready to be displayed or analyzed by technician and to be reported by physician. Nuclear medicine viewer program capable of remote connection to the storage computer will make requirement of personnel on the studying site unnecessary.

These are several computer programming language which can be used to create image application program such as C++, Java, Delphi etc, each language has advantage and disadvantage.

Delphi is a Rapid Application Development (RAD) ChulaView by Borland International, Inc. Delphi is a powerful, high-productivity application development environment that makes next-generation e-business development a snap. Delphi provides a full complement of powerful, standards-based tools to control and deliver business data.

Delphi is similar to Visual Basic from Microsoft, but where as Visual Basic is based on the BASIC programming language, Delphi is based on Pascal.

1.1 Interfile Introduction

Interfile is a "file format for the exchange of nuclear medicine image data" created I gather to satisfy the needs of the European COST B2 Project for the transfer of images of quality control phantoms, and incorporates the AAPM (American Association of Physicists in Medicine) Report No. 10, and has been subsequently used for clinical work.

It specifies a file format composed of ASCII "key-value" pairs and a data dictionary of keys. The binary image data may contain in the same file as the "administrative information" or in a separate file pointed to by a "name of data file" key. Image data may be binary integers, IEEE floating point values, or ASCII and the byte order is specified by a key "image data byte order". The order of keys is defined by the Interfile syntax which is more sophisticated than a simple list of keys, allowing for groups, conditionals and loops to dictate the order of key-value pairs.

Conformance to the Interfile standard is informally described in terms of which types of image data types, pixel types, multiple windows, special Interfile features including curves, and restriction to various maximum recommended limits.

Interfile is specifically NOT a communications protocol and strictly deals with offline files. There are efforts to extend Interfile to include modalities other than nuclear medicine, as well as to keep ACR/NEMA and Interfile data dictionaries in some kind of harmony.

A sample list of Interfile 3.3 key-value pairs is shown here to give you some idea of the flavor of the format. The example is culled from part of a Static study in the Interfile standard document and is not complete:

```
!INTERFILE :=
!imaging modality :=nucmed
!version of keys :=3.3
data description :=static
patient name :=joe doe
!patient ID  :=12345
patient dob :=1968:08:21
patient sex :=M
!study ID :=test
exam type :=test
data compression :=none
!image number :=1
!matrix size [1] :=64
!matrix size [2] :=64
!number format :=signed integer
!number of bytes per pixel :=2
!image duration (sec) :=100
image start time :=10:20: 0
total counts :=8512
!END OF INTERFILE :=
```

Figure 1 : A sample list of Interfile 3.3 key-value pairs.

One can see how easy such a format would be to extend, as well as how it is readable and almost useable without reference to any standard document or data dictionary.

Undoubtedly ACR/NEMA DICOM 3.0 to Interfile translators will soon proliferate in view of the fact that many Nuclear Medicine vendors supply Interfile translators at present.

To get hold of the Interfile 3.3 standard, see the Interfile sources, Interfile information contacts and Interfile mailing list described later in this document.

1.2 DICOM Introduction

In 1985, the American College of Radiology (ACR) and National Electrical Manufacturers Association (NEMA) published a standard which addressed the issue of vendor-independent data formats and data transfers for digital medical images. A revised version of the standard was published in 1988. In both versions, data transfer was defined for point-to-point connections, i.e., a networked environment was not considered. ACR and NEMA completed the third version of the standard which has been renamed "DICOM Version 3.0" in 1993.

DICOM stands for Digital Imaging and Communications in Medicine. The "Version 3.0" refers to the fact that there were two prior versions of the standard.

The Radiological Society of North America (RSNA) contracted the Washington University, Mallinckrodt Institute of Radiology to develop a version of the standard that could be used as a demonstration at the RSNA Annual Meeting in 1992. A second demonstration was held at RSNA '93. The DICOM standard was voted and passed by members of NEMA in late 1993.

Since 1993, the DICOM standard has been extended and revised, resulting in the recent release of the 2000 DICOM 3.0 Standard. New features include two additional parts and the approval of numerous supplements to the standard.

1.3 DICOM Standard

The Digital Imaging and Communications in Medicine (DICOM) standard was created by the National Electrical Manufacturers Association (NEMA) to aid the distribution and viewing of medical images, such as CT scans, MRIs, and ultrasound. The standard describes a file format for the distribution of images. This format is an extension of the older NEMA standard. Most people refer to image files which are compliant with the DICOM standard as DICOM format files.

A single DICOM file contains both a header (which stores information about the patient's name, the type of scan, image dimensions, etc), and all of the image data (which can contain information in three dimensions). This is different from the popular Analyze format, which stores the image data in one file (*.img) and the header data in another file (*.hdr). Another difference between DICOM and Analyze is that the DICOM image data can be compressed (encapsulated) to reduce the image size. Files can be compressed using lossy or lossless variants of the JPEG format, as well as a lossless Run-Length Encoding format (which is identical to the packed-bits compression found in some TIFF format images).

1.4 DICOM header

The Image shows a hypothetical DICOM image file. In this example, the first 794 bytes are used for a DICOM format header, which describes the image dimensions and retains other text information about the scan. The size of this header varies depending on how much header information is stored. Here, the header defines an image which has the dimensions 109x91x2 voxels, with a data resolution of 1 byte per voxel (so the total image size will be 19838). The image data follows the header information (the header and the imagedata are stored in the same file).

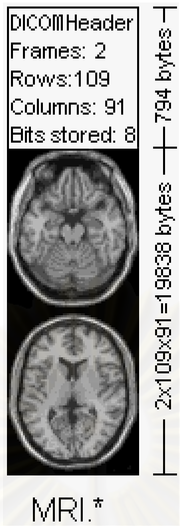


Figure 2 : Example structure of DICOM Image that shows Header of DICOM file.

First 128 bytes: unused by DICOM format
Followed by the characters 'D','I','C','M'
This preamble is followed by extra information e.g.:

0002,0000,File Meta Elements Group Len: 132
0002,0001,File Meta Info Version: 256
0002,0010,Transfer Syntax UID: 1.2.840.10008.1.2.1.
0008,0000,Identifying Group Length: 152
0008,0060,Modality: MR
0008,0070,Manufacturer: MRIcro
0018,0000,Acquisition Group Length: 28
0018,0050,Slice Thickness: 2.00
0018,1020,Software Version: 46\64\37
0028,0000,Image Presentation Group Length: 148
0028,0002,Samples Per Pixel: 1
0028,0004,Photometric Interpretation: MONOCHROME2.
0028,0008,Number of Frames: 2
0028,0010,Rows: 109
0028,0011,Columns: 91
0028,0030,Pixel Spacing: 2.00\2.00
0028,0100,Bits Allocated: 8
0028,0101,Bits Stored: 8
0028,0102,High Bit: 7
0028,0103,Pixel Representation: 0
0028,1052,Rescale Intercept: 0.00
0028,1053,Rescale Slope: 0.00392157
7FE0,0000,Pixel Data Group Length: 19850
7FE0,0010,Pixel Data: 19838

Figure 3 : Detail list of the DICOM file Header.

CHAPTER II

REVIEW OF RELATED LITERATURES

With the advent of filmless radiology, it becomes importance to be able to distribute radiologic images digitally throughout an entire hospital. A new approach based on World Wide Web technologies were ChulaView accomplishes this objective. DICOM Java Viewer Project (Josep Fernandez-Bayo et al) [1][2][3] involves a Web server that allows the query and retrieval of images stored in a Digital Imaging and Communications in Medicine (DICOM) archive. The images can be viewed inside a Web browser with the use of a small Java program known as the DICOM Java Viewer which is executed inside the browser

The Medical Image Processing Program (Bundhit Ninudomsak) [4] has multifunction for image processing. It can display various standard formats of digital image such as DICOM, Interfile, Bitmap and JPEG. It has also the capabilities to zoom, change the color table, and adjust window level and window width. This Program has not been able to connect to the internet.

ImageJ is a public domain Java image processing program inspired by NIH Image for the Macintosh. It runs, either as an online applet or as a downloadable application, on any computer with a Java 1.1 or later virtual machine. ImageJ was designed with an open architecture that provides extensibility via Java plugins. Custom acquisition, analysis and processing plugins can be ChulaView using ImageJ's built in editor and Java compiler. User-written plugins make it possible to solve almost any image processing or analysis problem

ezDICOM is a medical viewer for MRI, CT and ultrasound images. It can read images from Analyze, DICOM, GE Genesis, Interfile, Siemens Magnetom, Siemens Somatom and NEMA formats. It also includes tools for converting medical images from proprietary format.

In this study, the medical image viewer/browser program was ChulaView and can be used efficiently in Nuclear Medicine Department. It also has the capabilities to zoom, change the color table, and adjust window level and window width. Additionally, there are more functions to suit nuclear medicine need.

CHAPTER III

CONCEPTUAL FRAMEWORK, RESEARCH QUESTIONS AND RESEARCH OBJECTIVES

3.1 Conceptual Framework

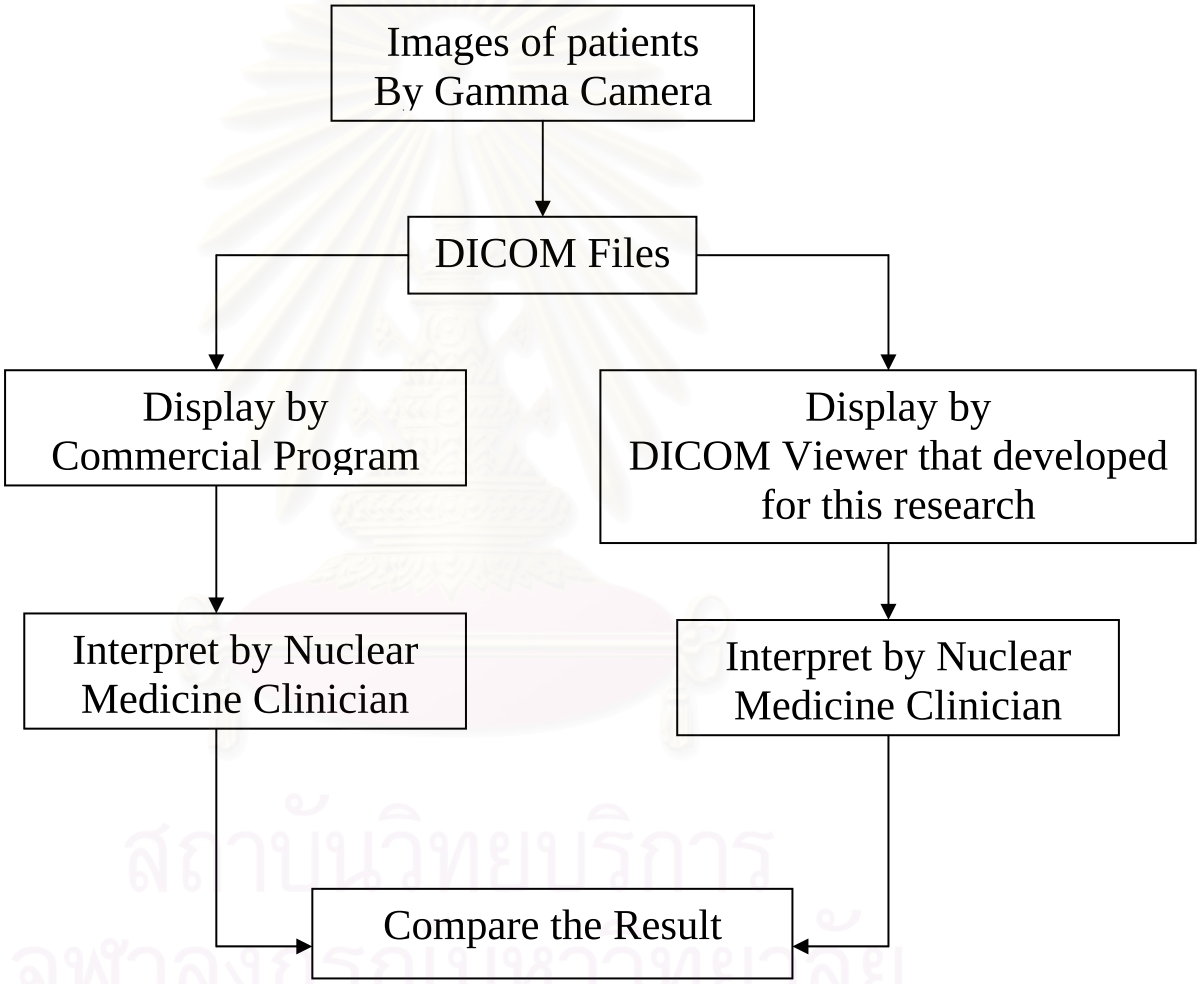


Figure 4 : Conceptual Framework

3.2 Research Question

Primary question

Is it possible to use personal computer as a tool facilitating the interpretation, picture archiving and communication in Nuclear Medicine?

Secondary question

Does developed Medical Image Viewer/Browser provide comparable result to commercial software?

3.3 Research Objectives

1. To develop Medical Image Viewer/Browser program that presents the approach for improving medical imaging and friendly interface focusing on Nuclear Medicine imaging.

2. The Nuclear Medicine Clinicians in King Chulalongkorn Memorial Hospital satisfy with this Medical Image Viewer/Browser.

3. To simplify interdepartmental relationships in a filmless hospital environment with the use of internet technology.

3.4 Hypothesis

The radionuclide images are displayed by using the developed viewer/browser program not different from the commercial viewer/browser program.

CHAPTER IV

RESEARCH METHODOLOGY

This research is divided into two section : program design and research methodology (program agreement test).

4.1 Program Design

This medical imaging viewer/browser program collects the features that are useful for Nuclear Medicine from other free Medical Imaging Viewer. It is able zoom, change the color table, adjust window level and window width, rotate picture and run cinema series that are necessary for viewing images in Nuclear Medicine

It can view the most common used image file type in Nuclear Medicine (Interfile, DICOM).

Graphic User Interface (GUI) of the program is friendly for Nuclear Medicine users. Because of most free Medical Imaging Viewer Programs are designed for MRI users, CT users, CR users, and other department in radiology, but not for Nuclear Medicine. So they have unnecessary features that are useful in Nuclear Medicine, users will lose non-benefit area in the hard disk. The program developed will concentrate on the features that are useful in Nuclear Medicine. So users will not lose non-benefit area in the hard disk.

The heart of the program is the DICOM Component freely distributed on internet. Most of free Medical Imaging Viewer uses this component. The DICOM component is the component that can display a DICOM file. A program developer can insert this component into the programs and then write the features required. After compilation, the program will be ready to use.

ezDICOM is a free DICOM component. Programmer uses ezDICOM as a starting point for a medical imaging viewer project. In particular, the ActiveX and CLX components allow programmer to drag-and-drop a fully functioning medical image viewer onto the software without the needs to learn any of the complicated details about medical image formats.

Developer use Delphi language, Delphi is a Rapid Application Development (RAD) environment that allows programmer to create Windows programs very quickly and easily. It was created by Borland in 1993 and is a descendant of the popular Turbo Pascal.

4.2 Research Maneuver

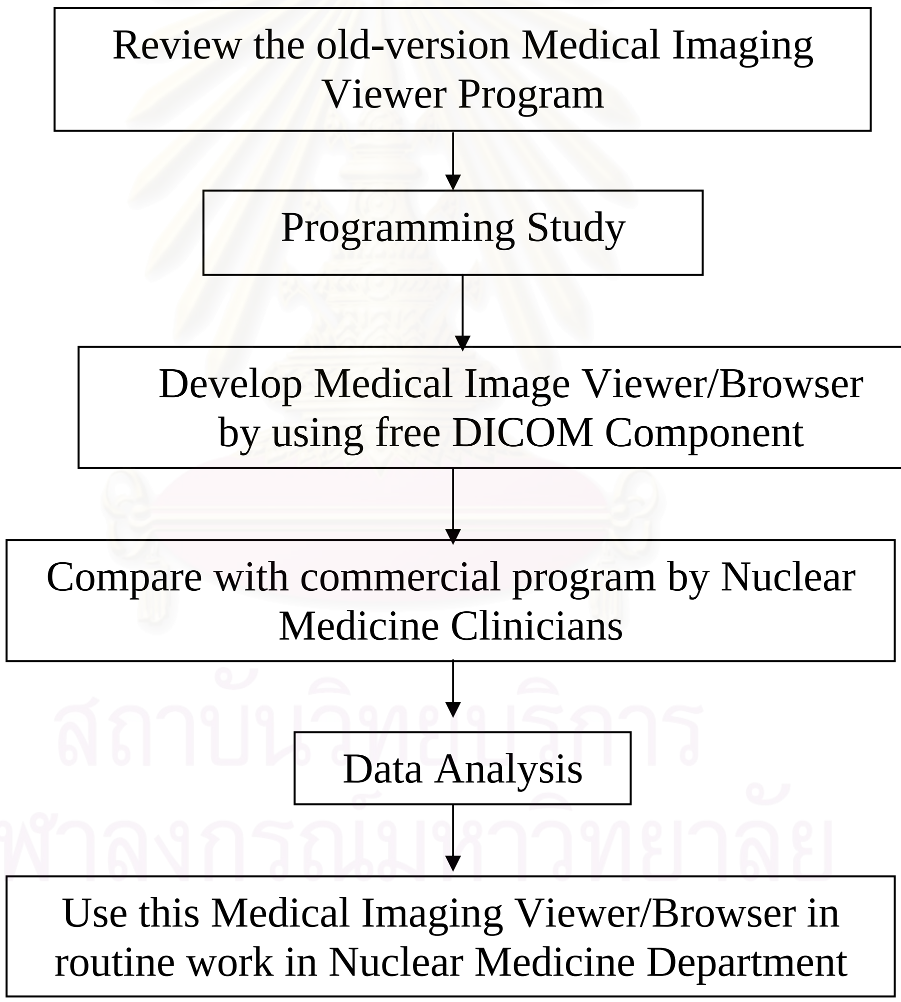


Figure 5 : Diagram of Research Maneuver

4.3 Materials

4.3.1 Hardware resources

4.3.1.1 PC Computer 1 unit

CPU	:	Intel Pentium 4, 1.7 GHz
RAM	:	256 Mbytes
Hard Disk	:	40 GB
Monitor	:	Super VGA Monitor
Peripheral	:	Keyboard, Mouse

4.3.1.2 Notebook Computer 1 unit

CPU	:	Intel Pentium4, 2.0 GHz
RAM	:	256 Mbytes
Hard Disk	:	30 GB
Monitor	:	LCD Monitor

4.3.2 Software resource

Operating System	:	Microsoft Windows XP
Compiler	:	Borland Delphi Version 7.0
DICOM Component	:	ezDICOM

4.3.3 Interfile and DICOM files

Case studies 100 cases from Division of Nuclear Medicine Department of Radiology, King Chulalongkorn Memorial Hospital.

4.4 Research Methodology

The objective of this research is to develop Medical Image Viewer/Browser that is friendly and useful for Nuclear Medicine Clinicians in King Chulalongkorn Memorial Hospital.

4.5 Population and Sample

4.5.1 Target Population

The population of this research is case studies imaged by Gamma Camera in DICOM files from the Division of Nuclear Medicine, Department of Radiology at King Chulalongkorn Memorial Hospital.

4.5.2 Sample

This research uses sample population of DICOM files in Nuclear Medicine Department randomly.

Bone scintigraphy	30 cases
Lung scintigraphy	30 cases
Myocardium Perfusion	10 cases
Vascular scintigraphy	30 cases

4.6 Measurement

Variables: Dependent Variable = Agreement

Bone scintigraphy	– site of lesion
Lung scintigraphy	– site of defect
Myocardium Perfusion	– site of defect
Vascular scintigraphy	– present of DVT

4.7 Outcome to be measured

The agreement of site and number of defect as a result of developed program and commercial program.

4.8 Data Collection

During a period of 6 months, DICOM files of patients diagnosed by Gamma Camera at Nuclear Medicine Department are obtained by following criteria;

Bone scintigraphy	– Bone metastasis
Lung scintigraphy	– Pulmonary embolism
Myocardium Perfusion	– Ischemic heart disease
Vascular scintigraphy	– Deep vein thrombosis

Nuclear Medicine clinicians will compare these four sets of images using a standardized protocol. Interpretations of four sets of randomly distributed DICOM images are performed individually in four separate sessions and time. Each observer is unaware of the patient's history and interpreted each image independently.

The presence or absence of lesions is evaluated using the following scoring system: 1, definitely negative; 2, probably negative; 3, indeterminate; 4, probably positive; and 5, definitely positive. The image quality for interpretation using the following scoring system: 1, poor; 2, fair; 3, good, 4, excellent for diagnosing. Finally, No. of lesions in each region are recorded individually. These responses are recorded and resorted by each program for statistical analysis.

Data is collected by evaluation forms filled out by the clinicians after they use this program in comparison to commercial program.

4.9 Data Analysis

The data from Image quality part, diagnostic part and image quantity part of bone studies are ordered scale, so they are analyzed with weighted kappa. The data from image quantity part of lung studies, myocardial studies and vascular studies are nominal scale, so analyzed with kappa. The weighted kappa and kappa score between the developed program and commercial program was calculating to correlate the agreement between the two programs. Reliability and reproducibility were assessed with the use of weighted kappa and kappa statistics. The weighted kappa and kappa coefficient represents the instances of agreement with the likelihood of agreement based on chance alone taken into account. The weighted kappa and kappa coefficient are analyzed by Medical program version 7.6.0.0. A kappa coefficient of 1.00 indicates a perfect agreement. A kappa value <0 indicated no agreement, 0.00 to 0.19 indicated a poor agreement, 0.20 to 0.39 indicated a fair agreement; 0.4 to 0.59 indicated moderate agreement; 0.6 to 0.79 indicated a good agreement and 0.8 to 1.00 indicated an excellent agreement. [6]

CHAPTER V

RESULTS

This chapter is divided into two sections, GUI of ChulaView (Developed program) and results from agreement test between ChulaView and commercial program.

5.1 GUI of ChulaView

The program can run on Microsoft windows operating system by double click on file ChulaView.exe and then the program will show main window and its details as show in figure 6.

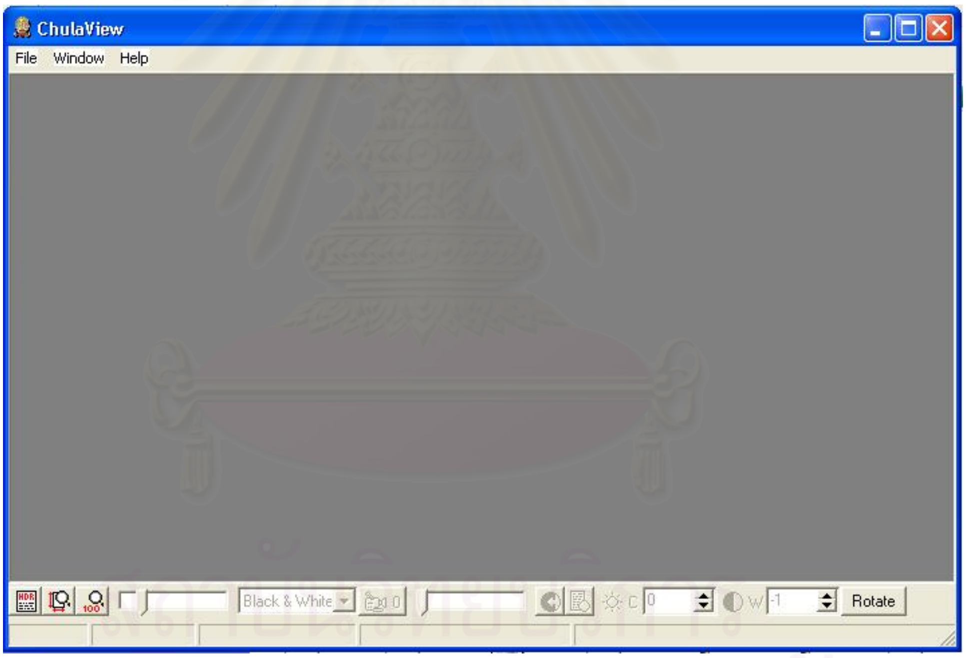


Figure 6 : Main window of ChulaView

5.1.1 Opening Interfile and DICOM files

To open Interfile or DICOM files, the appropriate command from the File menu is used. It can display all kinds of image studies as bone studies, lung studies, myocardial studies, vascular studies, and etc. These are shown in figure 7 – 10.

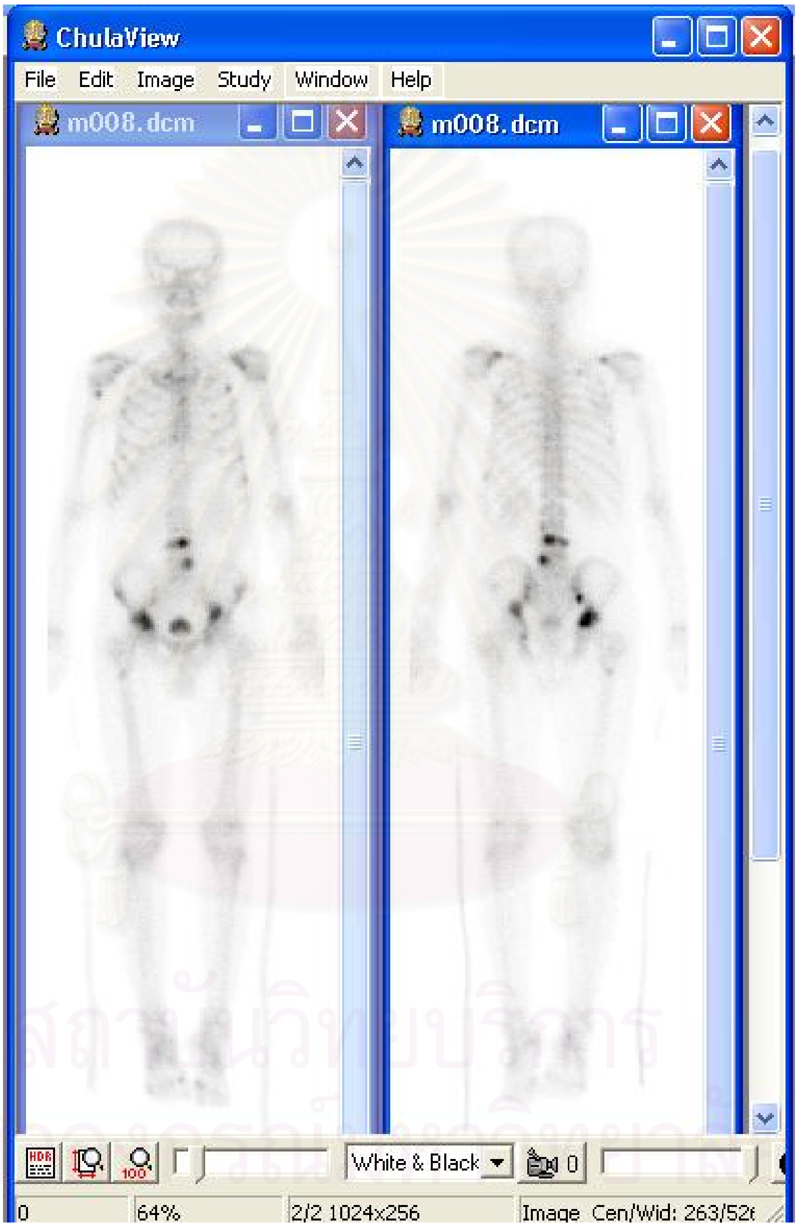


Figure 7 : ChulaView Display of bone images.

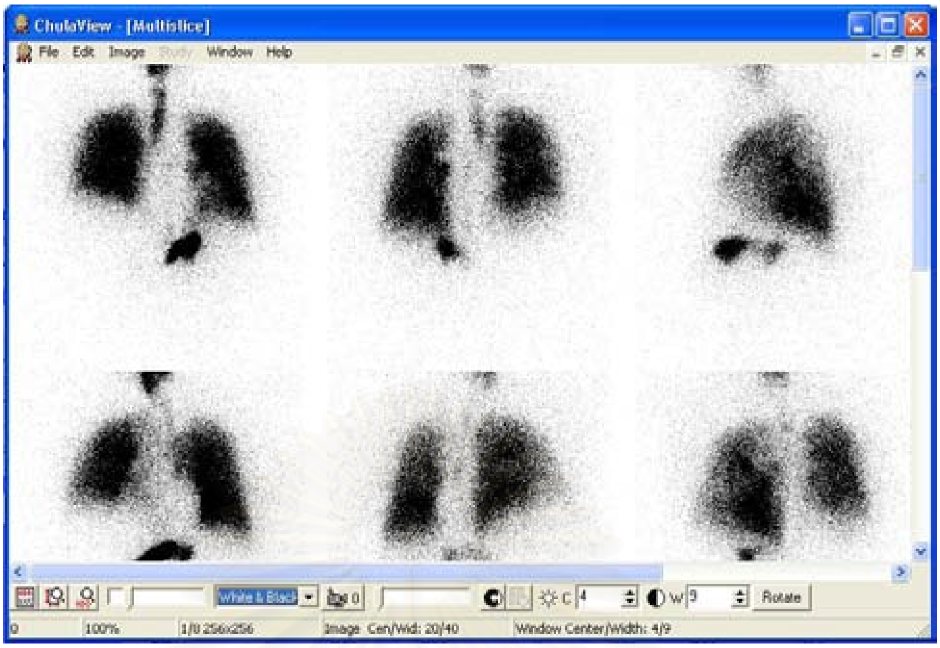


Figure 8 : ChulaView Display of lung images.

Figure 9 : ChulaView Display short axis of tomography image of myocardial perfusion images.

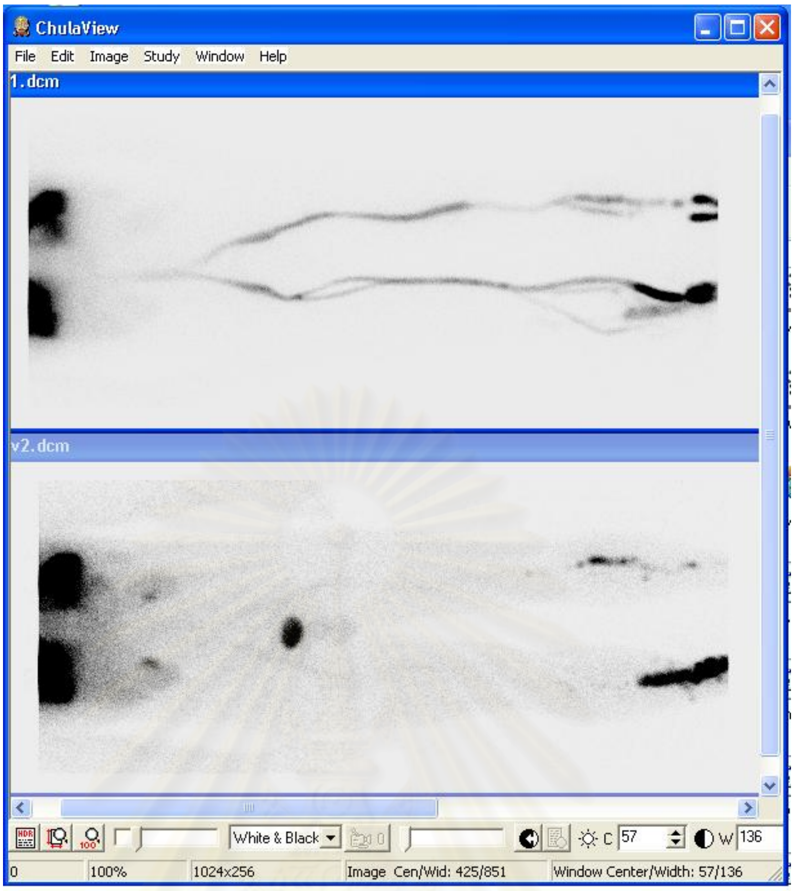


Figure 10 : ChulaView Display of vascular images.

5.1.2 Features of ChulaView

ChulaView has many features that are useful in Nuclear Medicine Imaging. These features are necessary for the clinician to interpret the Nuclear Medicine images.

Main menu

The main menu of ChulaView has many sub-menu such as File, Edit, Image, Study, Window and Help.

Figure 11 : Main menu of ChulaView

File Menu

The file menu of ChulaView has three sub-menus such as Open DICOM/Interfile to open image in DICOM and Interfile format, Close to close current image and Exit to close the program. Below the file menu the last images that have been displayed by program are listed.

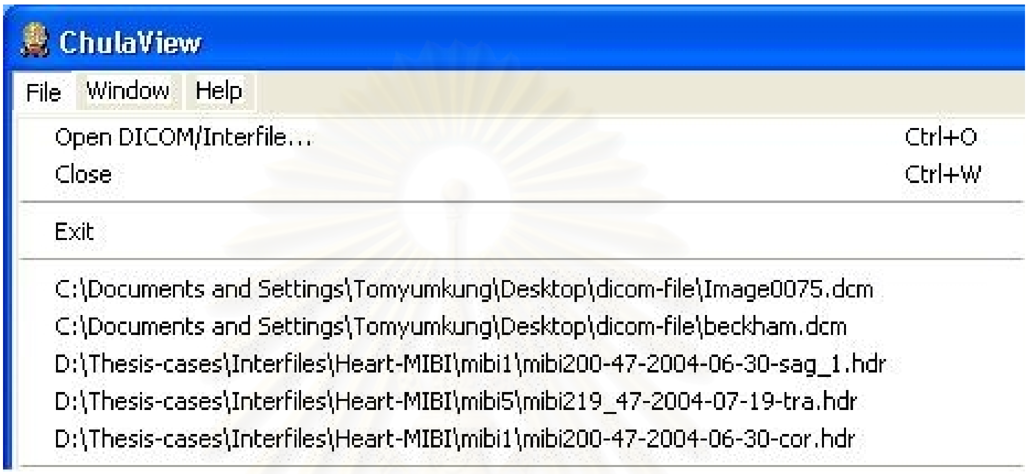


Figure 12 : File menu of ChulaView

Image Menu

The image menu of ChulaView has sub-menus such as Lower slice (shortcut key : F1) to display previous slice of image series, Higher slice (shortcut key : F2) to display next slice of image series, Mosaic to display multiple image in the same time, View Image Information (shortcut key : F3) to display header of image, Select Zoom (shortcut key : F4) to zoom image, Contrast Autobalance (shortcut key : F5) to auto adjust best contrast of current image, Smooth (shortcut key : S) to add a smoothing filter to image and Overlay to display information on the image.

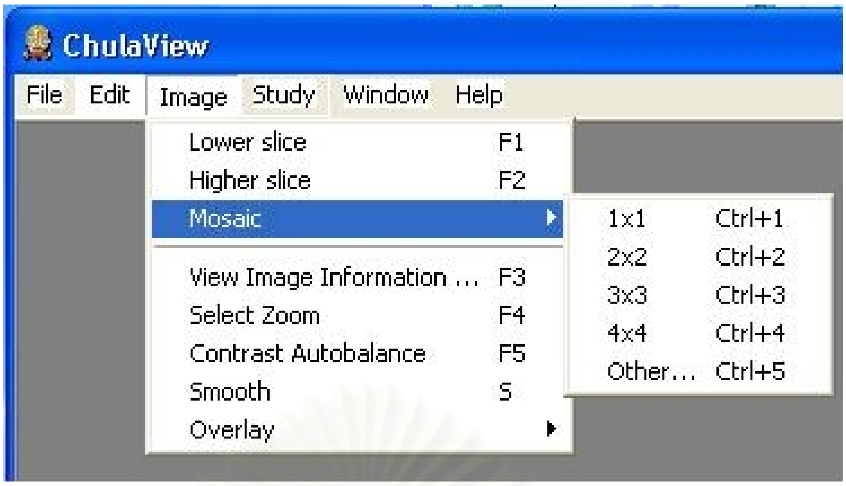
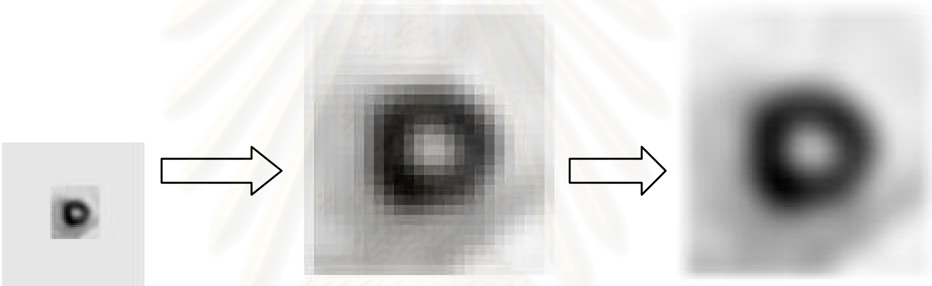


Figure 13 : Image menu of ChulaView



(a) **(b)** **(c)**

Figure 14 **:** Zoom and smooth feature of ChulaView (a) original image (b) image after zoom function (c) image after add smooth function.

Window Menu

Window menu of ChulaView has the similar feature to other windows application such as Cascade (shortcut key : F6), Tile (shortcut key : F7), Arrange Icons (shortcut key : F8), Minimize All (shortcut key : F9), Maximize All (shortcut key : F10) and Zoom for best fit (shortcut key : F11). Below the menu the name of the current image file is shown.

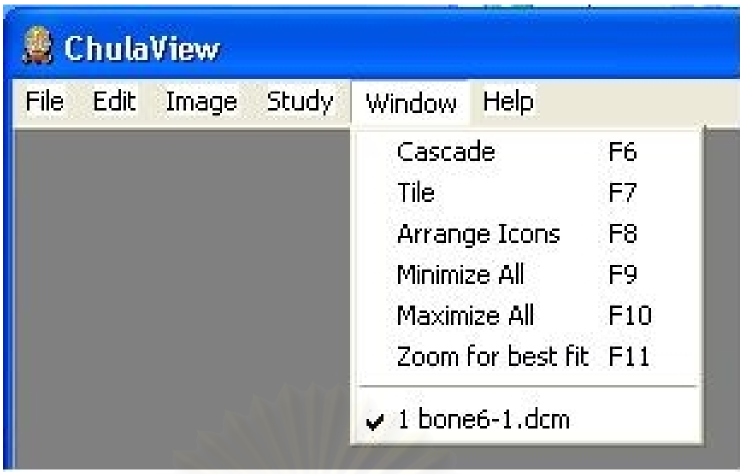


Figure 15 : Window menu of ChulaView

Display header of DICOM file

The header file contains information about the DICOM and Interfile can display. The header file has information about the DICOM file and Interfile such as Modality, Manufacturer, Institution Name, Study Description, Patient's name, Patient's ID, Patient's Sex, etc. User can push F3 key to go back to image display.

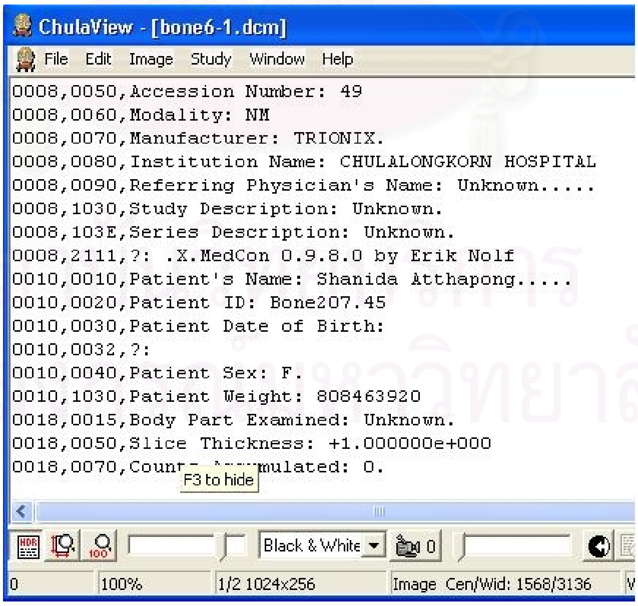


Figure 16 : Feature display header of file of ChulaView

Zoom feature

ChulaView is able to zoom into the image by sliding a zoom track-bar at the lower toolbar to the right, and can reset to original zoom by clicking the 100% zoom button.

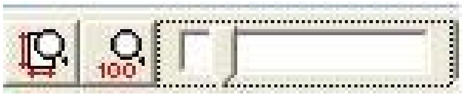


Figure 17 : The zoom feature of ChulaView

Change slide feature

ChulaView is able to change slide image in the series by sliding trackbar at lower toolbar to the right and change to previous image in series by sliding trackbar to the left.

Figure 18 : Change slide feature of ChulaView

Change color table feature

ChulaView is able to change color table of image such as White & Black, Black & White, Hot Metal, X_rain, X_hot, SPECTRUM, Rain_ramp, NIH_ice, NIH_fire, NIH, HOTIRON, Gold, GE_Color, FLOW, CARDIAC and BLACKBDY by selecting from the combo-box.

Figure 19 : Change color table feature of ChulaView

Display cine image feature

ChulaView is able to display cine image (continuous display) by click cine button in the lower toolbar (to use this feature, computer must have RAM over 512 MB).

Figure 20 : Display cine image feature of ChulaView

Change window width and window level feature

ChulaView can change window width and window level by input the window width value and window center value in the edit box and click the button beside the box. The other way to adjust window width and window level is to move the cursor over the image and clicking and dragging the mouse in difference direction : horizontally to the left to decrease window width, horizontally to the right to increase window width, vertically up to increase window center, vertically down to decrease window center.

Figure 21 : Manual change window width and window level feature of ChulaView

Rotate image feature

ChulaView is able to rotate image by clicking the rotate button at lower toolbar, each time click, image will rotate clock-wise 90 degree.

Figure 22 : Rotate image feature of ChulaView

Display status-bar feature

The Status-bar of ChulaView shows information of the currently displayed image such as percentage of zoom, slice number, matrix size, original window width and window center and current window width and window center.

Figure 23 : Status bar of ChulaView

5.2 Agreement Test

100 cases were interpreted by clinician, to compare agreement between ChulaView and commercial program. In these experiments, the results of studies are shown as following:

5.2.1 Part 1: Image Quality Part

Table 1 : Cross tabulation of bone studies in image quality part.

		ChulaView				Total
		Poor	Fair	Good	Excellent	
Commercial Program	Poor	0	0	0	0	0
	Fair	0	3	0	0	3
	Good	0	1	17	0	18
	Excellent	0	0	4	5	9
Total		0	4	21	5	30

Table 2 : Cross tabulation of lung studies in image quality part.

		ChulaView				Total
		Poor	Fair	Good	Excellent	
Commercial Program	Poor	0	0	0	0	0
	Fair	0	0	0	0	0
	Good	0	0	19	0	19
	Excellent	0	0	0	11	11
Total		0	0	19	11	30

Table 3 : Cross tabulation of myocardial perfusion studies in image quality part.

		ChulaView				Total
		Poor	Fair	Good	Excellent	
Commercial Program	Poor	0	0	0	0	0
	Fair	0	0	0	0	0
	Good	0	0	10	0	10
	Excellent	0	0	0	0	0
Total		0	0	10	0	10

Table 4 : Cross tabulation of vascular studies in image quality part.

		ChulaView				Total
		Poor	Fair	Good	Excellent	
Commercial Program	Poor	0	0	0	0	0
	Fair	0	6	2	0	8
	Good	0	0	3	8	11
	Excellent	0	0	0	11	11
Total		0	6	5	19	30

Table 5 : Agreement of ChulaView and commercial program in image quality part.

Case	Weighted Kappa coefficient	Level of agreement	P value
Bone scintigraphy	0.709	Good	0.120
Lung scintigraphy	1.000	Excellent	<0.001
Myocardial Perfusion	1.000	Excellent	<0.001
Vascular scintigraphy	0.958	Excellent	0.042

5.2.2 Part 2 : Diagnostic Part

Table 6: Cross tabulation of bone studies in diagnostic part.

		ChulaView					Total
		Definitely negative	Probably negative	Indeterminate	Probably positive	Definitely positive	
Commercial Program	Definitely negative	8	0	0	0	0	8
	Probably negative	0	0	0	0	0	0
	Indeterminate	0	0	0	0	0	0
	Probably positive	0	0	0	4	0	4
	Definitely positive	0	0	0	0	18	18
Total		8	0	0	4	18	30

Table 7: Cross tabulation of lung studies in diagnostic part.

		ChulaView					Total
		Definitely negative	Probably negative	Indeterminate	Probably positive	Definitely positive	
Commercial Program	Definitely negative	14	0	0	0	0	14
	Probably negative	0	0	0	0	0	0
	Indeterminate	0	0	0	0	0	0
	Probably positive	0	0	0	0	0	0
	Definitely positive	0	0	0	0	16	16
Total		14	0	0	0	16	30

Table 8: Cross tabulation of myocardial perfusion studies in clinical diagnostic part.

		ChulaView					Total
		Definitely negative	Probably negative	Indeterminate	Probably positive	Definitely positive	
Commercial Program	Definitely negative	2	1	0	1	0	4
	Probably negative	1	1	0	0	0	2
	Indeterminate	0	0	0	0	0	0
	Probably positive	1	0	0	0	0	1
	Definitely positive	0	0	0	1	2	3
Total		4	2	0	2	2	10

Table 9: Cross tabulation of vascular studies in clinical diagnostic part.

		ChulaView					Total
		Definitely negative	Probably negative	Indeterminate	Probably positive	Definitely positive	
Commercial Program	Definitely negative	14	0	0	0	0	14
	Probably negative	0	0	0	0	0	2
	Indeterminate	0	0	0	0	0	0
	Probably positive	0	0	0	2	0	2
	Definitely positive	0	0	0	0	14	14
Total		14	0	0	2	14	30

Table 10: Agreement of ChulaView and commercial program in clinical diagnostic part.

Case	Weighted Kappa coefficient	Level of agreement	P value
Bone scintigraphy	1.000	Excellent	<0.001
Lung scintigraphy	1.000	Excellent	<0.001
Myocardium Perfusion	0.478	Moderate	0.209
Vascular scintigraphy	1.000	Excellent	<0.001

5.2.3 Part 3 : Image Quantity

Table 11: Cross tabulation of bone studies in image quantity part : skull region.

		ChulaView (No. of lesion)				Total
		0	1	2	≥3	
Commercial Program	0	26	0	0	0	26
	1	0	4	0	0	4
	2	0	0	0	0	0
	≥3	0	0	0	0	0
Total		26	4	0	0	30

Table 12 : Cross tabulation of bone studies in image quantity part : sternum region.

		ChulaView (No. of lesion)				Total
		0	1	2	≥3	
Commercial Program	0	27	0	0	0	27
	1	0	3	0	0	3
	2	0	0	0	0	0
	≥3	0	0	0	0	0
Total		27	3	0	0	30

Table 13 : Cross tabulation of bone studies in image quantity part : right ribs region.

		ChulaView (No. of lesion)				Total
		0	1	2	≥3	
Commercial Program	0	25	0	0	0	25
	1	0	4	0	0	4
	2	0	0	0	0	0
	≥3	0	0	0	1	1
Total		25	4	0	1	30

Table 14 : Cross tabulation of bone studies in image quantity part : left ribs region.

		ChulaView (No. of lesion)				Total
		0	1	2	≥3	
Commercial Program	0	27	0	0	0	27
	1	0	2	0	0	2
	2	0	0	0	0	0
	≥3	0	0	0	1	1
Total		27	2	0	1	30

Table 15 : Cross tabulation of bone studies in image quantity part : whole spine region.

		ChulaView (No. of lesion)				Total
		0	1	2	≥3	
Commercial Program	0	18	0	0	0	18
	1	0	11	0	0	11
	2	0	0	0	0	1
	≥3	0	0	1	0	0
Total		18	11	1	0	30

Table 16 : Cross tabulation of bone studies in image quantity part : pelvis region.

		ChulaView (No. of lesion)				Total
		0	1	2	≥3	
Commercial Program	0	23	0	0	0	23
	1	0	4	0	0	4
	2	0	0	1	0	2
	≥3	0	0	0	1	1
Total		23	5	1	1	30

Table 17 : Cross tabulation of bone studies in image quantity part : right upper extremity region.

		ChulaView (No. of lesion)				Total
		0	1	2	≥3	
Commercial Program	0	29	0	0	0	29
	1	0	1	0	0	1
	2	0	0	0	0	0
	≥3	0	0	0	0	0
Total		29	1	0	0	30

Table 18 : Cross tabulation of bone studies in image quantity part : left upper extremity region.

		ChulaView (No. of lesion)				Total
		0	1	2	≥3	
Commercial Program	0	29	0	0	0	29
	1	0	1	0	0	1
	2	0	0	0	0	0
	≥3	0	0	0	0	0
Total		29	1	0	0	30

Table 19 : Cross tabulation of bone studies in image quantity part : right lower extremity region.

		ChulaView (No. of lesion)				Total
		0	1	2	≥3	
Commercial Program	0	25	0	0	0	25
	1	1	4	0	0	5
	2	0	0	0	0	0
	≥3	0	0	0	0	0
Total		26	4	0	0	30

Table 20 : Cross tabulation of bone studies in image quantity part : left lower extremity region.

		ChulaView (No. of lesion)				Total
		0	1	2	≥3	
Commercial Program	0	27	0	0	0	27
	1	0	3	0	0	3
	2	0	0	0	0	0
	≥3	0	0	0	0	0
Total		27	3	0	0	30

Table 21 : Agreement of ChulaView and commercial program of bone studies in image quantitative part.

Region	Weighted Kappa coefficient	Level of agreement	P value
Skull	1.000	Excellent	<0.001
Sternum	1.000	Excellent	<0.001
Right ribs	1.000	Excellent	<0.001
Left ribs	1.000	Excellent	<0.001
Whole spine	1.000	Excellent	<0.001
Pelvis	0.942	Excellent	0.055
Right upper extremity	1.000	Excellent	<0.001
Left upper extremity	1.000	Excellent	<0.001
Right lower extremity	0.870	Excellent	0.127
Left lower extremity	1.000	Excellent	<0.001

Table 22 : Cross tabulation of lung studies in image quantity part : left upper lobe region.

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">ChulaView</td><td rowspan="2">Total</td></tr>
<tr><td>Normal</td><td>Abnormal</td></tr>
<tr><td rowspan="2">Commercial Program</td><td>Normal</td><td>21</td><td>0</td><td>21</td></tr>
<tr><td>Abnormal</td><td>0</td><td>9</td><td>9</td></tr>
<tr><td colspan="2">Total</td><td>21</td><td>9</td><td>30</td></tr>
</table>

Table 23 : Cross tabulation of lung studies in image quantity part : left lower lobe region.

		ChulaView		Total
		Normal	Abnormal	
Commercial Program	Normal	22	0	22
	Abnormal	0	8	8
Total		22	8	30

Table 24 : Cross tabulation of lung studies in image quantity part : right upper lobe region.

		ChulaView		Total
		Normal	Abnormal	
Commercial Program	Normal	23	0	23
	Abnormal	0	7	7
Total		23	7	30

Table 25 : Cross tabulation of lung studies in image quantity part : right middle lobe region.

		ChulaView		Total
		Normal	Abnormal	
Commercial Program	Normal	25	0	25
	Abnormal	0	5	5
Total		25	5	30

Table 26 : Cross tabulation of lung studies in image quantity part : right lower lobe region.

		ChulaView		Total
		Normal	Abnormal	
Commercial Program	Normal	23	0	23
	Abnormal	0	7	7
Total		23	7	30

Table 27 : Agreement of ChulaView and commercial program of lung studies in image quantitative part.

Region	Kappa coefficient	Level of agreement	P value
Left upper lobe	1.000	Excellent	<0.001
Left lower lobe	1.000	Excellent	<0.001
Right upper lobe	1.000	Excellent	<0.001
Right middle lobe	1.000	Excellent	<0.001
Right lower lobe	1.000	Excellent	<0.001

Table 28 : Cross tabulation of myocardial perfusion studies in image quantity part : anterior wall region.

		ChulaView		Total
		Normal	Abnormal	
Commercial Program	Normal	7	0	7
	Abnormal	0	3	3
Total		7	3	10

Table 29 : Cross tabulation of myocardial perfusion studies in image quantity part : inferior wall region.

		ChulaView		Total
		Normal	Abnormal	
Commercial Program	Normal	8	0	8
	Abnormal	1	1	2
Total		9	1	10

Table 30 : Cross tabulation of myocardial perfusion studies in image quantity part : lateral wall region.

		ChulaView		Total
		Normal	Abnormal	
Commercial Program	Normal	8	1	9
	Abnormal	0	1	1
Total		8	2	10

Table 31 : Cross tabulation of myocardial perfusion studies in image quantity part : septum wall region.

		ChulaView		Total
		Normal	Abnormal	
Commercial Program	Normal	6	1	7
	Abnormal	2	1	3
Total		8	2	10

Table 32 : Cross tabulation of myocardial perfusion studies in image quantity part : apical region.

		ChulaView		Total
		Normal	Abnormal	
Commercial Program	Normal	9	0	9
	Abnormal	0	1	1
Total		9	1	10

Table 33 : Agreement of ChulaView and commercial program of myocardial perfusion studies in image quantitative part.

Region	Kappa coefficient	Level of agreement	P value
Anterior wall	1.000	Excellent	0.002
Inferior wall	0.615	Good	0.035
Lateral wall	0.615	Good	0.035
Septum wall	0.211	Fair	0.49
Apex	1.000	Excellent	0.02

Table 34 : Cross tabulation of vascular studies in image quantity part : left leg region.

		ChulaView		Total
		Normal	Abnormal	
Commercial Program	Normal	22	0	22
	Abnormal	0	8	8
Total		22	8	30

Table 35 : Cross tabulation of vascular studies in image quantity part : right leg region.

		ChulaView		Total
		Normal	Abnormal	
Commercial Program	Normal	20	0	20
	Abnormal	0	10	10
Total		20	10	30

Table 36 : Agreement of ChulaView and commercial program of vascular studies in image quantitative part.

Region	Kappa coefficient	Level of agreement	P value
Left Leg	1.000	Excellent	<0.001
Right Leg	1.000	Excellent	<0.001

CHAPTER VI

DISCUSSION

This chapter is a discussion of two sections, developing the program and program agreement test.

6.1 Developing the program

Borland Delphi computer language is chosen for this work, as Delphi is one of several new languages that use a programming style called object-oriented programming. In addition, Delphi is a Rapid Application Development (RAD) environment that allows the programmer to create Windows programs very quickly and easily.

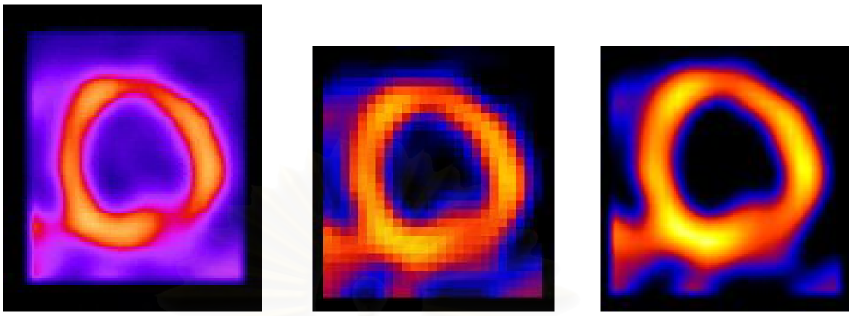
ChulaView used DICOM component from ezDICOM, which is freely distributed on internet. ezDICOM component is developed in Delphi and widely used in free medical DICOM viewers.

6.1.1 Advantage of ChulaView

ChulaView can be used efficiently in a Nuclear Medicine Department. It is able to open Interfile & DICOM file formats, zoom, smooth, change the color table, adjust window level & window width, and run cine series that are necessary for viewing images in Nuclear Medicine Imaging.

6.1.2 Disadvantage of ChulaView

ChulaView cannot connect to the internet. This feature could be implemented in upcoming versions of the program. The other problem is the zoom and smooth feature of ChulaView, especially are in myocardial perfusion images. Zoom and smooth features are necessary for myocardial perfusion images in Nuclear Medicine Imaging. Images from myocardium studies are tomography images (SPECT). So features supporting tomography images such as zoom and smooth should be implemented in the future. The follow figures show the problems about zoom and smooth feature in myocardial perfusion studies.



(a) (b) (c)

Figure 24 : Zoomed and smoothed short axis of tomography image of myocardial perfusion images (a) Image from commercial program (b) zoom image from ChulaView (c) zoom and smooth image from ChulaView.

6.2 Agreement Test

From table 1-4, the image quality between ChulaView and commercial program in bone studies, lung studies, myocardial studies and vascular studies were compared for agreement. Bone studies gave the lowest weighted kappa coefficient but it still showed a good agreement (0.709). Lung studies and myocardium studies showed excellent agreement i.e., weighted kappa coefficient =1.000 (Table 5).

Table 6-9; show the comparison of diagnostic agreement between the ChulaView and commercial program in bone studies, lung studies, myocardial perfusion studies and vascular studies. From table 10, the lowest weighted kappa coefficient was for myocardial perfusion studies (0.478 indicated moderate agreement), and the highest weighted kappa coefficient were bone studies, lung studies and vascular studies (1.000 indicated excellent agreement).

Table 11-20 show the quantitative agreement of images between the ChulaView and commercial program in each region of bone studies while table 21 shows the agreement comparison of bone studies in all regions. From table 21, the lowest weighted kappa coefficient was right lower extremity region = 0.870, pelvis region = 0.942 and other region = 1.000, but all regions indicated excellent agreement.

Table 22-26 show the quantitative agreement of images between the ChulaView and commercial program in each region of lung studies while table 27 shows agreement of lung studies in all regions. From table 27, the kappa coefficient of all region showed the excellent level of agreement with kappa coefficient = 1.000.

Table 28-32 show the quantitative agreement of images between the ChulaView and commercial program in each region of myocardial perfusion studies while table 33 shows the agreement of myocardial perfusion studies in all regions. From table 33, the lowest kappa coefficient was in septum wall region, kappa coefficient = 0.49 (indicated fair agreement). Inferior wall and lateral wall region have kappa coefficient = 0.615 (indicated good agreement) and anterior wall and apex region have kappa coefficient = 1.000 (indicated excellent agreement). Myocardial perfusion studies gave the lowest kappa coefficient in two parts (diagnostic and quantitative), because of the sample size was only 10 cases while other studies had sample size 30 cases. The other possibility for this lowest kappa coefficient may be the tomography images (SPECT), Therefore, some features of the ChulaView that needed in myocardial perfusion studies were not satisfied such as zoom, label image, window width and window level, and etc. It needs to increase sample size and improve some features supporting tomography images.

Table 34-35 show the quantitative agreement of images between the ChulaView and commercial program in each region of vascular studies while table 36 show the agreement comparison of vascular studies in all regions. From table 36, the kappa coefficient of left leg and right leg region showed the excellent level of agreement with kappa coefficient = 1.000.

The quantitative agreement of images between the ChulaView and commercial program are in all studies. The lowest kappa coefficient was myocardium studies in septum wall region (kappa coefficient = 0.211 indicated fair agreement), and the weighted kappa coefficient for the bone studies in all regions = 0.870 to 1.000 indicated excellent agreement. Lung studies and vascular studies have excellent agreement with kappa coefficient = 1.000.

CHAPTER VII

CONCLUSION

7.1 Conclusion

Nowadays, all digital medical devices use DICOM format to be the standard for digital imaging and communication between each other. However, the commercial DICOM image viewer programs are expensive and disable to modify any functions because of software protection system and licensed. This research is designed to develop a DICOM image viewer program for Nuclear Medicine Imaging. Methodology of this research is to test the evaluation of the performance of image loading and displaying by using the commercial software and the developed program. The results show that ChulaView was excellent agreement with commercial program to display medical images in bone studies, lung studies and vascular studies, and has a fair agreement to display medical image in myocardial studies. So that ChulaView presents the approach for improving Medical Imaging with friendly interface focusing on Nuclear Medicine imaging and Nuclear Medicine Clinicians in King Chulalongkorn Memorial Hospital satisfy with ChulaView.

7.2 Future trends

Since an early version of the program is presented, features for special Nuclear Medicine procedures need to be added, such as special functions, the ability of connection to the internet, simplifying interdepartmental relationships in a filmless hospital environment with use of internet technologies.

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APPENDIX

Diagnostic evaluation form

Bone scintigraphy

Case No…………

Date……./……../……..

Place……………………………………………………………………………………………..

Machine………………………………………………………………………………………

Viewing Software ☐ Commercial Software ☐ Developed Software

Image Quality
- ☐ Poor score = 1
- ☐ Fair score = 2
- ☐ Good score = 3
- ☐ Excellent score = 4

Diagnostic
- ☐ Definitely negative score = 1
- ☐ Probably negative score = 2
- ☐ Indeterminate score = 3
- ☐ Probably positive score = 4
- ☐ Definitely positive score = 5

Image Quantity

Region	No. of lesion
Skull	
Sternum	
Right Ribs	
Left Ribs	
Whole spine	
Pelvic bone	
Right Upper extremity	
Left Upper extremity	
Right Lower extremity	
Left Lower extremity	

Comment :

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Diagnostic evaluation form

Myocardium Perfusion

Case No…………

Date……./……../……..

Place………………………………………………………………………………………..

Machine……………………………………………………………………………………

Viewing Software ☐ Commercial Software ☐ Developed Software

Image Quality
- ☐ Poor score = 1
- ☐ Fair score = 2
- ☐ Good score = 3
- ☐ Excellent score = 4

Diagnostic
- ☐ Definitely negative score = 1
- ☐ Probably negative score = 2
- ☐ Indeterminate score = 3
- ☐ Probably positive score = 4
- ☐ Definitely positive score = 5

Image Quantity

Region	Normal	Abnormal
Anterior wall		
Inferior wall		
Lateral wall		
Septum wall		
Apex		

Comment :

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Diagnostic evaluation form

Lung scintigraphy

Case No…………

Date……/……../……..

Place…………………………………………………………………………………………..

Machine………………………………………………………………………………………

Viewing Software ☐ Commercial Software ☐ Developed Software

Image Quality

☐ Poor score = 1

☐ Fair score = 2

☐ Good score = 3

☐ Excellent score = 4

Diagnostic

☐ Definitely negative score = 1

☐ Probably negative score = 2

☐ Indeterminate score = 3

☐ Probably positive score = 4

☐ Definitely positive score = 5

Image Quantity

Region	Normal	Abnormal
Left superior lobe		
Left middle lobe		
Left inferior lobe		
Right superior lobe		
Right inferior lobe		

Comment :

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Diagnostic evaluation form

Vascular scintigraphy

Case No…………

Date……/……../……..

Place…………………………………………………………………………………………..

Machine………………………………………………………………………………………

Viewing Software ☐ Commercial Software ☐ Developed Software

Image Quality
- ☐ Poor score = 1
- ☐ Fair score = 2
- ☐ Good score = 3
- ☐ Excellent score = 4

Diagnostic
- ☐ Definitely negative score = 1
- ☐ Probably negative score = 2
- ☐ Indeterminate score = 3
- ☐ Probably positive score = 4
- ☐ Definitely positive score = 5

Image Quantity

Region	Normal	Abnormal
Left leg		
Right leg		

Comment :

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VITAE

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