THE ROLE OF MAGNETIC RESONANCE IMAGING AND COMPUTED TOMOGRAPHY IN DIAGNOSIS OF HEAD INJURY

THESIS

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I N T R O D U C T I O N

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INTRODUCTION

The head inlury is one of the most frequent and grave forms of neurologic disease . Head injury has early , as well as late sequelae , and early diagnosis helps much in reducing its morbidity and preventing its complications . The etiology of the head injury is obvious yet the biomechanics of its production are not entirely understood (Zimmerman et al. , 1978) .

Although these injuries may be immediately fatal, permanent neurologic and psychologic disability are most frequently associated with secondary lesions that develop after impact . It is necessary to initiate rapid and accurate decision in those patients who may require immediate surgery. (Shalen and Handel , 1981) .

Computed Tomographic scaning has a well established role in the early diagnosis of the head injury and its complicat--ions .

The Magnetic Resonance Imaging has evolving role in head injury diagnosis , which may affect its management in the near future .

The aim of this work is to study the evolving role of Magnetic Resonance Imaging and Computed Tomographic Scaning in the diagnosis of head injuries and try to issue a protocol of work using the two modalities .

F U N D A M E N T A L

P H Y S I C S

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C A T   S C A N I N G

A N D

M A G N E T I C   R E S O N A N C E

I M A G I N G

CT physices

Historical :

A new method of forming images from X-rays was developed and introduced into clinical use by the British physicist Godfrey Hounsfield in 1972 , and is refered to as computed transmission tomography , computed tomography (CT) or computerized axial tomography (CAT) . Many people regard this invention as the greatest step forward in radiology since the discovery of X-rays by Roentgen in 1895 . It resulted in 1979 in the Nobel Prize for Midicine being awarded jaintly to Dr. Hounsfield and professor A. M. Cormack

Hounsfield's work was based on research into data retrieval and transformation . In the course of this work it become clear that there were many areas in which large amounts of information were theoritically available but where the techniques of retrieval and presentation used were so inefficient that most of the available data were wasted . Hounsfield considered that this was particularly so in conventional X - ray examinations .

The basic and revolutionary assumption was that measurements taken of X-rays transmitted through the body contained information on all the constituents of the body in the path of the beam . By using multidirectional scaning of the object multiple data were collected . Their interpretation required a mathematical solution using a

computer to perform the calculation . This information could then be presented in a conventional raster form , and from these results a two-dimensional picture could be produced . In practice the system developed was similar to the principle of tomography already widely used in radiology and in which pictures are presented as a series .
(Sutton , 1987) .

TECHNICAL ASPECTS

In computed tomography the X-ray output is collimated to a very narrow beam . While passing through the patient it is partially absorped , and the remaining photons of the X-ray beam fall on radiation detectors instead of X-ray film . The detector response is directly related to the number of photons impinging on it and so to tissue density , since a greater proportion of X-ray photons passing through dense tissues are adsorped than are absorped by the less dense tissues . When they strike the detector the X-ray photons are converted to sintillations . These can be quantified recorded digitally . The information is fed into a computer which produces different readings as the X-ray beam is traversed around the subject . Even in its original form this meant that the computer dealt with a vast number of digital out representing the absorption in each tiny segment of the section traversed . This information can also be presented in analogue form as a two-dimensional display of the matrix on a scream where each numerical value is represented by a single picture element (pixel) . The more modern machines have improved the resolution by diminishing the size of each pixel .

The first machine had only two detectors and used sharply collimated beams of X-rays . The modern machines use a fan beam of X-ray and multiple detectors . The original machines took 4 - 5 minits to perform a single tomographic slice . The present day machines can obtain slices in 1 - 2 seconds in the fast mode of operation , though times varying form 5 - 10 seconds are used for high resolution in routine practice (Sutton , 1987) .

Data Presentation :

Most scanner now present the data obtianed as an analogue display of each tissue on a cathode ray tube . Presentation is usually in the form of a gray scale in which whiteness is proportional to the X-ray attenuation coefficient of tissue at each point of the scan . Thus radiopaque materials appear white and radiolucent tissue appears black . The range can be varied by changing the "gate" or "window" width (W) at will so that tissues within a wide range of densities or a narrow range can be evaluted . The central point orlevel (L) of the window can also be vaired . In routine work the "gate" width for brain work is 0 - 80 using the Hounsfield scale . The Hounsfield scale is an arbitrary one with air at - 1000 units and water at 0 units as fixed points . The numerical value assigned to the attenuation coefficient bears a linear relationship to the electron density of the tissue concerned.

MRI Physices (Sutton , 1987) .

MRI Physics

At the end of 1985 , more than 220 magnetic resonance (MR) scanners were in operation in the United states . The rapid development and acceptance of this new technology is atribute to its prover capabilities and to the promise MR holds for the future of diagnostic imaging .

Some basic features of CT systems (such as display consoles and array processor computers) could be directly transferred with modification to the new MR systems. Moreover , the intellectual climate in the medical community was realy to accept the multiplanar format offered by Magnetic resonance imaging (MRI) .
A decade of CT experience had laid the basic foundations for interpretation of cross - sectional images (Allen D. Elster , et al , 1986) .

Some Advantage and Disadvantages of MR Compared With CT.

Some advantages of MRI are that no ionizing radiation is used in the technique , fewer artifacts from dense bone and metal clips , imaging in multiple planes without moving the patient , signals from tissues are dependant on several chemical and physical properties , which may be studied independantly , future potential for flow measurments , spectroscopy , biochemical characterization and physiologic monitoring .
However disadvantages are that MRI has a slower scanning times than CT , high initial cost of the scanner , special

site planning and shielding , danger to patients with cerebral aneurysm clips , pacemakers and it has a potential of unknown effect of high magnetic field and claustrophobia in magent .

The Magent :

The strength of the magnetic field and how that field is produced lie at the heart of MR technology .
It is nessecary to know a little about the various magent types and sizes in order to be conversant in the field . All magnets used in MRI can be placed in one of three Categories - Permanent , resistive or superconductive (Allen D. Elster et al , 1986) .

Permanent mangets are gaints versions of the hand _ held horseshoe magnet used as children's toys . Permanent MR magnets are very stable and produce a uniform magnetic field. They are cheap to operate , since they require no power source or cooling system . The major disadvantage is their weight , which may be as great as 100 tons for large magent . The Fonar Beta 3000 scanner is the most popular example of a permanent images (Allen D. Elster et al , 1986) .

Resistive magents were the earliest type used in MRI relatively cheap to build , these magents are giant ferromagnetic cores with electric wire windings that produce their fields as solenoids (electromagnets) . The fields obtained are relatively low and nonuniform . Resistive magnets also require a large amount of electric power to operate . Several companies continue to make resistive MR scanners , but their popularity is decreasing (Allen D. Elster et al , 1986) .

Superconductive magnets are the type used in most clinical MR principle of operation is based on the phenomenon of superconductivity that occurs in certain metals when they are cooled to low temperatures (4 k) by liquid helium . At these temperatures near absolute zero , electric resistance in solenoid winding disappears , and a strong , uniform magnetic field is produced with no significant loss of energy . superconductive magnets produce the strongest fields of any magnet , and the fields are very uniform . Disadvantages include expense of construction and expense of cryogens (liquid helium and nitrogen) , which must be replenished every few weeks at a cost of several thousands dollars .

The strength of a magentic field by which magents are rated is measured in units called Gauss (G) or Tesla (T). The term Tesla is now perfered over the older term Gauss . For purpose of conversion ,

1 T = 10,000 G .

The magnetic feild strengt of magnets in most of today's MR scanners lies in the range of 0.15 to 2.0 T.

It is difficult to appreciate the size of the magnetic fields used in MR scanners , since the units Gausss and Tesla have little meaning except to physicsts .

As a point of raference , the strength of the earth's magnetic field on it's surface is about 1/2 G , or 0.00005 T.

The strength of 1.5 T MR scanner magnet can be appreciated by the force it would exert or nearby metalic objects (Allen D. Elster et al , 1986) .

The Meaning of Nuclear Magnetic Resonance :

The term nuclear reminds us that we are dealing with a process that involves the atomic nucleus , not the electron cloud surounding it . In research centers using special scanners , its possible to image by MR a number of different atoms , including hydrogen , sodium , potassium and fluorine In general clinical use today , however , only hydrogen imaging is performed . Since the most abundant hydrogen isotope contains only a single proton in its nucleus , we may conclude that MRI in clinical practice today involves only hydrogen protons .

The term magnetic refers to two things . First of all , the process of MR takes place within the bore of large mogent this magnet produces a tremendously powerful static field , denoted Bo (Static or constant magnetic field) . This static magnetic field has a strength many thousands of times that of the earth's own magnetic field . The Bo field remains on at all times throughout the imaging process . Additional smaller gradient and radio-frequency magnetic fields times superimposed on the static field for purposes of spatial encoding and nuclear stimuulation , but the Bo field remains constant and never shut aff .

The second magnet that MR referes to is the hydrogen proton itself . quantum theory imbues each proton with certain magnetic physical properties , allowing it to interact with energy in the electromagnetic spectrum . Each proton may be thought of as a tiny spinning magnet , which may interact with other nuclear magnets in neighboring atoms as well as with externally applied magnetic fields _ quantum theory limits this proton magnet to certain fixed energy levels and orientations . By jumping between these fixed (quantized) energy levels and orientations , each proton may absorbe , store and emit electromagnetic energy in the form of radio waves . These emmited radio waves are detected as the MR signal . MR signals from each small volume element of tissue are assembled to produce the final MR image .

The term resonace is used to describe any physical system that oscillates between high and low energy states . In the world of MR , this involves hydrogen protons absorbing and releasing energy in the electromagnetic spectrum by transitions between quantized energy levels . As will be described , such transitions can occure only when energy is supplied or absorbed at a specific frequency in the range of radio waves , called the larmer resonance frequency .

Although this oscillation of proton energy states is somewhat difficult to visualize , many examples of the resonance phenomenon surround us in the larger world . Well recognized examples of resonance include a vibrating tuning fork , a swinging pendulum , a plucked guitar string , and a child on a pogo stick (Allen D. Elster et al, 1986).

The process of MR signal generation can be thought of into two steps :-

(1) Stimulation to resonance

(2) Relaxation from resonance

Four Properties Determine MR Signal Strength :

How bright a dot appear on the final MR image is directly proportional to MR signal strength recorded from the volume element of tissue represented by that dot . In general , four physical characteristics of a tissue being imaged will determine how strong a signal that tissue emits when stimulated into magnetic resonance .

These four properties are :-

(1) the concentration of hydrogen protons in the tissue .

(2) the velocity at which these protons are moving .

(3) T1 relaxation effects .

(4) T2 relaxation effects .

Hydrogen Concentration :

Since MR is a phenomenon involving hydrogen protons , it is not surprizing that the recorded signal intensity from a tissue should be directly proportional to hydrogen concentration in that tissue . The relative hydrogen density