Advances in Radiology

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Wilhelm Conrad Roentgen set the field of radiology ablaze back in 1895 with his discovery of X-rays. Roentgen's advance in physics and medicine lit the path for those who followed his example, as various groups were eager and interested in creating and improving technical devices. He received a Nobel Prize in Physics for the discovery of X-rays in 1901.

The progress in medical imaging is mainly due to the change from analogue to digital imaging, continuing increase in computer power, advances in micro-instruments, communication technology and lately by the impact of molecular biology.

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Advances in computer power have made possible much of cross-sectional imaging as well as Picture Archiving and Communication Systems (PACS) and Tele-radiology. Many leading medical centers have become filmless and many others are in transition[1].

Tele-radiology promises access to sophisticated imaging and interpretation worldwide[2].

Digital Imaging

Although ultrasound, computed tomography, magnetic resonance imaging and nuclear medicine are digital, they have been displayed in analogue format in the form of films. Other modalities like digital radiography units and scanning of conventional films (computed radiography) are accepted technologies with resolution similar to the conventional film/screen. This advancement in technology is criticized as it allows image manipulation.

PACS made it possible for digital images to be transferred within the hospital's network, or to be studied from a remote location via Tele-radiology, thus improving patient's management through various consultations and minimizing the time for reaching a final decision in patient's care[3].

The PACS connects to the Radiology Information System (RIS) and the Hospital Information System (HIS), which negates the need to re-enter patient data and allows patient booking[4].

It is possible to track patient progress, to fetch images from the electronic archive to the appropriate workstations and to fetch as well previous studies for comparison and progress[5,6].

A new generation RIS/PACS platform is in progress. An innovative power viewer that

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promises to speed interpretation, reporting and 3D imaging studies, it also provides automatic registration and volumetric matching of 3D studies created at different times and by different modalities, directly within the viewer used by radiologist[7].

In addition, the Super PACS Architecture is in progress, which will allow healthcare providers to streamline workflow, since it will enable the sharing of patient imaging and information, while delivering a global work list that balances reading among on-site and off-site radiologists. This technology was presented at the European Congress of Radiology in Vienna 2009 and should be available in the second quarter of 2009.

The aim of medical imaging is to improve the quality and specificity while decreasing invasiveness and minimizing cost.

At the center of radiology rapid development are four diagnostic techniques: Computed Tomography (CT), Digital Subtraction Angiography (DSA), Ultrasound and Magnetic Resonance Imaging (MRI).

Computed Tomography (CT)

British engineer Godfrey Hounsfield invented the CT in EMI laboratories in England in 1972 and was awarded a Nobel Prize along with Allan Cormack in 1979[8].

CT can detect subtle differences in X-ray attenuation, while the human eye cannot detect difference in X-ray attenuation less than 2% on radiographic films. The CT within this range can detect densities like water, blood, fat and air, as well as normal and diseased tissue[9].

In conventional radiography, X-rays penetrate from one angle, while in CT a tissue slice is scanned from various angles; there is true tomography capability, elimination of scatter radiation and removal of much of X-ray film's noise.

CT system is formed of a conventional X-ray tube with a collimated narrow beam and a series of detectors to record the transmitted beam. The detectors measure the attenuation beam emerging from the scanned part whether body or brain. The computer then solves thousands of equations to read the attenuation coefficients and transform them digitally into cross-sectional image[9].

The intravenous iodinated contrast injection further enhances the difference between normal and abnormal tissue attenuation, improving detection efficiency to achieve specific diagnosis.

In conventional CT scanners, each image slice was obtained during breath holding. In the inter-slice period patient was allowed to breathe and the table moves to the next position. This understandably had several drawbacks:

1. Misregistration of slices due to the difference in depth of inspiration
2. Loss of contrast density due to the length of examination
3. Prolonged examination time resulted in patient discomfort especially seriously sick patients

With advancement in technology, Spiral CT became known. This technology is based on simultaneous scanning and table movement during a single breath hold, thus there is no inter-slice time and the abdomen for example can be scanned in a single breath hold within a period of 25 seconds. No misregistration is recognized and scans are obtained in the period of maximum contrast enhancement. Due to the short examination time, patient turnover have improved[10].

Spiral CT obtains a continuous block of data, which can be re-sliced into thinner slices or volume scanning that allows for 3D image reconstruction needed particularly in CT angiography (Figure 1), CT colonography, CT bronchography (Figure 2) or musculoskeletal.

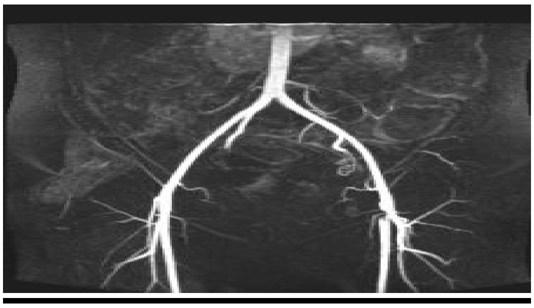

Figure 1: CT Peripheral Angiogram

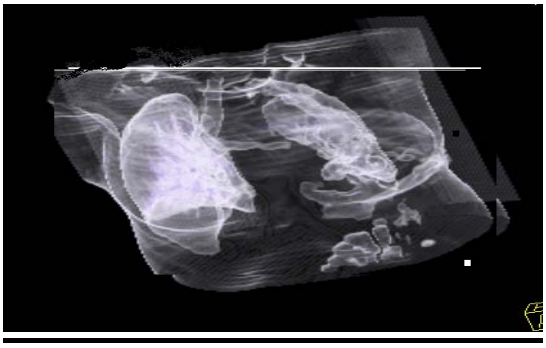

Figure 2: CT Bronchography Showing Narrowing of Left Main Bronchus

Spiral CT progressed to multi-detector computed tomography, with scanners obtaining 4, 8, 16, 32, 64 (Figure 3) and lately 160 slices simultaneously allowing higher image resolution within the time frame for maximum contrast enhancement required for angiography, allowing for dynamic imaging of the brain for stroke patients, lower extremity CT angiographies and CT coronary angiographies to evaluate coronary arteries and cardiac function. The high resolution obtained by 64-slice CT enables visualization of the entire coronary tree[10,11].

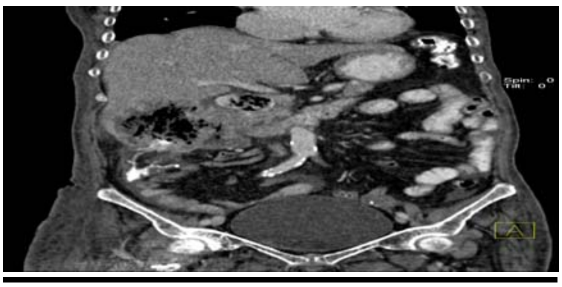

Figure 3: Reconstructed Coronal CT Images of the Abdomen (Multi-detector CT) Showing an Appendicular Abscess

In addition, several procedures use combine modalities. Some interventional procedures are performed under CT guidance; these include: biopsies, drainage of abscesses, nerve root blocks, radiofrequency ablations of tumors and cryoablation of tumors.

The trend is to create more specialized outpatient-type procedures, less invasive and with better imaging.

Magnetic Resonance Imaging (MRI)

The invention of this imaging modality was marked by the first clinical use in Nottingham University Hospital 1967, since then hundreds of MRIs are spread worldwide.

This technique depends on the relative density of protons within scanned segments of the body. The hydrogen atom is the source of the image.

When the patient is placed in the magnetic field, his /her positively charged hydrogen atoms become almost uniformly aligned. A radiofrequency is then pulsed into the body, to deflect the aligned protons. As the protons return to their original position energy is released, the strength of which is proportional to the number of aligned hydrogen protons that were deflected. The computer processes the data to form images of scanned area.

MRI was earlier applied to the evaluation of the central nervous system where it proved superior to CT in differentiating white and grey matter. White matter diseases not detected on CT were identified on MRI.

With stronger magnets, three or seven Tesla it became possible to scan the rest of the body with higher resolution (Figure 4). The seven Tesla system allows researchers to detect biochemical changes accurately, which could be associated with psychiatric and neurological diseases (Figure 5).

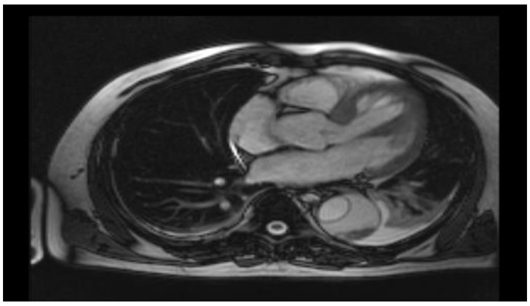

Figure 4: Axial MRI Images of the Chest, Showing Thoracic Aorta Dissection

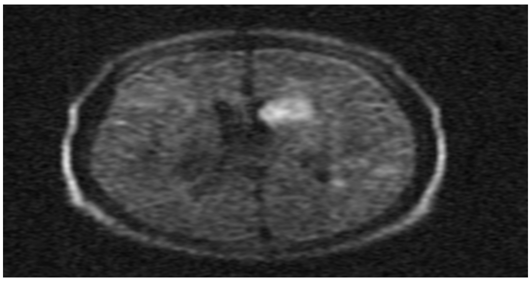

Figure 5: Cross Sectional Brain Diffusion Image Showing Acute Left MCA Territory Infarct

New studies in MRI include breast biopsies, cardiac stress testing, vascular, endorectal coils for prostate studies, and vaginal coils to enhance images of the cervix.

The use of paramagnetic contrast agents such as gadolinium will enhance the images and generate greater applications.

One of the latest techniques, which is still under evaluation, is whole-body MRI. This entails full-length slices of the whole body in any plane, it has been proposed for cancer screening or staging of known cancer, see Figure 6[10].

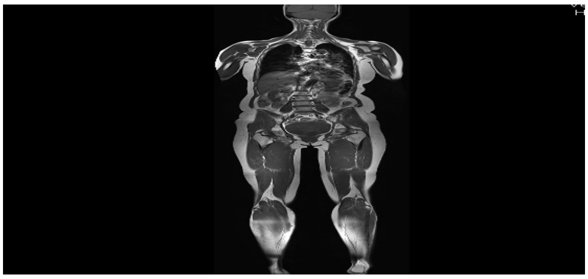

Figure 6: Whole-body MRI

MR spectroscopy has potential for assessing tumor spread and recurrence, and MR-equipped operating theatre enables peri-operative guidance of surgical resection of tumor tissue, which is already a reality. Percutaneous tumor ablation under MR guidance is possible.

Tissue-specific MR contrast agents for lymph nodes are likely to become available. This could assist in targeted therapy when the therapeutic agent attached to the tissue-specific contrast agent[12]. Multi-detector CT and 3D MRI have also made virtual endoscopy an increasingly accepted imaging technique. This technique is applied to every anatomic channel: colon, oesophagus, stomach, small bowel, bronchial tree, blood vessels, etc. this promises to reduce invasive procedures and limit them to targeted biopsy if virtual studies reveal abnormalities[13,14].

PET Scanning

Positron Emission Tomography (PET) is a technique in nuclear medicine using radiation-emitting agent tagged to normal metabolites, this can be monitored in the body to detect disease activity. The most common agent used is fluorodeoxyglucose (FDG); the radiolabeling is achieved in a cyclotron.

PET-FDG is most useful in myocardial perfusion and helps in detecting ischemia during rest and stress[15]. It is also sensitive in oncology detecting primary or metastatic tumors[16,17].

Whole body PET-FDG has recently been promoted as a cancer-screening tool, see Figures 7 (a), (b) and (c)[18].

Fusion of images from different imaging modalities like MRI, CT and PET is proving that advantages can be maximized, see Figures 7 (a), (b) and (c)[19]. Already PET-CT is used clinically. PET detects malignant lymph nodes and this is combined by the superior resolution of CT[20].

MRI-PET is in progress, which will have important implications in the brain[21].

Figure 7 (a): Reconstructed Coronal CT Image of the Chest Showing Left Axillary Lymph Nodes

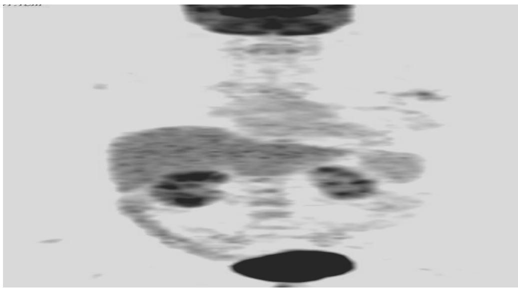

Figure 7 (b): PET Scan Showing Increased Uptake in Left Axilla

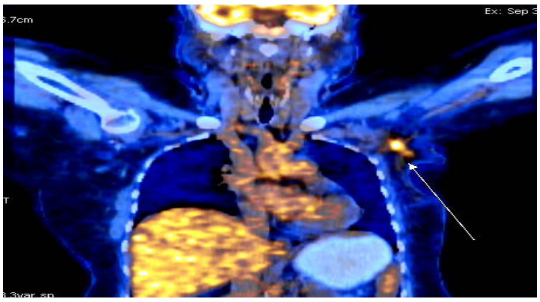

Figure 7 (c): PET/CT Showing Increase Uptake in the Left Axillary Lymph Nodes

Some of the illustrations are obtained from SMC oncology patients investigated abroad.

Interventional Radiology

Digital subtraction angiography, the presence of new catheter materials and new therapeutic embolizing and contrast agents have created a specialty in radiology, which is directly involved in therapeutic procedures.

The advancement in catheters has enabled percutaneous access to small vessels possible; therefore, stenting of intracranial arteries, treatment of intracranial aneurysms and thrombolytic therapy have become achievable.

Other therapies were made possible, which include the following: uterine fibroid embolization, percutaneous vertebroplasty, percutaneous aortic aneurysm stenting and radiofrequency tumor ablation.

With the advent of these expensive modalities, evidence-based guidelines are needed for cost-effective imaging[22].

Ultrasound

Research in ultrasound was conducted in 1794, when Spallazini proved that bats use hearing rather than sight for navigation. The first medical use of ultrasound was in 1942, when Karl Dusslik, an Austrian psychiatrist, tried to locate brain tumors using two opposing transducers and recording the emerging sound beam[8]. Since then, there has been rapid advancement in the ultrasound technology assisted by the advancement in electronics and computers.

Recent advances in piezoelectric materials and the large diffusion of broadband transducers made it possible to modulate pulse characteristics, using single, multipulse or multiline techniques that result in better penetration and spatial resolution. Ultrasound imaging uses harmonic component, which is generated by tissues or contrast agents.

Grey-scale flow imaging allows the simultaneous imaging of blood flow and tissue. 3D and 4D imaging has recently been introduced.

Elastographic imaging is still in progress, but the available results are promising, it provides visualization in two or three dimensions of RF ablation lesions to guide in the ablation process[23].

A similar technique can be applied to in vivo imaging of soft tissue without ablation. This was of value in detection of prostate cancer, evaluation of 3D modality for breast imaging and in strain distribution at the anterior cruciate ligament.

Digital Imaging and communications in Medicine (DICOM) specification has made integration of ultrasound with PACS system much easier[24].

Ultrasound made quite an impact on diagnosis especially cardiovascular, internal organs and peripheral circulation. The major limitation of ultrasound is its inability to penetrate air, hampering the diagnosis in abdomens with excessive gas or chest diseases. Percutaneous biopsy technique is made easy as well as percutaneous drainage of abscesses and aspiration under ultrasound guidance[25].

Genomics and Medical Imaging

Future advancement in medicine is going to be closely linked to genomics. To be able to participate in genetic medical imaging, images have to be obtained at the molecular or cellular level:

1. Gene expression using intracellular or extracellular reporter genes, this is a technique in animal imaging that uses, PET, optical imaging and MR[26]
2. Screening population at high risk, in order to detect the disease early
3. To provide guidance and follow up of gene therapy[27]

CONCLUSION

The advancement in radiology is an on going process. This review highlights the advances in the field of radiology.

The driving force behind these advances is the ever-increasing demands to make early accurate diagnoses using non-invasive procedures and administering minimally invasive treatment.

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