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Integrating Supply Chain Data Standards in Healthcare Operations and Electronic Health Records

Raja Jayaraman[a], Kamal Taha[b], Angelica Burbano Collazos[c]
[a]Department of Industrial & Systems Engineering, Khalifa University, Abu Dhabi, UAE
[b]Department of Electrical & Computer Engineering, Khalifa University, Abu Dhabi, UAE
[c]Department of Industrial Engineering, University of ICESi, Cali, Colombia
Email: raja.jayaraman@kustar.ac.ae; kamal.taha@kustar.ac.ae; aburbano@icesi.edu.co

Abstract— **Electronic Health Records (EHRs) together with supporting information systems offer myriad possibilities for system wide improvements to data access, work flow and integrated information exchange. Parallel to these developments providers must implement supply chain based data standards to their operations in order to realize system interoperability and comprehensive data integration. Supply chain data standards are universal, unique and unambiguous identifiers for products and locations. Integrating supply chain standards in provider processes, clinical workflow, and ultimately in EHRs offers an ability to track products, serves as a basis for cost and clinical effectiveness, improves patient safety and quality outcomes. In this paper, we present the significance and benefits of adopting and transacting using supply chain data standards, improvement areas within provider operations, potential advantages of integrating supply chain standards with EHRs and barriers to healthcare provider implementation.**

Keywords— Healthcare supply chains, EHR, Point-of-care, GS1 Data standards, Traceability, Clinical work-flow

I. INTRODUCTION

Healthcare systems throughout the world are undergoing rapid transformation by implementing new information technology products and software systems in an effort to provide cost effective and sustainable delivery of care. The cost of healthcare delivery has been steadily increasing over the past years forcing healthcare providers to find innovative ways to improve their operations. Over the past several decades rapid advancements in Information and Communication Technology (ICT), automation, and a host of technology enabled services have made significant advances and improvements in many industries. It is a strange paradox in healthcare that even the most sophisticated healthcare systems are afflicted with poor data quality, manual ordering system, errors and confusion. Examining healthcare systems holistically offers critical insights on areas of improvement and the need to implement systems such as EHRs, Computerized Physician Order Entry (CPOE), Clinical Decision Support System (CDSS) and supply chain based automation. Healthcare supply chain (HCSC) has often been overlooked when it comes to achieving cost savings and measurable improvements to deliver overall value. The supply chain processes and practices in healthcare providers that procure pharmaceuticals, medical devices, and vaccines and deliver it to point-of-care are often manual, ad-hoc, and outdated. Healthcare supply chain and related activities constitute the second largest expenditure for providers, offers abundant opportunities to provide tangible benefits such as cost savings, improve treatment outcomes, service quality, patient safety and satisfaction. Most global industries have understood the value of streamlining operations and competitively positioning their supply chains by implementing supply chain data standards. Supply chain data standards are unique, universal identifiers for products and locations that are used by all stakeholders in supply chain processes and transactions. It has often been argued that HCSC is quite different from traditional supply chains, yet these differences are due to the lack of automation, highly fragmented structure, presence of intermediaries, lack of use of supply chain data standards, limited data and information sharing between trading partners. A typical healthcare supply chain includes manufacturers, distributors, third party logistics, group purchasing organizations (GPOs) and providers. Unlike most industries where stakeholders work together create value, to eliminate process and data redundancies to achieve lower costs, in healthcare intermediaries largely benefit from the disconnectedness and the prevailing confusion. A recent study in the United States by Moses et al., 2013 on healthcare performance measures reports 17.9% of GDP being spent on healthcare, amounting to approximately $2.7 trillion per year. Successful supply chain practices adopted in most industries can be emulated to address the current needs of healthcare industry. The objective of this paper is to provide (i) directional insights on areas of process improvement due to implementing supply chain standards within provider operations, (ii) the need to integrate supply chain standards with EHRs, and (iii) critical barriers to provider adoption.

EHRs promise a variety of improvements including cost containment, improved patient safety, benchmarking comparative effectiveness of available treatment options, data portability and information exchange in a continuous and secure manner. In the United States, the earliest plan to implement EHRs can be traced back to a 1991 Institute of Medicine (IOM) report (Dick et al., 1997). In 2004, Office of the National Coordinator for Health Information Technology (ONCHIT) was created to oversee the progress of achieving a universal, interoperable EHR by the year 2014. These initiatives were further accelerated with funding from legislative policies, (i) 2009 American Reform and Reinvestment Act (ARRA) with provisions for enactment of

Health Information Technology for Economic and Clinical Health (HITECH) Act, (ii) 2010 Affordable Care Act (ACA), (iii) meaningful use criteria for hospitals, ambulatory care, individual and group practice to qualify for financial incentives by demonstrating the use of EHRs across various stages. Over the last decade healthcare providers have been engaged in several projects aimed to implement EHRs offering connectivity and exchange information through healthcare information backbone, Nationwide Health Information Network (NwHIT). Although considerable progress has been reported regarding EHR adoption by healthcare providers, actual usage rates vary based on functional capabilities. Based on recent data from ONCHIT, adoption rate of providers demonstrating basic set of EHR functions with clinician notes has increased from 9.4% in 2008 to 44.4% in 2012. Several articles have highlighted the role of EHRs in transforming the landscape of healthcare from a paper-based system to an organized and systemic service, despite these positive developments several early adopters have also struggled to realize the value and cost savings based on the defined meaningful use criteria. Stephen et al., 2012 expressed strong suspicions over achievable cost savings despite spending $1 trillion on Health Information technology (HIT), as evidenced by reported failures of EHR implementation by several progressive healthcare providers (Flood (2013), McCann (2013), Schectman (2012)). The reasons for the failed implementations are commonly attributed to poor vendor relations, inadequacy to reengineer the workflow process, rejection by end-users, inadequate planning of the implementation, lack of training and support, governance, technology projects treated as Information Technology(IT) related without the need for process reengineering. It is noteworthy that several principles in the meaningful use criteria establish a vital link between clinical information systems and provider supply chain process (Barlow, 2013). The recent meaningful use criteria 2.0 has an indirect effect that reinforces the role of supply chain data standards in improving efficiency, patient safety, quality in continuum of healthcare delivery (Barlow, 2010). The rest of the paper is organized as follows, in section II we present relevant literature on supply chain data standards and EHRs. In section III we define types and attributes of supply chain based data standards and its applications to healthcare, section IV we present improvement areas within healthcare provider operations due to implementation of supply chain standards. In section V the effects of improvements in EHRs due to supply chain standards is discussed and section VI highlights potential barriers to provider adoption. Finally we present our conclusions.

II. LITERATURE REVIEW

Supply chain standards and data synchronization have been in use for several decades in every major industry such as retail, manufacturing, transportation and logistics, highly relevant to healthcare industry. A 2006 industry report from Accenture® provides a business case for product data synchronization between various stakeholders in a supply chain. A quantitative assessment of benefits on adoption of Universal Product Code (UPC) in retail industry resulted in $17 billion savings over 25 years, combined with several productivity and performance enhancements (Garg et al, 1999). Rosenfeld and Stelzer (2005) discuss data synchronization issues in healthcare industry and advocate the adoption of supply chain data standards in provider operations. Chen and Prater (2013) explained the benefits of implementing Global Data Synchronization Network (GDSN) in pharmaceutical supply chain such as reduced counterfeiting, decreased medication errors, and increased supply chain efficiency. Du et al., (2012) studied the role of information sharing, and the factors that affect the willingness of companies to share information in supply chain networks. Musa et al. (2014) surveyed the recent trends and developments on various architectures, global standards, technologies and software for product tracking that enhances visibility at item level and aggregate levels, this study compares and analyzes the importance of product visibility in supply chains along with design choices. Steinfield et al, (2011) argue that to achieve effective Inter Organizational Systems (IOS) and solve information transparency problems; data and process standards are necessary, but insufficient. Standards need to be supported with suitable information technology architectures that are shared by stakeholders in the global supply chains. Boukef et al, (2011) prescribe Global Data Synchronization Network, GDSN to enhance the quality of data exchanged between various stakeholders in supply chain and to strengthen IOS. Wigand et al, (2011) advocates the use of Radio Frequency Identification RFID and related technologies, including Electronic Product Code Information Services (EPCIS) as a desirable infrastructure for the tracking uniquely identifiable, products in pharmaceutical supply chains. Nakatani and Ta-Tao (2012) discusses the deployment of GDSN based information system in consumer packaged goods industry, issues stakeholders in global supply chains must address to improve data quality and efficiency of business operations. Bottani et al, (2010) provides a quantitative assessment of the potential reduction in the bullwhip effect, and safety stocks due to real-time visibility in the supply chain offered by implementing RFID and the Electronic Product Codes (EPC) network, such implementation improves the economic profitability of a three echelon Fast Moving Consumer Goods FMCG supply chain. Wilson et al, (2012) studied the benefits of data sharing in perishable goods supply chain to reduce out-of-stock situations and inventory shrinkage, they conclude that without some fundamental changes to the retailers ordering process, data sharing alone does not provide substantial operational benefits. Moore (2012) evaluated the current state of unique identification of supplies in a large university hospital setting by examining the availability of the Global Trade Identification Number (GTIN) and GTIN barcoded medical-surgical supplies and found that over 53% of the products in a sample size of 104 contained a GTIN and usable barcode. Jayaraman et al, (2013) developed a decision support tool that enables potential healthcare providers to evaluate their readiness requirements to implement supply chain data

standards in their operations to quantify the potential impacts in terms of increased productivity, enhanced patient safety and reduction in errors. Buyurgan et al, (2011) present a novel adoption roadmap for healthcare providers to implement GS1 based data standards in their supply chains operations based on pilot studies at healthcare facilities.

Several recent studies highlight the role and benefits of EHRs to improve quality, cost effectiveness and affordability of care. Cresswell et al, (2012) argue EHR implementation efforts require effective technology adoption to occur in healthcare systems before considering larger-scale interoperability. Permitting adequate time and resources towards process re-design initiatives in nationwide implementation of EHRs in United Kingdom. Staggers et al, (2011) found that computerized patient summary report and the EHRs were minimally used during the handoffs, and the patient summary reports were incomplete and did not offer much help to nurses for encoding information. Xierali et al, (2013) examined EHR adoption among family physicians using two different data sources to assess variation in EHR adoption and demonstrate the possibility for data sharing among various medical boards and federal agencies in guiding EHR adoption. Herrin et al, (2012) assessed the impact of EHR implementation on primary care of diabetes mellitus and conclude EHRs can improve diabetes care and clinical outcomes. Appari et al, (2013) estimated the incremental effects of transition in EHR system capabilities on hospital process quality scale for heart attack, heart failure, pneumonia, and surgical care infection prevention. Their study showed that hospitals capable of meeting level 3 definition of meaningful use saw an increment in the quality, while hospitals that transitioned to more advanced levels reported a reduction. Gilmer et al, (2012) assessed the cost-effectiveness of Electronic Medication Record EMR-based CDSS for adults with diabetes from the perspective of healthcare system in United Kingdom to conclude EMR has the potential to modestly improve the quality of care for patients with chronic conditions without substantially increasing costs to the health care system. Recently, Tai-Seale et al, (2013) studied the reliability of data in EHRs for measuring process of care among Primary Care Physicians (PCPs), examined their relationship to clinical outcomes to concluded that process of care measures can augment patient-reported measures associated with clinical outcomes. Encinosa and Bae (2013) studied the impact of adopting five core medication use criteria in EHR helps recoup 22% of information technology costs on hospital-acquired adverse drug events (ADEs). Encinosa and Bae (2011) studied whether EMRs can decrease costs in reducing patient safety event concluded that EMRs does not reduce the rate of patient safety events. However, once an critical event occurs, EMRs can reduce death by 34%, readmissions by 39%, and spending by $4,850 (16%), a cost offset of $1.75 per $1 spent on IT capital. Thus, EMRs can contain costs by better coordinating care to rescue patients from medical errors once they occur but not proactively. Begum et al, (2013) studied clinician attitudes and experiences in quality recognition and financial incentive program using health information technology conclude that incentives are viable means to engage clinicians operating in small independently owned practices that participate in quality improvement programs. Menachemi and Brooks (2006) described the challenges in measuring the Return of Investment (ROI) on health IT applications such as EHRs, CPOE, and CDSS and advocate the need for multidisciplinary techniques for better understanding of ROI from health IT. Ford et al, (2006) studied EHR adoption rates among physicians in small practices and constructed a model to estimate the likelihood of universal EHR adoption and potential barriers that must be overcome. Linder et al, (2007) assessed the association between EHR usage, and the quality of ambulatory care in a nationally representative survey. Their study determined that as implemented, EHRs were not associated with better quality of ambulatory care. Kush et al, (2008) discussed various initiatives of standards for exchange of healthcare information.

III. DATA STANDARDS IN HEALTHCARE SUPPLY CHAIN

The scope of modern healthcare supply chains is broad as products are globally produced and sourced for consumption. Any adoption of supply chain data standards should preserve global harmony, approved by regulatory agencies and have received endorsement from majority of stakeholders. There are two competing supply chain based standards in healthcare, (i) GS1 system which is an analogue of the Universal Product Code (UPC) in the retail industry and (ii) Health Industry Business Communication Council (HIBCC) system. Due to the limited popularity and fewer endorsements by stakeholders in healthcare supply chain for the HIBCC standard we restrict our focus to the GS1 system. The US Food and Drug Administration's Uniform Device Identification (UDI) standards guidance supports both GS1 and HIBCC. No matter which standard gets fully adopted the scope of the implementation and the roadmap can be easily be converted as along as all stakeholders agree to identify products and locations with a chosen standard.

The central components of GS1 standards are Global Trade Identification Number (GTIN) for product identification and the Global Location Number (GLN) location identification. GTINs and GLNs are synchronized among stakeholders via data pools that connect to global registries, Global Data Synchronization Network (GDSN) for GTINs and GLN Registry. GLN provides a unique, unambiguous 13-digit identifier for location identification of all stakeholders in healthcare supply chain. Typically GLNs are associated with ship-to, bill-to and deliver-to locations in healthcare supply chain, and GLN registry is a global directory of all locations. The GLN Registry in healthcare is maintained by GS1, which provides accurate and reliable information of every location within healthcare supply chain. The granularity of GLNs assignment can can vary widely, for example, some providers may treat individual clinical unit which receive supplies directly such as operation room, cath. lab etc. with a GLN. The GLN Registry maintains a hierarchical structure of GLNs for large providers and integrated delivery network (IDN) in a

parent-to-child relationship format. GTINs are unique 14-digit identifier in both machine readable (barcoded) and human readable format for products including pharmaceutical, devices and medical surgical supplies. GDSN is a global registry that offers a secure, standard, and continuous synchronization of product information across various stakeholders in the healthcare supply chains and hospital Materials Management Information System (MMIS) via data pools. The centralized GDSN repository is accessed by stakeholders by connecting through data pools. GTINs are unique across the different units of measure, which means GTIN of a single dose of injectable drug is different from GTIN in a pack of six or a carton containing twenty four units of injectable drug. GDSN also maintains a hierarchical structure for GTINs of the same product across different units of measure. Along with GTINs, dynamic product attributes such as quantity, dimensions, item description, pricing etc. can be encoded. GDSN improves data accuracy by eliminating human intervention for product updates and multiple catalogue numbers for the same product sold through different vendors and distributors.

The most significant advantages of using GTIN in healthcare supply chains is due to the presence of secondary product information, such as expiration date, lot number and serial number. Products labeled with GTIN and secondary information in barcodes enables process automation, including data capture and validation at point-of-care, accuracy in documenting product usage in EHRs. The use of supply chain standards for pharmaceuticals is prevalent due to the use of National Drug Code (NDC) in hospital formulary and reimbursements. GTIN of a pharmaceutical product incorporates the NDCs and there exists a one-to-one relationship between NDCs and GTINs i.e. 10-digit NDC can be converted into GTINs and vice-versa. GTINs and GLNs are fundamental building blocks in the healthcare supply chains that enable track and trace capability for products and locations, critical to identify the origin, enables serialization that enhances the product visibility in the supply chain from manufacturer till point-of-care.
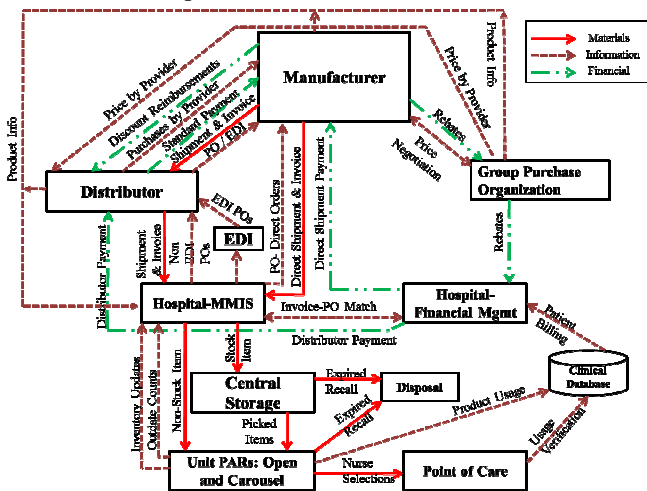

Figure 1: Material, information and financial flow in HCSC

IV. PROCESS IMPROVEMENTS IN PROVIDER OPERATIONS

It is common to notice several manual and redundant processes in procurement, storage and dispensing areas of the healthcare provider supply chain. Substituting manual processes with automated data capture using standardized GTIN barcodes on products (or RFID tags for expensive medical devices) results in significant improvements to efficiency and cost savings. Another common concern in hospital supply chain is to precisely locate a storage unit within the hospital, to prevent mis-shipments and wrong delivery; GLNs provide ease of location identification against which product deliveries can be validated. In 1996, Efficient Consumer Healthcare Report (ECHR) estimated an $11 billion saving opportunities from improvements in healthcare supply chain operations by automating manual requisition process, information sharing with trading partners, excessive transaction cost and lack of trust among trading partners. Nachtmann and Pohl (2009) extended the EHCR study to obtain specific understanding of cost and quality improvements in healthcare supply chain and update on the progress from EHCR study. Figure 1 is a representation of material, financial and informational flow in healthcare supply chain both internal and external to the provider. The complexity of the supply chain representation can be further exacerbated when several manufacturers and distributors are considered.

The crucial driver for the recommended changes in EHCR study relates to the adoption of supply chain standards in HCSC, particularly by providers. Despite the relative significance of standards, healthcare providers often perceive data standards implementation as an exercise of renumbering product inventories and PAR locations or broadly treat it as software project. Incorporating supply chain standards requires reengineering of clinical and non-clinical workflows, careful identification of the various processes and people that handle the products within and outside the hospital; in this section we discuss how several hospital specific operations which can be potentially improved due to data standards adoption, contributing to efficiency, cost savings and enhanced patient safety.

A. Procurement Process

Procurement process in the healthcare provider supply chain consists of ordering, receiving, invoicing, storage and distribution of products to several clinical units. Electronic requisition (via Electronic Data Interchange EDI) to transmit purchase order and receive invoices are quite popular and widely used by providers. Products that are identified using hospital custom numbers in EDI transactions are cross referenced at the receiver´s end. By adopting supply chain standards products can be identified uniquely, offers clarity on which product is being ordered, quantity and unit of measure. It is quite common that delivery locations are widely distributed within a healthcare provider, the use of GLNs in supply chain transactions helps to clearly identify the exact delivery location, avoid mis-shipments and wrong delivery. The changing trends in hospital purchasing led by initiatives

such as Just-In-Time (JIT) delivery, palletized shipments to clinical units greatly benefit due to GLN implementation. The issues discussed are operational and consume most time and resources to identify and correct within and outside providers settings. Product data synchronization through GDSN enables data integrity and accuracy among various stakeholders in the healthcare supply chain. The procurement process in pharmacy operations is quite mature and streamlined due to widespread use of NDC in the drug formulary.

B. Product Visibility and Inventory Management

Hospital Inventory management consists of the following processes: PAR and cycle counting, replenishment, clinical unit delivery and restocking. Some of the most difficult and challenging issues in inventory management are due to inventory inaccuracy, lower inventory turns and exceptionally high stock levels due to limited product visibility, manual inspection of on hand inventory and inability to properly record product retrievals. Supply chain standards enable products and locations to be properly identified to ensure correct product, in correct quantity is ordered and delivered resulting in reduced inventory shortage. Product inventory in healthcare shows stochastic characteristics, Akcan (2013) present a simulation-meta model to optimize on hand inventory and order level for providers. Standards based inventory management and barcode automation enables productivity improvements and real time visibility on inventory status, reducing out of stock, and costly rush orders.

C. Point - of – Care Application

Supply chain standards enable important patient safety rights to ensure right product is used, in right quantity, by right route, in right time on the right patient. Previous research strongly recommends validating a product before patient administration and documenting clinical use with standard identifiers prevents adverse events. A study by Poon et al, 2010, estimated that the use of item level bar code based medication administration can reduce medication errors by 41.4%. Since product supply chain standards also contain additional attributes related to expiration and can be validated before patient administration. Providers can gain significant improvements in process and productivity by leveraging advances in bar code symbologies and information encoded in them using standard identifiers.

D. Contracts and Rebate Process Accuracy

Healthcare providers in US procure bulk of their supplies using GPO contracts to leverage volume pricing and discounts. Providers become members of a GPO by paying an annual membership fee. GPOs act as an intermediary organization that negotiates prices for a product or a group of products from manufacturers by competitively bidding on provider's commitment to purchase minimum volumes over the contract duration. Once a successful contract is negotiated with a manufacturer, members of the GPO avail the negotiated contract price and a distributor is arranged between the manufacture and provider to service the contract. Contract compliance by hospitals provides favorable product pricing

and additional financial incentives in the form of GPO loyalty rebates. Healthcare distributors perform periodic sales tracings to determine products sales and contract price eligibility. Supply chain standards offer a panacea that enables GPOs to monitor contract compliance, and distributors to conduct accurate sales tracings. Significant cash flow are involved in sales tracing and loyalty incentives, which when done right, translates to cost saving opportunities, reduces discrepancy in PO invoice reconciliation process and offers pricing transparency.

E. Patient Billing and Insurance Claims

Supply chain standards enable providers to record product usage at the point of care or during product retrieval eliminating inaccuracies in billing. Lack of accountability and operational inefficiency are the critical areas of improvement for healthcare provider. Standards provide the vital linkages for providers to integrate item master (MMIS) with charge master (billing) for improved revenue capture and claims reporting. The need to re-label products with hospital custom identifiers for charge capture and patient records is eliminated; by scanning the standards based barcode present on the product. Insurance claims based on actual product usage can result in efficient processing and fast settlement.
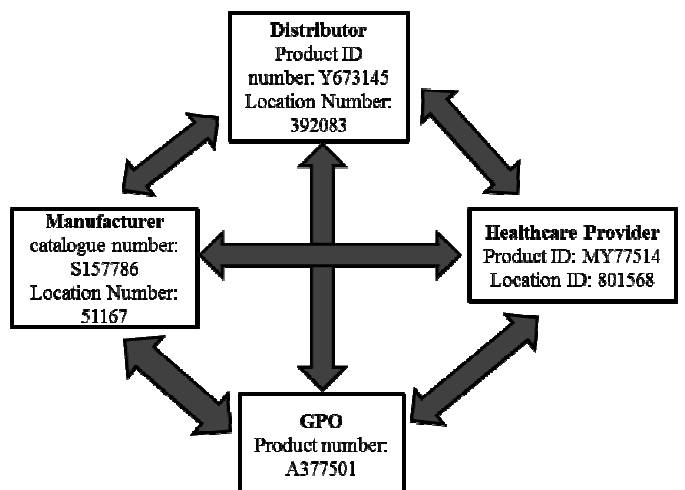

Figure 2: Custom number reconciliation between stakeholders in HCSC

Figure 2 describes a typical scenario of custom number reconciliation process between various stakeholders in HCSC for products and locations. Currently each stakeholder in HCSC uses custom identifiers to identify products and account numbers for locations resulting in lengthy, redundant and costly reconciliation process.

F. Recall and Expiration Management

A product recall is initiated by a manufacturer when a product is defective, contaminated or violates regulatory norms of safety and efficacy. Once a recall is notified to providers, it is crucial to verify whether they have ordered and received the product in the past. The recall administration process can be simplified and targeted, when providers implement supply

chain standards to query process purchasing databases with specific batch numbers to verify if the recalled product were ordered, stored, consumed. When a product is sourced from several different vendors, without supply chain standards it becomes a complicated task to track and trace purchasing and consumption pattern. Supply chain data standards enable quick identification of products that are close to expiration and proactive monitoring of on hand inventory to prioritize consumption or return for credit to suppliers.

G. Drug Safety & Traceability Framework

Tracking products in healthcare supply chain fundamentally requires the use of supply chain standards and efficient information exchange between various stakeholders. Providers being at the receiving end of the supply chain have the greatest responsibility to verify and authenticate products which enter their operations, mitigate risks to ensure patient safety. Supply chain standards facilitate the necessary system level components to prevent counterfeiting and implement traceability mechanism.

V. IMPROVEMENTS IN EHR DUE TO SUPPLY CHAIN STANDARDS

A. Interoperable systems

Supply chain standards offer the crucial link to effectively exchange and use product information across various disparate systems and databases in provider operations. A comparative analogy can be based on banks and financial institutions that use transaction based standards to facilitate messaging and interoperability across ATM machines and proprietary software. Supply chain standards permit data sharing and query capabilities for clinicians, pharmacists, and patients independent of end user application. System level interoperability requires disparate systems to transact, store and identify products in the same way within and outside provider settings, than simply exchanging information. Integrating supply chain data standards in EHRs helps reduce wasteful expenses by integrating business, functional and clinical needs of the healthcare provider.

B. Patient Mobility

The most significant application of EHRs is to support mobility that enhances access to data and bring updated patient information on diagnosis, condition and related factors independent of location or healthcare provider system. Patient centric EHRs that contain information on devices used, products consumed helps clinicians to better understand the patient´s history and improve decision making to save costs. EHRs that contain custom numbers or hospital based identifiers for products are not interpretable beyond the hospital settings and are practically useless.

C. Cost and Quality Comparison

Supply chain standards in EHRs enable studies on cost comparison, treatment effectiveness and offer the ability to quickly identify patients in the event of a product recall or malfunction. Merging supply chain data, costs, and physician utilization can provide comparative evidence on treatment option to make informed decisions and create suitable

interventions for improving overall population health. Supply chain standards enable cost comparisons on products and services and can eliminate fraudulent claims. The granularity of information about products consumed in treatment is valuable for both clinical and financial assessments. Data standards on EHRs can enable longitudinal studies on treatment effects of specific product classes translating to effective provider reimbursements. Data on physician preference items, costs and outcomes can be linked to important metrics such as readmission rates, length of stay, effects of drug interaction to compare trends that facilitate prioritized spending for providers.
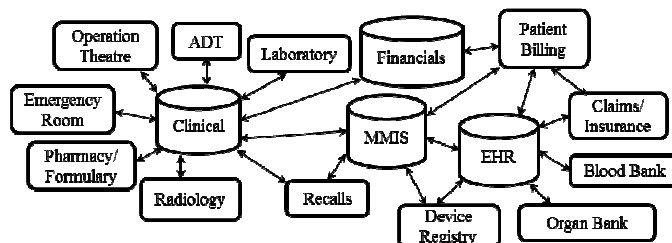

Figure 3: Integrating disparate IT systems and databases

Figure 3 illustrates how various systems and databases within healthcare provider share and store data. The level of interconnectedness between various systems depends on successful implementation of supply chain based standards. Currently most systems in hospitals exist as independent silos or are loosely interfaced. Supply chain standards based information exchange facilitates faster and reliable processes and system wide improvements.

VI. BARRIERS TO PROVIDER ADOPTION

A. Return on Investment

The biggest barrier for healthcare providers to implement supply chain standards is the justification for return on investment. Adopting supply chain standards requires significant investments in software, hardware infrastructure (barcode readers, wireless access points), reengineering work flows, training supply chain and other personnel. Quantifying the benefits in terms of hard cost savings is difficult to measure and realize immediately. Initially, providers can realize a combination of metrics related to productivity improvements, enhanced patient safety, and reduction in inventory and product expiration. Most providers assume adopting supply chain standards is an all or nothing choice but instead providers can implement supply chain standards in several stages across their operations and proportionately benefit.

B. Data Quality Issue

Provider information systems are filled with redundant, inconsistent, imprecise information that lead to errors, duplicative efforts, and additional costs. Although data standards offers a manageable solution, prior to implementing supply chain standards hospitals should first cleanse data in their internal systems to improve supply chain data quality.

Removing duplicate numbers and records from provider systems eliminates the need for repeated cross references, reduces errors and maintain several system interfaces.

C. Manufacturer's Resistance

Manufacturer compliance of supply chain based standards is not 100%, although majority of products used by providers carry standardized bar codes containing universally identifiable product information. A small portion of manufacturers either have implemented HIBCC standard or seeking regulatory direction to implement standards or have not implemented any form of standards. Manufacturers that were having standards based barcodes on some of the products required specific use case by providers; with the proposed 2012 Unique Device Identification (UDI) rules by FDA this reluctance can be overcome. During the transition phase, providers will have to identify a limited subset of products in their systems using custom numbers, effectively maintain dual numbering for limited duration.

D. Resistance to Change

Adopting standards at provider operations requires reengineering of clinical workflows on how products are retrieved, administered, billed, and recorded. Gaining the buy-in and communicating throughout the provider organization with clinical, non-clinical, administrative and operational staff is an important challenge. Implementing standards provides the ability to track and record supply consumption as a part of clinician's workflow, but automating operational and clinical processes can add human error. Communicating and change governance is vital to overcome the resistance on standards adoption.

E. Information System Readiness

The healthcare MMIS market is an oligopolistic, with over majority of providers using few MMIS products. It is interesting to note that none of the MMIS products currently have provision to store and transact with standards as primary fields, ability to query or support supply chain standards in reports. In order to make significant changes to accommodate standards, solution providers place the onus for demand from providers and regulators. As illustrated in Figure 3, there are several ancillary systems at provider end that are interfaced to MMIS system. It will be almost impossible for the providers to replace their existing MMIS due to their multiyear commitment with existing products or adopt a new product which supports standards. To truly adopt and implement standards in their operations the provider community should work with solution providers to find a suitable implementation plan.

CONCLUSIONS

In this paper we discuss the importance of healthcare supply chain data standards for providers, improvement areas in provider operations, potential advantages of integrating with EHRs and critical barriers to provider implementation. Supply chain data standards enable productivity improvement, cost saving and enhances patient safety. The global nature of healthcare products presents a vital challenge for providers to

properly identify products, manage expiration dates, track in the event of a recall and unambiguously interpret from EHRs. Linking supply chain data with EHRs provides a basis for cost and comparative effectiveness of treatment options. Despite the perceived advantages in adopting standards, healthcare providers are hesitant to implement supply chain standards in their operations due to deficiencies in their information system readiness, manual and error prone process that prevent sharing information internally and with trading partners. Healthcare providers are at the delivery end of healthcare supply chain and have the greatest concerns on patient safety, hence should approach supply chain standards implementation using systems engineering methods such as process reengineering, workflow improvement, scientific methods of inventory management, waste reduction, and quality tools. Healthcare providers often misinterpret supply chain standards as an all or nothing choice or as an information technology project. In several ways this paper addresses provider concerns on standards adoption, return on investment decisions and how standards can help to overcome operational barriers. Supply chain data standards offers practical solution to provider's hard pressing challenges on payment reduction, improvements to care delivery and process automation needs.

REFERENCES

[1] Akcan, S. (2013). A new approximation for inventory control system with decision variable lead time & stochastic demand. International Journal of Industrial Engineering: Theory, Application & Practice, 20(3-4).

[2] Appari, A., Eric J., M. and Anthony, D. L. (2013). Meaningful Use of Electronic Health Record Systems and Process Quality of Care: Evidence from a Panel Data Analysis of U.S. Acute-Care Hospitals. Health Services Research, 48, 354–375

[3] Barlow, R.D. (2010). The missing links between supply chain data, EHR/EMR software. Healthcare Purchasing News, 1, 10-15.

[4] Barlow, R.D. (2013). Supply Chain Searches for Meaningful Use Role- Relationship and Relevance under debate. Healthcare Solutions Bureau. URL: http://www.hcsbureau.com/articles-details.html?id=96

[5] Begum, R., Ryan, M.S., Winther, C.H., Wang, J.J., Bardach, N.S., Parsons, A.H., Shih, S.C. and Dudley, R.A. (2013). Small Practices Experience with EHR, Quality Measurement, and Incentives. American Journal of Managed Care, 19.

[6] Bottani, E., Roberto M., and Andrea V. (2010). The impact of RFID and EPC network on the bullwhip effect in the Italian FMCG supply chain. International Journal of Production Economics 124(2), 426-432.

[7] Boukef, C., N., Mohamed, C., H., and Moyez, L. (2011). Making and giving Sense of the Global Data Synchronization Network Standard Adoption. 2011 Proceedings of ECIS.

[8] Buyurgan, N., Rardin, R.L., Jayaraman, R., Varghese, V. and Collazos, A.B. (2011). A Novel GS1 Data Standards Adoption Roadmap for Healthcare Providers, International Journal Healthcare Information Systems and Informatics, 6 (4), 42-59.

[9] Chen, H. and Prater, E. (2013). Information System Costs of Utilizing Electronic Product Codes in Achieving Global Data Synchronization within the Pharmaceutical Supply Chain Network. International Journal of Information Systems and Supply Chain Management (IJISSCM), 6(1), 62-76.

[10] Cresswell, K. M., Worth, A., and Sheikh, A. (2012). Comparative case study investigating sociotechnical processes of change in the context of a national electronic health record implementation. Health Informatics Journal. 18(4), 251-270

[11] Dick, R.S., Steen, E.B., and Detmer, D.E. (1997).The computer-based patient records: an essential technology for healthcare. Institute for Medicine. National Academy Press, Washington D.C.

[12] Du, T. C., Lai, V. S., Cheung, W., and Cui, X. (2012). Willingness to share information in a supply chain: a partnership-data-process perspective. Information & Management, 49(2), 89-98.

[13] Encinosa, W. E., and Bae, J. (2013). Will meaningful use electronic medical records reduce hospital costs? American Journal of Managed Care, 19, eSP19-eSP25

[14] Encinosa, W. E., and Bae, J. (2011). Health information technology and its effects on hospital costs, outcomes, and patient safety. Inquiry, 48(4), 288-303

[15] Flood, G. (2013). EHR Project Loses U.K. Hospital 18 Million Pounds. Retrieved on 25 August, 2013. URL: http://www.informationweek.com/healthcare/electronic-health-records/ehr-project-loses-uk-hospital-18-million-pounds/d/d-id/1110453?cid=nl_iw_healthcare_2013-06-26_html

[16] Ford, E. W., Menachemi, N., & Phillips, M. T. (2006). Predicting the adoption of electronic health records by physicians: when will health care be paperless? Journal of the American Medical Informatics Association, 13(1), 106-112

[17] Garg, V., Jones, C., and Sheedy, C. (1999). 17 billion reasons to say thanks-The 25th anniversary of the UPC and its impact on the grocery industry. Price Water House Coopers Report.

[18] Gilmer, T. P., O'Connor, P. J., Sperl-Hillen, J. M., Rush, W. A., Johnson, P. E., Amundson, G. H., and Ekstrom, H. L. (2012). Cost-Effectiveness of an Electronic Medical Record Based Clinical Decision Support System. Health Services Research, 47(6), 2137-2158

[19] Herrin, J., da Graca, B., Nicewander, D., Fullerton, C., Aponte, P., Stanek, G., Cowling, T., Collinsworth, A., Fleming, N. S. and Ballard, D. J. (2012), The Effectiveness of Implementing an Electronic Health Record on Diabetes Care and Outcomes. Health Services Research, 47, 1522-1540.

[20] Jayaraman, R., Rardin, R.L., Buyurgan, N.,Varghese, V., and Collazos, A.B. (2013):A decision support tool for healthcare providers to evaluate readiness and impacts of adopting supply chain data standards, IIE Transactions on Healthcare Systems Engineering, 3:2, 110-126

[21] Kush, R.D., Helton, E., Rockhold, F., W., and Hardison, D. (2008). Electronic Medical Records, Medical Systems and Towers of Babel. New England Journal of Medicine, 358(16), 1738-1740

[22] Linder, J. A., Ma, J., Bates, D. W., Middleton, B., & Stafford, R. S. (2007). Electronic health record use and the quality of ambulatory care in the United States. Archives of Internal Medicine, 167(13), 1400-1405

[23] McCann, E. (2013). Setback for Sutter after $1B EHR crashes. Retrieved on 25 August, 2013. URL: http://www.healthcareitnews.com/news/setback-sutter-after-1b-ehr-system%20crashes

[24] Menachemi, N., and Brooks, R. G. (2006). Reviewing the benefits and costs of electronic health records and associated patient safety technologies. Journal of Medical Systems, 30(3), 159-168

[25] Moore, M, L. (2012). An Exploration of the Use of Global Healthcare Supply Data Standards in a Materials Management Information System. Dissertation - The Ohio State University.

[26] Moses, H., Matheson, D.H.M, Dorsey, E.R., George, B.P., Sadoff, D., Yoshimura, S. (2013). The anatomy of Healthcare in the United States. Special Communication. JAMA, 310(18): 1947-1963

[27] Musa, A., Gunasekaran, A., and Yusuf. Y. (2014). Supply chain product visibility: Methods, systems and impacts. Expert Systems with Applications 41(1), 176-194.

[28] Nachtmann, H., and Pohl, E.A. (2009). The State of Healthcare Logistics: Cost and Quality Improvement; Center for Innovation in Healthcare Logistics. University of Arkansas.

[29] Nakatani, K., and Ta-Tao, C. (2012). Global data synchronization: deployment and implementation issues of a global standard-based information system. International Journal of Services and Standards 8(2), 157-173.

[30] Poon, E.G., Keohane, C.A., Yoon, C. S., Ditmore, M., Bane, A., Korach, O.L.., Moniz, T., Rothschild, J.M., Kachalia, A. B., Hayes, J., Churchill, W.W., Lipsitz, S., Whittemore, A.D., Bates, D. W., and Gandhi, T.K. (2010). Effect of Bar-Code Technology on the Safety of Medication Administration. N Engl J Med 2010; 363:698

[31] Rosenfeld,W. L. and Stelzer J. L. (2005) Data synchronization in healthcare: A solvable problem. Sterling Commerce Report.

[32] Schectman, J. (2012). Kansas Hospital's Failed EMR Project Shows Peril of Vendor Relations Gone Bad. URL:http://blogs.wsj.com/cio/2012/06/26/kansas-hospitals-failed-emr-project-shows-peril-of-vendor-relations-gone-bad/

[33] Staggers, N., Clark, L., Blaz, J. W., and Kapsandoy, S. (2011). Why patient summaries in electronic health records do not provide the cognitive support necessary for nurses' handoffs on medical and surgical units: insights from interviews and observations. Health Informatics Journal, 17(3), 209-223

[34] Steinfield, C., Markus, M. L., and Wigand. R.T. (2011).Through a glass clearly: standards, architecture, and process transparency in global supply chains. Journal of Management Information Systems 28(2), 75-108.

[35] Stephen, S., and Koppel, R. (2012). A Major Glitch for Digitized Health-Care Records Savings promised by the government and vendors of information technology are little more than hype. Wall Street Journal. URL:http://online.wsj.com/news/articles/SB10000872396390440438474045776270419648310 20

[36] Tai-Seale, M., Wilson, C. J., Panattoni, L., Kohli, N., Stone, A., Hung, D. Y. and Chung, S. (2013), Leveraging Electronic Health Records to Develop Measurements for Processes of Care. Health Services Research. DOI: 10.1111/1475-6773.12126

[37] Wigand, R. T., Mande, D. M., & Wood, J. D. (2011). Information management and tracking of drugs in supply chains within the pharmaceutical industry. 2011 Eighth International Conference on Information Technology: New Generations (ITNG). IEEE.

[38] Wilson, D. D., Edward, and Gerald, Y. (2012). The effects of data sharing on a perishable goods supply chain. Dissertation- Massachusetts Institute of Technology.

[39] Xierali, I. M., Hsiao, C. J., Puffer, J. C., Green, L. A., Rinaldo, J. C., Bazemore, A. W., and Phillips, R. L. (2013). The rise of electronic health record adoption among family physicians. The Annals of Family Medicine, 11(1), 14-19

BIOGRAPHY

Raja Jayaraman is an Assistant Professor of Industrial & Systems Engineering at Khalifa University, UAE. He received his Ph.D. in Industrial Engineering from Texas Tech University, USA, a Master of Science in Industrial Engineering from New Mexico State University, USA, Masters and Bachelor degree of Science in Mathematics from India. His previous work experience is in healthcare industry focusing on quality improvements, innovation and cost effectiveness. His research interests include Applied Operations Research, Healthcare Systems Engineering, Supply Chain, Logistics and Mathematical Modeling. His publications have appeared in *IIE Transactions, Annals of Operations Research* and a variety of applied mathematics, management and technology journals.

Kamal Taha is an Assistant Professor in the Department of Electrical and Computer Engineering at Khalifa University, UAE, since 2010. He received his Ph.D. in Computer Science from the University of Texas at Arlington, USA, in March 2010. He has over 50 refereed publications that have appeared in prestigious top ranked journals, conference proceedings, and book chapters. Nine of his publications have appeared in IEEE Transactions journals. He worked as an Instructor of Computer Science at the University of Texas at Arlington, USA, from August 2008 to August 2010. He worked as Engineering Specialist for Seagate Technology, USA, from 1996 to 2005 *(Seagate is a leading computer disc drive manufacturer in the US)*. His current research interests include bioinformatics databases, information retrieval in semi-structured data, keyword search in XML documents, recommendation systems and social networks, and data mining. He serves as a member of the Program Committee, editorial board, and review panel for a

number of international conference and journal publications such as IEEE and ACM. He was included in the 2012 Edition of Who's Who in Science and Engineering. He is a Senior Member of the IEEE.

Angelica Burbano C holds a Ph.D. in Industrial Engineering from the University of Arkansas. She holds a MSOM from Universidad Icesi and a BS in industrial engineering from Pontificia Universidad Javeriana both in Cali, Colombia. She is a 2007 Fulbright Scholar. Dr. Burbano has previous experience in the food manufacturing industry. During her studies in the United States she worked a research assistant at the Center for Innovation on Healthcare Logistics CIHL, her work for CIHL focused on assessing the impact of GS1 standards adoption in the healthcare supply chain. Her research interests are related to the adaptation of existing manufacturing and logistics models and structures to the healthcare supply chain. She is part of the IE Department at Universidad Icesi since 1998. She has served as Director of the Undergraduate Program in Industrial Engineering (2003-2007), Director of the graduate program in Industrial Engineering (August 2012 – August 2014), and she is currently the IE Department Head.