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ABSTRACT

The healthcare industry is the largest industry in the US, and costs are growing rapidly. There is also an increase in waste, medical errors and patient injuries. One central problem is that hospitals have compartmentalized and disaggregated business models in which clinical specialists duplicate information. An international project called Integrating the Healthcare Enterprise (IHE) is underway to develop consistent information enterprise architectures for hospitals. The Operating Room (OR) is one of the most complex parts of the hospital, involving many other departments like laboratory, radiology, pathology, pharmacy, anesthesiology and billing, so a formal IHE design for the OR has not yet begun. This current research describes a collaborative workflow model for the OR using Event-Driven Process Chains, a popular and successful process reengineering tool used in ERP systems engineering.

Keywords

Healthcare integration, healthcare collaboration, decision support, clinical engineering, workflow, EPC, BPR, operating room

INTRODUCTION

The $1.4 trillion healthcare industry of the early 21st century is the largest single industry in the US, and it is projected to reach nearly 20% of the GDP by 2010 [4]. For MIS researchers and practitioners the healthcare industry represents one of the greatest opportunities and challenges in the coming years. Healthcare has a compartmentalized, disaggregated business model, causing rapidly escalating waste, and errors. Systems and standards are needed to create collaborative healthcare enterprises, and they should address issues like the following:

1. closer resource planning and allocation,
2. more efficient scheduling and planning,
3. timely, efficient, and error-free vendor management, and
4. knowledge-sharing between stakeholders.

This paper presents a design for the Operating Room (OR). This model is constructed using Event-Driven Process Chains (EPCs), popular Enterprise Resource Planning (ERP) systems re-engineering tools [2] used in many other industries. Although this approach may seem mundane for MIS experts, the stark reality is that to date little of such formal methodology has been brought to the hospital. Although a more robust and sophisticated modeling tool such as UML might be considered, EPC is ideal because it is easily understood by doctors, nurses, and other non-MIS experts who must participate.

Most medical information systems (IS) are isolated "islands," solely serving a unique medical specialty. Even if an IS helps deliver excellent care within the specialty, doctors, nurses, or technicians must aggregate, integrate, and interpret information from multiple computer systems manually. In a fully-implemented ERP system all participants from raw material suppliers to the customers are interconnected, but this rarely exists in healthcare enterprises [7].

II. BACKGROUND FOR THE STUDY

Clinical engineers [6], surgeons [8, 9], the Joint Commission on the Accreditation of Healthcare Organizations (www.jcaho.org), and the Emergency Care Research Institute [6] have all documented similar serous communication and system problems in healthcare that had terrible consequences. Well publicized errors include incorrect amputation of patient limbs, electrocution, and deaths. There is a strong movement arising to design new intra-organizational collaboration systems for healthcare.

The IHE Model for Healthcare Integration

The Integrating the Healthcare Enterprise (IHE) project is one such successful effort in this area and it provides interoperability within and between the hospital's compartmentalized information and management systems. IHE is a project that was spearheaded by the Healthcare Information Management System Society and the Radiological Society of North America [14, 15]. In 2003, the IHE project also joined forces with another of the major healthcare collaborations, Health Level 7 (www.hl7.org), providing access to internationally-recognized inter- and intra-organizational data coding standards. An early IHE goal was to facilitate the exchange of radiological images like X-rays, mammograms, CT, MRI, or PET scans between differing brands, models, and modalities. Equally-important, the IHE design facilitated transfer of critical billing and patient scheduling information from the RIS to the hospital's billing systems (often called a Hospital Information System – HIS), which also handles all Admission, Discharge, and Transfer transactions.

The IHE standards for RIS and HIS are well developed today, and hospital demonstration sites are beginning to emerge [14, 15]. Several annual international collaboration demonstrations are held to allow continuous development and improvement for these standards. A hospital laboratory IHE effort is now well established in France and a Cardiology-oriented effort has been launched with the American College of Cardiology [12, 13]. Each of these projects is at an early stage, and this present research is intended to extend those efforts by developing a preliminary design for the Operating Room (OR). This effort precedes any IHE initiatives in that area, because the workflow complexity of the OR often affects data to or from other IS "islands" like anesthesiology, billing, laboratory, radiology, pathology, patient and staff scheduling, and pharmacy.

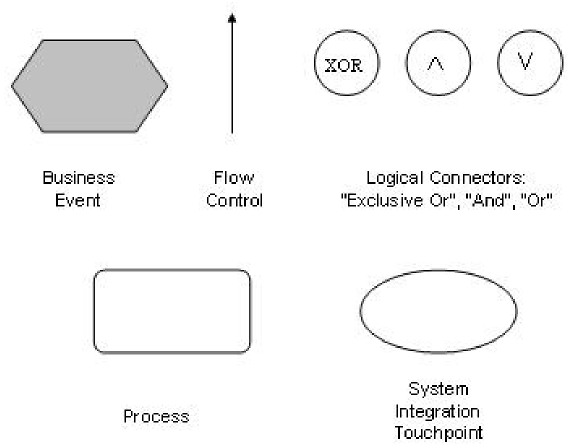

Figure 1 Examples of basic EPC icons

Methodology for the Design

Many tools have been developed to assist in process reengineering and deployment [2]. One popular and well-documented tool is the Event-Driven Process Chain (EPC) [2]. The EPC is used to identify core business processes and model them using a simple set of icons as shown in Figure 1. In the world of BPR, this relatively simple set of icons is used to create both "AS-IS" and "TO-BE" diagrams of the organization's core business processes (Curran and Ladd). Implementers can perform a Gap Analysis and identify areas where system integration is needed most, and can identify features that will be mapped to the new applications as well as key system integration touch points. The result is a set of diagrams that provide guidance for the reengineering and systems integration process. Ideally this step should be complementary to the development of standardized healthcare ontologies as is occurring with the IHE as well as other industries [14].

OPERATING ROOM SCENARIO

The operating room should support a safe, effective, and efficient surgical intervention. Although the primary stakeholder is the patient, in practice, most interactions within hospital and between departments are handled by surrogates (doctors and nurses). For example, the surgeon often has to make moment-to-moment technique and technology decisions that are based on his/her own risk/benefit assessment, guided by prior patient/family input. Many other stakeholders within and outside the hospital interact with the OR, and they need to be integrated effectively to ensure efficient and safe surgeries. In an elective surgery, for example, the patient and referring physician can usually choose when and where the surgery will take place, and appropriate supplies, staff, and other internal hospital/departmental resources might be effectively scheduled in advance. The stakeholders might be broadly grouped into "suppliers and customers," but the role of any one stakeholder may actually change during the surgical event. For example, during surgery pathology may supply the surgeon with very rapid tissue examination to determine if a tumor has been completely removed (i.e., a service supplier to the surgeon. The pathology department needs to receive the surgeon's diagnostic interpretation, however, in order to bill for its services, making it also an information customer of the surgeon.

The stakeholders may be by grouped by common clinical, administrative, or operational departments, including:

1. Clinical services (e.g., pathologist's evaluation of a tissue sample, including business office support such as bills, reports, and office consultations.)
2. Operational activities and resources (e.g., the laboratory equipment and facility, technical operators, quality assurance and maintenance services, and related reporting and billing support)
3. Necessary specialized supplies and services unique to the particular situation (e.g., special tissue staining chemicals or an outside consultant's independent diagnostic service.)

Common OR stakeholders/departments include: **Administration, Anesthesiology, Laboratory, Pathology, Radiology and Imaging, and Pharmacy**. Surgery truly depends on coordination of efforts and data between many individuals, departments, and their information systems. Currently, most healthcare enterprises depend on word of mouth and memory, causing many problems.

DOCUMENTING AND RE-ENGINEERING THE OPERATING ROOM CORE PROCESSES

The starting point for reengineering the OR is to examine core processes and information sharing requirements. Figure 2 shows some of the key information and workflow that must be coordinated by various departments and information systems in a hospital. (Legend: PIS – Pharmacy Information system; AIS – Anesthesia Information System; HIS – Hospital Information System; ORIS – Operating Room Information System; LIS – Laboratory Information System; RIS – Radiology Information system.)

The information-related tasks shown in Figure 2 represent an approximate time sequencing, which is elaborated in much more detail in the following section. The darker blocks in Figure 2 represent core, or required activities. The lighter blocks represent activities that may or may not be necessary.

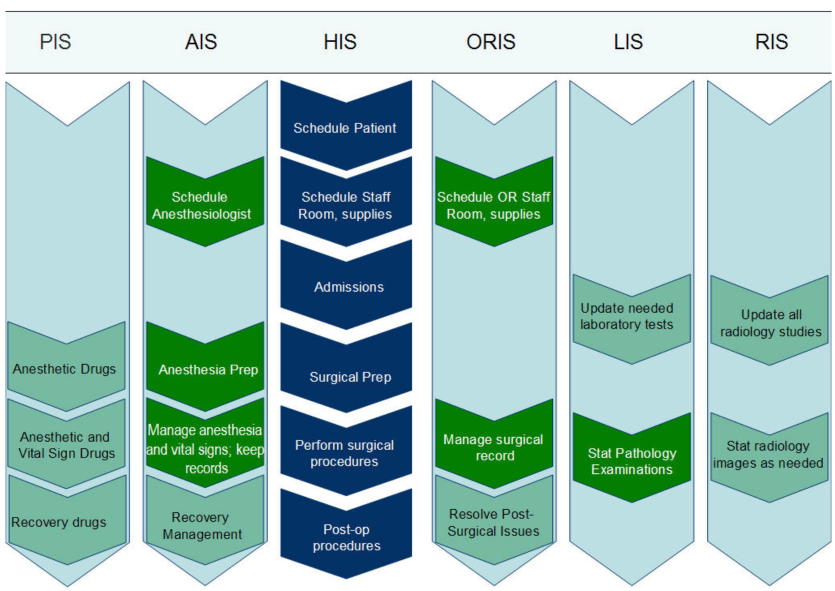

Figure 2 Key information and workflow in the OR

Figure 3 illustrates how EPC symbols document the information flow in an OR. At the top of Figure 3, the patient has made a decision to schedule an elective surgery. Two events must take place: the surgery must be scheduled at a time when all of the necessary resources (staff and facility) are available. Although many preliminary diagnostic procedures are likely to have been already completed, some pre-surgical blood work or X-rays may still need to be scheduled. Also, if the patient's situation is unique, special medicines, implants, or other supplies must be ordered in advance. At the bottom of Figure 3, all of the necessary requirements prior to surgery are complete, and no additional actions may be needed until the patient arrives for the surgery itself.

The EPC shown in Figure 3 is used to facilitate BPR by examining each process that requires inter-organizational collaboration. For example, in order to complete the staff resource scheduling (shown on the left hand side), the HIS, may need to communicate with the AIS and ORIS to determine availability of anesthesiologists, surgeons, and the associated nurses, facilities, equipment, and supplies. Similarly, the LIS and the RIS may be involved with the scheduling of the necessary pre-admission diagnostic studies.

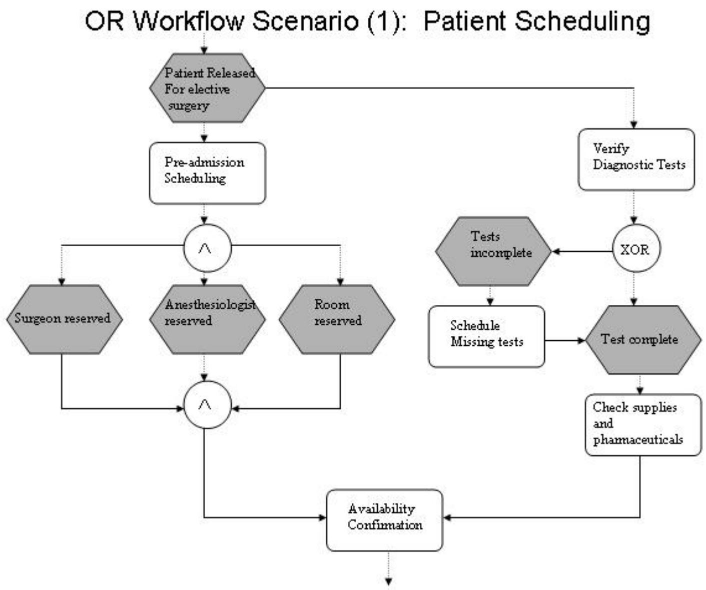

Figure 3 Event Process Chain (EPC) for scheduling patient surgery

In order to continue the BPR, an EPC of each affected system (AIS, HIS, LIS, ORIS, and RIS). Because each of these five systems is typically designed, installed, and maintained by different software vendors, little consistent information interchange processes or data structures can be found. Consider these four simple but very likely problems: 1) a single patient may have five completely different patient identification codes in the five information systems, each based solely on billing needs or prior services unique to that department's services for that patient; 2) the date and time stamps of the five systems are unlikely to be synchronized, creating gaps, inconsistencies, or outright contradictions in the records; 3) the procedure and diagnostic coding within each system is likely to be specific to the department due to unique billing and operational requirements for that specialty; and 4) requests for inter-departmental procedure and service scheduling are not likely to follow any consistent coding scheme, making it virtually impossible to automatically ascertain urgency, response time requirements, special process needs, etc.

Solution to similar problems is found in other IHE processes for radiology, for example [15]. The radiology IHE "integration profiles" contain explicit procedures for patient ID reconciliation, data and timing synchronization, procedure/process code matching, and patient scheduling conflict resolution. The challenge with integrating the OR is that there are many subtle, domain-specific challenges to address.

The goal of this current research is to use the EPC approach to clearly document how the OR and the other affected information systems currently function. The touch-points where each system needs input from, or sends output to, another IS will then be carefully studied. No two systems share data in the same format or structure, nor are they designed to share the proper fields to meet all requirements. These incompatibilities form the basis of a gap analysis, which documents each problem in detail. From the gap analysis, several strategies for resolution are possible, including:

1. Design a new software interface for the sending system;
2. Design a new software interface for the receiving system;
3. Design new software interfaces for both the sending and receiving systems;
4. Design middleware, which is intermediating software that translates the data from/to each system; and
5. Replace both systems with a new, integrated system.

Each of the above strategies imposes differing costs and risks, and the weight of these penalties may be different for each department. Ideally, the ultimate systemic solution will be flexibly adaptable to the ongoing evolution of IHE integration profiles, to support all of the remaining clinical departments in the healthcare enterprise.

CONCLUSIONS

No prior enterprise-wide, integrated information design architecture exists for healthcare. The EPC approach being used herein clearly documents the "AS-IS" function of the key hospital information systems that are involved with patient surgery. The EPC approach provides a standard evaluation, design, and documentation architecture for each clinical information system, regardless of vendor or prior inconsistent documentation. The EPC diagrams will be used to facilitate the critical BPR challenge of improving the information and workflow to support safe, effective, and efficient surgery. The EPC approach standardizes the system analysis tasks for all of the inter-dependent computer systems. This facilitates gaps analysis and development of remediation strategies. The EPC approach results in a well-documented final system that is readily amenable to future enhancements. It is expected that the EPC approach will facilitate the development, implementation, and adoption of IHE-compliant systems throughout the healthcare delivery process. This research is a first attempt at applying general cross-enterprise MIS process re-engineering tools and techniques to healthcare's IHE project. Further research is required in order to validate, extend, and apply these tools to the multiple complex business centers within the healthcare industry.

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