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What data integration means to the practicing dentist

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Practitioners all have been confronted with unscheduled, emergency care patients. Their immediate concern is usually pain relief, and they may not always provide accurate or complete information about their health history. They may be distracted by pain, lack the understanding of their health to answer appropriately, or by intention or oversight omit or provide faulty information. Faced with omissions and inconsistencies, practitioners make an extra effort to explore their health history and, if indicated, consult their physician. Although the information that is developed creates a more complete and more accurate picture of a patient's health, there is always a small risk of omission or misrepresentation of a significant item. Although chances are that this misrepresentation will have little impact on how the practitioner handles the case, there is that one case in a thousand that can ruin one's day and possibly one's practice.

What would that level of risk be if the practitioner did not have to rely on the information provided by the patient? What if he or she could obtain complete and accurate information from the perspective of another health care professional or practitioner? What would the practice financial picture look like if the practitioner did not have to spend nonreimbursable time exploring the intricacies of patients' health histories? What would it mean to the practice if patient information were in a form directly useable by the administrative and clinical support systems?

These questions have been explored extensively in the health informatics literature [1] over the past 20 years, with a consensus belief that information integration across the traditional boundaries of care delivery would accomplish the following goals:

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1. Improve the quality of care outcomes.
2. Reduce the risk in terms of relative amount and severity of adverse outcomes.
3. Make the delivery of professional services more efficient and economical.

A large and growing body of professional and trade literature notes that skillful implementation of an enterprise-wide electronic health record system achieves these expectations. To develop a technical approach and show how these benefits can accrue to the dental practice, practitioners must first build a foundation on the fundamental informatics principles as used in the clinical process and how dentists, like all health professionals, use information to make patient care decisions.

Fundamental informatics principles

Informatics principles are the foundation for the conceptualization, design, development, and implementation of information designed to support clinical practice. These principles are the basis for a shared understanding of the clinical process between clinicians and technologists for how and where technology is appropriately applied to improve clinical care. These principles also are the basis for a shared understanding of the knowledge management and decision-making processes so that the technology may be best used to make the clinician's information processing tasks more efficient and accurate.

The clinical process

Quality outcomes depend on making the right decisions at the right time linked with competent technical delivery. Decision making and the technical aspects of care delivery are illustrated in Fig. 1, which illustrates the components of the clinical process.

In this model of the clinical process, a patient in need of dental or other health services presents for care. Through examination and other fact-finding activities, the health care professional gathers a body of information about the patient, such as past health history, chief complaint, and signs and symptoms. This patient health information constitutes a body of findings. These findings are evaluated by the health care professional in a diagnostic process to produce a differential diagnosis.

The differential diagnosis, along with other information, such as patient health and quality-of-life expectations, form the input to a service or treatment planning activity. Increasingly, an expected result or desired outcome is specified in the treatment-planning step. The resulting treatment plan forms the roadmap for care delivery. All of these activities use decision making, assessment and reassessment, and a feedback loop to provide or identify the need for additional information.

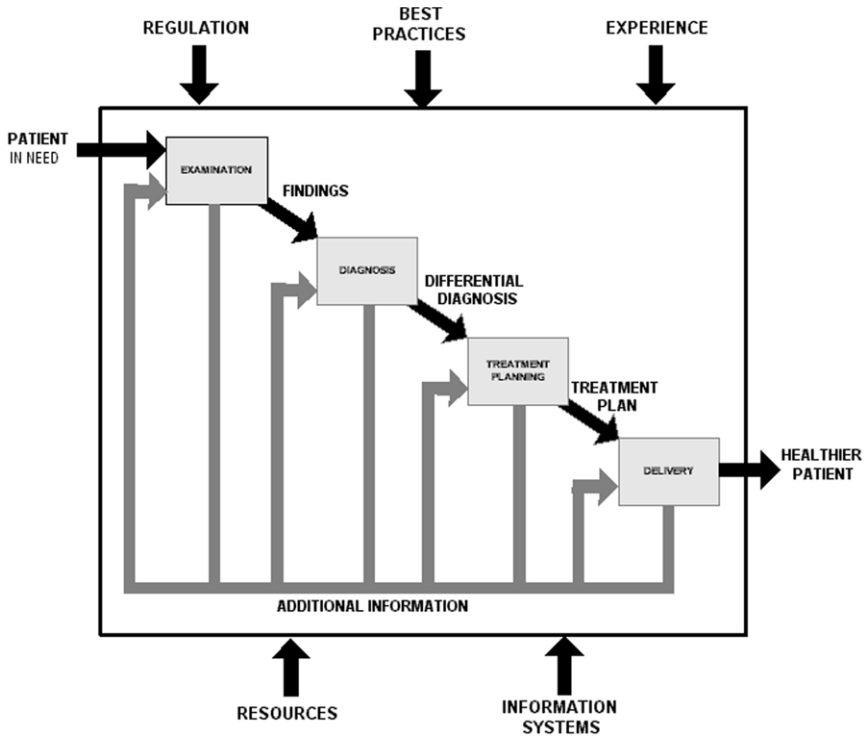

Fig. 1. Components of the clinical process.

All of these activities are performed under the control of a body of regulation, such as the federal and state authority, the spectrum of best practices developed by the health professions, and the personal experience of the practitioner. These activities are made possible by the use of resources, such as human expertise, supplies and equipment, and electronic and other information management technology. These steps collectively for the population as a whole, along with the information they use and the humanistic, scientific, and technical aspects of care delivery, are the basis for the arts and sciences of health care.

The best professional practices—essentially the methods and techniques learned in professional, postgraduate, and continuing education—are rules that practitioners use to guide decision making and technical performance. These best practices coincide with the common body of knowledge, which are usually well documented, and are shared among practitioners of a profession or a specialty. Experience, however, is a personal body of knowledge, often in the form of ''this works well in my hands under these circumstances.'' Professional meetings, literature, and other methods of information sharing serve to increase the common body of knowledge by sharing professional experience among practitioners. Best practices obtained

through training along with an individual's experiences form the body of expertise that the professional applies in delivering health care services.

Expertise = training + experience

Clinical expertise reflects a practitioner's total capability to produce a beneficial outcome for a patient. Expertise has two components: (1) experience is the skills and information acquired by the individual over a course of time, and (2) training is the skills learned from others. From its origin, dentistry, along with the other learned professions, has used training and experience as the principal means to develop professional expertise.

In dentistry, practitioners typically develop this expertise via the journeyman model of education. Most dental students enter the dental educational system with little or no care delivery experience. Early in the exposure to the clinical environment, the dental student is guided through the application of established rules by teachers who have knowledge and experience that the student lacks. As the student's body of experience grows, less reliance is placed on rules, and increasing clinical autonomy is afforded. The decisions that are made based on increasing experience have increasing value.

The three-tier information pyramid has become widely known, in which the foundation is data as elementary units of fact and measurement. Although the key point about data is existence, information is data placed in context in reference to other data. Information applies increasing meaning and significance to data. At the top of the pyramid is knowledge (ie, information within a human perspective). Progressing up this pyramid adds value to data.

Fig. 2 links the value of information in the information pyramid to the value of the decision process in the journeyman model. The rules used early in the dental education process frequently operate data. As apprentices, dental students progress toward journeyman status with graduation and licensure, and they acquire increasing levels of experience. Their decision processes increasingly draw on experience and are increasingly based on knowledge.

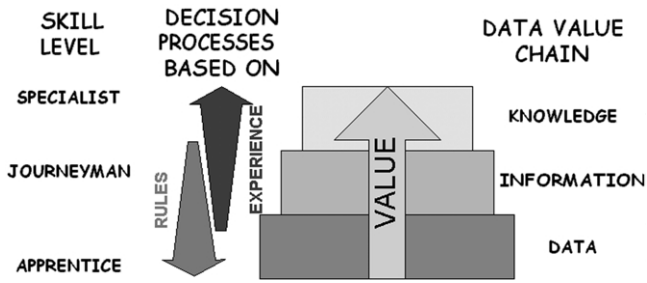

Fig. 2. Decision processes of the journeyman model and the information pyramid.

Two additional tiers add increasing value to the information pyramid by placing data further in the context of the human experience. Knowledge tempered by experience becomes wisdom, and wisdom enhanced by insight and creativity transforms into brilliance. As shown in Fig. 3, the decision processes that involve wisdom and brilliance are almost totally a function of experience, and the value is correspondingly greater.

Over the past 25 years, proponents of artificial intelligence have used various strategies to impart decision-making capabilities to machines. In dentistry, various approaches have included rules libraries, Bayesian or probabilistic analysis, fuzzy logic, and other techniques. All of these strategies have fallen short of true machine intelligence, because these techniques have not yet been able to cross the boundary between information and knowledge. They are unable to make decisions based on direct clinical experience.

At the apprentice level, as for a neophyte dental student's first encounter in the oral medicine clinic, rules are applied to diagnosis and experience that are developed through observation of actual cases. By the time dental practitioners have become clinical specialists at the master level, they have amassed a wealth of experience in decision making, clinical technique, and patient outcomes. Their decisions and care delivery are increasingly based on what works best in their own hands.

Also early in the experience in the oral medicine clinic students are taught first to view the patient as a whole and progressively narrow their focus to the chief complaint. The rationale for this rule is recognition that the patient presents as an integrated entity. The best quality decisions require that the decision maker gather as complete an information base as possible about the whole patient and subsequently separate the information needed to make the clinical decisions from irrelevant and confounding information. Drawing from the whole patient, some portion of the information that

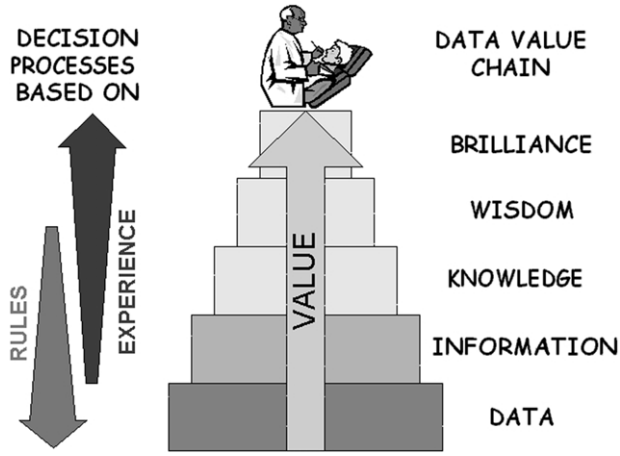

Fig. 3. Enhancing the value of the information pyramid.

contributes to a clinical decision lies outside the traditional anatomic, physiologic, and pathologic boundaries of the dental domain. Timely access to this information is essential. The degree to which the dentist has this access to information contributes to the quality of the care delivered and to the prevention of adverse and catastrophic outcomes.

Traditionally, standard operating procedures in dental practices require patients to provide their own health information. For most people and for most health conditions, this approach has proved to be an expeditious means to obtain health information of sufficient quality and reliability. However small, there still remains a potential for inaccurate or missing information to have a negative impact on the care outcome, contribute to a medical emergency, or adversely affect the health of the patient, doctor, or staff. In such situations, the doctor is placed in an untenable position of being accountable for the outcome of clinical decisions but is without control over the completeness or accuracy of the information used in the decision-making process.

Transforming principles into practice

Although technology can perform some of the rules-based decision processes used at the apprentice level, no current or anticipated technology can perform the same decision-making functions as the clinical specialist who operates at the master level. Even at the apprentice level, this technology routinely cannot be expected to make decisions regarding the best patient outcomes. Progressing from the apprentice through the journeyman and master levels, technology cannot function independently but is best used to assist the experienced practitioner. The most appropriate use of technology is to aid the practitioner by preventing errors of omission and commission.

Combining the features of the clinical process cascade with the journeyman model yields the fundamental functional requirements for a system that supports clinical decision making. The six functional requirements derive from the idea that technology must meet the following criteria:

- It delivers complete and accurate information.
- It is of the right type and amount.
- It is applied to the appropriate decision makers.
- It is available at the time and place of decision.
- It is in a form best used for decisions that must be made.

The conventional three-tier information systems architecture assembles essential information technology components to satisfy these requirements. This architecture consists of three layers: (1) the presentation layer, which interacts with the external environment (eg, human operators and other systems), (2) the application layer, which performs the mathematical and logical operations directed by the programming and human direction, and (3) the data layer, which organizes and stores information in fundamental elements.

This architecture represents the basic structure for conventional client-server and Web-enabled information systems. It also represents the basic structure for nonautomated processing of information; automation principles have been developed from the best concepts of human information processing. Most clinical, imaging, and administrative systems used in the dental practice use this architecture. All components of this architecture are equally essential: the system could not function absent any of these. The manner in which these fundamental structures are implemented and used determines the characteristics or personality of the system.

The presentation layer is most visible to the clinician. Because of this direct interaction with the human, its features are usually the measure by which the clinician determines utility, suitability, or goodness for a particular need. The clinician also may be aware of the application layer because its functions are manifest in the daily performance of the system. Least noticeable and rarely understood are the nature and functioning of the data layer. The data layer is embedded deeply within the system and typically resides as large, organized assemblages of microscopic magnetic zones on a disk drive. This data layer contains the key and essential information about any specific patient or the practice. The use of information in the presentation layer depends critically on how it is manipulated in the application layer and the form and structure of the data in the data layer.

Fig. 5 illustrates the application of this architecture to the three major information management processes of the dental practice. These components deal with the use of information for practice management, billing, and related administrative purposes; the use of information in the delivery and documentation of clinical care; and the interaction between the practice and the external professional environment as for a medical consult, a laboratory order, or an information request to a professional library.

These processes do not require digital technology. The term ''system'' as used in information system was actually derived from the life sciences, meaning a structure organized to perform one or more processes. Historically, communications in these external interactions have been performed by telephone, in person, or by mail. Likewise, information processing has been performed chiefly by the professional and administrative staff, whereas data have been stored in paper files and on film. Introduction of computer technology has only made these processes and communications more rapid, efficient, and capable.

As shown in Fig. 4, all of these processes function independently. All interact with humans differently. All have their own discrete set of tasks, and all have their own separate repositories of information. Information processing in care delivery and practice management requires the transfer of information from one set of processes for use in another (eg, when medical consult information from a telephone conversation must be transferred to clinical documentation; clinical services are documented on a superbill or walk-out statement and then transferred into a financial system). These information

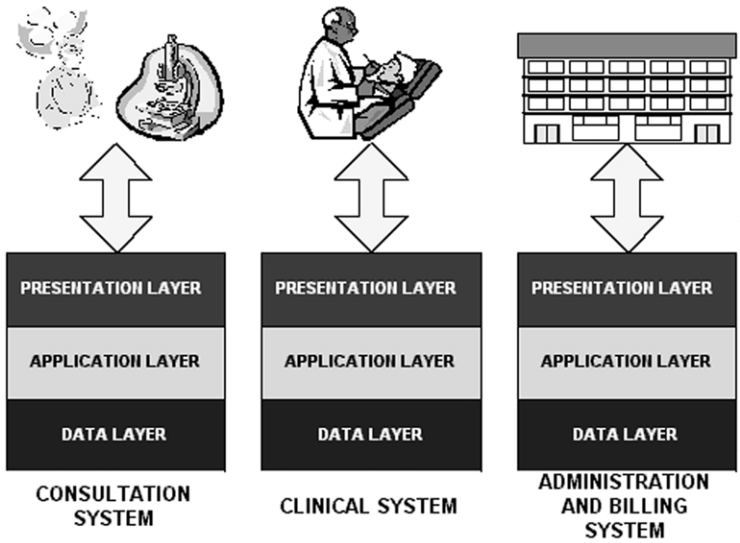

Fig. 4. Basic architecture of the interfaced practice system.

transfers require human interaction at the presentation layer and are labor intensive, prone to error, and an inefficient use of valuable human capability.

During the 1990s, practice system information systems streamlined this transfer of information by building bridges among these and other processes. These bridges allowed nearly automatic information transfer almost transparent to the human user. The number of separate computer systems was reduced by placing many program suites (eg, patient registration, charting, Internet communications) on a single system. The communication bridges among these systems were achieved via interfaces among the programs at the application layer and between systems through data communications at the presentation layer (Fig. 5).

Interfacing at the application or presentation level is an improvement over manual transfer of information. Interfacing is, however, only an intermediate systems solution to the information exchange problem. Early attempts at interfacing required building large numbers of individual links between programs and systems, a tedious and expensive developmental task. Data communications between systems, termed point-to-point messaging, became more reliable and economical with the introduction of messaging standards, such as Health Level 7. System developers found, however, that interfacing remained a less than ideal means to share data among programs and systems. Consequently, system developers began moving their designs toward integration at the data layer (Fig. 6).

Medical and dental systems developers drew on the experience outside of health care, particularly the concepts of enterprise-wide information systems that continue to gain favor in industry and commerce. The experience has

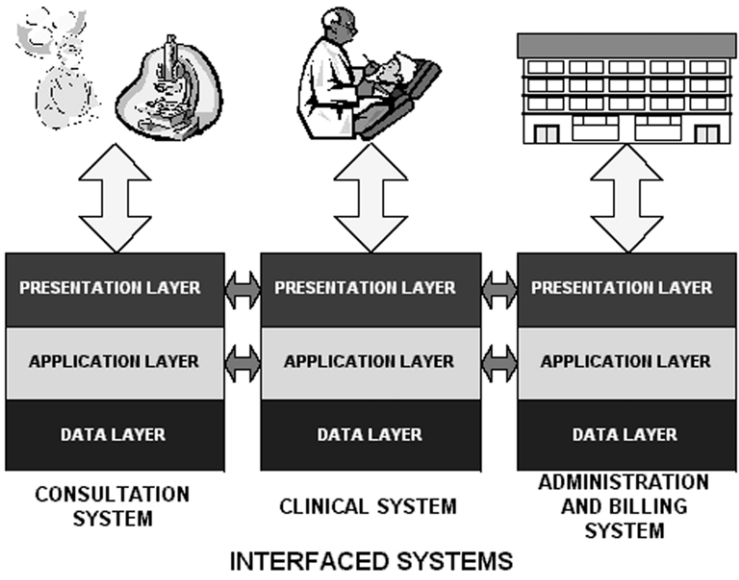

Fig. 5. Fundamental types of information processes in the practice.

indicated that integration at the data layer maximizes processing efficiency and smooth operation among system components and individual programs. Whereas interfaces among applications on single computer systems and between systems remain a primary communication mode, integration at the

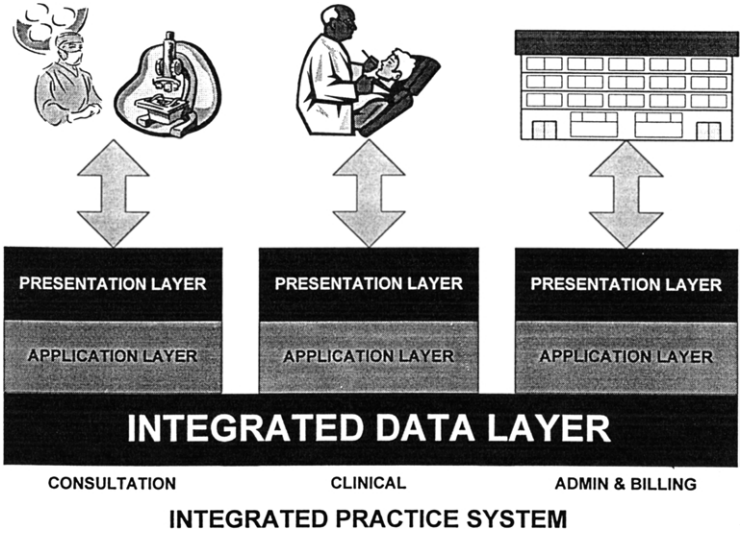

Fig. 6. Basic architecture of the integrated practice system.

data level is increasingly used because of increased performance, economy, and efficient storage of information.

The heart of the integrated system architecture (Fig. 6) is an enterprise-wide data system. For the dental practice this means a single database that supports the principal administrative, clinical, and communications functions of the practice. All clinical and administrative applications interact with this database, including:

- the registration application that enters patient demographic, contact, and reimbursement information.
- an enrollment and eligibility checker that draws on these data to contact the insurance companies.
- the scheduler that draws on registration data to make the patient appointments and records the purpose of the appointment.
- the charting and imaging programs that add examination and treatment planning data.
- the preauthorization application that confirms service coverage with the carrier by drawing on essential portions of examination and treatment plan data.
- the clinical data entries in the charting and imaging programs that document services provided.
- the financial applications that draw on the clinical data for billing.

All of these functions, and more, are supported within the practice on a single database. The next step is data integration beyond the walls of the practice.

Optimizing the value of information

Referring back to the clinical and decision-making processes and the architecture in Figs. 5 and 6, issues about information quality and interfacing to external systems remain. Although integration has been achieved in large part on the financial side, particularly because of the widespread adoption of the American National Standards Institute X12N standards (insurance transactions), the same effect has not been realized on the clinical side. For example, whereas some dentists may use electronic mail or the Internet to augment or replace telephone communications in medical consults, direct access to patient medical information has not been realized outside of hospital dentistry.

Patient-provided personal health information continues to be the weak link in the decision-making process. Practitioners rely on the information the patient provides and attempt to confirm and expand on it through medical consults. Dentists are better served by patient health information provided directly by the patient's medical provider, which accurately conveys clinical relevance. This information provides relatively instantaneous access to information from another doctor's point of view. Acquiring this information

directly from the medical provider's system optimizes quality and timeliness. It reduces risk, contributes to improved outcomes, and increases economy in care delivery.

Data integration across enterprises is the next threshold in systems evolution. Cross-enterprise data integration removes the barriers that prevent timely access to accurate and professionally meaningful health information. Recognizing the potential benefit of this access to information by all health practitioners, the American Dental Association House of Delegates in Resolution 92H-1996 stated:

> The American Dental Association believes that, for optimal patient benefit, with assurance of confidentiality safeguards, appropriate *health* information should be available at the time and place of care to practitioners authorized by the patient through the development of a computer-based patient *health* record.

This resolution was implemented by the development of standard data architecture for clinical information by the American Dental Association's Standards Committee on Dental Informatics and its acceptance by the American National Standards Institute. The American National Standards Institute/American Dental Association 1000 Standard Clinical Data Architecture for the Structure and Content of a Computer-based Patient Record was adopted by the American National Standards Institute as an American National Standard in February 2001.

This data architecture provides a consensus-approved set of data elements that can be built into an enterprise system and can streamline data communication across enterprises. The standard proper was derived from a logical model of the generic clinical process (see Fig. 1) and the fundamental clinical data items shared by all health professions. Its structures are suitable for point-to-point data transfer, such as using the Health Level 7 protocols, or Web-enabled exchange of clinical information, particularly through use of the emerging extensible markup language standards.

Use of this technology, and especially these health informatics standards, provides dental practitioners with an information management capability previously unavailable. In Donnabedian's classic quality construct of structure, process, and outcome, use of cross-enterprise data integration with the American National Standards Institute/American Dental Association 1000 Standard contributes to improved information systems structures and processes. In turn, these structures will improve the quality of patient outcomes. Cross-enterprise data accessibility will facilitate increased efficiency and economy of care delivery, improve outcomes, and reduce risk.

Reference

[1] Metzger JB. The potential contributions of patient care information systems. In: Drazen EL, et al, editor. Patient care information. New York: Springer; 1995.