Understanding CPR Architecture: An HIM Professional's Guide

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The continued evolution of the CPR offers numerous career opportunities for HIM professionals. But a knowledge and understanding of the fundamental concepts is critical for those who would take advantage of these opportunities. The authors offer an overview of the differences and interaction between the CPR component parts, the basic clinical and business functions they support, and the technology used to implement the CPR.

In 1991, the Institute of Medicine (IOM) outlined the architecture and functionality of the computer-based patient record (CPR).[1] In the following years, many clinicians and HIM and IS professionals alike have further defined the CPR,[2,3] reviewed its evolution,[4] discussed the challenges in implementing it,[5,6] and described its benefits.[7-10] Despite these laudable efforts, the IOM has stated that "a universal understanding of the concepts embodied in a CPR does not exist."[4]

This confusion is not surprising. The fact that the CPR is all-encompassing makes it a difficult concept to grasp, much less define, succinctly. In addition, over the years a number of related terms (e.g., the electronic patient record [EPR], document repositories, data repositories, data warehouses, and data marts) have been used interchangeably in the conceptualization, marketing, development, and implementation of the CPR -- further blurring the distinctions between its concept, its component products, and the technology used to implement it.[11-12]

The evolution of the CPR offers numerous opportunities for HIM professionals to expand their roles (see the practice brief "Data Resource Administration: The Road Ahead" in the November/December 1998 *Journal of AHIMA* for an overview). Those who understand the fundamentals of the technology will be best equipped to meet the challenge of managing and maximizing the use of their organization's data resources. This article is the first in a two-part series outlining the framework of the CPR to allow the HIM professional to gain a high-level knowledge of its components.

This article will explore the structure of the CPR and the distinctions that differentiate each constituent part. The second article (to be published in a future issue of the *Journal of AHIMA*) will extend the exploration of other parts of the CPR and will discuss the career paths developing from the conception, organization, and implementation of a CPR. Construction and processes may differ from one organization to another, but information management career opportunities are present in any enterprise, wherever the enterprise is on the path to development.

After reading this article, the reader will be able to identify at a high level:

- the differences and interaction among the CPR component parts (e.g., the role of a data repository in an EPR)
- the basic clinical and business functions they support (e.g., data repository for patient care versus data warehouses and marts for decision support)
- the technology used to implement it (e.g., data versus document repositories)

The subsequent article will point out how the construction, management, utilization, and maintenance processes involved in a CPR create career possibilities ideally suited to the skill sets acquired through education and experience by HIM professionals.

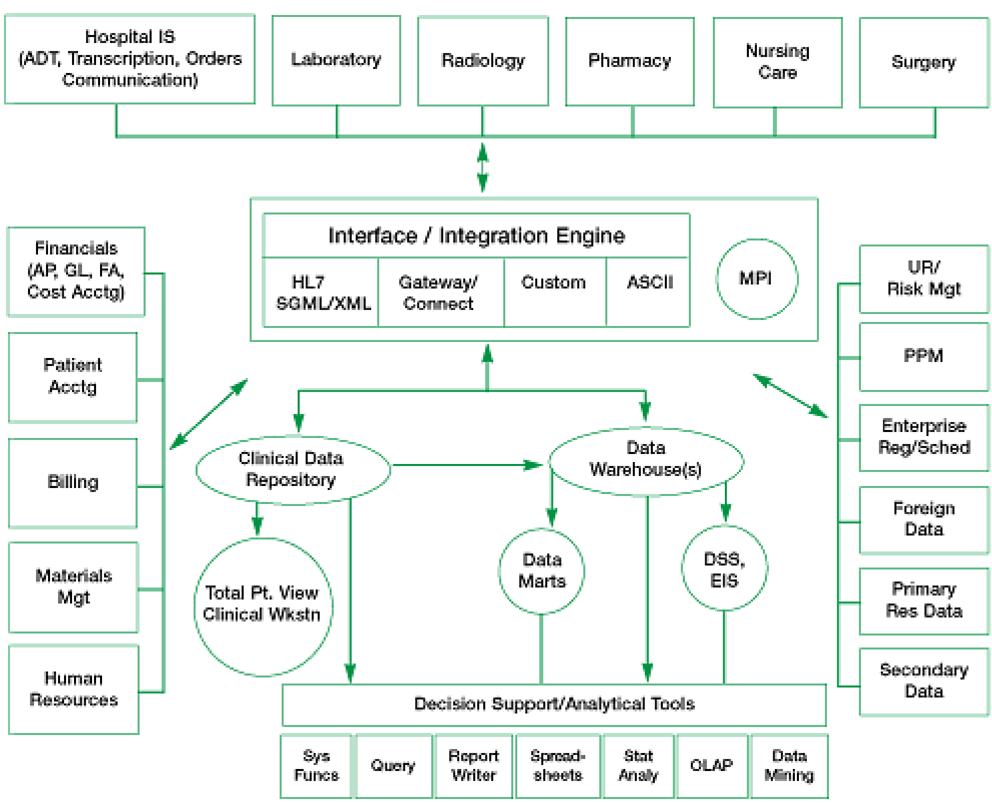
HIM professionals who have a solid foundation in the concepts and the framework of the CPR can use this knowledge to identify the products needed to implement the CPR, as well as to understand which components are best suited to support the process of care and which generate useful health information and knowledge for decision support.

The CPR as a Corporate Information Factory

In large part, the CPR functions as a corporate information factory[13] (see Figure 1). In healthcare, the corporate information factory is a complex information architecture consisting of:

- systems that support patient care and administrative processes at both the departmental and enterprise level
- foreign data collected outside the enterprise, which allows for a more longitudinal and complete view of the patient
- primary data collected within a department or across the enterprise so that clinical research can be conducted
- secondary data acquired by the enterprise, frequently used to compare departmental or enterprise performance against a benchmark and monitor the enterprise's ability to compete in the marketplace
- a process to standardize, cleanse, and integrate foreign data from external systems, along with data across the various departmental and enterprise-wide systems
- a system to view the integrated, multimedia patient data and support total, interactive patient care
- links to knowledge sources to support evidenced-based healthcare
- integrated databases and analytical tools that manufacture:
    - information and knowledge for clinical and administrative decision making
    - information and knowledge needed to simultaneously reengineer business processes and improve the quality of care
    - business intelligence to improve operational performance and achieve competitive advantage
- information portals on the Internet to assist clinical decision making

Figure 1—The computer-based patient record: healthcare's corporate information factory



The departmental systems within the corporate information factory may include those in the financial (e.g., accounts payable/receivable, general ledger, fixed assets, as well as general, cost, and patient accounting), administrative (e.g., billing and reimbursement, materials management, and human resources), and quality assurance (e.g., risk management/utilization review) areas. These systems are most prevalent because they were among the first generation of products on the market. More importantly, they were often needed to manage revenue and costs -- and thus ensure the financial viability -- of the institution.[14]

While the above systems are more prevalent, in actuality, clinical information systems are now more important because they are directly involved in the delivery -- and can thus help improve the quality and reduce the cost -- of patient care. These clinical departmental applications may include laboratory, radiology, pharmacy, nursing, and surgical information systems.

Enterprise-wide Systems: Integrating Data

The enterprise-wide systems may comprise the hospital information system (HIS) as well as those for physician practice management and enterprise registration and scheduling. Except for the HIS, enterprise-wide systems are less prevalent, as they have only recently entered the market and may be more applicable to integrated delivery networks (IDNs) rather than stand-alone institutions. If applicable, however, they, like the HIS, are extremely useful for coordinating operations across the network.

These existing legacy systems form a class called online transaction processing (OLTP) systems because they automate routine transactions. Admitting, discharging, or transferring a patient or performing a complete blood count (CBC) test are examples of a transaction. These systems may also be called operational information systems (OIS) because they help manage the operations of the department or enterprise.

In addition to operational information systems, some enterprises import foreign data -- i.e., data collected during patient care processes occurring outside of the organization. Immunization data is an excellent example. Immunizations may occur in schools, community and public health clinics, and other provider offices. By importing detailed data from the external provider, the enterprise can have a more comprehensive clinical and financial view of the patient.

Some enterprises may also collect data within a department or across the enterprise so that primary clinical research can be conducted. An oncology database, for example, might be developed to study the various forms of cancer in patients seen by an enterprise. (Note: Primary research may be more applicable in an academic health center than in those institutions where research is not mission critical.)

Lastly, some enterprises may purchase or in some other way collectively gather aggregated secondary data. Typically, such data are used for benchmarking or research purposes. For example, a consortium of hospitals may agree to gather operational data to compare productivity in radiology, nursing, or materials management against the benchmark institution within that group. Others may purchase, or get access to, a national cancer database so that they can contrast results from their primary research data against a national benchmark group. Still others may acquire demographic, payer, provider, claims, and regulatory data to benchmark costs, charges, and average length of stay by DRG, provider, payer, or patient group. They can then identify opportunities for savings, as well as monitor how well they are competing in the marketplace.

In addition to processing transactions or supporting research and benchmark studies, the above software applications and databases act as feeder systems to:

- another system that integrates the view of the patient and supports total patient care
- a class of products called decision support systems
- other research databases

Before data can be fed to these systems, however, it must be integrated. The software product that performs this function is called an interface engine.

An interface engine is useful for translating and sending data from one system to other systems downstream in the patient care process. For example, when a patient is admitted, the demographic data in the admission record from the hospital information system is sent to the interface engine, where it is translated into the formats needed by the laboratory, radiology, and nursing systems, and then sent to the respective systems. As a result, accuracy of the data is improved, and productivity is increased by not having to reenter the data multiple times.

Components of Data Integration

Allowing disparate systems to be autonomous -- by storing demographic data, for example, in their respective formats -- is satisfactory for departmental computing, where the data is contained within the boundaries of the business unit. However, such autonomy poses real problems if the patient is to be viewed in an integrated, multidisciplinary fashion, which is exactly what we want to do under the CPR concept. Consequently, some products also perform transformation, cleansing, and other integration functions. For that reason, products that go beyond simple interfacing have also been called integration engines.

A key component of data integration is, of course, linking records from all patient encounters across the health network into a single longitudinal record for each patient.[15] The product that performs this function is the enterprise master patient index (EMPI). The integration engine and EMPI products work in tandem to integrate records from the various systems before feeding the data repository or the data warehouse(s).

A variety of technologies can be used to integrate and exchange data, including:

- HL7, or Health Level 7, a standard for the electronic interchange of clinical, financial, and administrative data among compliant systems[16]
- SGML/XML, or Standard Generalized Markup Language/ eXtensible Markup Language, powerful languages that create documents, define data within them, and provide innovative ways to share data across systems[17-20]
- off-the-shelf products from vendors that make it easier to link and share data between databases
- custom interfaces -- e.g., programs written in COBOL that perform the interfacing or integration functions
- transfers of ASCII (American Standard Code for Information Interchange) data

The Difference between a CPR and an EPR

Once data has been integrated, it is then possible to have a total view of the patient longitudinally and within an entire episode of care. For a variety of reasons, the integrated data must be stored in a database that is different from those that store data for each of the operational information systems. That database is typically a clinical data repository (CDR).

Workstation functions in the CDR help clinicians view integrated data, make treatment decisions, and provide care in an integrated, multidisciplinary fashion. System (built-in) functions, along with e-mail and medical in/out baskets, give clinicians the ability to receive patient scheduling information, order tests, view lab and radiology results, receive alerts for abnormal results, request consultations, receive prescription refill requests, query the database for outcomes of previous patients with similar problems, discuss patients with insurers and other caregivers, and send messages to individual patients.

Together, the clinical workstation and data repository constitute an electronic patient record product. This is an important distinction between the CPR and the EPR. In this framework, the CPR is both a concept and an information architecture. As a concept, the CPR gold standard[1,11,22] is a vision toward which the industry is constantly striving. A large part of that concept is implemented within an information architecture. In this context, the CPR is an umbrella term that conveys the machinations of the corporate information factory (see Figure 1). The EPR, on the other hand, is a set of products (primarily the CDR and clinical workstation) within the information factory that implements a part of the CPR concept.

Some vendors, clinicians, and HIM and IS professionals may use the terms "CPR" and "EPR," along with "CPRS" (computer-based patient record system), "EHR" (electronic health record), "EMR" (electronic medical record), and "VHR" (virtual health record) synonymously. Using the terms interchangeably is less important than distinguishing between the CPR as a concept, the CPR as a corporate information factory, and the EPR as a product set.

The CPR is both concept and corporate information factory. The EPR is a set of products within the factory that implement an important part of the concept.

Distinctions Between a CDR, a Clinical Workstation, and an EPR

It is important to understand some of the features and limitations of the EPR, not just to eliminate the confusion between it and the CPR, but to clarify the relationship between its own component parts, as well as between it and other components within the corporate information factory.

Regarding the components of the EPR, there is less ambiguity about the functionality of the clinical workstation than there is about the CDR. For example, given recent product reviews,[11,22] a subset of gold-standard CPR functions implemented by EPR workstation products can be clearly identified. Moreover, a core set of those functions seems to be contained in a majority of the products on the market today. Some workstation products may comprise more than one module -- e.g., one that allows the clinician to view the patient's chart and one to discern business rules and trigger alerts. But there is little question about what makes up the clinical workstation.

The same cannot be said about the CDR, however. There appears to be greater confusion surrounding it,[23] particularly in how the moniker is used in marketing products. To be clear, in the EPR the workstation is the software that provides the clinical functions (orders, alerts, etc.), while the CDR is the integrated database needed to support the workstation. The two go hand in hand, but in terms of functionality, the CDR is not synonymous with the workstation.

Nor is the CDR synonymous with the EPR. As the integrated database, it is simply an important part of the EPR. The EPR is the business solution, the CDR is one of its underlying technologies. Without the business solution, the CDR is a database without use. A vendor may call its EPR product a clinical data repository for marketing purposes; but again, product labels are immaterial. It is more important to differentiate between the product name and its functionality.

In the EPR, the workstation is software that provides the clinical functions. The CDR is the integrated database needed to support the workstation.

Differences between Data and Document Repositories

Part of the confusion surrounding the EPR stems from past, and often blurred, distinctions between its underlying technology and the technology's use as a business solution. This may account for some of the ambiguity between a data repository and a document repository.

Document Repositories

From the technical perspective, a document repository is a database of scanned images, complete with face sheet, history and physical, orders, results, progress notes, consult reports, discharge abstract, insurance vouchers, and more. Using a technology called Computer Output to Laser Disk (COLD), documents are scanned, stored and indexed by patient identifier. The documents for a patient can then be retrieved either individually so that the clinician can immediately view a specific part of the record, or collectively to form the entire record.

Implemented as part of an EPR business solution, its strengths are many. As an electronic metaphor of the paper record, users may interact more easily with the system, with the added benefit of allowing multiple users to access a record at the same time. It can also help reduce operating costs and space for document storage, as well as the number of lost or misfiled documents, in addition to improving work flow, speeding reimbursement, and ensuring security, backup, and disaster recovery.[24]

There are, however, some potential drawbacks to a document repository. As scanned images, the data within the documents cannot be extracted, sorted, or manipulated. This drawback may be inconsequential for enterprises that place a higher premium on supporting the patient care process than on using patient-generated data for outcomes measurement, benchmarking, or research. But given various reporting requirements and pressures to improve quality while reducing cost, such enterprises may not be leveraging a strategic resource -- data -- to facilitate quality improvement, process reengineering, and research, in addition to supporting patient care.[7-9,25,26]

Data Repositories

In contrast, a data repository is technically a multimedia database. That is, it contains many, if not all possible data types -- structured (e.g., discrete lab values), semistructured (text, e.g., operative notes), image (e.g., mammographies), video (e.g., ultrasounds), voice (e.g., dictation), and graphics (e.g., a line graph of body temperature). Note that a data repository can store scanned documents, since a document simply looks like an image data type to the repository.

There are many advantages to a data repository in addition to those mentioned for a document repository. In terms of patient care, the data is readily available and can be easily accessed by multiple users. Its up-to-date information on lab results can help reduce duplicate tests. Its integrated data gives the clinician a comprehensive view of the patient (e.g., financial and clinical, longitudinal and episodic). In addition, it allows clinicians to query the database, the results of which may help them make better decisions.[25] Finally, the data can be compared against clinical pathways, allowing caregivers to monitor their practice patterns and adjust either their behavior or the guidelines accordingly.

In the future, knowledge sources (i.e., books and journal articles) may be linked to clinical concepts gleaned from data in the repository. There is promising research that could make such automated evidenced-based healthcare possible within the next decade. The technology might work in this way: Given the text in a journal article, statistical analyses can be performed calculating the frequency that words appear in the text, as well as a matrix of co-occurrences between words.[27] Each of the co-occurrences between the words probably indicates that some semantic meaning is present, roughly forming a concept. Similarly, concepts can be formed by analyzing the text of an individual's record in the data repository (e.g., pathology, radiology, and nursing notes).

By matching the concepts between the record and the literature in some automated fashion, an alert can notify the clinician that best practice literature is available for problems associated with that specific patient and display the literature accordingly. This technique might be extremely useful when the clinician has an unusual case. Though this technique should not hinder the clinician from performing the various tests he or she thinks is necessary, it could guide him or her to beneficial treatment regimens tried elsewhere. As a result, some tests or treatment options (and the cost of doing them) may be avoided.

In the future, evidence-based healthcare could be automated by linking knowledge sources to clinical concepts gleaned from data in the repository.

As with anything else, a data repository has its down side. The effort, technology, and cost to standardize and integrate data across the enterprise may be greater than implementing a document repository. However, its other suspected shortcomings may be attributed more to the EPR than to the CDR. The CDR suffers simply because it is a part of the EPR solution. For example, many EPRs were designed to support a single hospital rather than an integrated delivery network. Consequently, few EPRs work in both inpatient and ambulatory settings, such as clinics and doctors' offices. The database structure of the supporting CDRs therefore may have a more inpatient orientation.

Moreover, if a selected EPR is geared toward the inpatient setting, then supporting the entire continuum of care may mean implementing two EPRs, one each for the ambulatory and inpatient settings, working in partnership with a vendor to modify an EPR so that it can support the multiple settings of an IDN, or waiting until such a product arrives on the market. The drawbacks in these instances then can range from coordinating multiple CDRs to working with frequent changes in the design of the data repository until a marketable EPR product is released.

Nonetheless, the important part of the document repository versus data repository discussion is not the underlying technology. It is, rather, whether the business solution that each is a part of is the best one for the healthcare enterprise.

Merging the Document Metaphor with Multimedia Data

Some would argue that the best business solution combines the benefits of both technologies -- i.e., the ease of readability that a document affords with the ability to parse, or extract, multimedia data within it. That combination allows a clinician to view a chart and still provides a mechanism to either manipulate data or exchange data between systems. Fortunately, through SGML (Standard Generalized Markup Language) and XML (eXtensible Markup Language) -- tools used for more than a decade in the publishing industry -- and HTML (Hyper-text Markup Language) -- used to build documents for the World Wide Web -- this solution may be just a few years away from commercial implementation in healthcare information systems.

SGML essentially defines what is in a document through a structure called Document Type Definition (DTD). For example, the DTD may define a document as an insurance form, containing the patient's name, address, provider identification number, primary diagnosis, secondary diagnoses, procedures, procedure dates, charges, and so on. XML is a language that defines the structure of the data within the document using "mark-up tags." A name data structure, for example, would be tagged .

Usually, the data structures defined by XML are those attributes (name, address, etc.) within the DTD. However, XML also allows data to be defined outside the DTD. For example, an institution may define the attributes on a UB-92 claim form in the DTD in order to collect data and share it with insurers. However, the institution might add comment, severity adjustment, and outcome attributes for internal benchmarking or research purposes. When sharing data with insurers, only the data within the DTD is exchanged. But when doing internal benchmarking studies, the severity adjustment and outcomes data may be used as well.

HTML, a specific way of implementing SGML, is used to control how content is presented in a document. With HTML, for example, dynamic Web pages can be created with formatted text (e.g., font styles), images, and hypertext links to other pages. It is beyond the scope of this article to discuss the technology behind SGML, XML, and HTML. There are excellent references already available on the subject.[16-20] For the purposes of this article, the focus is on the benefits of using these languages to create documents and interactive forms.

First, SGML, XML, and HTML offer great flexibility, since text can be free form from document to document while containing the same data. For example, the narrative that one clinician writes in a history and physical may be different than what another writes, but the data elements contained within the two documents are the same since they conform to the structure of the history and physical DTD. Thus, the ability to define data structure while allowing the document to be more free form enables users to parse data elements within documents, or search for documents based on data contained within, while retaining a more natural user interface.

Second, instead of a document, a data entry form or patient screen could be developed using SGML/XML/HTML. When linked to a database, the attributes identified in form's DTD and tagged by XML could feed the database itself or be fed by the database. Thus, data exchange could be handled very efficiently. The promise of these benefits are so great that a special interest group of Health Level 7 is currently working on defining standards for various DTDs. Given the accomplishments of other industries in their use of SGML, XML, and HTML, there is every reason to believe that healthcare will enjoy equal success.

Conclusion

To take advantage of career opportunities the CPR presents, HIM professionals need to understand its fundamental concepts -- the difference between the CPR and the EPR, the functions of the CPR as a corporate information factory, and the differences between kinds of repositories. The knowledge of these tools, as well as an understanding of the framework for identifying those systems, the "pieces of the puzzle," that comprise the CPR information architecture, are key to the success of the HIM professional who wishes to help an enterprise use information and knowledge for both strategic and informational purposes.

challenges in integrating data across multiple systems

Data quality is of utmost importance when integrating data from disparate systems. However, there are many problems associated with data integration. Author W. Inmon has identified four of them; healthcare examples were conceived by the authors.

Encoding -- Encoding problems occur when two or more systems have data with the same meaning, but use different codes. For example, in one system, gender may be coded 'M' for male and 'F' for female, while another system may code '1' and '2' respectively. When this problem is encountered, data transformation must take place. HIM and IS professionals must decide which coding system should be used and then map one coding system to the other. This is a simple problem when there are just two systems. However, the problems are compounded when multiple systems must be integrated, as when implementing a clinical data repository or data warehouse.

Attribute measurement -- Attribute measurement problems occur when two or more systems have data with the same meaning, but use different scales of measurement. For example, one system may measure birth weight in pounds and ounces, while another may use kilograms. Again, data transformation must take place.

Multiple sources of data -- Typically, when implementing a data repository or a data warehouse, there may be dozens of systems from which data must be integrated. Usually, there are data elements across a number of these systems that have the same meaning. In these instances, some important issues should be considered. Which should be considered the "master system" from which that element is extracted? What criteria should be used to determine the master? Is it the quality of the data that comes from that system? Is it the point in the process in which the data element is captured (i.e., collected once, provided to many)? Does it depend on who the owner of the data is? Will the stakeholders in the enterprise agree to the designation of the master system? These issues are in addition to the encoding and attribute measurement problems above.

Conflicting keys -- Databases must have key fields that uniquely identify each record. More often than not, the unique identifier(s) is different between disparate systems. For example, one system may use a medical record number while another may use an account number; or two systems may use account number as the key field but either the formats are different or different account numbers are assigned. In such instances, linking records across the various systems is difficult.

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