A Nuclear Medicine Information System

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THE UNEVEN DISTRIBUTION of physicians and other health personnel in the United States is a familiar problem and a matter of grave concern (*1,2*). This situation is particularly serious in States having low income and sparse populations, but it also exists in proverty areas of urban centers (*3*).

Federal, State, and local authorities have used a variety of approaches toward uniform distribution of health resources. However, the problem of providing health personnel for rural areas has resisted easy solution. Geographic regionalization of health services (*4*) is a recent approach that has gained limited acceptance. This approach has been adopted by the Veterans Administration as a partial solution to the problem of providing modern health care in its rural hospitals (*5*).

Because of its location and its present affiliation with the St. Louis University School of Medicine and the Washington University School of Medicine and Dentistry (both in St. Louis, Mo.), the St. Louis Veterans Administration Hospital (John J. Cochran Division and Jefferson Barracks) was selected as a core facility in a regionalization program.

The core hospital provides the necessary sophisticated technology and professional services to the non-university-affiliated, primarily rural Veterans Administration hospitals. The rural hospitals benefit from interdigitation with the core facility in improving the quality of care for patients through the ready availability of modern technology and professional medical consultation (*6*).

In concert with the regionalization concept, a plan for a pilot program was developed by the Nuclear Medicine Service of the St. Louis Veterans Administration Hospital and the Section of Nuclear Medicine of St. Louis University to provide nuclear medicine services to patients in outlying Veterans Administration hospitals. This program, funded by the Veterans Administration Exchange of Medical Information Program, is presently being implemented; it is expected to be in full operation by mid-1974.

During the past 5 years the clinical capability of nuclear medicine has expanded, and nuclear medicine has assumed a unique clinical role in the diagnosis and care of patients. Nuclear medicine procedures are noninvasive and nondestructive and particularly suited to screening for disease (*7*). Clinical information provided by nuclear medicine procedures has augmented the diagnostic capability of the physician and has led to the recognition of disease processes early in their development (*8*). The growth and clinical impact of nuclear medicine in the United States is attested to by the availability of these procedures in most urban community hospitals and the recommendation of the Joint Commission on Hospital Accreditation that all hospitals should either have or have access to nuclear medicine facilities (*9,10*). Despite this national growth, nuclear medicine facilities are not available in the outlying Veterans Administration hospitals nor in many of the rural community hospitals throughout the medical district of the St. Louis Veterans Administration Hospital.

To provide high-quality nuclear medicine diagnostic services, it is essential for a nuclear medicine physician to interpret the procedures. A major impediment to establishing nuclear medicine facilities in rural areas has been the lack of suitably trained physicians. The nuclear medicine physician initiates laboratory procedures by selecting appropriate equipment and establishing development procedures, establishes quality control, and interprets results. Ideally, each hospital should have a physician of this type; however, insufficient numbers of these specialists are attracted to nonurban areas.

Nuclear Medicine Information System

The concept of the Nuclear Medicine Information System (NMIS) was developed after planners analyzed the services that a physician would provide and concluded that after a laboratory is established, the area of greatest physician interaction is in the interpretation of scanning procedures. The NMIS will provide services to outlying Veterans Administration hospitals within the context and need of regionalized health care delivery systems. Since information obtained by radionuclide imaging of organs (radioisotope scanning procedures) is ideally suited for computer processing (*11,12*), the NMIS will use existing electronic techniques and computer instrumentation to record, compact, and transmit clinical nuclear medicine data to the core facility for analysis and interpretation.

The system will link the central analysis station (core facility), physically located at the John J. Cochran Division of the St. Louis Veterans Administration Hospital, with peripheral laboratories in the veterans hospitals at the Jefferson Barracks, at Marion, Ill., and at Poplar Bluff, Mo. (fig. 1). In general, the information will be transmitted from the rural hospitals to the core facility and back; no information will be transmitted between peripheral stations. Two-way communication between the central analysis station and the remote hospital laboratory is required, but the major flow of information in terms of volume will be from the peripheral stations to the central analysis station.

The major portion of the NMIS will be devoted to the acquisition and transmission of clinical nuclear medicine data, which include the following information on patients: name, hospital number, social security number, study identification (brain scan, lung scan, and the like), and radionuclide (radioisotope) "images." In vivo, these images represent spatial and temporal distribution of the administered radionuclide; they may be static (obtained after the radioactivity has localized) or dynamic (obtained in rapid sequence during the initial distribution of the radioactivity) (*13–15*).

The peripheral hospitals will be able to perform routine static radionuclide imaging, which allows visualization of most organ systems—especially brain, lung, liver, and thyroid. The capability of imaging other organ systems—such as kidney, spleen, and bone—although less frequently required, will also be available. In addition, the peripheral hospital stations will provide rapid sequential scintiphotography or dynamic imaging procedures, which allow determination of the relative appearance and disappearance times of the radioactivity and the relative functions of organ system regions (*16*). This capability is extremely important because dynamic procedures when complemented with routine static images provide additional diagnostic information and not infrequently establish a diagnosis. Often the dynamic study provides the only evidence of a specific abnormality.

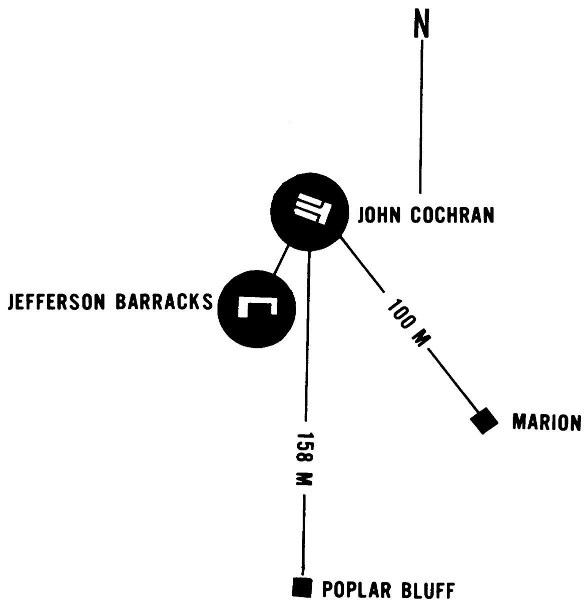
Although the rural hospital will not have a resident nuclear medicine specialist, capabilities as advanced as those in many modern medical centers will be available. Additionally, the system is designed to accommodate new clinical techniques as they are developed, and the fully equipped peripheral nuclear medicine laboratory can be easily converted to "stand alone" capacity so that in the future a nuclear medicine specialist could be recruited at that site.

In vivo non-imaging procedures—for example, thyroid uptakes, blood volumes, Schilling tests, and gastrointestinal blood loss—will be performed at the remote station by a trained technologist. The results of the procedures, pertinent history of the patient, and physical and associated laboratory data will be forwarded to the analysis station for critical review and interpretation. Blood samples for in vitro assay procedures—such as thyroxine, B_{12}, angiotensin, thyroid stimulating hormone, and growth hormone—will be shipped daily by common carrier to a laboratory specializing in these tests at the core facility. Centralization will provide comprehensive quality control and sufficient volume for ready availability of tests that are usually infrequently ordered.

Community Hospital Participation

Non-Veterans Administration community hospitals may participate in the NMIS under sharing agreements negotiated between the community

Figure 1. Geographic distribution of nuclear medicine information system: orginal configuration



hospital and the Veterans Administration. This participation may occur at the following three levels.

1. Local hospitals which have nuclear medicine facilities generally lack the capability for analyzing studies. The proposed system will provide analyses through the use of magnetic tapes recorded in local hospitals and transported to the analysis center.

2. Rural community hospitals desiring full on-site laboratory capability but lacking professional staff will be able to participate as full partners in the network. This participation will require acquisition of necessary computer hardware, described later, and negotiation of sharing agreements with the core facility.

3. Sharing agreements between the peripheral Veterans Administration facilities and local com-

munity hospitals would allow transport of patients to the VA facilities for nuclear medicine procedures.

Design of Imaging System

The NMIS is built around presently existing technical knowledge of data processing, communications, and nuclear medicine. The requirements for capability in dynamic imaging led to the selection of the gamma camera as the primary imaging device for the peripheral laboratories. The gamma camera, a scintillation detection device, is interfaced to the acquisition computer hardware. The distribution of radioactivity throughout a particular organ system is detected by the gamma camera, and the positional information generated by the gamma camera is translated into a specific address in the storage memory of the computer.

Figure 2 is a flow diagram of the NMIS at the remote facility. The gamma camera-computer combination will provide an interactive routine for the technologists at the peripheral stations and, as such, will provide a simple step-by-step prompting program that the technologists must follow before they start the patient's study.

All imaging studies accumulated at the peripheral stations will be prefaced by specific patient identification information, such as name, social security number, hospital number, and so forth. The transmitted information will also include relevant history and results of physical examination to assist the physician at the central analysis station in interpreting the imaging procedure. As the procedures are performed throughout the day at the peripheral hospitals, the images will be stored and then transmitted at a specific time to the analysis center at the core hospital. The data will be transmitted over conventional telephone lines through presently available communications systems. The majority of the data and specific patient files will be transmitted automatically to the central station. In an emergency, however, the laboratory technician at the remote site can gain access to the central station for immediate transmission of studies that require immediate interpretation.

The function of the core analysis station (fig. 3) will be reception and display of the data which have been transmitted from the remote laboratory terminals. The data received will be checked for errors that might have occurred during transmission and will be stored according to patient file and specific peripheral hospital file. The central analysis station (fig. 3) is similar to the peripheral stations except that it will have additional storage capacity for the data files from the peripheral stations, as well as the ability to display the patient information on a cathode ray tube or an oscilloscope for interpretation. After the data are received from the peripheral stations, certain data processing routines will take place at the central station.

Although there may be some minimal loss in radioisotope image resolution following acquisition and transmission, these losses will not interfere with the diagnostic utility of the images since they will be corrected for in the following manner: statistical variation in count rate will be corrected by spatial averaging, nonuniformity of the detector will be corrected by field uniformity correction factors, and data loss secondary to the system's inherent electronic dead time will be corrected by appropriate processing routines.

After the static and dynamic studies are interpreted, the information will be transcribed and the final report prepared on an off-line keyboard machine by the secretarial staff. After the reports have been prepared in computer-readable form, they will be loaded back into the computer at the central station and transmitted to the remote hospitals on a predetermined schedule. The hospitals will then have a printed report on the final interpretation of the patient's procedure. The results of procedures should be available to the referring physician in the early afternoon of the following day for routine procedures and within a matter of minutes for emergency procedures.

Personnel

A primary problem in initiation of the type of program described here is lack of qualified trained personnel in the areas to be served by the communications network. We plan to obviate this difficulty by recruiting and training potential technicians and other personnel from the specific geographic areas of the peripheral stations. It is hoped that the applicants will already be employed as X-ray technicians or medical technologists at the peripheral stations.

Our continuing training program will be designed to produce technologists who can assume the responsibility of the clinical nuclear medicine laboratory in the peripheral facility. The techni-

Figure 2. Remote facility: Technologists at the remote laboratories initiate procedures (START) with the entry of patient and study identification data. This information must be available to the system before the acquisition of image data from the gamma camera. Emergency procedures that are performed will be transmitted immediately to the central analysis station for interpretation (1). All other daily procedures will be compacted, stored, and transmitted sequentially at the end of the workday. Interpreted reports for these studies will be received by the appropriate originating hospital the following afternoon (2).

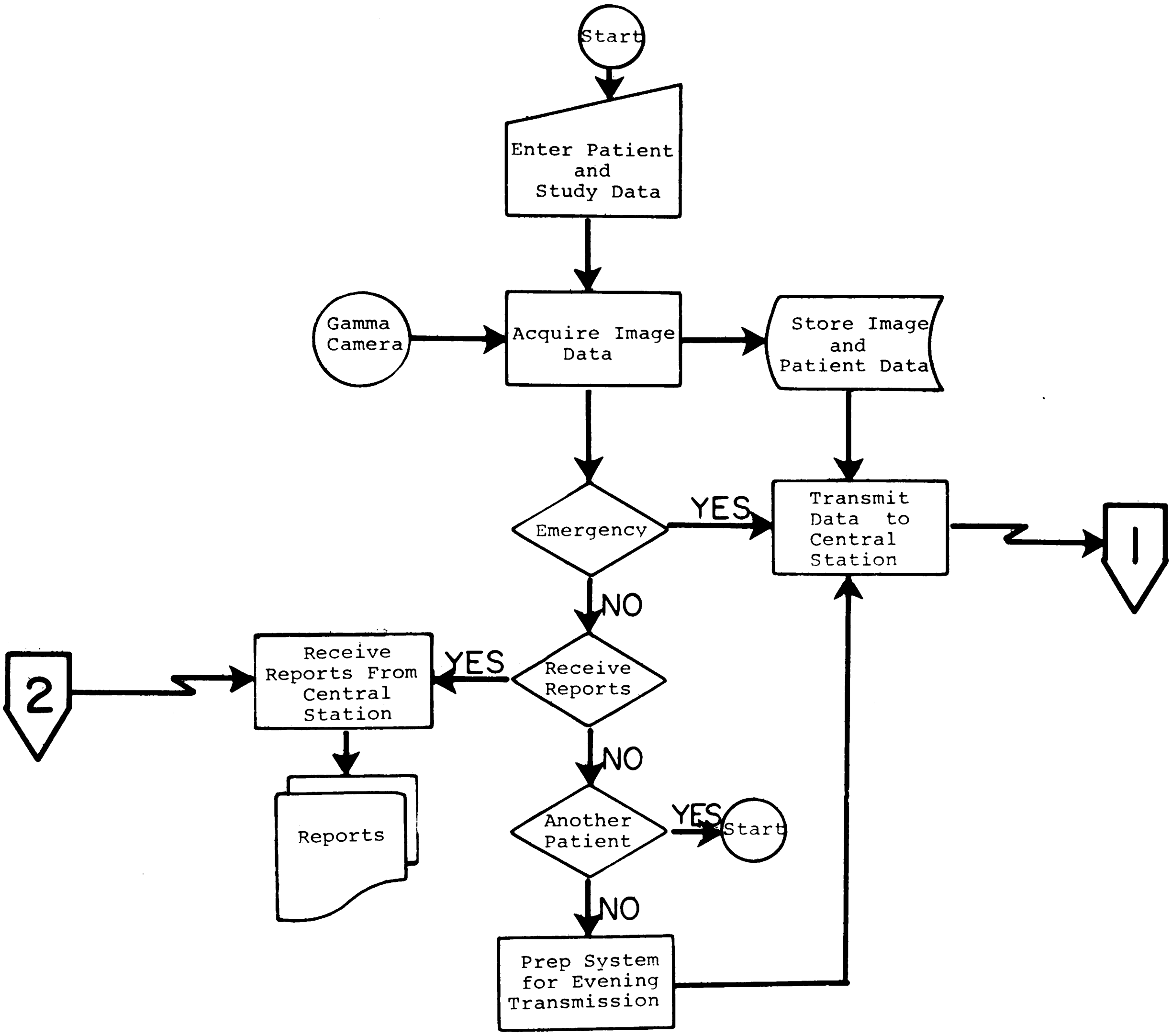
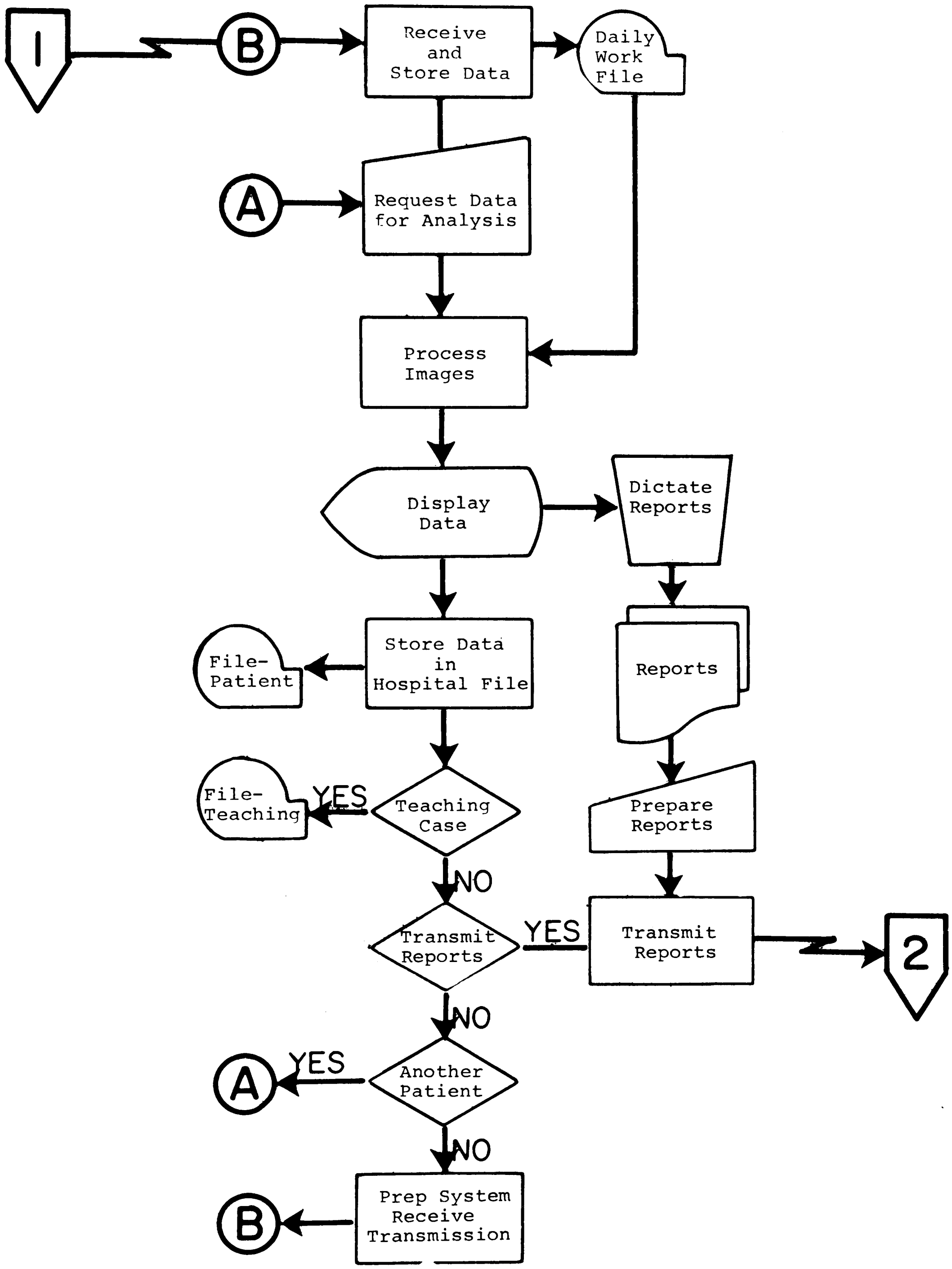


Figure 3. Central analysis station: Clinical data received from the remote laboratories (1B) will be stored as a daily work file and coded for easy retrieval. The system operator at the central station requests selective patient records and image data from the daily file before display and processing (1A). Interpretation of these data by the nuclear medicine physician generates dictated reports that are sent to the proper remote laboratory (2). All patient studies that are examined will be indexed and stored in a history file or teaching file for future reference.



cians will have gained the knowledge necessary to handle minor mechanical problems and to recognize possible radiation hazards and take appropriate action.

The task-oriented training will require little decision making by the technician. The computer components of the system will assist the technicians in setting up all the imaging procedures, and there will be little margin for error. The training program will rely heavily on pratical clinical experience and the gaining of technical proficiency in the diagnostic procedures that the trainee will be required to perform at the peripheral hospital.

Conclusion

The results of this pilot program should provide information concerning nuclear medicine systems to persons interested in the regionalization concept as a method of health care delivery. Plans are presently in progress to evaluate this approach in terms of cost effectiveness, methodology, and the impact of nuclear medicine on care of patients.

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In a plan for developing a Nuclear Medicine Information System, patient data generated and stored in peripheral hospital laboratories can be transmitted to a central analysis facility through a nuclear medicine communications network. A pilot program using this system is presently being implemented by the St. Louis Veterans Administration Hospital and the Section of Nuclear Medicine of St. Louis University under a grant from the Veterans Administration Exchange of Medical Information Program. The need for such a system is dictated by the geographic regionalization of health services and by lack of staff in remote areas who are trained in nuclear medicine.

The system provides for transmission and analysis of proved clinical nuclear medicine procedures as well as the newer aspects of nuclear medicine, particularly dynamic imaging of time-dependent concentrations of radioactivity in organ systems. The system will provide sufficient capability to accommodate new procedures in the foreseeable future without additional expense, and the diagnostic nuclear medicine procedures available and their interpretation will be comparable to those available in urban teaching centers.