# Automated Patient Report-Generation in Nuclear Medicine

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**The proliferation of computer-based office-management systems in the past few years has involved the private physician's office as well as the hospital laboratory. Many radiology departments have already adopted this approach for patient report generation and data storage. Due to the absence of commercially available software, some nuclear medicine departments will be interested in writing their own, but may not have enough experience in nonimaging computer applications to determine the performance needed for a practical system. A report-generation system for scintigraphic studies has been developed in our department over the past 2 yr. During this time an essential hardware/software performance level was established. Ideas for design of program flow that enhance staff acceptance of this concept are presented. Significant reduction of errors in report transcription and billing, together with reduced requirements for secretarial and clerical staff, make a general system like this cost effective.**

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Our nuclear medicine department has five physicians who share responsibility for image interpretation for about 60 studies per day, both in the main laboratory and in the exercise cardiac laboratory 22 floors away. Several logistic difficulties arise in transmitting dictated reports to a central office. They are transcribed, proofread, and perhaps retyped during the work day and occasionally on nights and weekends, distributed to key areas of the hospital, and overall status of the day's work is verified from different areas of the laboratory. Secretarial skill and familiarity with medical terminology may vary, and typing from audio cassettes where the audibility and quality of dictation is inconsistent may be frustrating. Secretarial turnover is often so high that a department spends considerable time training new people to perform these tasks. One goal of computerization has been to avoid these problems while still producing a high-quality, individualized patient report (Fig. 1).

## MATERIALS

Nuclear medicine personnel are familiar with digital computer features and performance requirements for image processing and complex numerical calculations. Systems that centralize the collection, storage, and retrieval of these images for nuclear medicine laboratories have been described (1–3), but the computer hardware requirements for a report-generation system differ considerably from those of computers used for image processing. Experience in the use of a computer for office-management functions was useful to us in selecting and designing an appropriate system. We selected a computer* with fast terminal speed, "static screen" hardware capability, and ability to print reports without forcing the user to wait until printing is finished before proceeding (a feature termed "spooling"). This system application uses a 64-Mbyte disk, a 23-Mbyte diskette magazine, a 256-Kbyte memory, 11 terminals distributed over a wide area of the laboratory, and printers capable of producing letter-quality documents on forms with four carbons (Fig. 2).

The static-screen capability is the single most important hardware feature, since it greatly simplifies user interaction with the computer. Under a static screen, 24 lines of information are displayed, allowing the user to move a cursor at will to different locations on the screen in order to select, add, or modify information. The terminal hardware enables characters to be written only on special areas of the screen, which are displayed with higher intensity to attract the user's attention. With a single keystroke the entire screen contents are read to memory, including both the preprogrammed text and data selected or entered by the user. This design allows information to be compacted into efficient arrays for user selection. Notice in Fig. 5 that a four-dimensional array (bone, left/right, area, and lesion appearance) allows over 2000

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HOSPITAL NAME
NUCLEAR MEDICINE SERVICE

NAME: JONES, WILLIAM  AGE: 64 SEX: M HOSP# 9999999 NM# 11111 ROOM: Y321*
CDX: CHEST PAIN, COPD  REQUESTING PHYSICIAN: DOE, JOHN
DATE: 23 JUL 83  PROCEDURE: LFT VENTR PERFM IMAG-STRESS
HOSP(S/T): S  DATE OF BIRTH: 111618  DATE OF ADMISSION: 072183
PATIENT PREP: 3.5 MG SN-PYROPHOSPHATE IV  RADIONUCLIDE: [TC-99M] PERTECHNETATE

DOSE: 25.8 MCI  ROUTE OF ADMINISTRATION: INTRAVENOUS

CURRENT MEDICATIONS: B-BLOCKER, LONG ACTING NITRATE, CALCIUM CHANNEL BLOCKER.

| VITAL SIGNS: | HEART RATE | BLOOD PRESSURE | RPP |
|---|---|---|---|
| RESTING | 52 | 110/86 | 5.7 K |
| PEAK EXERCISE | 120 | 155/100 | 18.6 K |
| 6' POST EXERCISE | 68 | 115/90 | 7.8 K |

MAX WORK LOAD 600 KP-M AT 60 RPM, TOTAL = 6540 KP-M, DURATION = 10 MIN, 20 SEC
CHEST PAIN: NO

REASON FOR STOPPING: FATIGUE

ELECTROCARDIOGRAM:

RESTING: NSST-T CHANGES.
EXERCISE: ST DEPRESSION 1-2 MM-V4,V5,V6.
POST EXERCISE: NSST-T CHANGES.

| LV AND RV INDICES: | LVEF | SYST LV VOL(%) | DIAST LV VOL(%) | DV/DT | RVEF |
|---|---|---|---|---|---|
| RESTING | 60. | 100 | 100 | | . |
| PEAK EXERCISE | 53. | 126 | 115 | 1 | . |
| 6' POST-EXERCISE | 64. | 92 | 100 | | . |

COMMENT: 1) DECREASES MODERATELY
2)
3)

WALL MOTION:

RESTING: NORMAL.

PEAK EX: APICAL - LV MODERATE HYPOKINESIS. SEPTAL - LV MILD HYPOKINESIS.
GENERALIZED - RV HYPOKINESIS

POST EX: NORMAL.

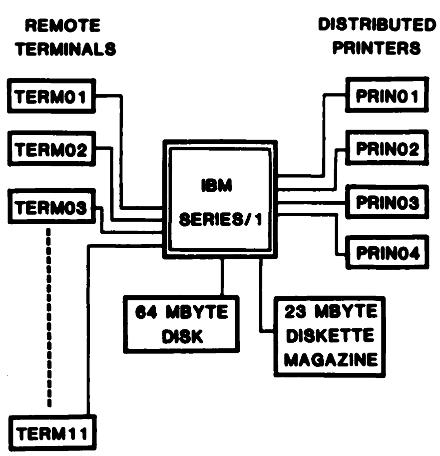
IMPRESSION: NORMAL RESTING STUDY. SUBOPTIMAL MAXIMAL RATE-PRESSURE PRODUCT. ABNORMAL RV RESPONSE TO EXERCISE. ABNORMAL LV RESPONSE TO EXERCISE AS MANIFEST BY A DECREASE IN LVEF, AN INCREASE IN ESV, A DECREASE IN SYSTOLIC DV/DT, AND A STRESS INDUCED WALL MOTION ABNORMALITY.

PHYSICIAN:
JOHN SMITH, M.D.

**FIG. 1.** Computer-generated report for exercise-gated radionuclide ventriculography. DV/DT = change in volume per unit time, ESV = end-systolic volume, LVEF = left-ventricular ejection fraction, LV VOL = left-ventricular volume, RPP = rate × pressure product.

individual permutations for a single observation to be made from this one screen for the skull bones (although not all make clinical sense in this case). This mode is much more desirable than a series of questions and answers using a terminal in the typical roll-screen mode found on most image-processing systems.

Another important feature of static screens is that no demands are made on the computer during insertion of the information on the screen—a critical performance consideration when several reports are being generated simultaneously from different terminals. In fact, a terminal is essentially disconnected from the computer while information is being entered on the screen. After the operator makes appropriate entries, a key is pressed to regain the computer's attention, and the screen is advanced. The time required to change from one screen menu to another (read the current screen, process and store the selected information, write the next screen, and overlay the default or previously selected data) is about 3 sec on this system, and is faster on others. A small delay in screen changing would occur only if several users attempted to



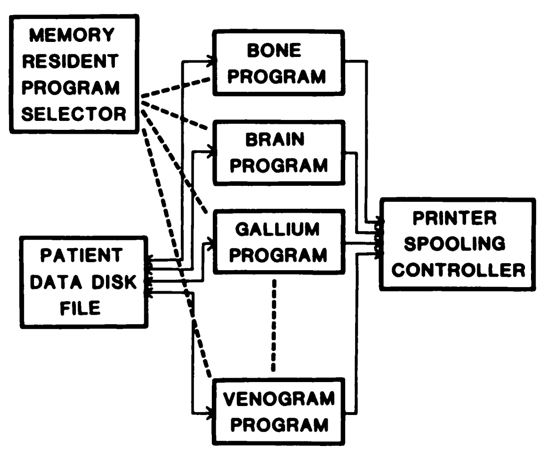




**FIG. 2.** A: System hardware configuration. In our laboratory remote terminals are located at patient-control station, clerical areas, physicians' reading rooms, radiopharmacy, and imaging areas. Printers are in clerical areas and satellite cardiovascular laboratory. B: Program flow for report generation. Memory resident program-selector calls up all individual organ programs (4 are shown here) as well as patient status listing and billing functions.

```
PF1=PRINT REPORT     PF3=ADVANCE PAGE      PF5=SAVE REPORT      ENTER=BRANCH
                     PF4=RESTART ENTRY
-------------------------------------------------------------------------------
NAME:_______________ AGE:___ SEX:  HOSP#            NM#______ ROOM___
CDX:                                  REQUESTING PHYSICIAN:____________
DATE: DD-MMM-YY  MOBL      PROCEDURE:BONE SCAN IMAGE ______________________
HOSP (S/T):          DATE OF BIRTH: MMDDYY     DATE OF ADMISSION:  MMDDYY
RADIOPHARMACEUTICAL: 99M-TC-MDP   DOSE:        MCI   ROUTE OF ADMIN: _IV______
SCAN PROCEDURE: _TOTAL BODY SCINTIGRAPHY WAS PERFORMED.____________________
IMAGE
IMMEDIATE BLOOD POOL IMAGING: _____________________________________________
-------------------------------------------------------------------------------
DELAYED SKELETAL IMAGING: @________________________________________________
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
```

**FIG. 3.** Main screen for demographics, dosage, and "image findings" portions of bone-image report. "@" marks cursor position before branch key is pressed.

change screens at the same instant. Consequently, the computer speed does not degrade noticeably as more terminals are used for this and other applications throughout the laboratory.

## METHODS

To take advantage of the static-screen capability, the software was designed to link a series of screens together. Primary screens contain the skeleton of the patient report, with spaces to be filled in by the operator. From the primary screen the operator can elect to branch to a number of secondary static screens from which text is selected and deposited back into blank spaces on the primary screen. Branching is accomplished by placing the cursor (a mark that one can move anywhere on the screen by keyboard command) on the particular space requiring information from a secondary screen, and pressing a designated key. This will cause a secondary screen to be displayed from which selections can be made. A key is then struck and all selections, properly processed to add the appropriate connecting words and form complete English sentences, are placed into the corresponding areas of the original main screen. In Figs. 3-6 this sequence is illustrated for a section of the bone image program. From the primary screen (Fig. 3), on which demographic and dosage information has already been entered, the physician places a cursor at "delayed skeletal imaging" and presses a key. A secondary "index" screen (Fig. 4) is displayed, allowing selection of one or more skeletal areas in which image abnormalities are present. In this case "7" for "skull" is chosen. A tertiary screen (Fig. 5) is then displayed, consisting of a four-dimensional array of possible image findings (2000 possible combinations). The appropriate image findings are selected, and with a final keystroke the data are entered in text format back into the appropriate blanks on the primary screen (Fig. 6). The operator then has the option of selecting additional skeletal regions from the secondary "index" page, or of indicating that this portion of the report is complete, allowing subsequent "image impression" data to be selected and entered.

Approximately 20 such report programs have been formulated thus far, one for each major imaging procedure. The physicians have designed each report menu, indicating the pertinent information with regard to possible image findings and the impression to be included for each type of study. Information can be entered into the patient's report in any order, but usually follows a fixed sequence. First demographic data are filled in by a secretary when the patient study is scheduled. Next, technical data such as radiopharmaceutical and activity, clinical diagnosis abstracted from the patient's chart, and calculated organ parameters—such as left-ventricular ejection fraction and effective renal plasma flow—are filled in by the technologist when the study is performed. Last, the actual image findings and interpretation are entered by the physician. For a study in which no abnormalities are found, an automatic normal report can be selected, causing a complete report to be filled out instantly, with a standard response in all of the appropriate areas. In all reports, the physician can add any amount of free text if something unusual must be noted or if additional comments are desired. Simple calculations within a report are automatically performed when certain blanks are filled in. For example, in the exercise gated blood-pool study, if blood pressure and heart rate are entered, the computer is programmed to sense this and automatically place a calculated rate × pressure product in the appropriate space of the screen. A complete miscellaneous report program is also available for freehand entry (or transcription by a secretary) of unusual or low-volume studies. All of these activities can be accomplished from any of the terminals distributed throughout the department, including the satellite cardiac exercise laboratory. The physician reviews the entire completed report on the computer screen, verifies the correctness of all the data, and enters his initials in a fixed location of the screen before the report is printed. The computer keeps track of all report-generation activity and prevents two operators from modifying a report simultaneously.

After report generation, a single keystroke allows the patient report to be printed. The programs make logical printing decisions so that reports are printed out not only in the main department but at other appropriate locations, such as the outpatient cardiology clinic 700 feet away in the case of a cardiac study. All printing is "spooled" to the disk, which allows the physician to begin filling

```
                                            ENTER=BRANCH BACK
-------------------------------------------------------------------
 X BONE
 _ BONE/JOINT                 SELECT PAGE: 7
 _ AUTO NORMAL
                        1.   VERTEBRAE AND RIBS
                        2.   PELVIS
                        3.   APPENDICULAR SKELETON
                        4.   JOINTS
                        5.   HAND
                        6.   FOOT
                        7.   SKULL
                        8.   MISCELLANEOUS (GENERALIZED METS, EXTRAOSSEOUS,
                                    RENAL, METABOLIC, TECHNICAL)
```

**FIG. 4.** This secondary "index" page allows subsequent branching to in skeleton's area of interest. Here number 7 (skull) is selected.

```
                              PF3=ADVANCE PAGE              ENTER=BRANCH BACK
PF2=BACK PAGE
-----------------------------------------------------------------------------
X TRACER CONCENTRATION IS:                                ALVEOL   SUPR    INFR   LATERAL
                                        BODY    RAMUS     ASPECT  ASPECT  ASPECT  ASPECT
___ FRONTAL BONE AND;          _
___ PARIETAL BONE AND;         _         _        _         _       _       _       _
___ OCCIPITAL BONE AND;        _         _        _         _       _       _       _
___ TEMPORAL BONE AND;         _         _        _         _       _       _       _
X R _ ZYGOMA AND;              _         _        _         _       _       _       S
___ SPHENOID AND;              _         _        _         _       _       _       _
___ ORBIT AND;                 _         _        _         _       _       _       _
___ MAXILLA AND;               _         _        _         _       _       _       _
X R _ MANDIBLE AND;            _         _        I         _       _       _       _
___ MASTOID BONE AND;          _         _        _         _       _       _       _
___ NASAL BONE AND;            _         _        _         _       _       _       _
X L R TM JOINT AND;            F         _        _         _       _       _       _
______________;                _         _        _         _       _       _       _
_ TRACER CONCENTRATION IS DIFFUSELY INCREASED IN THE CALVARIUM OF THE SKULL.;
_ A CURVILINEAR INCREASE IN TRACER CONCENTRATION CORRESPONDS IN LOCATION TO;
  THE SITE OF THE PATIENT'S CRANIOTOMY.;

R=RIGHT;      I=INCREASED IN;    S=INCREASED IN THE BONE AND SOFT TISSUES SR;
L=LEFT;   Q=QUES INC;   D=DECREASED IN;   F=DIFFUSELY INCREASED IN;   A=ABSENT;
```

**FIG. 5.** Tertiary static screen for skull on bone-image report. Selections made by placing characters into the matrix are as shown result in sentence in Fig. 6 after "delayed skeletal imaging."

in the next patient report without waiting for the printer to print out the one just finished. The computer spool then feeds these printing assignments, without any operator intervention, to the appropriate printers as they become available, an important feature common to many business-oriented computers. To avoid accidental issuance of unfinished reports, only those that have been initialed by the physician are specially marked by the computer for distribution.

In order to allow recent reports to be reviewed without the need to retrieve a filed printed report, the most recent 300 detailed reports are kept on a circular file on the disk. Through a single keystroke the computer will assemble and display the day's patient schedule from this file and highlight those reports that are not yet completed. Also from this file the computer automatically generates all appropriate charge codes, with additional special charges for such items as calculations of absolute ventricular volume or a surcharge for mobile studies. It senses which blanks have been filled in and what selections have been made, thus standardizing and minimizing errors in billing. At the end of the day the computer scans the patient studies and generates a daily list of charges to be sent to the main hospital data-processing center.

## RESULTS

In our experience, computerized report generation has required significantly less departmental time than standard dictation and transcription. After the physician becomes familiar with the menus, little more of his time is required to generate a report than to dictate one. The secretarial tasks of typing reports, proofreading, and retyping are completely eliminated, and final proofreading by the physician is not necessary. This has resulted in elimination of two secretarial/clerical positions in our laboratory.

Ease of use allows new nuclear medicine and radiology residents to adapt quickly to the system, and provides them with choices at key branch points that may have the educational advantage of directing them into a logical decision-tree process, stimulating their thoughts as to possible diagnoses, and prompting appropriate additional comments in the report. It also allows them to generate preliminary reports to be reviewed and modified if necessary by a staff physician.

This type of program lends itself easily to maintenance of a patient data base. Information selected from these detailed reports is automatically inserted into a disk file for long-term storage and subsequent retrieval. For example, a list of patients having undergone gated radionuclide ventriculography, with anterior wall-motion abnormalities and ejection fractions less than 30%, could be generated easily. Software support that is capable of rapidly storing and retrieving several hundred thousand patient records is a common feature of small business computers. To avoid accidental loss, however, care should be taken to store a current duplicate of the data base on an alternate medium such as magnetic tape. Alternatively, many small computers have existing communications facilities that allow them to interact with larger centralized hospital computers, providing access to an already existing data base. A problem encountered with the latter approach is that the information one wishes to store or retrieve may not be a part of the general hospital computer records.

## CONCLUSIONS

This program could be implemented on many small business computers. Memory requirements are somewhat dependent on program design. The storage of predefined choices on static screens rather than in the program itself, and the degree to which the

```
PF1=PRINT REPORT    PF3=ADVANCE PAGE     PF5=SAVE REPORT      ENTER=BRANCH
                    PF4=RESTART ENTRY
--------------------------------------------------------------------------
NAME:______________ AGE:___ SEX:  HOSP#           NM#_____   ROOM___
CDX:                                REQUESTING PHYSICIAN:_____________
DATE: DD-MMM-YY MOBL   PROCEDURE:BONE SCAN IMAGE
HOSP (S/T):          DATE OF BIRTH: MMDDYY    DATE OF ADMISSION:  MMDDYY
RADIOPHARMACEUTICAL: TC-MDP    DOSE:       MCI   ROUTE OF ADMIN: _IV______
SCAN PROCEDURE: _TOTAL BODY SCINTIGRAPHY WAS PERFORMED.___________________

IMMEDIATE BLOOD POOL IMAGING: ___________________________________________
--------------------------------------------------------------------------
DELAYED SKELETAL IMAGING: TRACER CONCENTRATION IS INCREASED IN THE BONE AND
  SOFT TISSUES SURROUNDING THE LATERAL ASPECT OF THE RIGHT ZYGOMA AND INCREASED
  IN THE RAMUS OF THE RIGHT MANDIBLE AND DIFFUSELY INCREASED IN THE LEFT AND
  RIGHT TM JOINT.__________________________________________________________
  -------------------------------------------------------------------------
  -------------------------------------------------------------------------
  -------------------------------------------------------------------------
  -------------------------------------------------------------------------
  -------------------------------------------------------------------------
```

**FIG. 6.** Resulting main screen for this portion of bone-image report.

HOSPITAL NAME
NUCLEAR MEDICINE SERVICE

NAME: NADIE, DON AGE: 63 SEX: M HOSP# 0000000 NM# 22222 ROOM Y234*
CDX: FACIAL TRAUMA REQUESTING PHYSICIAN: DOE, JANE
DATE: 20 JUL 83 PROCEDURE: BONE SCAN IMAGE
HOSP (S/T): S DATE OF BIRTH: 022320 DATE OF ADMISSION: 071183
RADIOPHARMACEUTICAL: 99M-TC-MDP DOSE: 15.0 MCI ROUTE OF ADMIN: IV

image
SCAN PROCEDURE: TOTAL BODY SCINTIGRAPHY WAS PERFORMED.

IMMEDIATE BLOOD POOL IMAGING:

DELAYED SKELETAL IMAGING: TRACER CONCENTRATION IS INCREASED IN THE BONE AND SOFT TISSUES SURROUNDING THE LATERAL ASPECT OF THE RIGHT ZYGOMA AND INCREASED IN THE RAMUS OF THE RIGHT MANDIBLE AND DIFFUSELY INCREASED IN THE LEFT AND RIGHT TM JOINT.

IMAGE
IMPRESSIONS: ABNORMAL BONE SCAN SUGGESTING OSTEOBLASTIC RESPONSE TO A TRAUMATIC INSULT. THE CHANGES IN THE TM JOINTS ARE CONSISTENT WITH DEGENERATIVE OR INFLAMMATORY DISEASE.

PHYSICIAN:
JOHN SMITH, M.D.

**FIG. 7.** Complete printed bone-image report.

computer system's software moves unused portions of the current program between memory and disk to conserve space (a common multiterminal manager feature), are major factors. Our IBM Series/1 computer was chosen because of its ability to perform distributed report generation as well as other unrelated specialized tasks, including asynchronous data input. A similar-sized system used mainly for report generation and other office-related functions (such as word processing) would cost about $80,000. Software development requires an experienced programmer, whose services should also be considered in the total cost.

Another important consideration is that the newest generations of many computers are remarkably service-free, a property critical in a department that has become dependent on a single machine. A computer that is unavailable even a few percent of the time due to malfunction can quickly kill departmental enthusiasm. Our computer, which is used continuously for these functions as well as for general word processing, has been down only once in 2 yr, and then for less than half a day.

It is likely that most nuclear medicine laboratories will eventually want to take advantage of the great opportunities for increased office efficiency made possible with a computer. A system purchased for this purpose should be carefully investigated to ensure that it will have certain features judged to be necessary for successful operation.

## FOOTNOTE

* IBM Series/1.

## REFERENCES

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