A DATABASE MANAGEMENT SYSTEM FOR NUCLEAR MEDICINE

by

SELIM DENTES

B.S. in E.E., Bogazici University, 1983

Submitted to the Biomedical Engineering Institute

in partial fulfillment of the requirements for

the degree of

Master of Science

in

Biomedical Engineering

Bogazici University

1985

A DATABASE MANAGEMENT SYSTEM FOR

NUCLEAR MEDICINE

APPROVED BY

Dr. Neil Miller .....

(Thesis Supervisor)

Prof. Dr. Necmi Tanyolac .....

Doc. Dr. Yorgo Istefanopulos .....

Yard. Doç. Dr. Albert Güveniş .....

DATE OF APPROVAL

April 25, 1985

I dedicate this thesis to Dr. Albert Guvenis and Dr. Neil Miller for their guidance and useful suggestions during the preparation of the thesis and to my family for their great support and patience.

TABLE OF CONTENTS

ABSTRACT

The purpose of this thesis is to develop a databank of Nuclear Medicine activities in Turkey. Until recently, no databanks existed in any field in Turkey. This was because the available technology was insufficient to establish such databanks. As a result, obtaining specific information about a subject in any field was time consuming and expensive.

However, today, the facilities exist to construct databanks and extensive work has been done to computerize and establish databanks of birth certificates, police records, and other information. The purpose of this thesis is to establish such a databank in Nuclear Medicine.

This system is meant to be used by all physicians (both Nuclear Medicine physicians and non-Nuclear Medicine ones), Nuclear physicists, chemists, University Biomedical Engineering students and staff, equipment suppliers and government agencies. Primarily, it will be most helpful to physicians in the eastern part of Turkey, where Nuclear Medicine centers are not available and for physicians who can not follow the recent developments taking place in this field in Turkey.

The thesis consists of two parts. The first describes the field of Nuclear Medicine. It has three sections. The first is a detailed description of the gamma camera, the second describes the isotopes and radiopharmaceuticals used in Nuclear Medicine imaging, and the third, Nuclear Medicine studies.

The second part of the thesis describes the database manager program, PC-FILE III, used to organize the data collected from Nuclear Medicine centers. It also has three sections. The first section describes how the database was designed, i.e. file definitions, data collection and distribution between them are given. The second section discusses the use of the database manager, and the last provides a detailed report derived from the database.

The thesis is concluded with examples of how the system is used, how it can be expanded for future needs, and the advantages and disadvantages of the system.

TURKCE OZET

Bu tezin konusu Türkiye'deki Nükleer Tıp aktiviteleri ile ilgili bir bilgi bankası kurmaktır. Türkiye'de çok yakın zamana kadar hiç bir konuda bilgi bankaları bulunmamakta idi. Bunun en büyük nedenlerinden biri kuşkusuz bir takım teknolojik imkanların yetersiz oluşu idi.

Tabiki, klasik yöntemlerle herhangi bir konuda bilgi sahibi olmak, hele Türkiye gibi büyük ve kalabalık bir ülkede hem çok büyük zaman kayıplarına hemde maddi kayıplara neden oluyordu.

Halbuki, bugün artık yeterli imkanlar bulunmaktadır ve bu konuda çalışmalar devam etmektedir. Bu tezin konusuda Nükleer Tıp alanında böyle bir bilgi bankası oluşturmaktır.

Bu sistemi kimler kullanabilecektir, kimlere hitap etmektedir? Bu sistem genelde, Türkiye çapında tüm tıp doktorlarına (Nükleer Tıp doktoru olsun, olmasın), Nükleer Tıp fizikcilerine, kimyacılarına, Üniversite Biomedikal Mühendisligi öğrencilerine öğretim üyeleri ve yöneticilerine, Nükleer Tıp cihaz satıcılarına ve hatta resmi makamlara dahi hitap etmektedir.

Bir örnek verecek olursak, Nükleer Tıp merkez-

leri bugün için genellikle Türkiye'nin batısında bulunmaktadır. Doğuda ise imkanlar çok kısıtlıdır. Örneğin doğuda herhangi bir tıp doktoru Nükleer Tıp'taki bir testin yapılmasına ihtiyaç duyarsa, en iyi sonucu Istanbul veya Ankara'da alabileceğini düşünerek hastasını bu illerden birine yollayabilir. Halbuki istediği çalışmayı yapabilecek başka bir merkez kendi iline daha yakında bulunabilir ve kendisi bir takım nedenlerden dolayı bunu bilemeyebilir (örneğin, bu alanda teknolojinin hızla ilerlemesinden dolayı, yeni açılan merkezlerden haberdar olamaması gibi). Bu da hem büyük bir zaman kaybına, hemde maddi kayıplara neden olur.

Halbuki, böyle bir sistemin varlığından haberi olursa, istediği çalışmayi yapabilen merkezleri bir telefonla öğrenebilir, ve hatta belli bir merkezde temas kurabileceği doktorların isimlerinide alabilir. Bütün bu işlemler 5-10 dakika gibi çok kisa zamanlarda tamamlanabilir. Bu da sistemin ne kadar kullanışlı olabileceğinin bir örneğidir.

Tez ana olarak iki bölümden oluşmaktadir. İlk bölüm Nükleer Tıp'la ilgilidir. Bu bölümde ilk olarak Nükleer Tıp'ta kullanılan enstrumanlar hakkında genel bilgiler vardır. Bunların içinden en popüler olan "Gamma Kamera'ları detaylı olarak anlatılmaktadır. Daha sonrada Nükleer Tip teşhis çalışmalarında kullanılan radyoisotoplar hakkında bilgiler bulunmaktadır. Bunla-

rin içinden Türkiye'de yaygın olarak kullanılan radyo-isotopların elde edilişleri ve özellikleri detaylı olarak verilmiştir. Bu bölümün son kısmında ise Nükleer Tip teşhis çalışmalarıla ilgili metodlar ve örnek olarak hangi metodlarla ne gibi çalişmalar yapıldıgı ve bu çalışmalarda ne gibi radyofarmasotiklerin kullanıldigi verilmektedir.

Ikinci bölüm ise toplanan bilgilerin derlenip toparlanması ve bilgi bankasını oluşturmaya yarayan programla, yani PC-FILE III ile ilgilidir. Bu bölümde ilk olarak sistemin tasarımı verilmiştir. Yani toplanan tüm bilgilerin hangi file'lara ne şekilde dağıtıldığı, hangi file'lardan ne gibi bilgilerin çekilebileceği bulunmaktadır. Daha sonra ise PC-FILE III'nin özellikleri ile kullanim kilavuzu bulunmaktadır. Bu bilgiler gayet detaylı olarak verilmiştir. Son olarakta elimizde hazır olarak bulunan bu bilgi bankasından çok detaylı bir raporun örnek olarak nasıl hazırlanabilecegi adım adım anlatılmıştır. Bu örnek rapor Appendix B'de bulunmaktadir. Bu gibi raporların hazırlanmasını kısa sürede sağlayacak alternatif metodlarda Appendix C'de bulunmaktadır.

Tezin en son kısmında ise bu sistemin örnek olarak kimler tarafından nasıl kullanılabileceği ve sistemle ilgili avantajlar ve dezavantajlar bulunmaktadır.

LIST OF FIGURES

I. INTRODUCTION

1.1 PURPOSE OF THIS THESIS

The purpose of this thesis is to establish a computerized Database Management System (DBMS) for radionuclides, radiopharmaceuticals, diagnostic procedures used in Nuclear Medicine, Nuclear Medicine centers, the staff of these centers, and inventory of nuclear medicine diagnostic imaging devices in Istanbul. The rationale is to provide a fast, up-to-date and accurate information retrieval system for clinicians and others practicing in nuclear medicine centers or wishing to utilize their services. In general, the users of this system will be physicians, physicists, biomedical engineering services, government agencies, health care administrators, equipment suppliers and staff and students studying in University Biomedical Engineering departments.

Nuclear Medicine is a diagnostic tool using the latest and most up-to-date technology. A great deal of research is being done on this topic to develop even more effective tools for diagnosis. This means that a great variety of new techniques, radiopharmaceuticals, diagnostic procedures and instruments are being developped continuously and new centers are being opened at a rapid pace. As time goes on, a vast amount of information from these centers is made available.

Consequently a need has developed to organize this information in a cogent and coherent fashion in one center such as our University. This organization is necessary and useful for the users of such systems, because they will now have one place to get current and reliable information without wasting time looking in multiple sources. By just placing a phone call, or where equipment exists by computer to computer communications, which will be described later, accurate information can be retrieved within a few minutes.

How such a system can be useful to a non-nuclear physician will be used as an example. The physician may suspect that his patient has a neurological problem and may think that brain scintigraphy is appropriate for making an accurate diagnosis. If he knows a database such as the one described in this thesis is available, he may easily find the centers where brain studies can be performed, the instruments in use, and the staff members responsible for these studies. He may then choose the center which he believes will obtain the most satisfactory results and send his patient there. Similarly, nuclear medicine physicians, too, can use this system to find the kind of techniques that are used in different centers. They then may send patients to the most appropriate center.

How can a nuclear chemist or physicist benefit

from such a database? The presence of physicists and chemists is essential in running a nuclear medicine department. They are the ones who develop new isotopes and combine them into kits to form new radiopharmaceuticals. A physicist may want to develop a new radiopharmaceutical for a special organ test. By using this database, he can have quick access to information related to the biological and physical characteristics of the various radionuclides and biochemicals that he may be interested in or he can obtain information on previously published articles about his research topic, where these studies have been tried and by whom.

Other people can also use this database for similar purposes. For example, this system will be very useful for government agencies. First, they are the regulators of nuclear medicine activities throughout the country. They set laws, limitations, standards, etc. to control radiation and standardize working conditions. One use of the database for them is for control purposes. They may look at each center's instruments and check whether it meets the standards set for that purpose. They can check whether the quality of the isotopes and radiopharmaceuticals is assured according to the regulations. They may also use it for statistical purposes. They may want to learn how many centers have advanced imaging devices, what the technical details are, how many patients can be checked per a certain amount of time, etc.

From the point of view of equipment suppliers, the database can be used for marketing purposes. They may get the information about which center has what instruments and they can contact them and offer alternatives for modernization, technical services, etc.

Other users of this database are staff and students of Biomedical Engineering and other departments in universities. For example, students can use the database to learn what a specific study is used for, what the main features of the study are, how the patient is prepared and how much time the test takes. This can save the student a tremendous amount of time looking for the same information in a number of diverse and scattered sources. He may get detailed information within minutes and moreover if he wants to get practical information about this specific study, he can find the addresses of centers where he can see the actual application and even find the appropriate person to talk to about details.

So, as we see, this database has a very large application and will be a useful tool for people who want to obtain specific information quickly. One further reason that this database will be useful for a large group of users is that there is no need to learn a complicated computer operating system to use it. It uses very simple rules that can be learned quickly even

by those who are not experienced computer users.

Until now, we discussed the purpose of this database in Nuclear Medicine and for whom it was useful. Why is there a need for this database? To answer this question we have to know what Nuclear Medicine is, what kind of studies are done in this field, what its advantages are over other classical or radiological studies and how the parameters can be collected and organized to form a flexible and useful database. After that we will show how to retrieve specific information from it and how to prepare reports.

1.2 BASIC PRINCIPLES OF RADIONUCLIDE IMAGING

Nuclear Medicine is a separate scientific branch of medical practice which uses radioactive substances called radiopharmaceuticals in the diagnosis of diseases. In this discipline, Nuclear Therapy is also included, but we will only concentrate on the diagnostic procedures and in particular Nuclear Medicine imaging. In Nuclear Medicine Diagnostic Imaging we mainly use the radiation effect of certain radionuclides to get physiological information about specific areas of the body. In order to conduct a Nuclear Medicine study, a radiopharmaceutical is prepared which plays a physical role in the human body and which meets certain requirements for the safety of the patient.

This radiopharmaceutical, used as a tracer, is taken up by specific organs called targets. Since it is designed to show the physiology of a specific system, its distribution within this system can give us useful information about various pathologies. This information can be best obtained by imaging the radiopharmaceutical distribution. A functional image is obtained rather than an anatomical image which could normally be obtained by using radiological imaging techniques. The function of an organ may be as important as its anatomy, such as in the case of the detection of metastases in a bone scintigraphy. Because of the ability to show physiology, nuclear medicine imaging is a very important modality among the other imaging modalities.

The radiopharmaceutical is a biochemical chosen to perform a specific function labelled with an appropriate radionuclide. The rays emitted from the radiopharmaceutical can be recorded by special devices such as gamma cameras or rectilinear scanners and an image of the radiopharmaceutical distribution can thus be obtained on a CRT or Polaroid film.

Nuclear medicine procedures are extremely complex and necessitate close collaboration between physicists, electronics engineers, physicians, chemists , nurses, etc. Furthermore, there are strict standards to be met in order to assure the safety of patients and

personnel. Quality assurance of radiopharmaceuticals and devices are also vital in obtaining correct diagnostic information. In the following, the various components of a typical nuclear medicine center will be discussed after quickly giving a brief history of this growing field.

1.3 HISTORY

The history of nuclear medicine started soon after the discovery of x-rays by Roentgen, when Becquerel discovered natural radioactivity. In 1921, Von Hevesy carried out the first biological radioactive tracer experiment and, in 1927 Kotzareff produced one of the first images using isotopes, making an autoradiograph of the kidneys following intracardiac administration of a radium solution to animals. Artificially produced radionuclides were first produced by Joliot and Curie in 1934 and two years later, John Lawrence carried out the first investigations using I-131, which had been produced on his brother Ernest's cyclotron. With the introduction of charged particle accelerators in the late 1930s, a large number of isotopes became available for medical purposes, but I-131 remained the principle radionuclide used in clinical practice until the early 1960s. Because of the beta radiation emitted and the long (8 day) physical life, I-131 delivered a high radiation dose to the patient. The solution to the apparently irreconcilable requirements of a long

halflife to permit ease of commercial distribution and of a short halflife to reduce radiation dose was found in the development of parent-daughter generators, particularly

113Sn-->113mIn and 99Mo-->99mTc.

Side by side with the development of radiopharmaceuticals, there was a gradual improvement in radiation detectors. During 1930s and 1940s, radiation detectors were based on the phenomenon of gas ionization: the ionization chamber, the gas proportional counter and the Geiger-Muller counter, the latter gaining widespread use. Kallman laid the foundations of nuclear medicine imaging when he developed the scintillation crystal coupled to a photomultiplier, during the early 1940s. This offered much superior sensitivity and improved image quality compared with the GM tube. In 1948, Hofstadter introduced the sodium iodide scintillation crystal, activated by the addition of small quantities of thallium (NaI(Tl)) which is used in almost all current imaging equipment. All early work relied on the hand-held probes. The first images were obtained by placing a grid over the patients neck following the administration of radioiodine and recording the count rates at 1 cm intervals with an end-window GM tube. By joining points exhibiting the same counting rate, an isocount contour image of the thyroid gland was obtained.

In 1951, Cassen invented the rectilinear

scanner, in which calcium tungstate crystals were moved automatically back and forth in a raster pattern. The scintillation detector outputs were used to activate a pen linked to the detector, an image being built up from ink dots, regions of high-dot density corresponding to areas with a high concentration of radiopharmaceutical. A subsequent refinement was the replacement of the pen with an intensity modulated light source which was used to form an image on standard x-ray film.

In most nuclear medicine departments, the rectilinear scanner has been superceded by the gamma camera (Anger,1958), the operation of which is described in full detail in the next part of my thesis. Current use of rectilinear scanners is limited mainly to small organ imaging (such as thyroid imaging) and the techniques employing high-energy radionuclides, where the greater crystal depth (up to 12.5 cm) of scanner offers a much higher detection efficiency than is obtained with a gamma camera.

This was how nuclear medicine was introduced to modern medical practice. In Turkey, the practice of nuclear medicine started in 1966. Technetium was first obtained in Turkey in the University of Ankara Medical Faculty-Nuclear Medicine department from molybdenum obtained from CNAEM by using the extraction method (suggested by Harper and developed by Powell Richards in the U.S.A. Brookhaven National Laboratories) and was

routinely used on patients. Nuclear medicine studies are now becoming common in Turkey. Today, in Istanbul, there are six centers, three of them private centers; and three of them state hospitals. In general, today, there are nuclear medicine centers in nine cities of Turkey. They are Istanbul, Ankara, Izmir, Bursa, Antalya, Adana, Diyarbakir, Konya, and Trabzon. Istanbul and Ankara have the most equipment.

II. ABOUT NUCLEAR MEDICINE

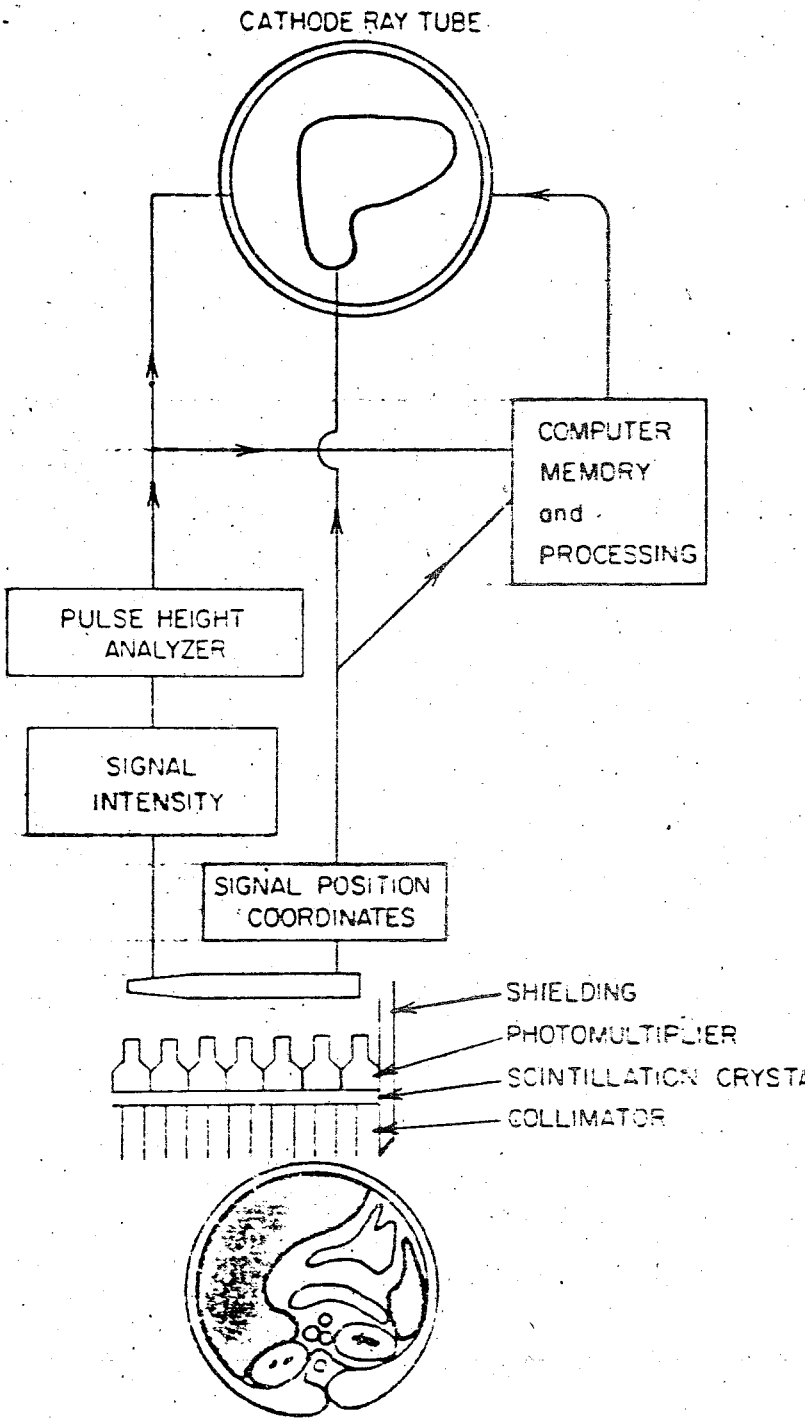
2.1 NUCLEAR MEDICINE IMAGING

There are many instruments used in nuclear medicine, including rectilinear scanners, gamma cameras, dose calibrators, well counters, etc. Today, the gamma cameras are the most widely used.

A gamma camera converts photons emitted by the radionuclide in the patient into a light pulse and subsequently into a voltage signal. This signal is used to form an image of the distribution of the radionuclide. The basic components of a gamma camera system are the collimator, scintillation crystal, an array of photomultiplier tubes, a pulse height analyser, a cathode ray tube, and the control console. A computer may also be an integral part of the system (see figure 1).

2.1.1 Collimators

The collimator is made of perforated lead and is interposed between the patient and the scintillation crystal. It is designed to reduce scatter which allows the gamma camera to localize the radionuclide in the patient. Collimators perform this function by absorbing and stopping most radiation except those arriving almost perpendicular to the detector face; radiation striking the collimator at oblique angles will not be



ure 1. Gamma camera ematic. A cross-sectional ge of the patient is shown at bottom, with a final image ne liver seen on the cathode tube at the top.

included in the final image. There are two basic types of collimators: Pinhole and Multihole.

Pinhole collimators: The radiation must pass through the pinhole aperture in order to be imaged, and the image is always inverted on the scintillation crystal (see figure 2a). Since very little of the radiation coming from the object of interest will be allowed to pass through the pinhole over a given time period, the pinhole collimator has very poor sensitivity. Collimator sensitivity refers to the percentage of incident photons that passes through the collimator. The poor sensitivity of a pinhole collimator makes placement near the organ of interest critical. Pinhole collimators are routinely used for very high resolution images of small organs, such as thyroid, and certain skeletal regions.

Multihole collimators: The holes in a multihole collimator may be aligned in such a way as to be be diverging, parallel or converging. The parallel-hole collimator is the most widely used (see figure 2). It consists of parallel holes with a long axis perpendicular to the plane of the scintillation crystal. The septa which is the lead wall between holes, absorb gamma rays that do not emanate from the direction of interest. Therefore a collimator for use with high-energy gamma rays has much thicker septa than a collimator for low energy rays (see figure 2f and

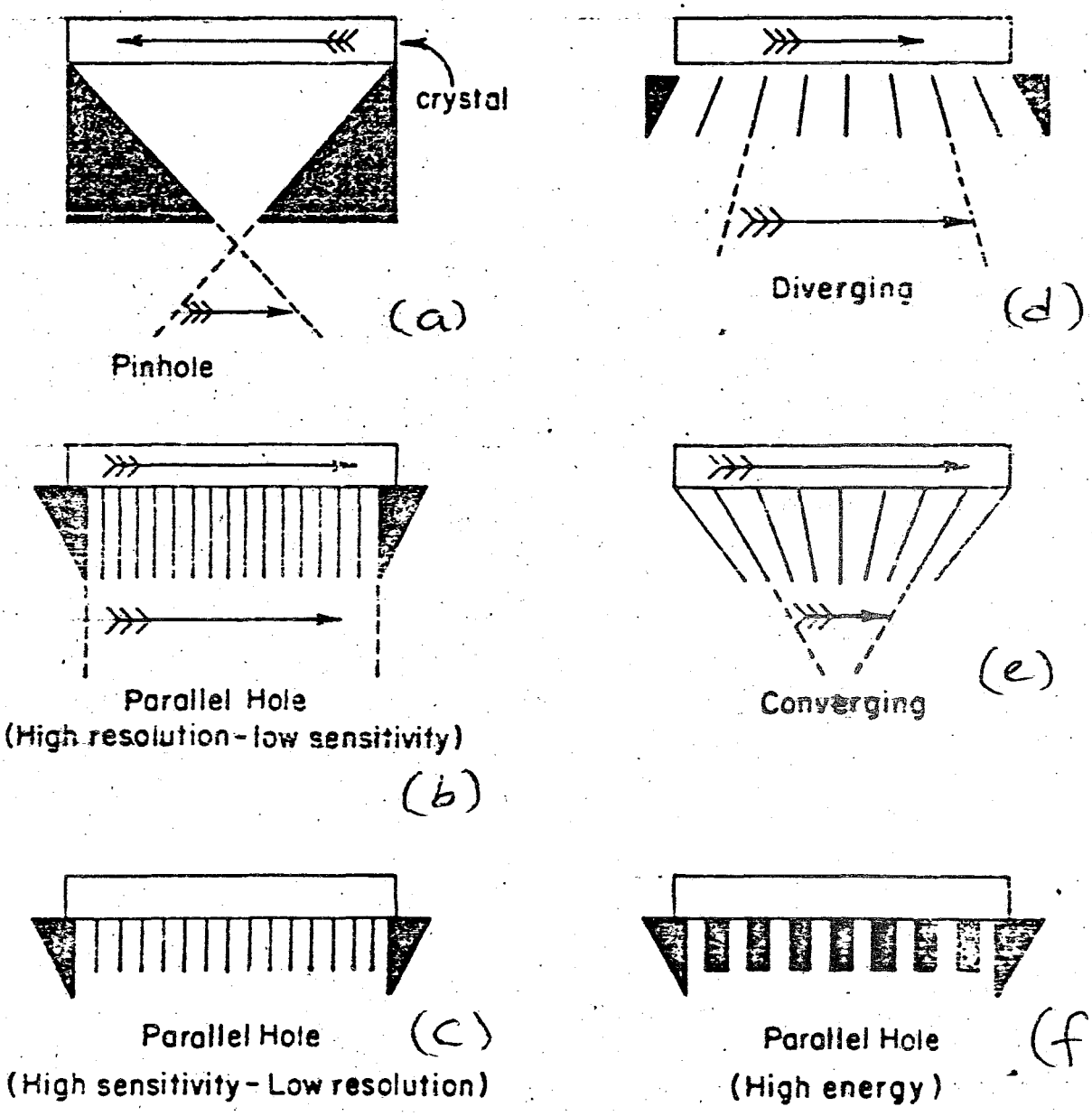


Figure 2. Types of gamma camera collimators.

2b,c). The septa are generally designed so that septal penetration by unwanted gamma rays do not exceed 25 per cent.A parallel-hole collimator is chosen corresponding to the energy of the isotope being imaged. Low-energy collimators generally refer to a maximum energy of 150 keV, whereas medium-energy collimators have a maximum suggested energy of approximately 400 keV. Collimators are available with different lenghts and different widths of septa. In general, the longer the septa, the better the resolution but the lower the count rate (sensitivity) for a given amount of radionuclide. The count rate is inversely proportional to the square of the collimator hole lenght. If the lenght of the septa is decreased, the count rate will increase and resolution will decrease (see figure 2b and c).

With a parallel-hole collimator, neither the size of the image nor the count rate will change significantly with the distance of the object of interest from the collimator. This is due to the fact that as the object is moved small distances away from the crystal, the inverse square law reduces the number of counts. However,this is compensated for by the increased viewing area of the collimator. On the other hand, resolution is best when the object of interest is as close to the collimator face as possible (see figure 3), and scans with multihole collimators are usually obtained with the collimator in contact with the patient.

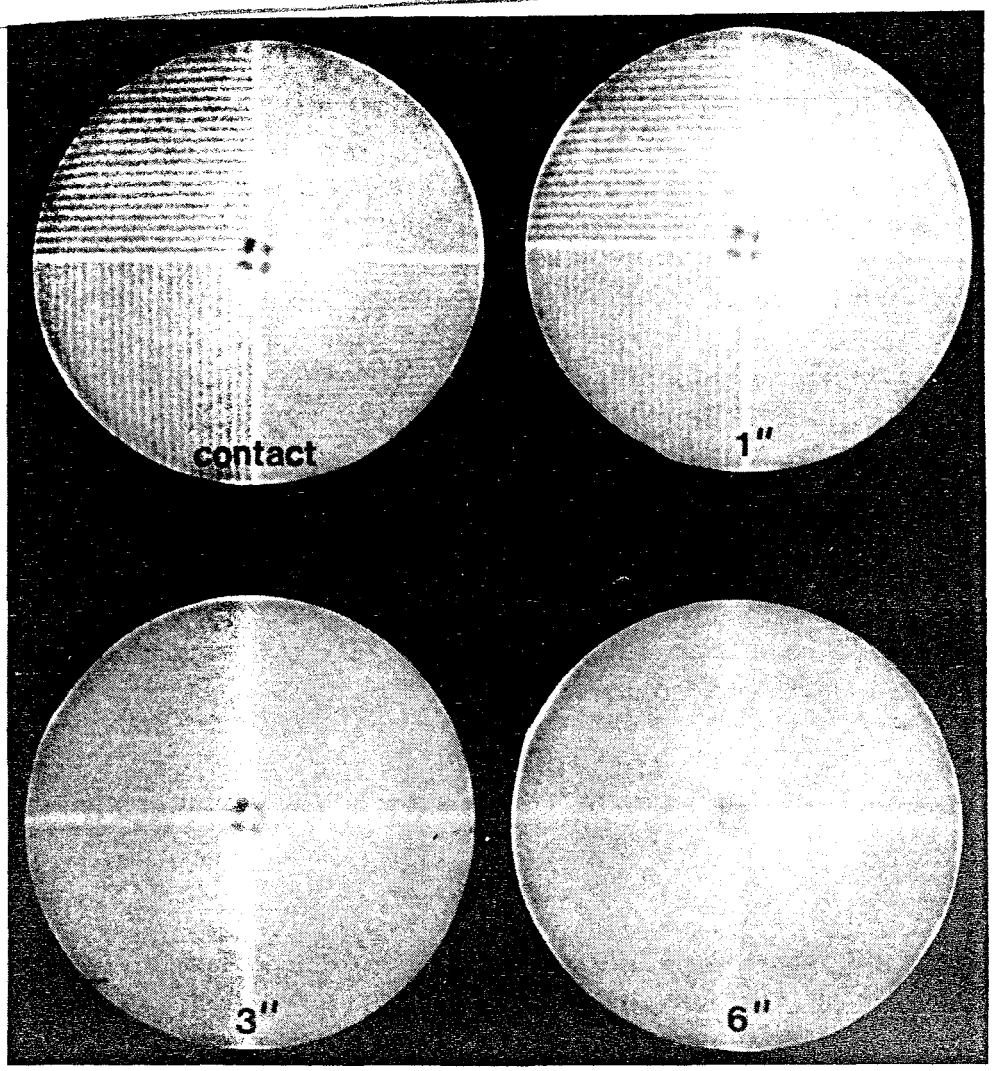


Figure 3. Loss of resolution as a function of distance from the collimator. The images are of a bar phantom in contact with and at varying distances from the collimator face. At distances greater than 1 inch, the pattern of the bar phantom essentially disappears.

A diverging collimator is one whose holes and septa begin to diverge away from the crystal face (see figure 2d). Generally, use of a diverging collimator will increase the imaged area by approximately 30 per cent over a parallel-hole collimator. The image itself, however is slightly minified. With a diverging collimator, both the sensitivity and the resolution get worse as one moves away from the collimator. The sensitivity worsens since the area being imaged gets larger, but the object imaged does not get larger and the inverse square law predominates. Diverging collimators are utilized particularly on cameras with small crystal faces, to image large organs, such as lungs.

A converging collimator has holes that converge toward a point (usually 50 cm) in front of the collimator (see figure 2e). This convergence results in a magnified image being formed in the crystal. Sensitivity increases as one moves away from the collimator face until one reaches the focal point, beyond which the sensitivity begins to decrease. Resolution, however, decreases with distance. A converging collimator may be used for examination of small areas such as the posterior fossa on a brain scan. Some collimators have an insert that may be reversed to achieve the result of either a diverging or a converging collimator.

Radiation emerging from the patient and passing through the collimator may interact with a thallium-activated sodium iodide crystal. Interaction of the gamma ray with the crystal may result in ejection of an orbital electron (photoelectric absorption), producing a pulse of fluorescent light (scintillation event) proportional in intensity to the energy of the gamma ray. Photomultiplier tubes (PMT) along the posterior crystal face detect this light and amplify it. The crystal has an aluminum housing that protects it from moisture, extraneous light, and minor physical damage. The crystal may be from 10 to 21.5 in in diameter and from 0.25 to 0.5 in thick. A longer diameter crystal has a longer field of view and is more expensive but has the same inherent resolution as a smaller-diameter crystal. The thicker the crystal becames, the worse the spatial resolution but the more efficient the detection of gamma rays. As the gamma energy of the isotope is increased, the efficiency of the crystal is markedly reduced. For example, with iodine 131 (364 keV) efficiency is reduced to approximately 20 to 30 per cent. Most crystals in new gamma cameras are either 1/4 or 3/8 in thick. With a thinner crystal the overall sensitivity (count rate) decreases by about 10 per cent since more photons pass through, but there is approximately a 30 per cent increase in spatial resolution, because the PMTs are closer to the event and thus can localize it more accurately and because there is an increase in light collection.

2.1.3. Photomultiplier tubes

Photomultiplier tubes (PMTs) convert a light pulse into an electrical signal of measurable magnitude. An array of these tubes is situated behind the sodium iodide crystal and may be placed directly on the crystal, connected to the crystal by light pipes, or optically coupled to the crystal with a silicone-like material. A scintillation event occuring in the crystal is recorded by one or more PMTs. Localization of the event in the final image depends on the amount of light sensed by each PMT and thus on the pattern of PMT voltage output. The summation signal for each scintillation event is then formed by weighing the output of each tube. This signal has three components: Spatial coordinates on an X and Y axis as well as a signal (Z) related to the intensity. The X and Y coordinates may go directly to instrumentation for display on the cathode ray tube or may be recorded in the computer. The signal intensity is processed by pulse height analyser. The light interaction caused by a gamma ray generally occurs near the collimator face of the crystal. Thus, while a thicker crystal is theoretically more efficient, the PMT is further away from the scintillation point with a thick crystal and is unable to determine the coordinates as accurately. Therefore, spatial resolution is degraded. The number of PMTs is also very important for the accurate localization of scintillation events and thus for spatial resolution. The greater the number of PMTs, the greater will be the

console, image exposure time is selected which is usually a preset count, a preset time or preset information density (ID) for the image accumulation. Information density refers to the number of counts per square centimeters of the gamma camera crystal face. Other controls are intensity and persistence which regulates the lenght of time the light dots composing the image remain on the screen of the CRT image. In up-to-date gamma cameras there are two CRTs, one for operator and another for photographic purposes. Hard copy images can also be taken on Polaroid film or transparent sheet film.

2.1.5. Resolution

Resolution usually refers to either spatial or energy resolution. Energy resolution is the ability to discriminate between light pulses caused by gamma rays of differing energies. Spatial resolution refers to the ability to display discrete but contiguous sources of radioactivity. The spatial resolution of various gamma camera systems is usually given in terms of either inherent or overall resolution. Inherent resolution is the ability of the crystal, PMT detector and accompanying electronics to record the exact location of the light pulse on the sodium iodide crystal. Today modern cameras have inherent resolutions as low as 2 mm.

Overall spatial resolution is the resolution capacity of the entire camera system, including the

collimator resolution, septal penetration,and scattered radiation.

There are several ways of examining the performance of collimators. The simplest method of examining overall spatial resolution is to determine the Full Width at Half Maximum (FWHM) of the line spread function. This refers to the profile response of the gamma camera to a single point source of radioactivity, and reflects the number of counts seen by the crystal at different lateral distances from the source (see figure 5). The source is often placed 10 cm from the crystal for such measurements. The FWHM is expressed as the width in centimeters at 50 per cent of the height of the line spread peak. The narrower the peak, the better the resolution.

While spatial FWHM is useful for comparing collimators, it often does not give other desirable information and does not necessarily relate to the overall clinical performance of the collimator. More difficult but perhaps more encompassing measurements of collimator performance are line spread and modulation transfer functions. These take into account other factors for optimizing collimator design such as the presence of scattering material and septal penetration. As seen in figure 5b, the septal penetration occuring in the collimator may be completely undetected by the measurement of FWHM alone. When the overall spatial

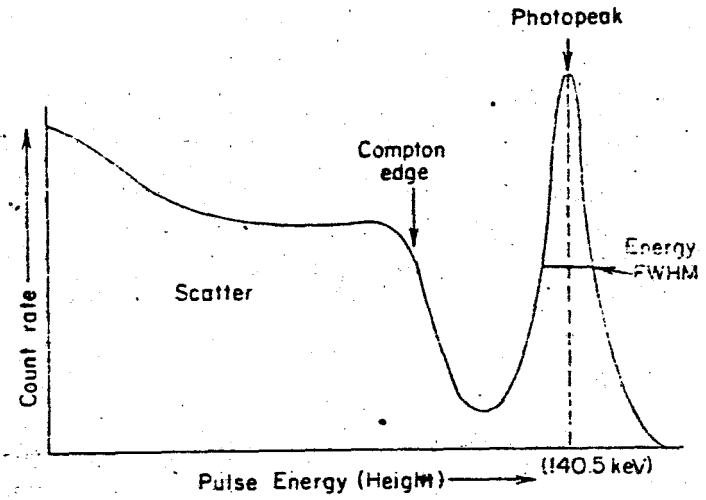


Figure 4. Energy spectrum of technetium 99m. For optimal imaging purposes, the pulse height analyzer will record only those counts from the region of the photopeak and not from other isotopes or from scattered radiation.

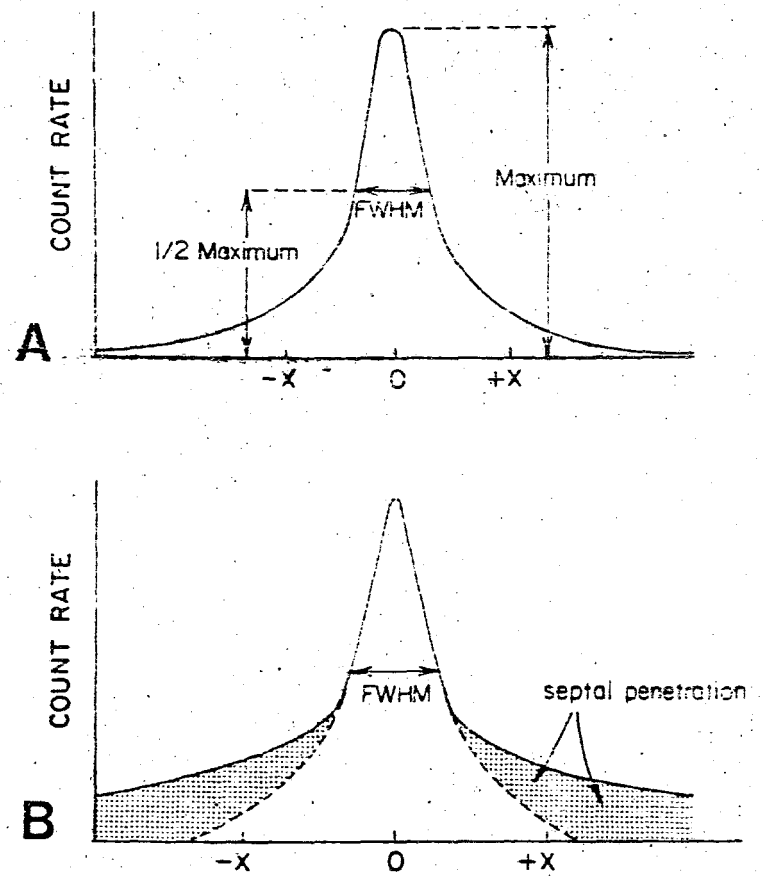


Figure 5 (A) The FWHM is the response in count rate to a single point source of radioactivity at different lateral distances from the point source. With septal penetration (B) the image may be significantly degraded even though FWHM is unchanged.

resolution of the system with high-energy isotopes is considered, the limiting resolution is that of the collimator. When low-energy isotopes are imaged, the intrinsic resolution becomes more important than the collimator resolution. As the energy of the incident gamma ray decreases, the intrinsic resolution of the crystal decreases markedly, due to the fact that the lower-energy gamma rays provide less light for the PMTs to record; thus, there is more statistical uncertainty regarding the origin of the gamma rays. The overall system resolution, Rs is given by Rs=(Ri2 +Rc2)1/2 where Ri is inherent resolution and Rc is collimator resolution.

Another category of resolution is energy resolution or the ability of the imaging system to separate and distinguish between photopeaks of different radionuclides. If the energy resolution is good the photopeaks will be very tall and narrow, if the energy resolution is poor the photopeaks will appear as broad bumps in the energy spectrum. The FWHM concept is also utilized to examine energy resolution and is usually quoted for the relatively high energy (662 keV) photon of Cs137. With lower energy photons, the energy resolution is worse.

An important point about the electronics of the system is not to have scintillation events occuring so fast that, it is unable to count each one of them as

a separate event.If two equal light pulses occur too close together in time, the system may perceive this as one event with twice the energy actually present. Such an occurance would be eliminated by the energy window of PHA, and none of the information from the two events would be imaged; thus, the sensitivity of the system would be diminished.The time after an event during which the system is unable to respond to another event is referred to as "dead time". Dead time can be important in high-count-rate dynamic studies (in the range of 50000 counts per second), particularly with single crystal cameras. Usually with 20 per cent window and scattering material most cameras have dead times of 5 to 10 usec with Tc99m.

2.1.6. Other Imaging Devices

There are specialized gamma cameras apart from conventional ones in the hospitals and centers throughout the world and in Istanbul. One example is wholebody scan cameras. Whole body imaging is accomplished by either placing the patient on a moving table or having the gamma camera detector head move over the patient.

Another specialized imaging device is the Anger Tomoscanner. This is also a scanning camera providing a whole-body image, although images are focused at different depths within the patient's body, in a manner similar to radiographic tomography. The

radioactivity at different planes project onto the detector with different degrees of magnification and speed of travel across the detector and can therefore be separated. Tomoscanners have essentially the same resolution in each plane and provide sharp tomographic images of excellent quality.

Finally, there are portable gamma cameras used primarily in cardiac stress laboratories and intensive care units. These cameras require much less space than standard cameras and most are available with the associated components.

Other instruments used in nuclear medicine laboratories are sodium iodide well counters used for performing invitro studies as well as for quality control and assurance procedures, and dose calibrator to calibrate a dose of isotope prior to injection. The dose calibrator can measure quantities in mCi range whereas in well counters, the upper limit is uCi range.

Another system is the single probe counting system. Single probe counting systems employ only one crystalline detector and are quite useful for measuring thyroid uptake of radioactive iodine, and cardiac output. Typically the crystal is 5 cm in diameter and 5 cm in thickness, with a cone-shaped (flat-field) collimator. And as other instruments, a PMT is at the crystal base.

Although one finds limited use of rectilinear scanners in the United States and some part of Europe, they are still used in centers of Istanbul. Rectilinear scanners are devices for imaging the distribution of radioactive material within the body. It is a systematic point sampling device that forms its image by moving over (scanning) the field of interest. Basically,the rectilinear scanner is a rigid bar with a radiation detector at one end and a light and stylus at the other (see figure 6). When the detector detects radiation, the light flashes, exposing some film, and the stylus taps, marking some paper. The rigid bar provides position data linking the radiation detector and the flasing light. The motion is two way, i.e. alternatively left to right and right to left.

2.2 ISOTOPES AND RADIOPHARMACEUTICALS

It is generally accepted that the most useful radiation used in nuclear medicine imaging is gamma radiation. So the isotopes to be used should contain a high percentage of gamma radiation (compared to alpha and beta radiation). A second restriction in choosing suitable isotopes is related to safety problems of radiation. The isotopes used should not have very high radiation energies. Otherwise they can cause permanent damage to the tissue or organ. In general, studies have shown that radionuclides with energies between 50 to 500 keV are useful for diagnostic purposes and they do

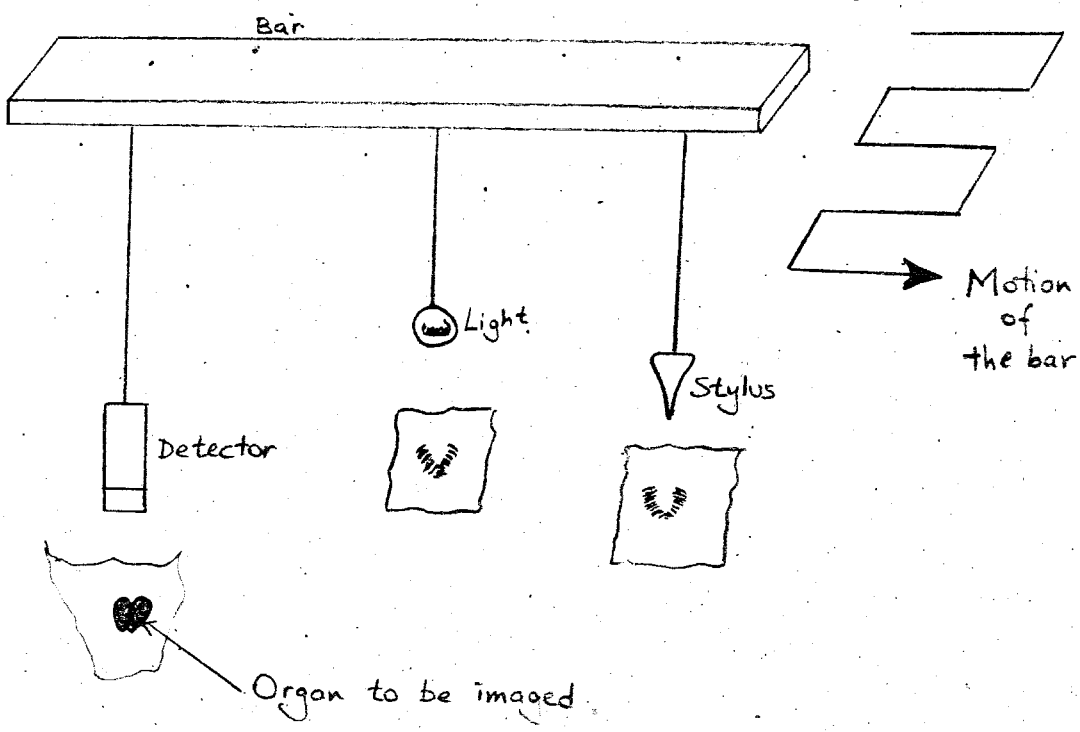


Figure 6. Schematic of a rectilinear scanner.

not have critical negative effects on organs provided that special precautions are taken in their use. The halflives are also an important consideration and need to be taken into account together with the energy problem. Lastly, their production is important. They should be easily produced and should have low cost.

Most radioactive materials that are used in hospitals for diagnostic purposes are not readily available in nature. That means we have to generate them. Today, it is possible to do this by particulate bombardment or fission. Both methods alter the neutron-proton ratio in the nucleus to produce an unstable isotope. Bombardment essentially consists of the irradiation of the nuclei of selected target elements with neutrons in a nuclear reactor or with charged particles (alpha particles, protons, or deutrons) from a cyclotron. A bombardment reaction can be shown by the equation azX+n----->a+1zX+gamma . For example 98Mo+n----->99Mo+gamma. Once the bombardment is completed, the daughter isotope must be physically separated from any remaining and unchanged target nuclei as well as from any target contaminants. Thus it is obvious that the completeness of this final separation process as well as the initial elemental purity of the target are vital factors in obtaining a product of high specific activity. Because cyclotron isotope production almost always involves a transmutation (charge of Z) from one element to

another, this process aids greatly in the separation of the radionuclides producing carrier-free isotopes. (A carrier-free isotope is one that has none of the stable element accompanying it). Radionuclides made by neutron bombardment, which does not result in a change of elemental species are not carrier-free since the chemical properties of products are identical and thus not as easily separated.

Fission isotopes are simply the daughter products of nuclear fission of Uranium 235 or Platinium 239 in a reactor and represent a multitude of radioactive materials, with atomic numbers in the range of roughly half that of Uranium 235. These include I-131, X-133, Sr-90, Mo-99 and Cs-137 among others. Because many of these isotopes are present together in the fission products, the desired isotope must be carefully isolated to exclude as many as contaminants as possible. Thus many carrier-free isotopes are produced in this manner.

Neutron bombardment and nuclear fission almost always produce isotopes with neutron excess, which decay by beta emission. Cyclotron-produced isotopes are usually neutron-deficient and decay by electron capture or positron emission. Some examples of cyclotron-produced isotopes include I-123, F-18, Ga-67, In-111 and Tl-201. In general, cyclotron-generated radionuclides are more expensive than those produced by neutron

bombardment or fission.

One important property of isotopes is the radioactive decay. But, before explaining this, let us define a few terms that are widely used in nuclear medicine.

ACTIVITY: The amount of radioactivity present i.e. the number of disintigrations per second. Its unit of measurement is the Curie (Ci) which is 3.7*1010 disintigrations per second.

SPECIFIC ACTIVITY: The activity per unit mass of material (mCi/gr). For a carrier-free isotope, the longer the half-life of the isotope the lower the specific activity.

We know that radionuclides decay in an exponential fashion and the term half-life is often used casually to characterize decay. Half-life usually refers to the physical halflife, which is the amount of time necessary for a radionuclide to be reduced to half of its existing activity. The physical half-life is given by th=0.693/v where v is the decay constant. V and therefore the physical half-life haye characteristic values for each radioactive nuclide. The following formula is very useful for nuclear medicine:

$$A=A0e-0.693t/th$$

where A is the activity of a particular radioisotope

present at a given time t, given a certain activity A0 at time zero. For example, if we have 5 mCi of Tc99m today, 24 hours later the amount remaining will be 0.31 mCi, where half-life of Tc99m is six hours.

Similar to the physical halflife or physical decay of a radionuclide, the biological halflife refers to the time it takes an organism to eliminate half of an administered compound or chemical on a strictly biologic basis. On the other hand, the effective halflife which incorporates both the physical and biological halflives and is the one that should be considered in diagnostic studies. For example, if a non-radiactive chemical compound were given to an individual and half of it was eliminated by the body within three hours then the biological half-life would be three hours. Effective halflife is defined as follows: 1/teff=1/tb+1/th Thus if the biological half-life is three hours and the physical half-life is six hours the the effective half-life is two hours.

Before giving some examples of widely used radionuclides in nuclear medicine, the following list represents the characteristics of isotopes that are most desirable for nuclear medicine diagnosis.

1)Minimum of particulate emission

2)Primary photon energy between 50 to 500 keV.

3)Physical half-life greater than the time required to prepare material for injection

4)Effective halflife longer than the examination time

5)Suitable chemical form and reactivity

6)Low-toxicity

7)Stability or near-stability of the product.

WIDELY USED RADIONUCLEIDES IN NUCLEAR MEDICINE.

2.2.1. Technetium 99m

Tc99m has no particulate emission, a six hour halflife and predominant (98 per cent) 140 keV photon energy with only a small amount (10 per cent) of internal conversion. It is the most widely used isotope in nuclear imaging procedures. It is obtained by separating it from the parent molybdenum 99 (67 hour halflife) in a generator system, which may be either an alumina column type or a solvent extraction type. Mo-99 for generators is generally produced by neutron irridation of Mo-98 or by chemical separation of Uranium 235 fission products which in the latter case, Mo-99 is nearly carrier-free and has a high specific activity.

In the alumina generator system the molybdenum activity is absorbed on an alumina column. By passing physiologic saline over the column, Tc99m is eluted or washed off the column as sodium pertechnetate ($Na^{99m}TcO_4^-$). This type of generator is commonly used in hospital nuclear medicine departments. In the solvent extraction method, Tc99m is separated from a solution of aluminum hydroxide containing the

equilibrium pair (99Mo-99mTc). Separation of the two species is possible using methyl ethyl ketone because sodium pertechnetate is highly soluble in organic solvent. This method produces highly concentrated quantities of Tc99m and is usually only utilized by commercial radiopharmacies. Technetium can exist in a variety of valence states ranging from -1 to +7. When eluted from an alumina column generator, Tc99m is present primarily as heptavalent (+7) pertechnetate. In the preparation of radiopharmaceuticals, Tc99m pertechnetate can be reduced from +7 to a lower valence state, usually +4, to permit the labelling of various chelates. Following IV injection, Tc99m pertechnetate is loosely bound to protein and rapidly leaves the plasma compartment. Over half leaves the plasma within several minutes and is distributed in the extracellular fluid. It rapidely concentrates in the salivary glands, choroid plexus, thyroid gland, gastric mucosa, and functioning breast tissue. Excretion is by the gastro-intestinal and renal routes. Although Tc99m pertechnetate is excreted by glomerular filtration, it is partially reabsorbed by the renal tubules, with the result that only 30 per cent is eliminated in the urine during the first day. The biodistribution of Tc99m pertechnetate is markedly influenced by the pretreatment of patients with potassium perchlorate, sodium perchlorate, or potassium iodide. Finally Tc99m pertechnetate gives a column dose of 1 to 2 rads per 10 mCi.

2.2.2. Iodine

Two isotopes of iodine, I-123 and I-131 are clinically useful for imaging and may be administered as iodide. Iodine 123 has a 13.3 hour half-life and decays by electron capture to tellurium 123. The photons emitted are 28 keV (92 per cent) and 159 keV (84 per cent) gamma rays. I-123 is usually produced in a cyclotron by bombardment of Sb-121, Te-122,or Te-124. Another method is to bombard I-127 to produce X-123 and let this decay to I-123. The cyclotron production and short halflife make I-123 expensive and distribution on a nationwide basis difficult. Iodine 123 has a wholebody dose of 0.04 rad/mCi and a thyroid dose of 16 rad/mCi.

Iodine 131 is a much less satisfactory isotope from an imaging viewpoint because of the high radiation dose to the thyroid and its relatively high photon energy. Hovewer, it is widely available, is relatively inexpensive, and has a relatively long shelf life. I-131 has a half life of 8.06 days and decays by beta emission to stable Xenon 131. The principle mean beta energy (90 per cent) is 192 keV. Several gamma rays are also emitted, with the predominant photon being 364 keV (82 per cent). Iodine 131 gives a wholebody dose of 0.5 to 3.5 rads/mCi and a thyroid dose of 100 to 2000 rad/mCi.

When iodine is orally administered as the iodide ion, it is readily absorbed from the gastroin-

testinal tract and distributed in the extracellular fluid.It is concentrated in a manner similar to Tc99m pertechnetate in the salivary glands, thyroid, and gastric mucosa. As with pertechnetate, there is a renal filtration with tubular reabsorption. Urinary excretion is the predominant route (35 to 75 per cent in 24 hours) although there is some fecal excretion as well.

2.2.3 Thallium

When a thallium metal target is bombarded with protons in a cyclotron, lead 201 is produced, which can be separated from the thallium target and allowed to decay to thallium 201. Thallium 201 has a physical half-life of 73.1 hours and decays by electron capture to mercury 201.Mercury 201 emits characteristic x-rays from 68 to 80 keV (94.5 per cent) and much smaller amounts of gamma rays with higher energies. Since Tl-201 is cyclotron produced it is extremely expensive. Thallium 201 is normally administered as a chloride and rapidly clears from the blood with a halflife of between 30 seconds and 3 mins. Since it is roughly a potassium analog, it is rapidely distributed throughout the body, particularly in muscle. Thallium 202 (95 per cent photon at 493 keV) contamination should be less than 0.5 per cent and if present in greater quantities can significantly degrade images.

These are the most important isotopes used widely throughout the world and especially in centers

in Istanbul. Other less widely used isotopes include Xenon 133 which is a relatively insoluble and inert gas, and is most commonly used for pulmonary ventilation studies, having a physical half-life of 5.3 days with principle gamma photon energy of 81 keV and a beta emission of 374 keV; Gallium 67 which has a half life of 78 hours with principle gamma photons 93 keV (40 per cent), 184 keV (24 per cent), 296 keV (22 per cent), and 388 keV (7 per cent); Gallium 68 which has a 68 minute halflife, being a positron emitter; Indium 111 which has a physical half-life of 67 hours with 173 keV (89 per cent) and 247 keV (94 per cent) photon energies; Indium 113m having a physical half-life of 1.7 hours with 392 keV photon energy. Among these isotopes, Ga-67 and In-111 are cyclotron-generated. The others are generator produced isotopes. Finally, several isotopes are used in the production of positron-emitting radiopharmaceuticals. Among these are Fluorine -18 (half-life 109minutes, produced by cyclotron bombardment of Oxygen-18), Carbon-11 (half-life 20.3 minutes), Nitrogen-13 (half-life 10 minutes), Oxygen-15 (half-life 124 seconds), and Gallium-68 (half-life 68.3 minutes). But since we do not have positron emission studies in Turkey, yet, these studies will not be included in the database.

2.3 NUCLEAR MEDICINE STUDIES

2.3.1. Static Studies

A nuclear medicine image shows the distributi-

on of a particular function or combination of functions of the systems, its vascularity, the cellular uptake, the time of transit and the rate of loss of the radionuclide. These processes are frozen at the time of the test in relation to the time of injection of the radiopharmaceutical when a static image is produced. In other words, images are taken after the radiopharmaceutical goes to the specified organ and comes to equilibrium there. There are a few ways of displaying the data collected by the gamma camera, but the most commonly used ones are displaying on Polaroid film or storing collected data in a computer, processing it and displaying it with a CRT. The latter has many advantages. The computer can be used to generate a display which contains all the information or can programmed to present the image in such a way as to allow the operator to highlight different parts of it at different times. For example, with computer assisted picture processing techniques, variable background subtraction or threshold cutoff, contrast enhancement and filtering can be done to produce a better picture of the area of interest. Whereas with the image taken on a Polaroid film, it is not possible to make an analysis at different times and conditions specified.

2.3.2. Dynamic studies

Dynamic imaging records how the activity in in the region under investigation váries with time from the moment of intravenous injection of the radiopharma-

ceutical. This series of images gives a visual impression of the function of the system which is often of considerable clinical interest. For example, is the heart beating normally? Has the activity been retained in the renal pelvis? The real task of the dynamic study is to derive from these composite images quantitative information about the particular process that the radiopharmaceutical is tracing. These functions include the rate of loss of activity from the blood to the organ of interest, sometimes called "clearance"; the rate of uptake of the radiopharmaceutical by the organ of interest; the transit of the tracer through the organ, usually described by a mean transit time, and the distribution of transit times; and the rate of removal or loss of the tracer from the organ. The mean transit time is defined as v/f where v is the volume of distribution of the tracer and f is the flow rate through the system. In contrast to static studies where resolution is of prime importance, in dynamic studies sensitivity is essential.

2.3.3. Emission Computed Tomography

The basic principle of emission computed tomography (ECT) is that the radioactivity being emitted by the patient is measured from many different angles. ECT may be either single photon emission computed tomography (SPECT) using isotopes such as Tc99m, or positron emission tomography (PET), in which circuits are used to record high energy (511 keV) annihilation

photons, providing extremely accurate localization. PET generally uses short lived cyclotron-produced isotopes such as Carbon-11, Nitrogen -13, Oxygen-15 and Fluorine-18. PET has therefore been limited to those facilities with rapid access to a cyclotron and as stated before, it is extremely expensive. SPECT is more limited than PET, particularly since varying depths of the radiopharmaceutical in the body cause a wide range of tissue attenuation. The advantage of SPECT over PET is that the former may be performed using current imaging equipment and can be used with most radiopharmaceuticals. The radiation dose is also low, and with the rapid advencement in computer software many artifacts have been eliminated. In Turkey, SPECT studies are done only in the nuclear medicine department of Cerrahpasa Medical School.

Some common examples of studies performed in nuclear medicine centers and the radiopharmaceuticals used in these studies are:

Examples of dynamic studies:

1)Liver scintigraphy..... Tc99m-pertechnetate

2)Brain scintigraphy..... Tc99m-pertechnetate

3)Kidney scintigraphy..... Tc99m-DTPA

4)Lung scintigraphy..... Tc99m-MAA

5)Bladder scintigraphy..... Tc99m-IDA

6)Gastric emptying rate..... Tc99m-S-Colloid

7)Spleen scintigraphy..... Tc99m-S-Colloid

Examples of static studies:

1)Liver scintigraphy..... Tc99m-pertechnetate

2)Brain Scintigraphy..... Tc99m-pertechnetate

3)Kidney scintigraphy..... Tc99m-DMSA

3)Lung scintigraphy..... Tc99m-MAA

4)Spleen scintigraphy..... Tc99m-S-Colloid

Examples of tomographic studies:

1)Brain scintigraphy..... Tc99m-pertechnetate

2)Spleen scintigraphy..... Tc99m-S-Colloid

3)Liver scintigraphy..... Tc99m-S-Colloid

DTPA, DMSA, MAA, S-Colloid, and others are all readily available in kits and are labelled with radionuclides to produce radiopharmaceuticals. As seen from the list, each kit has the property to be absorbed by a specific organ and when labelled with radionuclides, the organ becomes radioactive. The amount of radioactivity (principally of gamma rays) are detected by gamma cameras and processed accordingly,as described earlier.

Detailed information about indications and procedures can be found in the CODES file of the database; explained in the second part of the thesis.

III. DESIGN OF A DATABASE MANAGEMENT SYSTEM FOR NUCLEAR MEDICINE

The database manager that is used for this project is PC-FILE III. It was written for the IBM-PC and will run on IBM PC-compatible computers, as well.

A file consists of records, with each record containing a number of fields. The program and application rules will be explained later, in detail.

3.1 SELECTION OF RECORD FIELDS FOR A NUCLEAR MEDICINE DATABASE MANAGEMENT SYSTEM

Five files were created to organize the data collected. They are STAFF, ISOTOP, INSTRUMT, ORGAN, and CODES. The contents of each file are as follows:

STAFF: This file consists of the staff in nuclear medicine departments of state hospitals and private centers in Istanbul. The records in this file have the following fields:

Title: This is the position of an individual in his center. For example, a physician might be a professor, assistant professor, or a doctor. Staff other than physicians may be a physicist, chemist, technician, or nurse.

Name: The first name of the individual.

Last name: The last name of the individual.

Center: The center in which he or she works.

City: The city where the center is located.

Address code: This field contains the code for the address and telephone number(s) of the center. The information can be found in the CODES file.

Information can be retrieved using the LISting facility of the database manager described in detail in the next section. For example, we can find physicists working in a specific center, all physicists working in the nuclear medicine centers in Istanbul, or all physicians who are professors and have first names "Ali". It is possible to sort information with many logical combinations using the facilities of this file.

ISOTOP:This file contains the isotopes used in nuclear medicine studies, their production methods, physical characteristics, radiopharmaceuticals produced by them, centers where the studies are performed with the radiopharmaceuticals listed in the records, and distributers of radiopharmaceuticals. Included in this file is some information from the INSTRUMT file. This was done to minimize passing from one file to another and reduce

the time spent in retrieving data. The fields defined in this file are the following:

Isotope: The name of the isotope.

Half life: The half-time of the isotope.

Energy: The energy of the principle gamma rays emitted.

Prod*method: The production method of the isotope.

Radiopharma: A radiopharmaceutical produced with this isotope. The symbol letters apart from the isotope show the kit labelled with the radionuclide.

Radioph code: The code of the radiopharmaceutical. The extended name of the radiopharmaceutical can be found in the CODES file by using this code.

Study: The nuclear medicine study performed using the radiopharmaceutical stated above.

Study code: The code for this study where information is obtained from the CODES file.

Study center: The center where the study is performed.

Center code: Address and telephone numbers of the

center cited above.

INSTRUMT: The instrumentation file. It consists of records of all the nuclear imaging devices available in nuclear medicine centers in Istanbul. The fields are:

Instr name: Instrument name and model.

Instr code: Instrument code. This field is not used for the time being, but it is included because it will be useful in the future when an inventory control system is implemented.

Center: The center where the instrument is located.

City: The city where the center is located in.

Center code: The code in which the full address and telephone numbers of the center can be found in the CODES file.

Resolution: The resolution of the instrument.

Count rate: The maximum count rate of the instrument.

Window width: The window width used to obtain the technical data listed in this record.

Energy: The energy used to get the data listed in

this record. e.g. the data is obtained using a specific energy and window width and results will change if one of these parameters is changed.

Field of view: This is the maximum field that the instrument can see.It is given in millimeters.

Wholebody: This field shows if the instrument is capable of wholebody scanning. Some instrument systems can move the patient bed from head to foot. On the other hand the gamma camera can move from one end to another for a wholebody scan while the bed remains stationary. In this case the data for this field will be defined as "completely capable". Others without either facility are still able to do wholebody scans in pieces; small sections at a time. In this case the data for the field will be defined as "partially capable". And some are not capable to do wholebody scans, at all. There the data is defined as "not capable".

Calibr__rate: This shows how frequently the instrument is calibrated. The data entered are routinely used calibration intervals. If the intrument should be serviced, it is calibrated before placed in use.

Machine__cost: This shows the approximate cost of machine.Unfortunately,this information is not reliable. Costs change as will conditions of purchase. It is

however, included to give a rough estimate about costs and enable us to compare costs between instruments. This information might be especially useful for marketing purposes, for equipment suppliers, etc. Staff, also who want to buy a specific instrument may use this data as a factor in their search.

#of patients: This field shows the number of patients that are imaged per day, with the instrument entered in the record. This is not a maximum. It is the average number of patients checked per day.

Study: It shows the typical studies performed with each machine.

Study code: This field gives the code which summarizes the study, the detailed indications, procedure, and preparation can be found in the CODES file.

Radiopharma: This shows the radiopharmaceutical used for the study stated above.

Radioph code: This is the code of the complete name of the radiopharmaceutical (entered symbolically in the Radiopharma field), detailed in the CODES file.

Scan speed: This gives the scan speed of rectilinear scanners, or moving cameras, etc. in

cm/min.

Scan time: This gives the amount of time which the scan takes.

Collimator: This gives the type of collimator used for the study mentioned above. It may be a parallel, convergent or divergent (i.e. a multihole) collimator or a pinhole collimator with a certain number of holes.

Line space: This data shows with how much space between lines the scanning is performed. It usually applies for rectilinear scanners and shows the spacing resolution of a specific scanner.

The INSTRUMT file is the largest. It consists of most of the information related to nuclear medicine imaging devices, studies, radiopharmaceuticals and centers. It does not include staff, other technical details and explainations of radionuclides and studies.

ORGAN: This file consists of organ imaging studies. For example, what radiopharmaceutical is used for a specific organ study, how it is administered, how a patient is prepared for the study, what instrument settings are needed in order to get high quality pictures and a summary of why the study is performed and what procedure are followed.The fields in this file are the following:

Study: This gives the name of the study.

Study code: Using this code, detailed information about the indications for this study, what procedure is applied and how the patient is prepared before the study if needed could be retrieved from the CODES file.

Organ: This field shows the organ that is studied.

Radiopharma: This gives the radiopharmaceutical used for the study mentioned above.

Radioph code: The code which the complete name of the radiopharmaceutical can be found in the CODES file.

Dose: This shows the dose of the radiopharmaceutical given to the patient for that specific study. Some numbers may change from application to application. Therefore, some data were entered as a range rather than a single number.

Route of adm: This field explains how the radiopharmaceutical is administered e.g. orally or intravenously.

Time of adm: This field shows the time interval between the administration of the radiopharmaceutical and the beginning of the study. For dynamic studies the

radiopharmaceutical is administered immediately before the study starts, but for static studies there is a time delay between administration and study.

Quantization: This field indicates whether counting is done or not in a specific study. The data for this field is "Yes" or "No".

Comp process: This field indicates whether computer processing of the data is necessary or not. The data for this field is "Yes" or "No".

Light apertu: This is related to the focusing of the picture. Either large , medium, or narrow apertures are chosen according to the organ and the study.

Spectro set: This field shows where the spectro energy is set. For example, for Technetium, it is set to 140 keV peak and a certain window is chosen, such as 10 percent which makes a 14 keV window. Again, this is one of the factors which affect picture quality. Data for this field is given in the form:

" 140 keV peak, 30 keV window "

Bckgnd erase: This shows the percentage of background erase from the total picture to obtain better resolution. For example, there might be some region which the radiopharmaceutical can be held by the study area and by a smaller amount in the surrounding

area. By specifying a background area, the background activity can be subtracted by computer processing and thus a better quality picture is obtained. This is typically used in the liver, spleen, and brain studies.

Contrast: This shows the amount of contrast needed to obtain a sharp picture. It might be low, medium, or high depending on the application.

CODES: The last file is the CODES file in which all of the codes are explained in detail. The codes are organized as follows:

Instrument codes.....: 100-199
Radiopharmaceutical codes: 200-299
Study codes.....: 300-399
Distributers.....: 400
Centers.....: 600-699

The fields in this file are:

Code: This field lists the specific codes found in the other files.

E1 through E20: These fields are each 65 characters long. There are a maximum of 20 lines. These fields contain text, addresses, and other details.

Instrument codes are not included into the CODES file although the range 100-199 is allocated for them. The instrument code field was opened for future applications and is not used presently. Between 200 to 299, the name of each radiopharmaceutical is given in full detail. Between 300-399 studies are explained. For each study, the INDICATION , PROCEDURE and patient PREPARATION are summarized. Code 400 only has the distributers of radiopharmaceuticals in Turkey. Codes between 600 to 699 give the full address and telephone numbers of each center.

3.2 THE USE OF THE DATABASE MANAGEMENT SYSTEM

This section explains how PC-FILE III works, what the main features are, and how it can be expanded for future needs.

As the name "DBMS" implies, PC-FILE III is a database manager. A database manager controls a number of files created by the program. When PC-FILE III is booted, the first question asked is on which drive the databases previously created are, or new databases are to be stored. After answering this question, the databases previously defined will be listed. You are then asked which one you wish to enter. If no file has been created, nothing will be listed on the screen.

Therefore, the first file name entered will be the first database established which then must be defined. The definition of the database is straightforward. There are two questions to be answered: Field name and field length. To define a numeric field a "#" is put at the end of the field name. PC-FILE III will sum data in numeric fields automatically.

The following definitions will be used throughout the remainder of this thesis.

Field: A meaningful piece of information. For example, first name, last name, quantity, etc.

Record: The collection of fields that describes one individual entity in the database. For example, let us suppose that we have a collection of cards on which last name, name, street, city, and telephone fields are defined. Each card defines one record.

Database: The collection of all individual records. Throughout the text the name "file" will be used with database interchangeably.

When the definition of field names and their lengths is complete, the (enter) key is pressed and you leave the definition procedure. At this point, the DBMS will open a header file called filename.HDR in which there are field names and field lengths of the database

defined above. Each time a file is called, the first thing the DBMS does is to load the filename.HDR file following which it returns to the master menu screen, shown below:

```
[F1]  ADD a record.
[F2]  MODify a record
[F3]  DELete a record
[F4]  DISplay a record
[F5]  FINd a record
[F6]  LISt or clone
[F7]  SORt the index
[F8]  EXPort or other utilities
[F9]  Alter a field NAMe
[F10] END or change database
 KEY  Set up the smart keys

Your command:
```

All of the functions in the menu except the last one can be initiated by pressing the related function key between F1 and F10, or by entering the three capital letters of the command shown in the listing above.

3.2.1. Adding a Record

This is used to enter new records to the database. By pressing the F1 key or entering ADD, the DBMS will display the first field name. The user then enters the data for that field. The DBMS will then

display the second field name, and the user enters the related data for it. This continues until data for all fields are entered. After that, the DBMS will list all the data entered again and ask whether they are accurate. If not, a modification facility is available to change any field in the record. After finishing the modification, PC-FILE III again asks whether all the data is accurate. If it is, the record is recorded on the diskette. The same procedure is followed for each succeeding record. To leave this mode, press the (enter) key when PC-FILE III asks for data for the first field of the record. It will returns to the master menu screen. In this mode, if there is repetitive data to be entered, then there are two keys that can be used for duplication: A single quote or a single apostrophy. For PC-FILE III, the maximum number of records is 10000.

3.2.2. Modifying a Record

This mode is used to modify records and can be entered by pressing the F2 key or typing "MOD" and entering it. The DBMS then asks which record you wish to modify and displays:

"KEY or #n,*,+,-,\"

Key is the data in the first field. If the data of the first field of the record to be modified is entered then that record will be listed and you will be asked "Which field to modify". However, usually, it is

difficult to remember the data in the first field of a specific record, especially in large databases, so other ways of finding the record exist. One is to enter the record number. Each record is numbered automatically as it is created. Record numbered 17 can be called by entering #17. The contents of the record will be listed after entering #17 and the DBMS will ask which field you wish to modify. If #17 is not the record that is to be changed then press enter to the question "which field to modify". The screen again displays "KEY or #n,+,-, *,\" . You may then enter a new record number or "+" which shows next record, or "-" which shows preceeding record, or "*" which shows the most recent record worked on, or "\" which shows the last record in the database. A specific record can be easily located and any number of modifications could be made to that record. To leave this mode, press enter when the DBMS asks "KEY or #n,+,-,*,\". The master menu screen will reappear.

3.2.3. Deleting a Record

By pressing the F3 key or typing "DEL" and entering it,the delete mode is entered. The DBMS again asks "KEY or #n,+,-,*,\" and accordingly one of them is chosen. After the sought after record is found, the DBMS will display "Type DELETE, or press (enter)". If that record is the one that you wish to delete, then the word "DELETE" should be typed and entered. In this

case, the record will be deleted and a number of slashes (/) will fill in the data part of that record. If the record found is not the one you wish to delete, then press (enter) and the DBMS will again display "KEY or #n,+,-,*,\" again. This way,the correct record could be found and deleted (or not). If the (enter) key is pressed while the DBMS waits for an answer to "KEY or #n,+,-,\" then that mode is left and the master menu screen will be displayed.

3.2.4. Displaying a Record

This mode is initialized by pressing the F4 key or entering "DIS" to the DBMS. After initialization, the question:

"KEY or #n,+,-,*,\"

will appear, again. By typing the record number or +,-,*,\, the sought after record is found. If hard copies of a record is desired in the same format as shown on the screen, then they could be obtained by pressing the Shift and PrtSc keys on the keyboard. Pressing (enter) will cause the DBMS to leave this mode and return to the master menu screen.

3.2.5 Finding a Record

This mode is very useful for searching records. The DBMS is capable of finding records containing a specific piece of information specified by

the operator. The "find" mode is initialized by pressing the F5 key or typing "FIN" and entering it. The DBMS displays the message:

"xxx(scan full field ?xxx(soundex)" and asks "Look for:----------"

The data to be searched for should be entered. A special feature of PC-FILE III is that the data to be entered need not necessarily be typed in fully, just enough characters that uniquely identifies it is sufficient. This feature is valid for all modes of the DBMS, thus making typing shorter. There are two additional ways to search records apart from simply entering data. The first is to enter the data with a ">" preceeding it. Then all the records containing that piece of information anywhere in the field will be returned.

For example, if ">mit" is entered then all records containing "Smith", or "transmit", etc. will be found.

A second method is to enter the data with a "?" preceeding it. Then all the records with a field sounding like the data entered will be returned. For example, if "?Andresen" is entered then all records containing "Anderson", "Andersen", "Andrews", etc. will be returned. This is a very powerful method of searching records.

After the DBMS completes its search, it begins to list all the records containing the data entered. After it displays one record, it displays the message:

"S to stop,or press (enter)"

If "S" is entered then it will stop listing the records and ask "Which field to search for", again. If the (enter) key is pressed, the DBMS will terminate that mode and return to the master menu screen. Otherwise, the search may be continued by giving a field name and then the appropriate data. If the answer to the question "S to stop, or press (enter)" is (enter) then other records containing the data specified will be displayed,and when the last record is displayed, it will ask "Which field to seach for". You then proceed as above.

3.2.6 Listing the Records

This mode is entered by pressing the F6 key or typing "LIS" from the keyboard and entering it. This is the mode used in preparing reports. There are many ways to prepare reports in this mode. In addition, logical and mathematical operations could be performed in preparing them. Moreover new databases from existing ones may be created.

As soon as the mode is initiated, the DBMS looks for report formats created previously and lists them on the screen and asks:

"Which format,or press (enter)"

In our version of PC-FILE III, there are a few pre-prepared formats which will be described later. If one of these is to be used in preparing a report,then simply the name of that format should be entered. If not, then the (enter) key should be pressed. If the enter key is pressed then all the field names in the database will be shown and the prompt "Column=0 Field to list " will appear. Then the field that should be in column 0 should be chosen and typed. Again, there is no need to type the whole name but just enough characters to identify it uniquely. After entering the first field name, again the prompt "Column=0 Field to list" will appear. And another field is entered, etc. When all the fields that you wish to appear in the report are chosen, press the (enter) key to terminate the selection of fields. All fields selected will be listed side by side on the output report, separated by one space. If extra spaces between the fields are required, there are two ways to accomplish this. The first is by using ">nn". If, for example, ">5" is entered when asked for the "Field to list", then there will be five spaces between the field entered before ">5" and the one that will be entered after ">5". The second is by using tabbing i.e. "=nn". If, for example, "=50" is entered when asked for the "Field to List", then the next field to be entered will be listed starting at column 50.

Another facility available with PC-FILE III is the backspace i.e. "<" facility. If a backspace is entered when the "Field to List" prompt appears then the one space between two fields will be removed and both will be printed on the output report side-by-side.

If the relative record numbers are also required to appear on the report then "*" should be entered when the "Field to List" prompt is displayed.

If a "/" is entered then a carriage return and line feed will occur and fields will be listed line-by-line on the output report. This is very useful if mailing labels are to be printed.

If some constant value is required to be on the output report, then it should be entered in double quotes when the "Field to List" prompt appears on the display. This might be useful in putting remarks on the report.

Another important facility is that calculations between fields can be performed and the output can be printed to the output report with a new heading. Only addition, subtraction, multiplication and division (+,-,*,/) is allowed as the mathematical operators. For example, when

(fieldname*fieldname)Heading:11.dd

is entered when the "Field to List" appears, the two fieldnames entered above will be multiplied and the

result listed under the heading given by the operator. "ll" is the total width of the output column and should include all digits plus the "-" sign and the decimal point, "dd" is the number of digits that you wish appear to the right of the decimal point. There is one limitation in constructing the formula, that is, only one right and one left parantheses can be used. In other words, nested calculations cannot be done, and all calculations will be executed from left to right sequence. These features allow nicely organised output reports to be prepared.

After finishing the "Field to List" part of the "LIS" mode, PC-FILE III asks the " Title of the report". If a title is entered at this point, then it will be saved with the report format. But if the title might change with different applications, then the (enter) key should be pressed. In this case, the same question will be asked when another report is prepared with the same format. Next PC-FILE III will ask "Save this report format?". If the reply is "Y" then it will ask for a name and save it under this name. This is the report format PC-FILE III lists when the F6 key is pressed or "LIS" is typed and entered to initialize the list mode. By choosing one of the report formats created for repeated use, there is no need to repeat all of the above steps. If the report will be used only once then there is no need to save it and the answer to the question "Save this report format" should

be "N".

There are a few characters that can be put in front of the title of the output record. They are the following:

"ØH" : If "ØH" is entered (with no quotes and uppercase) then there will be no title nor heading lines to be printed.

(Note: Ø is numeral zero, not the character O)

"ØD" : If "ØD" is entered followed by the title then no detail lines will be printed on the report.

"ØT" : If "ØT" is entered followed by the title then no totals will be printed at the end of the report.

"ØC" : If "ØC" is entered followed by the title then the computer will pause at the bottom of each printed page and give the operator a chance to change paper.

"1H" : If "1H" is entered followed by the title, then only one title line and one heading line will be printed. This is used when printing a report which uses multiple print lines for each record and the operator wishes to only have the first multiple heading lines print at the top of each page.These options can also be

used in combination. For example, "0H0T" will cause only data lines (no headings or totals) to be printed.

After saving (or not saving) the report format, PC-FILE III will ask whether to "List on Printer, Screen, or Disc (P,S,D)". One of these should be chosen. If "P" is chosen, then PC-FILE III will ask "Shall I print an alignment pattern?". This is to check whether the printer is working correctly. If everything is connected correctly then a pattern of X's will be printed (one line only) provided the answer is "Y". If everything is okay then answer "N".

Next,it lists all the fields again and asks:

"Field to trigger subtotals,or "

"press (enter) for no subtotals"

This only applies for numeric fields. If a field name is entered then subtotals will be printed whenever the named field changes in value. If (enter) is pressed then no subtotals will be printed. Finally, PC-FILE III asks

"List all records or selected records (A or S)"

If the answer is "A" then all the records will be printed. If only some of the records i.e. selected records are to be printed then the answer should be "S". In this case,there are facilities to retrieve the required information by using logical operators. First it asks:

"Field to select on:"

After selecting the field, it asks: "Compare how? >,<,=,<>". The field selected will later be compared to some value which will be entered as the next step. Here one of the logical operators is selected. And it then asks "Compared to value:". The value to be compared is entered. Until now one field was selected and compared to some value. If multiple comparisons are necessary, then it asks "And, Or, or End". If "A" (i.e. And) is chosen and in a similar manner the second field to be compared to some value is entered, then all records satisfying both comparisons will be printed in the record.

When the selection is finished "E" (for End) should be entered and all the records satisfying the list of logical operations will appear on the output record. A maximum of 10 And/Or comparisons can be made, and all the logical operations are made from left to right sequence.

The same procedure applies for the "S" (i.e. the screen) mode. Detailed examples of how to prepare and print reports will be explained later and sample reports can be found in the appendix.

The disk, "D", option is used for cloning a new database or preparing labels or reports and saving them on the diskette. Preparing labels and reports are almost the same, except that you do not print the headers, etc. by choosing an appropriate ØH, ØT, ØC,

ØD, 1H combination in the title of the report. Cloning is a different procedure and is mainly used to create an entirely new database from an existing one. The procedure is as follows:

After entering the "LIS" mode and choosing the field names to be listed as described above, without saving the report format, the "D" option should be chosen when asked "List on Printer, Sreen, or Disk (P,S,D). Then the question "Clone, labels, or report " will appear. The answer should be "C". PC-FILE III will ask if you wish to "Change any field lengths? "If there are fields whose length you wish to change it should be done at this point. It then asks on which disk drive you wish the new database to be recorded. The answer should be chosen accordingly.It will then ask the operator to specify a name for the new database. The name given should be different from others in the same drive. If the name given is the same as one of the existing files in the same drive then the older one will be destroyed.

The last question it asks is "List all records or selected records". This should be answered appropriately as before. PC-FILE III wii then create the new database, i.e. create newfile.HDR and newfile.DTA files. In addition newfile.INX, is created by sorting the new database. After that, it will return to the master menu screen, staying in the original database.

If the new database contains names that should be altered then the "NAM" command which will be discussed later may be used.

3.2.7. Sorting the Database Index

This mode is used in order that output reports be printed in a specific sequence. It is entered by pressing the F7 key or typing "SOR" and entering it. PC-FILE III will load a special sort program into the computer, print out all the fieldnames and ask:

"Sort field #1"

At the same time, it will ask: "Ascending or Descending (A or D)". One of them should be chosen and the same procedure continues until the (enter) key is pressed when asked "Sort field #n".A maximum of 10 fields can be sorted at a time. Optionally, a field name followed by an offset,and then followed by a lenght can be entered. For example, PC-FILE III will sort "Name,1,6" on the first six characters, rather than "Name" which sorts the entire fieldlength. This type of sorting is much faster than sorting on the entire field.

After leaving the identification procedure, PC-FILE III will ask which drive you wish to select as the work drive. There, an empty work drive should be specified. Also, to help speed the sort, it is best to make the work drive different from the database data-drive.

3.2.8. Using the Utilities

There are other utilities provided with PC-FILE III. They are copying, renaming, deleting, exporting or merging databases. To get to the Utilities menu, either F8 should be pressed or "EXP" should be typed and entered. The utilities menu is then displayed on the screen and the appropriate utility should be chosen. Users familiar with IBM PC-DOS may also perform these functions from the DOS environment.

3.2.9. Altering a Field Name

Field names may be changed at any time by pressing the F9 key or typing "NAM" and entering it. A list of all the field names will be displayed and PC-FILE III will ask

"Which field name to change:"

After the name is chosen, the prompt "Enter the new name" appears and the new name is entered. The same procedure is followed for other fields. By pressing (enter) when "Which name to change" is asked, PC-FILE III will return to the master menu screen.

3.2.10. Ending the Program/Changing to a New Database

To end the program and return to the DOS operating system or to change to a different database

F10 should be pressed or "End" should be typed and entered. PC-FILE III will ask:

"Quit,Change File,or Resume (Q,C,R)":

To end the program, "Q" should be entered. To process a different database, "C" should be entered. "R" is provided to return to the current database. If F10 is pressed by mistake then PC-FILE III can be made to return to the working file by entering "R".

3.2.11. Setting up the "Smart" Keys

The keys "0 to 9" can be preloaded with data and/or commands. When they have been set up with data or commands, they can be executed by pressing the "Alt" key and the appropriate number key. To enter this mode "KEY" is typed and entered. After entering the KEY mode, the status of all smart keys will be displayed and PC-FILE III will ask

"Which key to set up?".

The desired number key is pressed and entered at this point. PC-FILE III will then prompt the operator to enter data for that key. After entering the data the same question "Which key to set up" is displayed and other keys may be set up in the same way described above. If (enter) is pressed when asked "Which key to set up", then PC-FILE III will leave this mode and return to the master menu screen. The data can be up to 75 characters long. Pressing the (enter) key can be simulated by a slash (/) in the data of a smart key.

For example:

DIS/#15//

means go to the DISplay mode and display fiftienth record of that file and return back to the master menu screen.

Finally, the specifications of the database are:

Minimum Ram memory required.....96K

Minimum Disk drives required.....1

Minimum Disk storage.....160K

Maximum drives supported.....8

Maximum field lenght.....65

25 if 40-character display screen

25 if more than 21 fields in the database

Maximum field name lenght.....12

Maximum fields per database

For 80-character display.....41

For 40-character display.....21

Maximum record lenght.....1430

Maximum records per database.....9999

Maximum number of sort control fields.....10

Maximum number of compares for print record selection.....10

Maximum number of calculated fields in report..20

As you can see from the above, the Nuclear Medicine System can be expanded very easily to meet future needs.

3.3 PREPARING REPORTS

From a users perspective, this is the most valuable feature of the database. It is possible to prepare output reports of the users design. A sample report was prepared and included in Appendix B. This report is a highly detailed one and its preparation is described below. The aim was to prepare a report on liver scintigraphy. The details required were to:

1)List specifications about the test including an explanation of liver scintigraphy;

2)List all centers in Istanbul where liver studies are performed;

3)Learn the names of the physicians of one specific center in Istanbul listed in (2) above in order to obtain up-to-date practical information about the study; and,

4)Obtain the address and telephone numbers of this center.

Characteristics of studies were obtained from the "ORGAN" file. The file can be entered by pressing F6 or typing "LIS" followed by (enter) to enter to the "LIST" mode. The first question that appears is "Which format, or press (enter)" (see page 77). Press (enter). All the fields are now available and the fields that you wish appear on the output report can be chosen. (See page 77). In the sample report, organ_name, radiopharma, dose, route_of_adm, and time_of_adm were

selected. After finishing the selection the (enter) key is pressed. At this point,"Title of the report" is asked. Here any title can be entered. In the sample report the title "ØTCHARACTERISTICS OF LIVER STUDY" was entered (See page 78). The next question is "Save this report format?". Since this report is a sample one and will not be used frequently, it was answered "N".(see page 78). But if a report is important and will be used frequently, then "Y" should be entered. In this case, "Name for this format" will be asked and an appropriate name should be entered under which the report format will be stored. This is the name which is then entered when "Which format, or press enter" appears when the F6 key is pressed from the master menu screen. Next, the question "List on Printer, Screen, or Disk (P, S, D)"is displayed. Since we wanted the report in printed form, "P" was entered. The printer should be ON when "P" is entered (see page 79). If the printer is ON and is set up correctly the answer for "Shall I print an alignment pattern" should be "N" (see page 79). And then the question "Field to trigger subtotals, or press (enter) for no subtotals" should be answered (see page 80). Since in our report, there were no fields to total, the (enter) key was pressed. After that "List All records or Selected records (A or S) is displayed. Since the aim was to obtain only information about liver studies "S" was entered (see page 80).When "S" is selected, all field names were shown again and "Field to select on" was displayed (see page 81). In this sample report,

"study name" was selected. For the question "Compare how >,<,=,<>" (see page 81) "=" was entered. "Compared to value" was asked next and "liver scintigraphy" was entered (see page 82). For each of the responses, there is no need to type the entire name. Entering only enough characters to uniquely identify the name is sufficient. Therefore "liver" or even "liv" would be enough to identify "liver scintigraphy". The last question asked is "And, Or, or End". Since there was no other field to select, the answer was "E" (see page 82). This completed the first part of the report and as soon as "E" was entered the report was printed. Notice that,in the beginning of the title of the report, there is "ØT" and then the title. "ØT" was specially entered there in order to prevent totals to be printed at the end of the report.

The next part of the report was to print an explaination of what the study was used for, what the procedure was, etc. Since this information existed in the "CODES" file, we left the "ORGAN" file and entered the "CODES" file using the F10 key while viewing the master menu screen. Before doing this, the "study code" was obtained by using the "DIS" or "FIN" mode in the "ORGAN" file. After that we have to go to the "CODES" file and press the F6 key. We are again in the "LIS" mode. Here fields E1 to E20 are chosen. Between each field a slash (/) was entered to print data line-by-line. However, there is no need to prepare the report

format from the beginning. There is a ready-to-use format called "TEXT" in the diskette. Therefore, entering "TEXT", when "Which format, or press (enter)" is asked, PC-FILE III will do all the preparatory work. Since we wanted neither the titles nor totals to be printed, we entered "ØHØT" to the "Title of the report" question. The remaining procedure was the same as the previous one except that the field "code" was chosen and the appropriate "study code" was entered to print the explaination of the study.

In the third part of the sample report, we printed all the centers in Istanbul where liver studies were performed. This part of the report can be prepared from the "INSTRUMT" file. We left the "CODES" file and entered the "INSTRUMT" file, and pressed F6. Within the fields we chose "instr name", "center" and "city". From the first field it was possible to learn which instruments a center had available to use in liver studies. The title of the report was chosen "ØTLIVER STUDIES IN CENTERS OF ISTANBUL", and in the last part "study" was chosen for the "Field to select on" question. On the printout, we saw that there were many centers performing liver studies and we chose "Cerrahpasa Tip Fakultesi" as a sample. To obtain the names of the physicians working there, we entered the "STAFF" file. We chose "title", "name", "last name" as the fields to appear in the printout. The rest was similar to the previous set up except the last part.

Since, physicians were classified according to their degrees and since we wanted to have all physicians on the output report, we had to choose professors (prof), assistant professors (doc. dr.), and doctors (dr.) from the records.In order to do that, we first selected "title" as the "Field to select on", and compared with "prof". Then, we entered "O" (Or) and selected "title" again as the "Field to select on:" and compared with "doc.dr". After selecting "O" (Or), we again selected "title" and this time compared with "dr.". Finally we entered "A" (And) and selected "center" as the "Field to select on" and compared with "Cerrahpasa Tip Fakultesi". Finally, "E" was entered to indicate we had finished preparing the report. Printing the report started after the return was pressed. All the professors, assistant professors, and doctors were "Or"ed , i.e logically selected from the records and in the last operation only the staff (here physicians) working in "Cerrahpasa Tip Fakultesi" was printed out.

The final part of the report was to obtain the address and telephone numbers of this center. For this purpose, we again entered into the "CODES" file by pressing the F10 key, thus leaving the "STAFF" file. Before passing to the "CODES" file, we looked at the "center code" using the "DIS" or "FIN" facility of PC-FILE III and then passed to the "CODES" file. We again used the report format "TEXT" and in the last part, gave the "center code" to have the address and

telephone number(s) of this center printed. This completed the sample report.

As seen from above, the report was a very detailed one. We used four files out of the five available and it took about 20 minutes to prepare. But it shows how flexible PC-FILE III is in preparing reports.

There is even an easier way to prepare reports by the use of programmable "smart keys". In Appendix B, a list of smart keys to quickly prepare reports, and examples of short,simple reports are shown. To initiate a smart key, pressing only the "Alt key" and the appropriate "number key" is sufficient.

ORGG	STAF	INST1	INST2	ISOT
CODDEN	KOKO	KO	A	B
C	KODD	REPORT1	REPO	REPO2
REPO3	REPO4			

Which format, or Press [ENTER]:

---

study
study code
organ name
radiopharma
radioph code
dose
route of adm
time of adm .
quantization
comp process
light apertu
spectro set
bckgnd erase
contrast

Column= 0. Field to List, or action:

```
study
study code
organ name   B 1
radiopharma  B 2
radioph code
dose         B 3
route of admB 4
time of adm  B 5
quantization
comp process
light apertu
spectro set
bckgnd erase
contrast
```

Title of Report:
OTCHARACTERISTICS OF LIVER STUDY

```
study
study code
organ name   B 1
radiopharma  B 2
radioph code
dose         B 3
route of admB 4
time of adm  B 5
quantization
comp process
light apertu
spectro set
bckgnd erase
contrast
```

Save this report format?N

```
study
study code
organ name      B 1
radiopharma     B 2
radioph code
dose            B 3
route of admB 4
time of admn    B 5
quantization
comp process
light apertu
spectro set
bckgnd erase
contrast
```

List on Printer,Screen,or Disk(P,S,D):P

Please setup your printer.
Shall I print an alignment pattern?N

```
study
study code
organ name
radiopharma
radioph code
dose
route of adm
time of adm
quantization
comp process
light apertu
spectro set
bckgnd erase
contrast



Field to trigger subtotals, or
press [Enter] for no subtotals:
```

```
study
study code
organ name
radiopharma
radioph code
dose
route of adm
time of adm
quantization
comp process
light apertu
spectro set
bckgnd erase
contrast



List All records or Selected (A or S):S
```

study
study code
organ name
radiopharma
radioph code
dose
route of adm
time of adm
quantization
comp process
light apertu
spectro set
bckgnd erase
contrast

1. Field to Select on:study

---

study B
study code
organ name
radiopharma
radioph code
dose
route of adm
time of adm
quantization
comp process
light apertu
spectro set
bckgnd erase
contrast

Compare how? >,<,=,<> =

```
study       B
study code
organ name
radiopharma
radioph code
dose
route of adm
time of adm
quantization
comp process
light apertu
spectro set
bckgnd erase
contrast


Compared to value:( )xxx permitted )
liver scintigraphy
```

```
study       B
study code
organ name
radiopharma
radioph code
dose
route of adm
time of adm
quantization
comp process
light apertu
spectro set
bckgnd erase
contrast


And, Or, or End (A,O,E):E
```

IV. DISCUSSION

The purpose of this thesis was to construct a unique databank related to nuclear medicine activities in Istanbul. The most attractive part of this work is the fact that all the data in the files created is real. I visited each of the six Nuclear Medicine centers and The Cekmece Nuclear Search and Education Center in Istanbul. I collected the information according to a prepared plan, organized it, and put them into the five files created defined in the design of the DBMS section of this thesis. Users can easily manage these files via the utilities provided by PC-FILE III.

Although PC-FILE III is a very flexible database management system and can easily be used, it has one major disadvantage. It can not link between the five files created, automatically. For example, it is not possible to get information about a specific study available in the "CODES" file from the "ORGAN" file. In order to obtain this information, the "ORGAN" file must be left and the "CODES" file called. The data is then retrieved by giving the study code after calling the "LIS" or "DIS" command or using one of the smart keys available for that purpose. Nevertheless, despite this one disadvantage, the system is easy to use and even non-computer oriented personnel can use it without

difficulty after some practice.

Because the databases contain information about nuclear medicine centers, staff, studies, and radiopharmaceuticals in Istanbul, it is certain that it will be widely applied.

There is an important point about the database that should be considered. The system is not complete. Some fields are empty and need to be filled in when reliable information can be obtained. Because of different institutional policies it was not possible to get information about some subjects in the depth needed Although there is no information in these fields, they were still defined and included in the files because of their importance. They can be completed later.

The next important step should be to expand this system and make it usable nationwide, by adding information about all other nuclear medicine centers available in Turkey. A simple example of how important such a database for Turkey is that there are health care facilities (including those not having nuclear medicine capability) ranging from very small to very large. Some of them are state hospitals and some are private centers. Not all of them have the facility to utilize nuclear medicine techniques because of the expense in establishing such centers. Only nine out of 67 cities in Turkey have nuclear medicine centers and

not all of them have the capacity to do every nuclear medicine study. For example, SPECT (Single Photon Emission Computed Tomography) studies can only be performed in one center in Turkey; in "Cerrahpasa Tip Fakultesi- Istanbul", and there is only one machine there to do this type of work. Because of the limited resources in Turkey, they must be used as efficiently as possible.

Istanbul and Ankara have the most and therefore offer the opportunity for the most comprehensive studies. This is not the case for the eastern part of Turkey. As an example, let us take a city where there is no nuclear medicine center and does not have facilities for a physician to meet his patient's need using classical methods. He may decide to send his patient to another center having appropriate facilities. Usually the physician sends his patients to Istanbul or Ankara since they think that the problem can be best solved in those cities. But a high percentage of the physicians may not follow the rapid developments taking place in Turkey and thus sending patients from the east to the west is expensive and causes a great deal of time to be wasted, if a closer center meeting the physician's and patient's needs is available. A simple phone call can provide valuable information within minutes. Thus with a few minutes work many thousand liras and a lot of time could be saved. The latest up-to-date and reliable

information can be obtained quickly and easily.

Another advantage of such a system is that the staff of one institution can contact the staff available in other Nuclear Medicine centers. This is accomplished by using the "STAFF" file. Full addresses and telephone numbers are found in the "CODES" file. Thus it is possible to get useful information, quickly.

The system is also suitable for expansion (see Appendix D). By using the "ADD" command, new records can be added to the system. (See Adding a record in page 55). The problem is who to assign the responsibility for maintaining the up-to-date database. Having just one center for such an application seems to be the best alternative. Changes or additions could easily be made by authorized personnel of this center. In this way the control of the database is centralized assuring the quality and integrity of the data. If everybody has access to data entry, then mistakes could easily destroy the integrity of the database. Control should be centralized and one center should assume the responsibility of maintaining the database.

Finally, the database is valuable for potential purchasers of nuclear medicine devices. A potential buyer may check whether the instrument to be bought exists in other centers in the same city. If exists, he may decide to choose another device which

will provide an alternative means of diagnosis. This may not always be the case, especially for the hospitals in Istanbul and Ankara, but at least they will be aware of the resources of other institutions. This use of the database will be most useful for centers in the eastern part of Turkey where nuclear medicine imaging devices are rather limited and thus cooperation between hospitals with limited resources is important.

V. CONCLUSION

Until recently, the importance of the concept of centralization of information resources in one organization was not grasped very well. It may have been due to the lack of computer technology wherein it was not possible to construct large databanks. But, today, it is possible and more than that, it is necessary. This concept applies not only to nuclear medicine but also to many other fields. It is a necessity because the technological developments in every field are taking place so fast that with conventional methods, it is not possible to keep technologically up-to-date. Moreover people do not want to waste valuable time searching for information using time-consuming conventional methods. Therefore establishing of databases like the one described in this thesis is very important for developping countries such as Turkey. Examples outside the technology fields include, birth certificates, police records, poison control, etc. It is no longer necessary to handle vast amounts of data using time-consuming traditional paper methods. This is especially true for overpopulated countries, like Turkey where the amount of paper generated is vast. The implications of using this approach for developping countries is vast.

I hope that this thesis, in some small way,

helps demonstrate the value of this approach, not only in Nuclear Medicine but also in other very quickly developing disciplines.

APPENDIX A

ABBREVIATIONS:

PC-FILE III	: The name of the database manager program.
DBMS	: DataBase Management System.
PMT	: PhotoMultiplier Tube.
PHA	: Pulse Height Analyser.
FWHM	: Full Width at Half Maximum.
CRT	: Cathode Ray Tube.
ECT	: Emission Computed Tomography.
SPECT	: Single Photon Emission Computed Tomography.
PET	: Positron Emission Tomography.

APPENDIX B

A VERY DETAILED, COMPLEX SAMPLE REPORT:

CHARACTERISTICS OF LIVER STUDY

04-17-1985 AT 15:05

organ name	radiopharma	dose	route of adm	time of adm
liver	tc s-colloid	1 to 5 mCi	intravenous	15 min prior to scannin

*****LIVER SCINTIGRAPHY*****

INDICATIONS:Evaluation of a liver scan should include:
1)The size,shape and position of the liver and spleen.
2)The homogeneity of activity within the organ,
3)The presence of any focal defects in activity,and
4)The relative distribution of colloid among the liver,spleen and bone marrow.

PROCEDURE:Adequate accumulation of Tc99m-S colloid for imaging the liver takes about 10 mins.After that,multiple rapid-sequence images at a rate of 1 image every 2 to 3 seconds for 30 to 60 seconds are taken.Thus an abdominal perfusion study may be obtained during the initial pass of the injected bolus of the radiopharmaceutical through the abdomen.

PREPARATION:None.

LIVER STUDIES IN CENTERS IN ISTANBUL

04-17-1985 AT 14:35

instr name	center
cgr acticamera 3400 series gammatom	cerrahpasa tip fakultesi
ohio-nuclear series100 gamma camera	capa tip fakultesi
siemens scintimat 2 rectilinearscan	capa tip fakultesi
siemens gamma camera	okmeydani ssk
pho-gamma 4 camera nuclear chicago	cerrahpasa tip fakultesi
gamma camera pho-gamma.5 siemens	nukleer tip merkezi
large-field maxicamera general elec	buyuk laboratuar

ALL PHYSICIANS IN CERRAHPASA TIP FAK.
04-17-1985 AT 14:41 Page 1

title	name	last name
prof. dr.	husrev	hatemi
dr.	ilhami	uslu
prof. dr.	irfan	urgancioglu
dr.	mari	benli
prof. dr.	tarik	kapicioglu
prof. dr.	vessam	seyyahi

CERRAHPASA TIP FAKULTESI

Address: Istanbul Universitesi,Cerrahpasa Tip Fakultesi
CERRAHPASA-ISTANBUL

Telephones: 524.19.69 ....Santral
525.74.69 ....Nuclear Tip Enstitusu

APPENDIX C

READY-TO-USE SMART KEYS AND SOME SAMPLE REPORTS PREPARED WITH THEM:

Some smart keys in the following files have been programmed in order to prepare frequently-used reports easily and quickly. In all the files, "Key 0" was loaded with data to change files, i.e. pressing "Alt-0" will automatically leave the current file and the program will return to the beginning, asking for the drive of the new file.

Similarly, "Key 9" was loaded with data to terminate the PC-FILE III program, i.e when "Alt-9" is pressed while being in the master menu screen, PC-FILE III will terminate and return to the DOS environment.

The keys programmed are:

In the STAFF, ISOTOP, and ORGAN files:

0 : end/c/ .....To change file.

9 : end/q/ .....To end PC-FILE III

In the INSTRUMT file:

0 : end/c/ .....To change file.
6 : lis/study/p/n/0T ....These two keys are used to
7 : //s/study/=/ find centers performing a specific study.
9 : end/q/ .....To end PC-FILE III.

In the CODES file:

0 : end/c/ .....To change file.
1 : lis/text/r/p/n/0H0T//s/code/=/
To print explanations.
6 : lis//e1///n/p/n/0H0T//s/code/=/
To print the extended name of a radiopharmaceutical.
7 : lis/address/r/p/n/0H0T//s/code/=/
To print the address of a center.
9 : end/q/ .....To end PC-file III.

It is possible to prepare reports quickly using these keys. For example, we can prepare some parts of the report in Appendix B quickly using these keys:

To find which centers perform liver studies, we simply press "Alt-6" in the INSTRUMT file and all the preparatory work will be done by the program and it

will ask a title for the report. After entering the title, we press "Alt-7" and all the remaining questions will be answered by the program. It is then necessary to only enter the study name, i.e "liver scintigraphy" or just "liver", and answer the last question "And, Or or End A/O/or E" as E.

Similarly, the explaination regarding liver studies can be printed easily by pressing "Alt-1" in the CODES file, entering the study code and then "E".

In order to print the extended name of a radiopharmaceutical, pressing "Alt-6", entering the radiopharmaceutical code and then "E" in the CODES file is all that is necessary.

In order to print the address of a center press "Alt-7" and enter the center code and then "E" in the CODES file.

In the last part of this appendix, a sample report has been prepared using keys six and seven to find which centers can perform thyroid scintigraphy. The procedure is as above and all of it took less than two minutes to prepare. The report is in the following page.

CENTERS PERFORMING THYROID SCINTIGRAP

-16-1985 AT 13:38 Page

str name	center	city
io-nuclear series100 gamma camera	capa tip fakultesi	Istanbul
lo scintigraphy superscanner ds8	okmeydani ssk	Istanbul
ctilinear scanner nuclear chicago	cerrahpasa tip fakultesi	Istanbul
mma camera pho-gamma 5 siemens	nukleer tip merkezi	Istanbul
rge-field maxicamera general elec	buyuk laboratuar	Istanbul
o-gamma 4 camera nuclear chicago	Istanbul Nukleer Tip Merk	Istanbul

APPENDIX D

EXPANDING THE SYSTEM FOR TURKEY:

Although the thesis deals only with the facilities in Istanbul, it is designed so that it can be expanded to include all facilities throughout Turkey. The system is designed in such a way that no additional programming is necessary. By means of the "ADD" command, new data can be entered.

For these purpose a questionnaire was prepared and sent to all the Nuclear Medicine centers in Turkey. As the results are received the data will be entered. The questionnaire can be found in pages 100, 101, and 102.

TÜRKİYE'DEKİ NÜKLEER TIP MERKEZLERİNİN 1985 YILINDAKİ DURUMU

STAFF (PERSONEL)

Bu bölüme Nükleer Tıp Merkezinizin personeli yazılacaktır. Örneğin bölüm başkanı, diğer yardımcılar, doktorlar, fizikçiler, kimyacılar, var ise elektrik ve diğer mühendisler, ve devamlı çalışan hemşireler. Bilgiler aşağıdaki forma göre doldurulmalıdır.

MERKEZİNİZİN VEYA :
BÖLÜMÜNÜZÜN ADI VE
TAM ADRESİ

TELEFON NUMARALARI :
(Nükleer Tıp Bölümünüzün
ayrı numaraları varsa
belirtin.)

ADI	SOYADI	ÜNVANI	DALI

INSTRUMENTS AND STUDIES (CİHAZLARINIZ VE YAPILAN ÇALIŞMALAR)

Bu kısma merkezinizde bulunan tüm Nükleer Tıp resimleme cihazları, örneğin gamma kameraları, rectilinear tarayıcılar ve ayrıca uptake cihazları eklenecektir. Bundan başka, her bir cihaz ile yapmış olduğunuz çalışmalarıda aşağıdaki forma göre belirtiniz. Formun ilk kısmında alet ile ilgili bir kaç teknik soru sorulmuştur. Bunları aletinizin kataloğundanda bulabilirsiniz. Örneğin resolution, window width (pencere aralığı) ve enerji birbirinden bağımsız değildirler. Burada rezolusyonun hangi enerji ve pencere aralığında ölçüldüğü belirtilmektedir.

INSTRUMENT NAME :
AND MODEL
(Cihazınızın markası ve modeli)

RESOLUTION (mm) :
(Rezolusyon)

WINDOW WIDTH :
(Pencere aralığı)

ENERJİ (keV) :

MAXIMUM COUNT :
RATE
(Aletinizin maksimum sayabilme kapasitesi)

FIELD OF VIEW :
(Cihazınızın gördüğü maksimum alan mm olarak)

WHOLEBODY :
CAPABILITY
(Tüm vücut taraması yapabilirmi. Bir kerede yapamazsa parça parça yapabilirmi? Belirtin.)

FREQUENCY OF :
CALIBRATION
(Kalibrasyon zamanları yılda)

MACHINE COST :
(Aletinizin alış değeri.)

NO. OF PATIENTS :
(Bu cihazla günde

Çalışmalarınızdaki radyoizotopları nereden temin ediyorsunuz ? :

Çeşitli radyofarmasötikler elde etmek için kullanılan kitleri nereden temin ediyorsunuz ? :

Servis ve bakım problemleriniz var mı ? : Evet -- Hayır --

Aletlerinizde ariza olduğu zaman servisi hemen yapılabiliyormu ? : Evet -- Hayır --

Aletlerinizin servisini kimler yapıyor ? :

Yıllık ortalama bakım maşraflarınız nedir ? :

Yapılan servislerden memnunmusunuz : Evet -- Hayır --

Koruyucu bakım yaptırıyormusunuz : Evet -- Hayır --

Kalibrasyonları nerede yaptırıyorsunuz ? :

Bundan sonraki sorular her bir alet ile yapılan çalışmalar ile ilgilidir. Her alet için ayrı ayrı cevaplandırılması gerekir.

ALETİN ADI	YAPILAN ÇALIŞMA	KULLANILAN RADYOFARMASÖT

REFERENCES

1) Essentials of Nuclear Medicine Imaging
by Fred A. Mettler, and Milton J. Guiberteau.
1983 by Grune & Stratton, Inc.

2) Imaging for Medicine, Volume 1
by Sol Nudelman and Dennis D. Patton.
1980 Plenum Press

3) IEEE Medical Electronics Monographs 28-33
Medical Imaging Techniques by B.W.Watson
1979 Peter Peregrinus Ltd.

4) Mediko'84 Tip Dergisi
1984 Sayi 2

5) PC-FILE III user's manual
by Jim Button
1984 Buttonware and Microsoft Corporation

6) IBM PC users' guide
by International Business Machines.