Integrating Radiology and Hospital Information Systems: the Advantage of Shared Data

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ABSTRACT

Information management is central to modern patient care. Computerization of information management has resulted in both departmental systems which serve information needs in locations such as the Radiology Department and in hospital-wide information systems which seek to integrate management of clinical data from many departments. For each of these systems to achieve the goal of maximizing both the effectiveness of health care workers and the quality of patient care, they need to share the data that they capture. Below we discuss a variety of applications, both currently available and in the realm of research protocols, that depend on a high level of communication between Radiology Information Systems and Hospital Information Systems. These examples suggest the benefits of integrating the medically relevant data collected by all of the computer-based information systems in the hospital setting.

INTRODUCTION

Information is central to the delivery of medical care. This simple fact is well understood. It is the driving force behind continuing efforts to apply computers to the task of managing information in the hospital setting. However departments in the hospital often adopt computerization as an answer to their local information needs without considering the long term need to share clinical data across departments. As Hospital Information Systems (HIS) become the repository of more and more of the clinical data produced in the inpatient setting, the focus will change. Research into better approaches to capturing clinical data will yield to efforts to better apply it to the problems of care delivery. In this setting increased attention must be paid to providing universal access to the clinical content of each department's data base.

The Radiology Department provides a case in point. It has long been among the most computerized of the departments in the typical hospital. The presence of highly automated equipment leads not only to a significant degree of computer literacy but also to a high level of expectations concerning the future of automation in the medical setting. A variety of Radiology Information Systems are available in the market place and satisfy many of the needs for management information in the Radiology Department. However, in most cases the exchange of information, particularly clinical information, between the Radiology Information Systems (RIS) and the Hospital Information System (HIS) is severely limited. The best of these systems succeed in passing patient identifiers, demographics, and billing information in one direction and the x-ray reports in the other. We believe that the full benefit of computers in radiology will only be realized when all information collected in the radiology department and all information collected in the remainder of the hospital can be transparently exchanged and made available in either system.

In this paper we discuss the promise of processes that use data originating in the Radiology Department in applications running on a HIS and of processes that bring data from the HIS to bear on problems in the Radiology Department. We believe that by fully integrating information from the HIS and RIS we can better address the information needs of both.

LINKING HIS AND RIS

The processes discussed below are dependent on a tight link between the hospital information system and the radiology information system. Much of the research described has been undertaken at the LDS Hospital using the HELP Hospital Information System. In this system the RIS is a module built into the HIS. All of the data structures and many common applications (i.e., admitting, data review, etc.) are shared between the two systems. Indeed many of the applications used in the Radiology Department are written in HELP's internal system's integration language, allowing the sharing of certain functional components between processes that run in radiology and processes that run on the medicine and surgery wards.

This arrangement, however, is unusual. Many institutions have a HIS and a RIS provided by different vendors, running on different hardware with different fundamental data structures and programming philosophies. In this setting, an interface capable of passing any requested set of data in one system to the second system is necessary to support the type of integrating processes described below.

PROCESSES BENEFITING FROM INTEGRATION

The processes that benefit from this bi-directional data flow can be broken into 5 categories. These

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categories are 1) those that improve work flow in radiology, 2) those processes that enhance the availability of x-ray data for clinical care, 3) those that improve access to clinical data in the x-ray department, 4) those that assist in quality assessment and improvement activities in radiology, and 5) those that bring expert systems technologies to common problems in the delivery of care and the evaluation of x-ray examinations. These functions are not mutually exclusive but are intermingled in many of the applications used in radiology and in the clinical areas. Nonetheless, for purposes of simplicity we will discuss them separately.

Advantages in Radiology Work Flow

Among the most common rationales for integrating a RIS and a HIS is the desire to reduce duplication of effort and improve work flow in the radiology department. First, integration eliminates the need for duplicate admission procedures for each system. Admission data, demographics, insurance information, and even known allergies are entered only once.

Second, radiology ordering can be integrated into the general order entry routines available in the HIS. The orders, complete with appropriate supplemental information (the attending and ordering physicians, patient location, need for special handing, reasons for the examination, etc.) are passed to the RIS where the appropriate paper work is printed and the process of executing the order is initiated.

Third, the problem of scheduling an examination is brought into the larger arena of complete patient scheduling. Without this form of integration, computer-assisted scheduling applications can never prevent conflicts caused by simultaneous planned procedures in different departments.

These are simple results of exchanging data between the HIS and RIS. Nonetheless, they can have a significant effect on the efficiency with which the Radiology Department functions.

Accessing X-ray Data in the Clinical Care Setting

The fundamental product of the radiology department is the x-ray report. This important source of clinical information is generally produced in the radiology department and is the principal contribution of the RIS to the clinical data available for patient care. Bringing these reports to the attention of the clinicians caring for the patient is more often the province of the HIS. Clinical data review is typically an important function of these computer systems. Information is accessed through terminals attached to the HIS and is presented using an interface that maximizes the ease of the clinician in locating, reviewing and, if needs be, printing relevant data. If the product of the radiology department is to be integrated into this data review environment, the x-ray report must be transferred into the HIS's data base. Then this information may be reviewed in an integrated fashion by those caring for the patient.

X-ray reports are typically available only as a natural language document representing the words of the radiologist, dictated and transcribed to produce the final x-ray report. While this form is adequate for review, either on paper or at a terminal attached to the information system, it is not suitable for a variety of other tasks. Among these are research, automated forms of audit, and automated clinical decision making tasks. We believe that future RISs will be required to provide much of the clinically relevant data produced there not only in a free text form, but also in a coded format suitable for computer processing [1].

A variety of tools are available to manage the encoding of x-ray reports. Two of the most promising are the direct entry of x-ray results using bar codes or computerized questionnaires and the conversion of free-text reports into a coded form using processes that parse the natural language.

Our experience with these approaches leads us to believe that bar code or questionnaire based input is suitable principally for procedures with either a high incidence of normal examinations or where a very limited number of abnormalities can be expected. The principal example of this is in screening mammography [2,3,4].

Natural language recognition is a more general approach. No change is required in the behavior of the radiologist and transcriptionist. The report, when complete, is encoded by background processes that determine the findings described and the interpretations made and place the appropriate data structures into the patient's file.

Unfortunately natural language understanding is one of the more challenging realms of artificial intelligence. Developing processes that are consistently accurate has been difficult. We have been using a process called SPRUS (Special Purpose Radiology Understanding System) based on a semantic model of natural language recognition [5]. It functions in the artificially narrowed realm of purely diagnostic chest x-ray findings and interpretations. Its accuracy has been measured at a rate of 87% for findings and 95% for those diseases cited as possible interpretations of these findings. While far from perfect, this degree of accuracy has allowed the system to make a useful contribution to a computerized expert system used by the infectious disease department to identify nosocomial infections [6].

In situations where the RIS tracks, in detail, the status of patients' examinations, clinicians accessing the HIS may have an additional advantage. Integration of the two systems will allow users to easily determine the status of each pending or ongoing examination and will help locate the patient when he is away from his room.

Data Review in Radiology

Users in the Radiology Department also have a need for clinical data. A variety of studies have demonstrated inaccuracies in radiographic interpretation [7,8,9]. Other studies suggest that the availability of data enhances the accuracy of x-ray interpretation [10,11]. One of the more common requests of radiologists is for easy access to a patient's clinical data at the time his films are being reviewed. Unfortunately the time constraints in most radiology practices make a leisurely review of the patient's chart or even of well-organized computerized records impossible. To remedy this situation processes can be developed that examine a patient's data and pick a small subset to bring to the radiologist's attention. We have experimented with and plan to implement a tool capable of finding and presenting a subset of clinical data likely to be most informative for the procedure done and the patient being examined [12]. This approach promises to provide the radiologist a chance to see appropriate clinical data while minimizing demands on his time.

The other important user of clinical data in the radiology department is the x-ray technician. Access to test information from the laboratory and elsewhere allows him to screen patients for contraindications before doing potentially dangerous procedures. An example is the need for review of a patient's renal function prior to the use of contrast agents. In situations such as this the availability data from the HIS in the Radiology Department can prevent morbidity and mortality.

Quality Assessment

One of the challenges in the Radiology Department is the implementation of effective quality assurance programs. Programs for the maintenance and calibration of equipment are standard parts of every department. Programs that measure and attempt to improve the quality of the work done by technicians and other staff are becoming increasingly common. However, programs that provide effective audit of the radiologists are commonly modest at best and are often all but non-existent.

In those instances where the interpretations of practicing radiologists are reviewed, one or more additional radiologists are typically employed who reexamine a set of films and attempt to confirm the impressions of the original reader [8.13]. An alternative is to use each radiologist as his own reviewer by having him reread films in a blinded manner and by then comparing the two interpretations. Each of these review techniques can be expensive [14]. The principal cost involved is that of the radiologists' time spent in the replicate examinations of the films. However, these multiple readings are necessary to provide a standard against which the individual interpretations can be compared.

The appearance of clinical data bases has made possible a different standard. Among the data collected in the modern medical computing facility are a variety of outcome measures that can be linked to x-ray results. These outcomes are recorded as results of biopsies, discharge diagnoses, post-therapy lab values, etc. A review based on correlating these data with the x-ray reports can reduce or eliminate the need for rereading the films. It allows development of an outcome-based assessment of quality.

There are two possible approaches to this form of audit. The first involves a simple comparison of the specific interpretations made by the radiologist with an outcome determined by other means. An example of this approach is the comparison of breast biopsy results with the interpretations made of mammograms [15]. In this case the pathology department provides the gold standard against which each radiologist's accuracy is measured. While a reasonable estimate of true positive rates and false positive numbers is rapidly available, a more detailed look at accuracy requires that records from the radiology, surgery, and pathology department be examined over a period of years. This allows estimation of the frequency of previously missed breast cancers in returning patients.

This form of audit is focused on specific interpretive statements in the radiologist's report. Analogous opportunities for assessing accuracy can be exploited whenever clinical data found in the HIS confirm concrete interpretive statements routinely made by the radiologist. This is common in conditions where radiological procedures are done to discover surgically correctable diseases.

The approach described above concentrates on diagnostic statements in the radiology report. However, much of each report is descriptive in nature. In some realms (i.e., chest radiography) it is not uncommon to see reports limited to descriptive information. We believe that the descriptive part of the x-ray report can also be critiqued when outcome data is available from the HIS. We have tested an application that uses a diagnostic expert system to convert these raw findings into probability-based diagnostic impressions [16]. The results can be compared to the discharge diagnoses captured in the HIS and evaluated according to how consistently they match this gold standard.

This approach shows promise. It is able to discriminate among x-ray readers with different levels of experience and appropriately discriminates the consensus reports of panels from the efforts of individual readers. We are continuing to test and refine this technique with the goal of making it a standard part of quality control in our radiology department.

Decision Support

Future medical information systems will have the ability to store and manipulate essentially all of the clinical and management data generated by each patient.

To this they will add a set of tools designed to expedite and enhance patient care. Expert systems technologies, now relatively rare in medical information systems, will clearly be a standard part of future systems. The services that they provide in the Radiology Department will be dependent on the availability of extensive clinical information imported from the HIS.

Automation of simple alerting procedures will be among the first applications of expert systems in this setting. Most RISs currently have some mechanism to protect against duplication of orders. To this will be added the ability to alert department personnel during the ordering process if the presence of laboratory findings, medications, or ongoing disease processes signals relative or absolute contraindications to intended examinations. We have tested prototypes of these functions and they appear eminently practical.

A second application that may prove valuable in this setting is an expert system dedicated to assisting in the development of a plan for the radiological work-up. An example of this sort of tool has been tested at the University of Chicago [17]. Unfortunately, this system was not able to access clinical information from a HIS. All data required for its function came from the user at the time he ran the program.

The use of expert systems for planning work-ups may presage a larger planning role for computers in medical settings. Practice guidelines, whose development is part of an effort to achieve a flexible standardization in patient care [18,19], invite implementation in a computerized setting. Our experience with developing computerized ventilator care protocols has led us to believe that only through computerization will guidelines of significant complexity be ever effectively implemented [20,21]. In the future, these protocols will behave much like the computerized x-ray work-up plan described above. However, ready access to clinical data present in the information system will be a prerequisite for the function of these tools.

Data from the radiology department also will play a part in the functioning of expert systems in the HIS. An application that uses x-ray data to assist in finding nosocomial infections is mentioned above [6]. Other uses in patient management are emerging. As encoded x-ray findings become more regularly available, more decision-making applications will seek to use these data to assist in recognizing patients with specific pathologic patterns and in planning their care.

CONCLUSIONS

In the discussion above, we describe some of the potential advantages associated with the exchange of clinical and management data between a HIS and an RIS. The continuing increase in the amount of data available in each of these systems promises to magnify the advantages of an interface that effectively integrates the data bases of the departmental and the hospital systems.

This discussion has concentrated on the objectives and requirements of the Radiology Department. Other hospital departments face similar needs. Departmental systems are available for pharmacy, respiratory therapy, and nursing departments to name a few. In each of these cases, attention to the need for sharing clinical data will yield benefits both for the department as it pursues its unique goals and for the patient as he reaps the benefits of care delivered with the help of integrated information systems.

References

1. Haug PJ. Diagnostic Coding in the Radiology Department. Current Imaging (1991); 3:99-105.

2. Sickles EA. The usefulness of computers in managing the operation of a mammography screening practice. AJR (1990); 155:755-761.

3. Haug PJ, Tocino IM, Clayton PD, Bair TL. Automated management of screening and diagnostic mammography. Radiology (1987); 164:747-752.

4. Adams HG, Campbell AF. Automated radiographic report generation using barcode technology. AJR (1985); 145:177-180.

5 .Haug PJ, Ranum DL, Frederick PR. Computerized extraction of coded findings from free-text radiology reports. Radiology (1990); 174:543-548.

6. Evans RS, Larsen RA, Burke JP, Gardner RM, Meier FA, Jackobson JA, Conti MT, Jackobson JT, Hulse RK. Computer surveillance of hospital-acquired infections and antibiotic use. JAMA (1986); 256:1007-1011.

7. Koran, LM. The reliability of clinical methods, data and judgments (parts I and II). NEJM. (1975) 293: 642-646 and 695-701.

8. Herman PG, et al. Disagreements in chest roentgen interpretation. Chest (1975) 68:278-282.

9. Rhea JT, Potsaid MS, DeLuca SA. Errors of interpretation as elicited by a quality audit of an emergency radiology facility. Radiol. (1979) 132: 277-280.

10. Doubilet P, Herman PG. Interpretation of radiographs: effects of a clinical history. AJR (1981) 137: 1055-1058.

11. Schreiber MH. The clinical history as a factor in roentgenogram interpretation. JAMA (1963) 185:137-139.

12. Haug PJ, Beesley D. Automated Selection of Clinical Data to Support Radiographic Interpretation. Fifteenth Annual Symposium on Computer Applications in Medical Care (1991) pp 593-597.

13. Baines CJ, McFarlane DV, Wall C. Audit procedures in the national breast screening study: Mammography interpretation. J Can Assoc Radiol (1986) 37:256-260.

14. Hessel SJ, Herman PG, Swenson RG. Improving performance by multiple interpretations of chest radiographs: effectiveness and cost. Radiology (1978) 127:589-594.

15. Sickles EA, Ominsky SH, Sollitto RA, Galvin HB, Monticciolo DL. Medical audit of a rapid-throughput mammography screening practice: methodology and results of 27,114 examinations. Radiology (1990); 175:323-327.

16. Haug PJ, Clayton PD, Tocino I, Morrison JW, Elliot CG, Collins DV, and Frederick PR. A Tool for Continuous Audit of Report Quality in Radiology. Radiology (1991); 180:271-276.

17. Kahn CE. Validation, clinical trial, and evaluation of a radiology expert system. Meth. Inform Med.(1991); 30:268-274.

18. Linton AL, Peachy DK. Guidlines for medical practice: 1. The reason why. Can. Med. Assoc. J. (1990); 143:485-490.

19. Peachy DK, Linton AL. Guidlines for medical practice: 2. A possible strategy. Can. Med. Assoc. J. (1990); 143:629-632.

20. Sittig DF, Pace NL, Gardner RM, Beck E, and Morris AH. Implementation of a computerized patient advice system using the HELP clinical information system. Computers and Biomedical Research (1989); 22:474-487.

21. Henderson S, East TD, Morris AH, and Gardner RM. Performance evaluation of computerized clinical protocols for management of arterial hypoxemia in ARDS patients. Thirteenth Annual Symposium on Computer Applications in Medical Care (1989), pp.588-592.

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