สำนักงานวิทยทรัพยากร จุฬาลงกรณ์มหาวิทยาลัย

CHAPTER 2

BACKGROUND

This chapter is consist three parts: (1) development of medical technology in Thailand; a) fundamental of Magnetic Resonance Imaging; b) magnets and static magnetic fields; (2) MRI technology in Chulalongkorn Hospital; (3) MRI technology in Eastern Seaboard Hospital;

2.1 Development of medical technology in Thailand

The innovation of diagnostic imaging technologies in Thailand has started in the beginning of 1990's . Medical imaging was born with the discovery of x-rays in 1895 by Roentgen in Germany. By 1900, x-rays were being used to diagnose fractures, gall-stones and kidney stones, foreign objects in the body, and lung disease. Bismuth was used beginning in 1996 to allow x-ray pictures of the gastrointestinal tract. Department of radiology were established in the early decades of this country, and it diffused rapidly and came into widespread use throughout in our country. In the following developed as below:

1) Dr. Adamsen had use *X-ray machine* for diagnostic imaging in 1895. The image, or an x-ray film, is produced when a small amount of radiation passes though the body to expose sensitive film on the other side. The ability of x-rays to penetrate tissues and bones depends on the tissue's composition and mass. The different between these two elements create the images. The chest x-ray is the most common radiologic examination. Contrast agents, such as barium, can be swallowed to highlight the esophagus, stomach and intestine, and are used to help visualize an organ on film. The first x-ray machine was installed at Chulalongkorn hospital in 1904.

2) Computed Tomographe (*CT-scanner*) was a revolutionary diagnostic device, combining x-ray equipment with a computer and a cathode ray tube (or other imaging device such as a video screen), to produce imaging of cross section of a human body and shows organs of interest at selected levels of the body. They are the visual equivalent of bloodless slices of anatomy, with each scan being a single slice. CT examinations produce detailed organ studies by stacking individual image slices. CT can image the internal portion of organs and separate overlapping structures precisely. The scans are produced by having the

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source of the x-rays beam encircle or rotate around the patient. X-rays passing though the body are detected by an array of sensors. Information from the sensors is computer processed and then displayed as an image on a video screen. The total number of the CT - scanner was below 100 within last 5 years. This number has growth to over 200 today.

3) Interventional radiology is cardiac catheterization procedures. Open heart surgery and interventional cardiology are tertiary technologies, which was invasive treatment of patients. Ninety percent of these involve two kinds of invasive procedures carried out on patients with coronary artery disease : coronary bypass operation (CABG) and percutaneous transluminal coronary angioplasty (PTCA) , also known as balloon dilatation, and other newest methods, including laser and stents. These procedures, which are termed revascularizations.

Coronary artery disease is characterized by stenosis of the coronary arteries, which result in the heart receiving an inadequate supply of oxygen, a condition known as ischemia. The stenosis is almost always caused by artherosclerosis , which is chest pains (angina pectoris) in the patient. Clotting at the site of the arthersclerosis thickening lead to a sudden increase in symptoms (unstable angina pectoria).

PTCA was used for dilating the stenosis by using a balloon, which is introduced into the coronary artery using a catheter and digital subtraction angiography *(DSA)* with a contrast media. DSA can make roentgenologic investigation of the abdominal aorta and the renal, iliac, femoral, and popliteal arteries, which used in cardiac catherterization laboratories.

In the period 1990-1996 the number of cardiac catheterization laboratories in Thailand increased steadily from five to ten, mainly in medical school hospitals.

4) Nuclear Medicine (*NM*) is innovation of diagnostic imaging which studies document organ function, in contrast to conventional radiology which creates images upon anatomy. Many of the nuclear medicine studies can measure the degree of function present in an organ, often times eliminating the need for invasive surgery. Moreover, nuclear medicine procedures often provide important information which allows the physician to detect and treat a disease early in its course when there may be more success.

It is nuclear medicine which can best be used to study the function of a damaged heart or restriction of blood flow to parts of the brain. The liver, kidneys, thyroid gland and many other organs are similarly imaged. A patient undergoing a nuclear medicine exam receives a very small amount of radioactive substance, or radiopharmaceutical, to diagnose or treat disease. These radiopharmaceuticals produce emissions and are specially formulated to be collected temporarily in the specific part of the body to be studied. There are two types of camera ; *SPECT* (single proton emission computed tomographe) and *PET* (positron emission tomographe) is used to transform these emissions into images. These images are stored on film or in a computer for review. Radiation doses from nuclear medicine are in general comparable or less than those of diagnostic radiology.

Today, nuclear medicine covers a broad span of medical specialists, ranging from pediatrics to cardiology and psychiatry. There are nearly 3[illegible] were in Thailand

5) Magnetic Resonance Imaging (*MRI*) is a new imaging method which uses a combination of magnetic fields and radio waves. A magnetic fields aligns certain nuclei (mostly hydrogen) in the body in the same direction. These nuclei are then tilted by and application of radio waves (nuclear spin resonance). When radio waves are withdrawn, the nuclei go back to their aligned position and in the process, release radio signal which picked up by sensors. These sensors reconstruct images of the body with the help of computer.

MRI produces images which are the visual equivalent of a slice of anatomy. MRI, however , is also capable of producing those images in an infinite number of projections through the body. MRI uses a large magnet that surrounds the patient , radiofrequencies , and a computer to produce its images. As the patient enters an MRI scanner, his body is surrounded by a magnetic field up to 8,000 times stronger than that of the earth. The scanner subjects the nuclei of the body' s atoms to a radio signal, temporarily knocking them out of alignment. When the signal stops, the nuclei return to the aligned position, releasing their own faint radio frequencies from which the scanner and computer produce detailed images of the human anatomy.

A) Fundamental of Magnetic Resonance Imaging

The newest product of the medical imaging technology revolution is the magnetic resonance imaging (MRI) scanner. This imaging technique was first introduced in the early 1980's. Originally it was introduced as the nuclear magnetic resonance scanner (NMR). The word nuclear caused some confusion because of the association with radioactive nuclear medicine used in diagnostic imaging and so was dropped because no nuclear radiation is involved. The imaging technique is new, but nuclear magnetic resonance has been around for quite some time. It was employed in chemistry and physics to obtain information about complex molecules and molecular motion.

MRI provides cross-sectional, or three-dimensional, images without using x-rays or radioactive materials. It produces images by the use of a strong magnetic field and radio waves.

The MRI technologies must be able to perform MRI procedures without constant supervision of technical detail. As in other imaging modalities, it is important that the radiographer have a thorough knowledge of anatomy. Judgments concerning the MRI pulsing sequence, gradient magnetic field, and anatomic slice orientation must be made.

A knowledge of the characteristics of magnetic fields, electromagnets, and atomic structure is useful in the type of imaging. The computer is utilized in magnetic imaging just as in CT, and thus a basic knowledge of how computer constructs the image is helpful. Patient care responsibilities apply in MRI very much the same as in other diagnostic imaging. A knowledge of sterile technique in administering contrast media in needed. In addition, there are other tasks such as maintaining records and scheduling.

The equipment uses for imaging consists basically of large electromagnetic coils surrounding a second electromagnetic coil capable of delivering pulse of radio waves. The patient lies inside the hollow, cylindrically arranged magnetic coils and is subjected to magnetic field thousands of times more powerful than the earth's magnet field. When the magnetic field acts on the patient's body, the nuclie of the body's atoms, mostly the hydrogen atoms, arrange themselves parallel to each other like rows of tiny magnets.

Normally, the spinning atoms' nuclei point randomly indifferent directions. When the patient is in the magnetic field, some of the spinning hydrogen nuclei line up in the same direction as the polarity of the magnetic waves. As this instant a pulse of radio waves is emitted by the second inside electromagnetic coil, causing the spinning nuclei within the tissue to change their angle of rotation because of the absorbed energy of the radio-frequency pulse. The images produced by the changing angle of rotation produce signal that are analyzed to produce an image that shows varying densities of hydrogen in the body part.

The MRI produces images of body parts that are surrounded by bone in clear, unobstructed detail, making it especially useful for studying the brain and spinal cord. It can showed the detail of nerve they made by such diseases as multiple sclerosis. MRI can also detect brain tumors that may be obscured by bone in other imaging procedures.

There is an obvious disadvantage in the MRI scanning. Because the body is placed in a strong magnetic field, metallic articles on the patient, for example, jewelry, and metallic objects inside the patient, such as hip joint prosthesis plates, screws in bones, or surgical clips, are also affected by the magnet.

B) Magnets and static magnetic fields

Three types of magnet are used in commercially available MRI systems : superconducting, resistive, and permanent. All have in common that they can generate large, uniform magnetic fields. They differ in the cost to produce the magnet, the strength that can be produced, energy requirement to support the magnet, and the direction of the main magnetic fields (above 0.5 T).

Superconducting magnets. By far the most commonly used magnet is the superconducting magnet. This type of magnet is ratable in that the magnetic field can be maintained for a very long period of time without requiring a constant source of energy. This allows the used of this type of magnet in systems that require extremely strong magnetic field (above 0.5 T).

A superconducting magnet is based on the principle that a moving electric charge induces a magnetic field. Further, if the charge moves in a cycle, the magnetic field is generated along a line orthogonal to the circle.

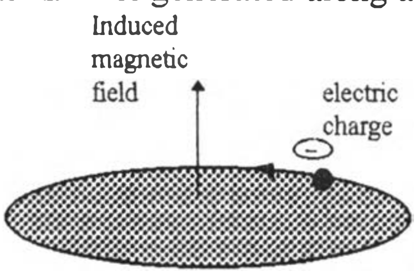

Figure 2.1 The direction of superconductive magnets

(See figure 2.1) this is to curl the fingers of your right hand, then stretch out your thumb (as if you were trying to hit a ride along the side of the road). Imagine that the fingers of your hand represent the direction of electric current. Your thumb then points in the direction of the magnetic field generated by the current of your fingers.

A superconducting magnet consists of many winding of wire that carry an electric current. The magnetic field generated by this cylinder of wires runs in the direction along the long axis of cylinder.

Because of the requirement that the cylinder be wide enough to accommodate a human for imagine (typically 55 to 70 cm in diameter), the magnet is generally very long in order to provide an uniform field large enough for imaging.

As you might expect, the current required to generate very large magnetic fields (as large as 2 T) is quite great. Therefore the energy required to maintain this current must be quite great as well, since the resistant in the wires of magnet will cause the current to decay over time.

We are able to reduce the energy requirement by taking advantage of a principle called *Superconductivity*. This phenomenon, this covered in 1911, is a state in which the resistant in a conductor goes to zero at very low temperatures. The temperature is in fact typically very closed to absolute zero. Therefore the wires of the magnet are batched in liquid helium at 4K to maintain the superconductive properties of the magnet.

The liquid helium can be insulated by filling with liquid nitrogen. This layer of insulation keeps the liquid helium from boiling off quickly. A magnet equipped which both helium and nitrogen tanks will require that those liquid be refilled periodically.

It has become common recently for magnets to be equipped with only a liquid helium tank and a refrigeration unit that keeps the helium cold. This reduces operating costs by eliminating the requirement for liquid nitrogen, but this reduction is balanced by the cost of the electricity required to run the refrigeration unit.

Resistive magnets. Resistive magnet a similar to superconducting magnet in that there are typically coils of wire through which a magnetic field is induced. However, the wires are not cooled to a superconductive state. Therefore the wires are resistive, and if a current were applied and the power supply disconnected, the current would eventually die out.

The major different, therefore, is one of trades-off in operating cost. A resistive magnet does not require liquefied gases (cryogens), but it does required a power supply to keep the magnet at a stable field. As a result of the increase in cost, these magnets are not seen in commercial system at field strengths over 0.4 T.

Permanent magnets. The permanent magnet is gaining in popularity for system that operate at magnetic fields up to about 0.4 T. A large part of this popularity is due to the fact that a permanent magnet hard few requirement to maintain it. While a superconducting magnet requires cryogens, and a resistive magnet requires a power supply to maintain its current, a permanent magnet requires neither.

The direction of a magnetic field of a permanent magnet (see figure 2.2) is along a line connecting the two poles of the magnet. The distance between the poles faces of the magnet is generally a trade-off between the weight of the magnet, the desired strength of the field, and the minimum distance necessary to fit a human for imaging. A smaller gap allows for a stronger field, and therefore, a lighter magnet to create the field.

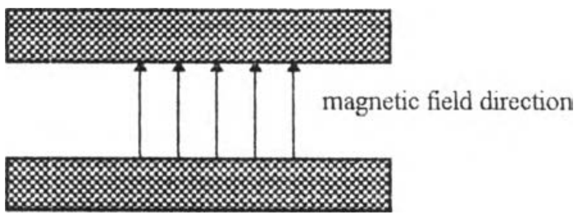

Figure 2-2 : The direction of magnetic field lines between the poles of a permanent magnet

The magnets used in MRI have various types and strengths. Magnetic field strength (MFS) for clinical use is measured by Tesla (T) and may range from 0.64 T to 2.0 T. There are two main types of magnets: electromagnets which depend on circulating currents of electricity to generate its magnetic field, and permanent magnets (< 0.3 T). Electromagnets can be further subdivided into resistive (0.2-0.4 T) or super conducting (>0.3 T), depending on their conductors. Super conducting electromagnets need coolants to maintain operating temperatures.

The first MRIs were of lower MFS units (<0.5 T) . In the mid 1980s higher MFS (>1.5 T) were increasingly being procured. More recently, there has been achieve in the trend back to lower level MFS with improvement in technology.

Subjectively, radiologist said that a higher MFS gives a better image. Studies have recommended the used of higher MFS for head and spinal studies. However, there are no completed studies which can directly demonstrate the superiority of higher MFS over low MFS. Preliminary resource from two studies show no significant diagnostic different between low (0.5 or 0.64 T) and high (1.5 T) MFS.

Patients who cannot undergo an MRI examination include those dependent upon cardiac pacemakers and those with metallic foreign bodies in the brain or around the posterior fossa.

Magnetic Resonance Imaging technique was introduced into our country in the mid 1990s. Adoption of MRI technology as apart of country's increasing of modernization of hospitals , particularly hospitals which are located in big cities.

Until recently, major hospitals in big cities in which MRI technology has been installed , have shown increasing needs of the use of such diagnostic tools, also increasing the number of potential diseases which need to be detected by the MRI technology.

2.2 MRI technology in Chulalongkorn Hospital

Chulalongkorn Hospital, the Thai red cross society is one of the largest and the oldest hospitals in Thailand and is one of the two sister hospitals belonging to the Thai Red Cross Society. The hospital was founded in 1914 in memory of King Chulalongkorn, King Rama V. It has older 80 years.

The main function of the Faculty of Medicine are to provide medical care and the training ground for medical personnel. The Faculty of medicine is also responsible for the development of **medical technology and advancement of medical care** , while the hospital reciprocates by providing equipment, medicine, medical supplies, personnel and the space for such treatments.

Many of the doctors in the early day who contributed to the progress of the hospital had received their medical education and training abroad. These doctors led down a firm basis of medical care at the hospital. The modern technology of the hospital really began some 30 years ago. Difficult surgery, previously unheard of, took place at the hospital for the first time in Thailand.

Chulalongkorn Hospital became the pioneer in heart surgery when a British trained surgeon, Professor Smarn Muntabhorn performed and open- heart surgery successfully in 1953. During the 60's and early 70's many graduated of the Faculty of Medicine went abroad to the US, Britain and Germany for further training.

As they returned to Thailand from their ventures, Chulalongkorn Hospital began a new chapter to enjoy the fruits of hard work of these pioneers ; neurosurgery, eye surgery , general surgery , urology , cardiac surgery, orthopaedics, etc, to name just a few specialties that began to flourish in Chulalongkorn hospital.

Chulalongkorn Hospital became the country's first in the field of transplantation: **corneal transplantation in 1962, kidney transplantation in 1972, heart transplantation in 1987, liver transplantation in 1987, and bone marrow transplantation in 1991.** Other specialties followed, and 1987 saw Thailand's first test-tube baby born in Chulalongkorn Hospital.

Modern equipment were installed : **CT scanners, MRI, a Lithotriptor, cardiac catheterization equipment, a linear accelerator** for the treatment of cancer and many more. To make a full use of these facilities, the hospital became one of a major post-graduate training centres in Thailand.

Many challenges exist in the future. As the world becomes a world of **high technology** , many new treatment are available and makes people live longer, sometimes at and expensive cost. Chulalongkorn has been carrying a heavy burden because a high proportion of out patients are **non - paying patients** .

Can Chulalongkorn Hospital keep up with these modern treatment and make high technology treatments available to all, irrespective of races, nationality, and economic status? The running expenses for these kinds of treatment will be high.

The high technology equipment find the longer life expectancy which means a higher number of geriatric patients seeking care at the hospital. As people live longer, they will be seen more often with cancers, coronary diseases and AIDS. They will require a large proportion of the hospital resources : beds, medicine, medical technology, with its high medical care costs.

a) Location

Chulalongkorn Hospital has located on 1873 Rama IV Rd., pathumwan , Bangkok , Thailand. Its area about 50 Acres (136 Rai) ,the total number of buildings are 80 buildings. It located on the main road of Rama VI , Angree Dunant and Rajdamri Rd.

Table 2.1 Capacity of Chulalongkorn Hospital

Capacity :	ward	(number of beds)
Number of patient	68	1,433
Medicine	28	322
Operating room (surgery)	27	355
Obstetric	32	187
Gynecology	-	74
Pediatrics	10	142
Ophthalmology	-	37
ENT	-	38
Orthopedics	-	58
Intensive Care Unit	-	116
Phychiatrics	-	14
Radiology & Nuclear Medicine	-	82
X-Ray rooms		13
CT Scanner Unit		2
MRI Unit		1
Ultrasonography Unit		10
Cardiac Cath Lab (DSA)		1

b) Personnel

The personnel members consist of medicine member and Red Cross member. The personnel as surveyed on 1997 are as follows :

Table 2.2 Number of personnel in Chulalongkorn Hospital

Position	Thai Red Cross	Medicine
Doctors	48	331
Resident Doctors	-	370
Dentists	12	-
Registered Nurses	1,348	3
Practical Nurses	662	-
Assistant Nurses	596	-
Others	2,342	530
Total	5,008	1,234

c) Clinical services

The medical services in the Department of medicine consist of 16 specialties: 1) Cardiology; 2) Infectious Diseases; 3) Dermatology; 4) Neurology; 5) Nephrology; 6) Endocrinology; 7) Respiratory medicine and Tuberculosis; 8) Heamatology; 9) Rheumatology; 10) Allergy and Immunology; 11) Geriatric medicine; 12) Gasto - enterology; 13) Clinical epidemiology; 14) Medical Oncology; 15) Nutritional medicine; 16) Toxicology

Table 2.3 Number of In-Patient and Out-Patient per year

Fiscal year	No. of OP cases	No. of IP cases
1987	622,802	38,577
1988	638,226	39,134
1989	722,004	38,722
1990	837,289	36,115
1991	879,836	35,638
1992	879,981	38,284
1993	941,943	39,024
1994	970,511	41,528
1995	957,138	41,220
1996	1,071,266	44,731
1997	1,181,895	48,199

Table 2.4 Hospital services and special clinics in 1997

Department/Clinic	No. of QP case	No. of IP case
Medicine	338,476	11,392
Surgery	65,982	8,346
Obstetric	64,796	14,732
Gynecology	49,135	2,379
Pediatric	70,336	4,038
Ophthalmology	75,500	2,026
Otolaryngology	52,053	1,573
Dentistry	17,757	-
Orthopeadic	48,250	2,062
Rehabilitation Medicine	38,549	-
Psychiatry	22,022	179
Radiology	34,811	1,454
Forensic Medicine	6,628	-
Emergency Center	52,945	-
Health Education	36,126	-
Parasite Clinic	456	-
Social Medicine	34,520	-
Family Planning Clinic	16,630	-
Wound and Other	4,079	-
Special Clinic	118,498	-
Extra Clinic (Rm.No.9)	34,346	-
Total	1,181,895	48,199

e) Department of Radiology : Diagnostic , Radiotherapy , Nuclear Medicine. The Department is responsible for three services with the amount of services as followed :

1) Diagnostic Radiology 136,718 cases
2) Radiotherapy 43,982 cases
3) Nuclear Medicine 43,318 cases

The department provides the most comprehensive Radiology Services. The following equipment are available in the Radiology Department :

CT-scanners, MRI, Ultrasounds, Mammography, Bone Densitometer, SPECT, Angiography

Table 2.5 Financial status in department of Radiology (1997)

Items:	Charged		Free charge		Total	
	cases	total(B.)	cases	total(B.)	cases	total(B.)
X- Ray exam	93,903	29,280,552	25,942	12,117,821	119,845	41,398,373
CT-scan	4,352	17,550,199	1,427	8,038,201	5,779	25,588,400
Ultrasound exam	6,816	5,669,457	1,591	1,385,743	8,407	7,055,200
MRI scan	1,239	10,967,034	303	4,408,966	1,542	15,376,000
Cobolt Tx.	10,870	1,916,199	3,358	1,032,211	14,.228	2,948,410
X- Ray Rx.	218	136,000	31	6,200	249	142,200
Radium and Cecium	96	277,265	32	242,735	128	520,000
Ca. Cervix	1,738	52,770	81	2,430	1,819	55,200
Linear Accelerator	12,162	5,677,500	2,077	1,752,740	14,239	430,240
CT simulator	1,150	663,220	440	290,780	1,590	954,000
Block	3	6,000	1	2,000	4	8,000
Planing System Tx.	8	8,000	1	1,000	9	9,000
Mask	69	136,700	70	186,500	139	323,200
Port Film	25	5,100	274	163,010	299	168,110
Microselectron	365	1,198,500	58	430,300	423	1,628,800
Radioisotope	54,940	16,003,031	2,681	1,582,193	57,621	17,585,224
Total	187,954	89,547	38,367	31,642,830	226,321	121,190,357

2.3 MRI technology in Eastern Seaboard Hospital

As Thailand's economic and social development continues to surge forward, the provision of top quality health care facilities becomes one of the country's main priorities. In 1996, the hospital was officially opened on January 1, Eastern Seaboard established from MRI diagnostic center in Chonburi Province.

Located on Eastern Seaboard (Aung si-la) T. Sa-med A. Muang about 1.5km. from city of Chonburi province. Its reputation in the rapidly growing private health care market. It was a reputation based on a firm policy of providing efficient world class health care services with medical innovations.

Since the hospital has undergone and become one of the Eastern Seaboard Hospital in Thailand which provides 24- hour medical services for in- patients and out- patients with covering an area of eastern region of Thailand.

In keeping with its proud heritage, the new 250- bed Eastern Seaboard Hospital sets new standards in one- stop, high quality health care for both inpatients and outpatients. In a comprehensive range of dedicated clinics which include :

Traumatic center, Orthopaedic center, Neurosurgery center. Thoracic surgery center. Breast cancer center, Diabetic & Thyroid center, Plastic and Reconstructive center, Dialysis center, Cardio- vascular center, MRI, CT scan and Ultrasound diagnostic center, Gastro- Intestinal tract center and Hemorrhoid center, ENT. Center, peri and post Menopausal clinic, Infertile clinic, Geriatric clinic, Pedriatic clinic, Physiotherapy center and Dental center.

The diagnostic and therapeutic center

At this extensively equipped center, Eastern Seaboard Hospital provides a full range of high technology diagnostics for the speedy and accurate diagnosis and treatment of most medical conditions. Technique available include MRI and CT scanning, and color doppler ultrasound.

A complete range of patient accommodation is available on ten floors, including 116 bedded singer rooms, 60 deluxe private rooms, 12 VIP suites, and six royal suites for handicap patients. All rooms are equipped with computerized nurse call, cable television, and electric beds as standard amenities.

Six operating theaters include those specially equipped for Laparoscopic Cholecystectomy, Thoracoscopic surgery, Arthroscopic surgery, and a complete range of general surgical procedures.

Table 2.6 Capacity of Eastern Seaboard Hospital

Capacity	number of beds
Number of patient beds	250
Intensive Care Units	28
Labour Room	4
Operating Room	6
Out-Patient Department	28
In-Patient Department	194

Source : Chonburi Diagnostic center

Table 2.7 Personnel members as survey in Diagnostic center:

Position	Number
Radiologist	3
Radio Technologists	5
- Full time	3
- Part time	2
Registered Nurse	1
Practical Nurse	6
Clerk	3
Total	18

Source : Chonburi Diagnostic center

Table 2.8 Hospital investment:

Items	million Baht
Sitting costs	7
Building and Construction	20
MRI Equipment	60
CT Scanner	20
Facilities and Supplies	2
Autofilm Processing Mixer	1
Total	100

Source : Chonburi Diagnostic center

Table 2.9 Number services in Eastern Seaboard Hospital

Hospital services	Number of cases
Number of Out-Patient	
visit per day	100
visit per year	36,500
Number of In- Patient	
per day	35
per year	12,775
Number of CT scanned / day	4-9
Average cases of MRI / day	4
Average cases of MRI / month	88
Number of MRI scanned / year	1056

Source : Chonburi Diagnostic center