Integration of Text, Image, and Graphic Data From Different Sources in Laboratory Reports

Example of Kidney Stone Reporting System

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Abstract

Laboratory analyses may generate multiple data types that may reside in disparate systems, and combining data into a report often requires laborious, error-prone methods. Kidney stone analysis, which includes biochemical composition analysis and gross feature documentation, is an example of such a situation. We developed the kidney stone reporting system (KISS) that integrates patient and specimen information from the laboratory information system, digital images of stones, and analytic instrument data into a concise report for the ordering clinicians. The database management environment facilitates archival and retrieval capabilities. Implementation of the system has reduced the number of manual steps necessary to produce a report and has saved approximately 30 technologist hours per week. Transcription errors have been virtually eliminated. The KISS represents an innovative use of standard tools to integrate text, image, and graphic data from disparate systems into an integrated laboratory report, without the need for expensive interfaces.

Integrating different data types from disparate sources into cohesive reports presents a challenge and an opportunity to add value in the management of laboratory information. Laboratory analyses may generate multiple data types that may reside in separate systems, and integrating data into a report, if attempted at all, often requires laborious, error-prone manual methods. Kidney stone analysis is an example of such a situation.

Nephrolithiasis is a common affliction in the United States, with a prevalence that varies with race, sex, and geographic region and ranges from 4% to 9% in men and from 1.7% to 4.1% in women.1 Laboratory analysis of kidney stone composition has a central role in the evaluation of people with nephrolithiasis in that the results of stone analysis guide appropriate medical therapy aimed at preventing recurrence.2-4 In addition to analyzing the biochemical composition of stones, the laboratory documents their number, size, color, and weight. Digital images of stones convey this information in a report more effectively than can only words and numbers and are useful to document gross features, especially considering that stones are destroyed during composition analysis.

We describe a system that automates the process of integrating different data types that originate from disparate systems and that provides for optimal communication of information to the requesting clinicians. The system uses standard, off-the-shelf programming tools to bring together text, quantitative, graphic, and digital image data. The system also creates a database that facilitates archival, retrieval, reprint, and query capabilities.

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Materials and Methods

Previously, creation of a specialized kidney stone analysis report in our laboratory required multiple manual steps. A technologist first typed the patient’s demographic information and test order information, including ordering physician and client account data, into a word-processing template. Second, results of gross examination (size, weight, color) of the stone(s) were typed into the document. Separately, the technologist captured a digital image of the stone(s) that then was manually copied and pasted into the report, where further adjustment of the position and size of the image in the template was required. Finally, a copy of the infrared absorption spectrum graph from the spectrum analysis system was pasted into the template. After assembly of these elements, the technologist printed the report for distribution. The file subsequently was available only as a word-processing document, with no effective method to search and retrieve previous reports. To prepare a report, a technologist needed to access data manually in 3 separate areas or systems, and the overall process was error-prone. In general, approximately 15 to 20 minutes were required to perform the report preparation steps, which involved manual steps of typing records, inserting images, and copying and pasting data from separate applications.

To improve the efficiency of graphic reporting for kidney stone analysis, we designed a kidney stone reporting system (KISS) that automates many of the steps described and also provides enhanced database management functionality. The KISS downloads patient and specimen information from the laboratory information system (LIS), inserts digital images, generates an infrared absorption spectrum graph from quantitative instrument data, and assembles the data into an integrated, graphic report tailored to the requesting physician’s requests.

The KISS was developed using Visual Basic programming language (version 6.0, Microsoft, Redmond, WA) and uses the SQL Server relational database management system (version 7.0, Microsoft) and Crystal Report Designer report writer software (version 6.0, Seagate, Vancouver, British Columbia). Visual Basic modules serve the purposes of designing the graphic user interface, implementing the application logic including managing data retrieval from different sources, and accessing the relational database. The report writer component combines the text, chart, and image into an integrated report. The relational database maintains patient and specimen records and manages inquiry of previous cases. The system has been implemented on a personal computer with a 400 MHz Pentium II processor and 96 MB RAM running Windows 98 operating system (version 4.0, Microsoft) in a local area network environment.

A detailed description of the process of creating integrated kidney stone reports follows. Data input originates from 3 different electronic sources and 1 paper source (Figure 1). The technologist first generates the worksheet in the LIS (Sunquest Information Systems, Tucson, AZ) for kidney stone analysis in the format of a text file. The KISS then downloads this text file from the LIS and automatically extracts patient demographic and test order data into the database. The KISS also prints a custom worksheet on which the technologist can record descriptive information that includes calculus color and weight and the results of composition analysis (eg, 100% calcium oxalate). A digital image is captured in JPEG (Joint Photographic Experts Group) format using a camera (VIZCAM 1000, Canon, New York, NY) and digital image capture software (GrabIT Pro version 2.0, AIMS Labs, Fremont, CA) for the cases in which an image has been requested. After imaging, the Fourier transform infrared (FT-IR; Spectrum 1000, Perkin Elmer, Boston, MA) spectral analysis for biochemical composition is performed, and the quantitative data results are stored in text file format. The calculi are ground into powder and consumed during this analysis.

After these data-generation steps, the KISS creates integrated reports as follows: For each individual case, the “User Input” module presents an online form in which the patient demographic data and test accession number data have been previously entered automatically as a result of the earlier steps. The KISS user interface is illustrated in Figure 2. The technologist enters requesting physician and client information (eg, client name), as well as the stone color, weight, and composition from the KISS worksheet, into the data fields in the User Input Module. The User Input Module provides drop-down lists and pick lists of standard entries for many fields to improve the speed, accuracy, and standardization of data entry. Next, the “Show Graphics” module associates the digital image file and the spectral analysis data file through use of the specimen accession number and is responsible for displaying these data to the user and incorporating them into the report. During this process the “Draw Chart” module transforms the spectrum analysis data file into a graphic spectrum representation, which is displayed in the final report (Figure 3). Finally, the “Report” module does a final confirmation of the elements and prints the report. The Report module also writes the data to a database table for later search and retrieval. A detailed flow chart for the KISS is shown in Figure 4.

Kidney stone analysis without photograph or without photograph and data graph also may be requested on a submitted specimen. Such requests are ordered on a different worksheet in the LIS. For these reports, the KISS downloads information from the respective worksheets and proceeds as described in the preceding text, except for logic that
bypasses the image insertion and chart-drawing steps, as appropriate for such orders.

Following report generation, the KISS provides the capability to upload the alphanumeric result information—dimensions, weight, color, biochemical composition—back into the LIS for electronic reporting. This upload is accomplished through the use of a script, or macro, in a terminal emulator program (SmartTerm, Esker Software, Madison, WI). After logging into the LIS, the technologist initiates a macro that automatically uploads the results through the use of the LIS result entry function. Each result so entered into the LIS must be verified (or rejected) by the technologist before it is released and before the system proceeds to the next specimen. The alphanumeric results then are available online in the LIS and in the institution’s electronic medical record system (for inside patients) to which the LIS is interfaced.

**Results**

Approximately 60 to 70 kidney stone analysis reports per week are processed using the KISS. These reports include text, image, and graphic data from different sources. Of the analyses, 84% have included stone photographs and data charts, 9% data chart and no photograph, and 7% neither a photograph nor a data chart. The number of manual steps necessary to produce a report has been reduced, and transcription errors have been virtually eliminated. Previous reports are reprinted immediately on request. Technologist acceptance of the system has been favorable. The saving in full-time equivalents is estimated at 30 hours per week. All reports are provided in a timely manner and in compliance with the clinician’s requirements. The only system failures have occurred as a result of external factors, such as network failures or unavailability of the LIS.

**Discussion**

We describe a method for integrating different data types for the purpose of reporting the results of kidney stone

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**Figure 1** Diagram of the different data sources and types integrated by the kidney stone reporting system. FT-IR, Fourier transform infrared spectroscopy; LIS, laboratory information system.

**Figure 2** Screen capture of the main data entry screen for the kidney stone reporting system. Patient demographic and specimen information downloaded from the LIS is displayed in the upper third of the screen. Gross characteristics of the stone and biochemical composition analysis results are entered into fields in the lower half of the screen. Pick lists (mid-lower right) facilitate entry of these data. At lower left is the digital image of the stone, and at lower right is the infrared spectrum graph generated from the raw data (as described in the text).

**Figure 3** Example of final report from the kidney stone reporting system that is provided to the ordering clinician.
analysis. The KISS represents an innovative use of standard, commercially available software products to integrate text, image, and graphic data originating from disparate systems into an integrated laboratory report, without the need for expensive interfaces.

The mission of the laboratory is to provide information necessary for clinical decision making and patient care. Laboratory analyses generate multiple different data types that may include text, quantitative, graphic, and digital image data. Combining the different types of data produced during laboratory analyses into a comprehensive report can maximize the effectiveness of the information presented to clinicians who are relying on the report to guide diagnostic and therapeutic decisions. Unfortunately, these data types often reside in multiple separate systems, and integrating them into a report often requires laborious procedures, which are inefficient and fraught with potential for error. The management of data produced during kidney stone analysis is an example of such a situation.

Laboratory analysis of kidney stone composition has a central role in the evaluation of people with nephrolithiasis because the results of stone analysis guide appropriate medical therapy aimed at preventing recurrence. Approximately 70% of stones are the common calcium stones with oxalate, phosphate, or, most often, both anions. Other types of stones are those consisting of uric acid, cystine, or struvite (magnesium ammonium phosphate with carbonate). The metabolic conditions underlying the formation of these latter types are disorders of uric acid metabolism and/or acidic urine for uric acid stones, the autosomal recessive disorder cystinuria for cystine stones, and infection with urea-splitting organisms for struvite stones. A person in whom stone analysis reveals one of these types of stones is classified immediately as being at high risk for recurrence based on the metabolic conditions underlying the formation of such stones, and specific therapy can be started.

In the future, digital images and other data types will have an increasing role in the practice of pathology and laboratory medicine. The multimedia electronic medical record systems of the future have been described that will incorporate images and signal-based technologies (eg, electrocardiography) as key components. Recently, Crowley et al described the usefulness of digital images in routine anatomic pathology practice and the electronic medical record. The system reported herein is novel because it presents both digital images and graphic display of data in a clinical laboratory report. This method of presentation provides a perspective of the test result information not conveyed by alphanumeric (text) characters alone. These reports containing images and graphs have proven to be highly requested by ordering clinicians in our environment. Furthermore, capture and archive of a digital image documents gross features of these specimens that subsequently are destroyed during analysis.

Reaction among physicians receiving the reports has been highly favorable. The capability to provide such reports has been a determining factor for some groups in the decision to have kidney stone analysis performed at our institution. Those requesting kidney stone analysis from our laboratory must specify whether they want the reports to include photographs of stones and/or data graphs. The fact that more than 80% of the orders for kidney stone analysis received in our laboratory request the report option that includes photographs and graphs suggests that these features add value for the requesting clinicians. Use of the system has improved the patient communication aspect of patient management. The reports illustrate the source of the patient’s symptoms and can be used as a communication tool by the physician.

The model used in our system is suited ideally to the setting of low-volume, specialized testing such as that encountered for kidney stone analysis. The KISS pulls together information from separate, stand-alone applications (digital imaging, spectral analysis, LIS) in a manner that otherwise would require customized and costly interfaces and involvement of multiple vendors with varying priorities and timetables. Even if interfaces were financially justifiable, the LIS lacks the capability to support the use of digital images. Moreover, our method enables rapid adaptation to end-user requirements and is flexible and easy to maintain.
While this system was developed in a laboratory that conducts a relatively high number of kidney stone analyses, implementation of such a system may be practical for lower volume laboratories to the extent that the test volume or qualitative service expectations justify any such expenditure of effort and money. Individuals in a hospital information technology department or even persons in the laboratory might have adequate abilities with the industry-standard and widely used software tools used for this system. Such services may be readily available on a project basis from software contractors as well. For laboratories that do very few such analyses, development of such a system may not be practical.

The alphanumeric results that include stone biochemical composition, dimensions, color, and weight are uploaded back into the LIS and are available online in the LIS and (for internal patients) in a distributed environment in the institution’s electronic medical record system to which the LIS is interfaced. Because these production systems and interfaces do not have the capability for handling digital images, the image components are not available online. In the future, as systems incorporate and institutions deploy such image-handling capability, providing digital images as part of electronic reports will be more feasible. Under consideration in our laboratory is the possibility of providing Web-based access to such reports, through the Intranet or securely over the Internet.

In addition to improved reporting of laboratory results, a number of other important benefits have been realized as a result of implementation of the system. Medical technologist time spent on manual data retrieval and entry, as well as on other manual steps necessary to produce a report, has decreased substantially. Keystroke errors have been virtually eliminated. As a consequence, the laboratory has realized the capacity to absorb a higher testing volume for these analyses. Previous reports can be reproduced and reprinted almost immediately on request.

The KISS described herein demonstrates the capability for laboratories to use off-the-shelf tools and standard programming techniques to produce integrated reports that include nontextual data types. This method could be a model for laboratories that are interested in ways to combine graphic and image data with text from multiple sources and to reduce manual steps involved in such a process.

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References