The Johns Hopkins Radiology Reporting System[1]

Paul S. Wheeler, M.D., Donald W. Simborg, M.D., and Joseph N. Gitlin, D.P.H.

Radiologists can comprehensively report diagnostic radiographs by computer with a speed approaching that of dictation. This is the main mode of radiographic reporting used at the Johns Hopkins Hospital. Support functions include information storage, retrieval, statistics, and billing. Costs are comparable to stenography. The system can be run from a large time-sharing computer or dedicated minicomputer. A commercial stand-alone version will soon be available.

INDEX TERMS: Computers • Radiology and radiologists, design of radiological facilities • Reports

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A COMPREHENSIVE, automated, diagnostic radiographic reporting system has largely replaced conventional dictation and transcription at the Johns Hopkins Hospital. Radiologists report diagnostic interpretations directly by probing terms on a visual display terminal linked to a computer. The information appears instantly on a cathode ray tube (CRT) for confirmation, followed by printout, report dispersal, and storage. Previous attempts to automate the reporting process have utilized mark-sense sheets (1) or some form of coded or mnemonic input by the radiologist (2–4). This system avoids these less acceptable modes of human interface. Speeding the availability of printed diagnostic reports is one of many automated support services which can improve departmental efficiency. Such services include report transmittal by remote printer or CRT display, storage and retrieval of reports on computer disc or tape, billing and statistical functions, and availability of computer-retrievable diagnostic information for medical audit or research.

The system has been used routinely at Johns Hopkins since 1972 with progressive expansion which now includes the bulk of adult general radiology. It is based upon work begun in 1967 (5) which initially utilized a matrix keyboard as the means of communication between radiologist and computer. The current system can be supported by a large computer or a dedicated minicomputer. A stand-alone commercial version has

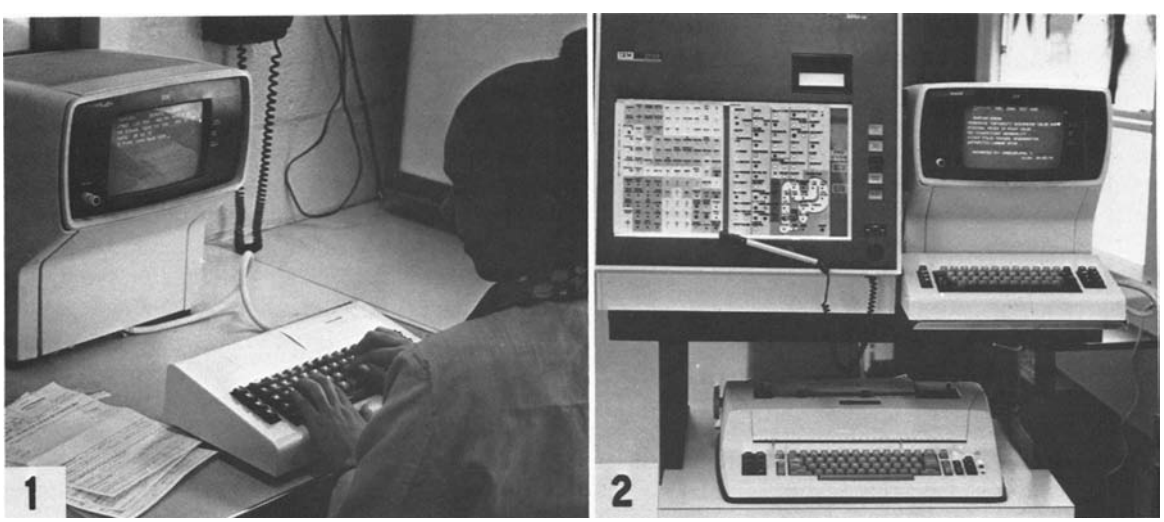

Fig. 1. Heading information entered by keystroke for later use in reporting, statistics, and billing.
Fig. 2. Reading station includes reporting terminal, CRT for proofreading reports, and communications typewriter.

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Fig. 3. Reports printed in triplicate. Computer stores them permanently in code form.

recently been developed by an industrial group and will be tested in late 1975 and early 1976 by TRI-Service Medical Information System at Travis AFB and the Huntington Avenue VA Hospital in Boston.

REPORTING PROCESS

Upon completion of a radiographic examination, each case is given an accession number and the identifying patient information is entered by a clerk into the computer using a keyboard with CRT verification (Fig. 1). The information includes the patient's name, hospital number, age, race, sex, location, requesting physician, date of study, radiographic section, and up to six separate radiographic procedure codes. These data are automatically edited before serving three functions: printing the header on the report; tabulating departmental statistics; and, in the near future, producing a bill for service.

In the reading room the radiologist signs in by probing his physician code on the reporting terminal (Fig. 2). If a resident is involved, two names can be entered which will print automatically at the end of each report until the next radiologist signs in (or until final sign-off).

The accession number assigned to the case is then entered by the radiologist and results in the identifying information appearing on the CRT and the pertinent examination frame being automatically displayed on the reporting terminal (Fig. 2). The films are read and the terms and phrases for the interpretation are probed on the terminal with instant display of the report on the CRT for confirmation. In the case of multiple examinations, when END EXAM is probed, the next specific examination frame automatically appears and reporting continues. When all examinations in the case are reported, the radiologist's name and the date and time appear at the end of the report. Reports are in concise telegraphic style (Fig. 3) accentuating positive findings, degree of certainty, diagnoses, advice, and relevant measurements.

At present, four terminals are used simultaneously to report approximately 400 examinations daily. Report printing in triplicate occurs at a central location where copies are separated for distribution. Previously reported cases can be reprinted if necessary. All completed reports are available for on-line display at remote terminals for 7–10 days and are then transferred in compact coded format for long-term storage on magnetic tape. Search programs are available for case retrieval based on multiple parameters of disease type, anatomy, and patient characteristics. Essentially any form or combination of terms used in a report except those manually typed can be used as search keys. At the central inpatient viewing facility, all radiographs and reports are kept on viewers throughout the patient's hospitalization.

REPORTING TERMINAL AND DISPLAY LOGIC

The display system was designed to present diagnostic terms and phrases in such a way as to permit a radiologist to approach the reporting speed of dictation. This required a terminal with a large viewing area so that searching for terms over multiple displays could be kept to a minimum. The IBM 2760 (Fig. 2) was chosen for both its large display area and its color-graphic capability. The left half is constant with terms applying to all examinations: statements of normalcy, negation, degree of certainty, measurements, adjectives, advice for further study, and access points to different body areas, differential diagnoses, and the pathology–anatomy lexicon. The right half of the terminal is a screen on which frames of 16mm color film are projected under computer control. Each half of the display area is a grid matrix with 120 (10 rows × 12 columns) probe-activated points (Fig. 4).

Each examination type, *e.g.*, HAND (Fig. 5), CHEST, SKULL, AXIAL TOMOGRAPHY, AORTOGRAM, *etc.*, has a specific "main frame" with carefully chosen pathological, anatomical, and descriptive terms sufficient to report most cases. Pathology is listed alphabetically in columns on the left portion of each frame and anatomy is presented usually with simple diagrams on the right. The use of graphics speeds the reporting process since it is faster to find an anatomical term on a picture than in a group of words.

Color has two functions. Logically related terms can be grouped by background color; pathology, for example, always has a yellow background. Pathology terms with large black or colored probe points have differential diagnoses (Fig. 6) which can be displayed instantly. A large black probe point indicates a support frame with up to 72 terms. A colored probe point indicates a portion of a frame containing the differential terms in a zone matching the probe point color (Fig. 7).

Terms on the frames can be probed in any desired order with individualized differentials as in dictation. Most cases are reported from the "main frames" alone. The differential frames are used for complex or proved cases. Extremely rare diseases or anatomical sites can

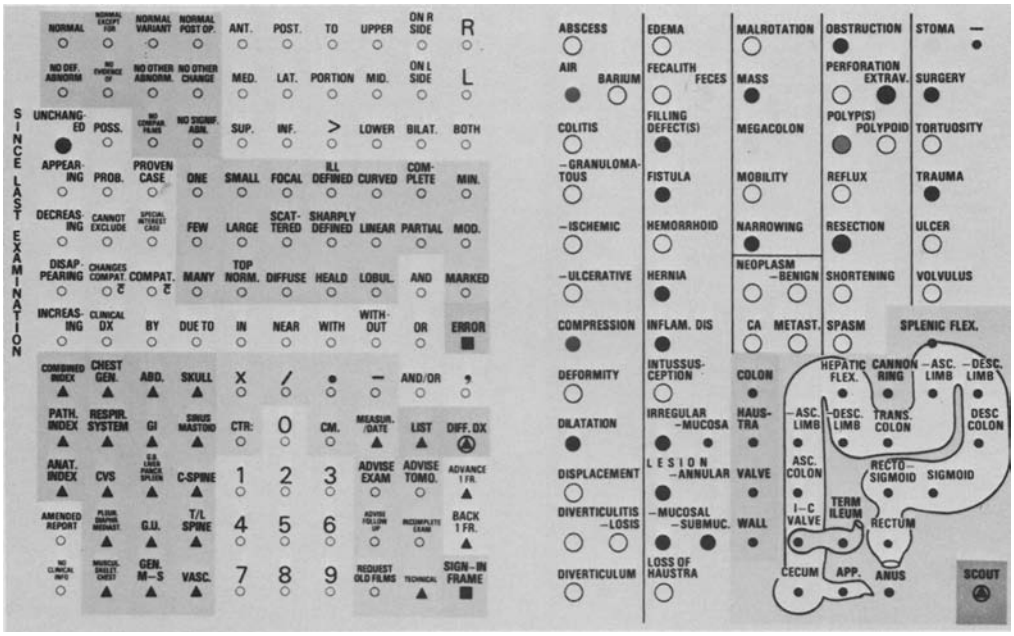

Fig. 4. Reporting terminal display. Left side is constant and right varies with examination type. Terms are entered by probing.

be handled by the pathology–anatomy lexicon frames. New conditions or very unusual descriptive detail can be typed or dictated as a separate note. For general radiology approximately five sentences are typed for every 100 cases. The proportion of cases with significant pathology is comparable to other large hospitals located in large cities. Base-line cardiothoracic ratios are included in most normal chest cases for future reference.

PRACTICAL FACTORS IN COMPUTER REPORTING

Costs: The system costs $50,000 per year including rental of all terminals, computer time, and clerical service. Approximately 108,000 examinations (two-thirds of the departmental workload) are reported annually on the system. Although reporting of complex cases takes longer than dictation owing to the "look-away time", the number of staff radiologists has not been increased nor have scheduled reporting periods been prolonged owing to the system. Six transcriptionists have been replaced by the system at a savings of $48,000 annually. Automated billing from the system is expected to increase correct charge capture by a significant amount over the present manual system.

Storage, retrieval, and transmission: Storage of information on disc or tape files provides availability for reproduction and transmission by several means. When the surgery and pathology departments get their records in machine-readable form, it will be possible to develop automated feedback on diagnostic accuracy. As medical audit activities increase in scope, it will be important for all branches of medicine to maintain information in a form which can be analyzed by computer.

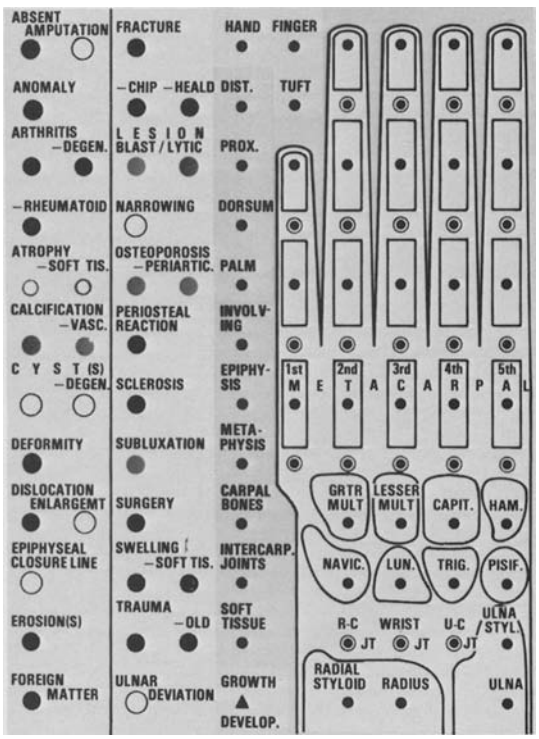

Fig. 5. "Main Frame" for reporting hand-wrist-finger examinations.

Concise vs. traditional descriptive reports: The content of a diagnostic radiographic report is a function of the radiologist's training and the preference of referring physicians. Traditional reports describe, interpret, and end with a summary impression. There has been a

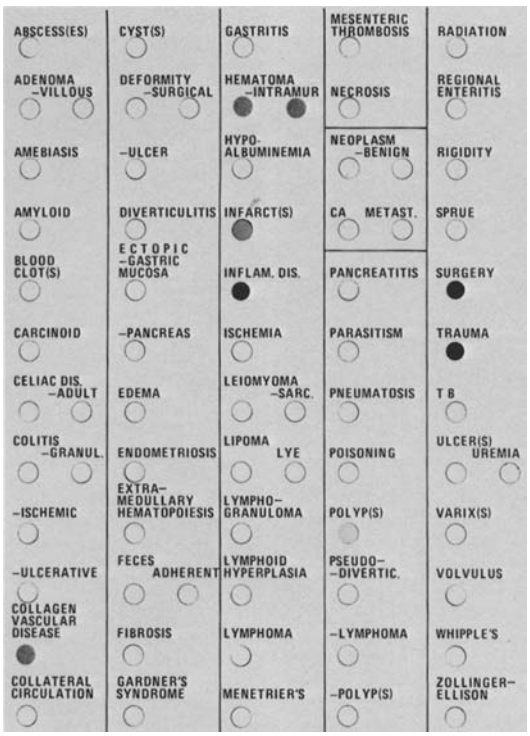

Fig. 6. Full frame differential for gastrointestinal mucosal lesions. Selections can be made in order of likelihood.

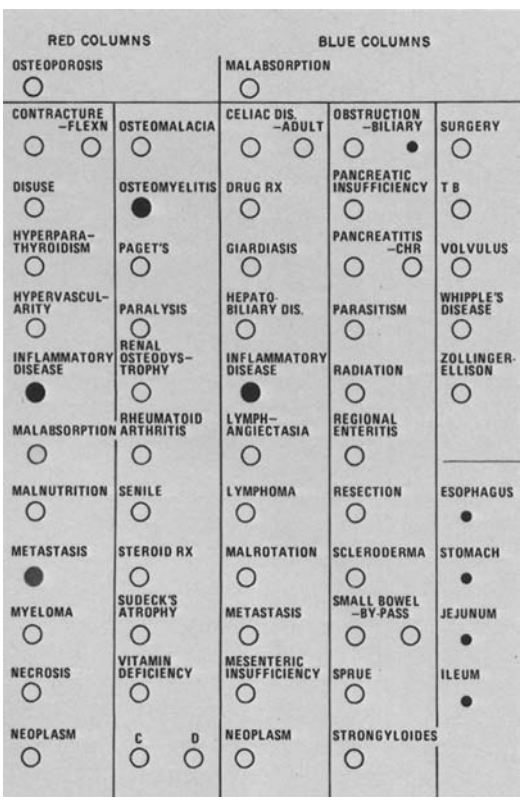

Fig. 7. Differentials for osteoporosis and malabsorption. The background colors match the appropriate probe points on the "main frames".

move toward concise reports exemplified by the Mayo Clinic, the University of Michigan Hospital, and others, limiting reports to diagnostic and anatomical information with appropriate advice for further study. This permits efficient reporting, compact storage, and follows the logical precedent set by other major communication systems.

DISCUSSION

In its present stage of development the radiology reporting system has displayed advantages, disadvantages, and some unknown aspects which a current evaluation effort will help define. The system meets the needs of a large radiology department with staff and residents who use it 7 days a week, 24 hours a day. It produces immediately available diagnostic information, source-recorded and proofread at the time of reporting. Since all terms and phrases are automatically translated into four-digit codes, long-term storage and retrieval for teaching, research, and medical audit are facilitated. Terminology is standardized, including degrees of certainty and change. Radiology reporting has been integrated into the overall hospital information system. Costs are equivalent to dictation and revenues will probably increase owing to more accurate billing. Furthermore, computer costs are generally going down, whereas personnel costs (such as for stenography) are inflating.

The known disadvantages of the system include the fact that it does require radiologists to learn a new technique. Reporting complex cases is slower than dictation. After three to eight hours of practice a radiologist can generate reports at about 50% of dictation speed. With two weeks of regular use, the radiologist can report at 80–95% of dictation speed. Another disadvantage is that the radiologist must look away from films while probing the terminal. The number of radiologists reporting simultaneously is limited by the number of terminals. Because an ideal case load is 100/day/station, it is not cost-effective to install a reading station in low-volume reading areas. This is the reason for not reporting all Johns Hopkins interpretations by computer. Finally, computer down-time and terminal breakdowns can be frustrating interruptions for the radiologist. Unscheduled computer down-time has been monitored carefully during the past twelve months and has averaged 2.1 hours per week out of a 24 hour, 7 day week.

Special studies are underway to measure the effect of the system on the quality of the reports, the acceptance by attending physicians, the error rates compared to dictation and changes in duplicate examination rates. The system has been implemented successfully in a private radiologist's office (Dr. Dorothy Cooney, Chicago, Ill.) and is being installed at another medical center. Since the IBM 2760 is available on a limited basis only, commercial versions of this system should ease availability in the future.

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Department of Radiology
Johns Hopkins Hospital
Baltimore, Md. 21205