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HEALTHCARE INVENTORY AND SUPPLY CHAIN MANAGEMENT: A LITERATURE REVIEW

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Abstract- This paper presents a literature review of healthcare inventory management, supply chain management, and related technologies. We classify the existing studies in the literature by identifying the subclasses for each of the three categories. The healthcare inventory management literature, excluding blood inventory management (it has been well reviewed by several recent survey papers), is classified into critical and non-critical items. The healthcare supply chain management study is grouped into two classes of the network design and the logistics management. The implementation of advanced technologies of RFID and e-business in healthcare supply chain management is also discussed. The review shows the increasing research interest in the healthcare supply chain management in recent years. We believe the high healthcare cost could be alleviated by better managing healthcare supply chain with quantitative models and implementations of various information technologies, which requires more researches.
Key words - healthcare supply chain management, healthcare Inventory, healthcare technology management

1. Introduction

High health expenditure has become a critical issue in the United States and other countries [1-2]. The rising cost of healthcare increased faster than rising costs from inflation [3]. There are several reasons behind the increase of the healthcare expenditure, including population growth, technological advance, rapid increase of drug price, and growth in health manpower cost [4]. The other causes such as demographic change, increasing percentage of elderly people, advancement of technology, rising standard of living also contribute to the rising healthcare expenditure [5]. The National Coalition on Health Care[1] reports that the total healthcare expenditures in the U.S. will rise to $2.5 in 2011, or 16.4% of the country's gross domestic product (GDP). By 2018, that number is expected to reach $4.4 trillion and represent 20% of the GDP. World Bank research showed USA health expenditure, in terms of Health expenditure per capita[2], is significantly higher than any other countries. The second largest expense after labor for healthcare providers is supplies, which usually consume one-fifth of their revenue from patients [6]. Researchers [7-9] estimated the potential benefit of an efficiently managed healthcare supply chain would range from 2 percent to 8 percent of hospital operating costs. In general healthcare medicines, which usually require high availability, have high inventory cost and stock out cost, compared to regular items. High inventory cost occurs due to irregular demand, high item price, obsolescence possibility, and strict storage requirement. Events such as massive accidents, terrorist attacks, disease outbreaks, or natural disasters may create surge demand. In response to this kind of demand, healthcare supply chains need to keep high inventory levels to ensure high availability of medicines to save people' lives. In the healthcare sector, most of the time goods are over paid in order to ensure availability. The trade off to over paying would be suffering loss of clientele due to poor customer service, inferior clinical outcomes, and decreased revenue when the asset is unavailable [10]. It is quite challenging for healthcare sector to maintain high availability of low demand pharmaceutical items with a short shelf life. One solution is the use of expedited shipping once those items are needed. The shipments are costly and frequently represent the inability of the system to manage demand and of the distributors to manage clients' needs. In general, the higher the availability of a healthcare item for immediate use, the higher is the logistics costs of the good.

Risk can prevent from achieving the ability to reduce supply chain cost. The major risks associated with healthcare supply chain are: strategy risk, market risk, demand risk, and implemental risk [10]. Supply managers' lack of knowledge about the availability of a product in the market place and inability to understand how a product will be used in the hospital and whether there are clinicians' preferences for specific brand cause strategy risk. Market risk occurs due to lack of price transparency in much of healthcare item purchasing. Demand risk in health care occurs due to: 1) uncertainty associated with disease patterns in a hospital or a system's population, 2) the supply managers' lack of understanding of disease

[1] http://nchc.org/issue-areas
[2] http://data.worldbank.org/indicator/SH.XPD.PCAP

trends, 3) failure to understand and manage clinician preferences, and 4) inability to carry out value analysis effectively. Implemental risk is related to the problem that hospitals face when implementing supply chain strategy. This is due to the fact that hospitals are highly departmentalized organizations and lack, in general, fundamental protocols to facilitate communication regarding materials that are used in an integrated fashion to produce outstanding clinical outcomes.

A research by Schneller and Smeltzer [10] indicates that equal collaboration among the supply chain members is seldom in the healthcare industry. Although distributors and manufacturers often exercise power by presenting a unified face to hospitals, increasingly there are tensions between suppliers and distributors [11]. Both hospitals and distributors are characterized by their powers to influence the healthcare supply chain but the power balance differs from one situation to another situation. It is not clear if the hospital systems or the manufacturers can be classified as more important and having more power with the distributors [10]. Existing misaligned incentives among key stakeholders in the healthcare supply chain — manufacturers, distributors, GPOs and hospitals, including materials management professionals, doctors and other clinicians — contribute to discontinuities in the healthcare supply chain. Thus, healthcare supply chain management is challenging compared to the supply chains for other products. In this paper we will review the related literature in healthcare, trying to cover existing studies in the area of healthcare inventory, supply chain, and technology management. In this paper the related literature of blood products will not be reviewed since some recent studies have presented a very comprehensive literature review of supply chain management of blood products (e.g., [12]). The remaining of this review is organized as follow. Section 2 provides the classification of studies. Sections 3 through 5 review the related literature of healthcare inventory, supply chain, and technology management respectively. Section 6 presents the final conclusion and remarks.

2. Classification of Studies

We classify the related healthcare management studies into three main categories of inventory management, supply chain management and technology management. Based on the problems that each category addresses, each category is classified further into subcategories. The inventory management related studies are classified based on whether the involved items are critical or non-critical. In a healthcare setting, critical items include a small number of items that are generally very expensive on a per unit basis, are considered perishable, have a short shelf life, and/or require expensive storage facilities on site. Examples of these items include injectable medical supplies, pharmaceutical supplies, and surgical supplies. All the other supplies are considered non-critical. Examples of these items include tubing, suture sets, latex examination gloves, and plastic/disposable sheeting. The majority of investment in healthcare inventory is in critical supplies, representing around 60% [13]. The supply chain management related studies are classified into supply chain network and logistics studies. The supply chain network studies mainly focus on the design of supply chain network and performance of the chain while the concentration of logistics related studies is on topics such as transportation and routing. We also classify technology management studies as Radio-Frequency Identification (RFID) and other information technology advances. The RFID-related study mainly discuss the current and potential advances and benefits of using the RFID or wireless technology in the healthcare sector and the later class has a broader perspective over the healthcare firm's that is how healthcare firm's can benefit from the IT advances. Table 1 shows the trend and number of healthcare inventory, supply chain and technology management studies from 1995 to 2011.

Table 1-Trend and number of classified healthcare studies

Area of Study	Year															Total
	95	96	98	99	00	01	02	04	05	06	07	08	09	10	11	
Inventory	1			1	1	1		1		2	1	4		4	1	17
Non-critical								1		2	1	3		4	1	12
Critical	1			1	1	1						1				5
Supply chain		2	1			2	1	3	3	2	2	2	4		5	27
Network		1	1				1	1	3		1	2	2		5	17
Logistics		1				2		2		2	1		2			10
Technology												2	2		3	7
RFID												1	2		2	5
Other IT												1			1	2
Total	1	2	1	1	1	3	1	4	3	4	3	8	6	4	9	51

3. Healthcare Inventory Management

Generally the inventory management and distribution between and within the hospitals is discussed and studied under the title of material management. Implementing periodic review order-up to level servicing approach is one of the distinctive features of material management in a hospital. A major issue in setting order-up to level for different items in a healthcare system is that these levels tend to reflect the desired inventory levels of the patient caregivers rather than the actual inventory levels needed in a department over a certain period [13]. Various studies have tried to address different problems in healthcare material management that we will review in the following Sections of 3.1 and 3.2.

3.1. *Non-Critical Item Inventory Management*

Some studies in this class use stochastic approaches toward their inventory management problems (e.g., [14-17]) and others mainly focused on how to address the emergency items (e.g., [18]). Another stream of studies addresses the inaccuracy in inventory management (e.g., [19]). There are also other approaches and perspective toward inventory management of non-critical items in the literature, which will also be reviewed in this section.

Mohebbi and Hao [14] derive the stationary distribution of the on-hand inventory under a continuous-review policy by considering a single-item stochastic inventory system that alternates randomly between two possible states of available and unavailable following a two-state continuous-time homogeneous Markov chain. They assume that the supplier is unreliable and the system faces a compound Poisson stream of demands and Erlang-*k* distributed lead times. To develop their model, a scenario is considered where the processing of the outstanding order is interrupted at every supplier's transition epoch from the available to the unavailable state, and is restarted from the outset upon the supplier's regaining its available state. Beamon and Kotleba [15] argue that there is not much research in humanitarian supply chain management, particularly in the area of inventory control, so they try to address this limitation by developing a stochastic inventory control model that determines optimal order quantities and reorder points for a long-term emergency relief response where the challenge is the irregular demand patterns and unusual constraints inherent in large-scale emergencies. In his Ph.D. dissertation, Rosales [17] studies a new hybrid inventory control policy with both periodic and continuous replenishments, under both deterministic and stochastic demands. For the stochastic demand case, he develops a simulation-based optimization approach to find policy parameters and estimates the long-run average cost of the defined policy. His basic problem setting is for a single item and he later extends the basic model to consider multiple items. Four different hybrid-joint replenishment policies for two items are then proposed. The comparisons are made between the performance of the four hybrid-joint replenishment policies with the performance of traditional periodic and continuous review joint replenishment policies. Lastly, he studies a two-bin inventory replenishment system that is used at hospitals to store a large number of supplies and implements radio frequency identification technology. The two-bin replenishment system allows continuous-time tracking of inventory levels. Rosales [17] formulates a semi-Markov decision model for the two-bin replenishment system and obtains the optimal replenishment policy. A linear program is built to find the optimal average cost and policy parameters for the semi-Markov decision model.

Jacobson et al. [16] propose a stochastic model that considers the probability that all children can be immunized according to the Recommended Childhood Immunization Schedule over a given time period and the expected minimum vaccine supply. The model is used to assess the impact of pediatric vaccine stockpile levels on vaccination coverage rates. Their model assesses the pediatric vaccine stockpile levels recommended by the United States Department of Health and Human Services under the setting of vaccine production interruptions, which are assumed not to last more than six months. The results show that their proposed vaccine stockpile levels are adequate to meet future vaccine production interruptions. They also conclude that a moderate investment in higher vaccine stockpile levels than ones recommended by US Department of Health would lead to a significantly reduced risk of stock-outs. Ozbay and Ozguven [18] also develop an efficient and quick-response humanitarian inventory management model to determine the safety stock that could prevent disruptions at a minimum cost. The inventory problem is a sub-problem of the general humanitarian supply chain problem. As another stream of studies, Cyrille [19] investigates the inventory inaccuracies between book inventory and physical inventory on hand as drivers of low product availability in hospitals. His thesis identifies Imperfect Demand Recording as a hospital-specific source of such inaccuracies.

Madadi et al. [20] compare decentralized ordering model and centralized ordering model to investigate the effect of collective ordering by retailers on the system-wide inventory cost. They consider a multi-level (supplier–warehouse–retailer) environment and include the transportation cost in the inventory management decisions. Little and Coughlan [21] propose a constraint-based model with restrictions on space, delivery and criticality of items for determining optimal stock levels for all products at a storage location. They also validate their model on sterile and bulk items in a real-world setting of an intensive care unit in a local hospital. Nicholson et al. [13] compare inventory costs and service levels between an in-house three-echelon distribution network and an outsourced two-echelon distribution network for non-critical healthcare items. They show that the recent trend of outsourcing non-critical medical supplies using the two-echelon network not only results in inventory cost savings but also does not compromise the quality of care. On the supplier's side, He et al. [22] propose a production-inventory model of deteriorating items that are sold to multiple-markets with different selling seasons. They argue that from the perspective of production management, it is important to exploit the opportunities from the different selling seasons of geographically dispersed markets for deteriorating items. They also provide a solution procedure to find the optimal replenishment schedule for raw materials and the optimal production plan.

The current research of healthcare inventory management does not consider the presence of different stakeholders and does not thoroughly understand how different inventory systems may affect them. de Vries [23] develop a conceptual model to fill the gap by exploring the process of reshaping a hospital inventory system of medicines with a case study. Rossetti [24] provides a comprehensive literature review of applications of inventory management within the healthcare value chain and discuss the alternative models to the traditional GPO based organization of the health care value chain. He also introduces the potential research areas where little research has been done.

3.2. *Critical Item Inventory Management*

Since critical items are generally expensive, are perishable, have a short shelf life, and/or require expensive storage facilities on site, it is important to model their inventory system in a more sophisticated way. Most studies use the stochastic approach toward modeling the critical item inventory systems (e.g., [25-28]). In a study of stochastic process associated with a continuous review perishable inventory system with the (s, S) policy, Ravichandran [27] derives an explicit expression for the stationary distribution of the stochastic process, representing the inventory level for the lost sales case, under a specified aging phenomenon of a batch of items. The optimal reorder level is determined by minimizing the total expected cost per unit time, which is obtained through the stationary distribution of the inventory level. Similarly, Liang [28] uses a probabilistic approach to study a continuous review inventory system with perishable items, zero lead time and renewal batch demand. He derives a closed form long run average cost function under the (*s*, *S*) replenishment policy by studying an embedding Markov chain for the base setting. However, the problem becomes computationally intractable for more general settings with positive lead time because the state space explodes with different ages of all items in on-hand inventory, so he develops a heuristic method to obtain the suboptimal inventory replenishment policy. Berk and Gurler [25] also use the Markov Process approach to study a continuous review (*Q*, *r*) inventory policy for perishable items with Poisson demands, fixed shelf lives, and constant lead times for the lost sales case. They use the stationary distribution to build the expected cost rate function for the optimal inventory policy. The numerical experiments show that their model result in significant improvement in cost rates over the previously proposed heuristics in the literature. Using a Markov renewal approach , Liu and Liang [26] consider an (*s*, *S*) continuous review perishable inventory system with a general renewal demand process and obtain closed-form solutions for the steady state probability distribution of the inventory level and system performance measures by long-run average cost.

A fixed-critical number policy is also intensively studied in the literature, where orders are placed each period so that total on-hand inventory, regardless of ages, is returned to a single fixed number. Cooper [29] studies such a policy in a perishable inventory system. He obtains a family of upper and lower bounds on the expected number of outdates per unit time and on the steady-state distribution of the number of outdates per unit time, which also lead to bounds on higher moments of the number of outdates. He also compares the results with nonperishable inventory systems, as well as bounds on the distribution of the ages of the youngest and oldest inventory in the system. According to his results, while the upper bounds are sometimes better and sometimes worse than those previously published, one of the new lower bounds on the expected number of outdates are always tighter.

4. Healthcare Supply Chain Management

A typical healthcare supply chain is a complex network consisting of many different parties at various stages of the value chain. There are three major types of parties in a healthcare supply chain [30]: 1) producers who manufacture products, 2) buyers who are wholesalers or distributors, and 3) healthcare providers as users. There is a large amount of inventory in a traditional healthcare supply chain, resulting in a relatively small number of deliveries and consequently low transportation and ordering cost but high inventory holding cost [24]. Several studies have tried to develop different models to improve the performance of the traditional healthcare supply chain that will reviewed in Sections 4.1 and 4.2 under subclasses of healthcare supply chain network and healthcare logistics respectively.

4.1. *Healthcare supply chain network*

Realizing optimal supply chain network designs considering cost-reduction and efficiency may have significant competitive advantages in providing a firm's customers with the demanded products. Regarding the healthcare supply chains, proper designs of supply chains will have positive effects on the health and wellbeing of citizens, on the economy, and even on national security. An important problem faced by the healthcare industry at the supply chain design stage is how to balance the future capacity with anticipated demands while there is significant uncertainty in clinical trials. The ability of locating supply chain nodes in tax havens and optimizing of trade and transfer price structures results in interesting degrees of freedom in the supply chain design problem [31]. Numerous researches have been conducted to address this set of important problems in the healthcare and pharmaceutical sector.

Shah [31] summarizes important issues in pharmaceutical supply chain design and operation listed the literature and further identifies key issues and strategic challenges in pharmaceutical supply chains. One big issue is the network design of supply chains and its configuration (e.g., [32-36]). With the objective of the determining optimal capacities of supply chain network activities, Nagurney et al. [33] propose a mode to design supply chain network for critical products such as vaccines, medicines and food that may be in need and used in case of pandemics, disasters and attacks. Assuming a multi-product system, they define the capacities in the form of manufacturing, storage, distribution and study the optimal multiple product flows. The solution to their model provides the investment on capacities and product flows at minimal total cost, with the satisfied demands of multi products at different locations. While considering the uncertainty in demand, their model's objective is to minimize the system-wide cost. In addition, their model can determine if a product should be outsourced or produced in-house.

Rego and de Sousa [35] propose a model to design and evaluate alternative strategies for the configuration of a hospital's supply chain. Their model is designed strongly based on several interviews with managers responsible for the hospital's supply departments. Considering the dimension of real life instances and the combinatorial complexity of the problem, they also design a metaheuristic to solve the problem. Sinha and Kohnke [36] propose a framework to help understand the growing demand for care and the potential avenues for meeting the demand (i.e., supply of care) based on affordability, access, and awareness and to provide a guideline of supply chain design for the healthcare sector. Their proposed approach is mainly used to identify an integrated system of continuous improvement and innovation initiatives relevant to narrowing the gap between the demand and supply for high-quality, cost-effective, and timely care. Rivard-Royer et al. [37] employ

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a hybrid version of the stockless system with the assumption that the distributor supplies high-volume products for the patient care units. The study reveals marginal benefits from the hybrid method for both the institutions and the distributor. Rossetti et al. [34] examine the way by which biopharmaceutical medications are purchased, distributed, and sold throughout the supply chain. They combine multiple interviews with key informants at each level of the value chain to derive key insights into the major change drivers that have influence on the future of the biopharmaceutical supply chain.

Some studies in this area target at the barriers that may affect implementation of the best supply chain management practices. McKone-Sweet et al. [38] try to identify the challenges or barriers for hospital supply chain initiatives through reviewing the related literature and case studies. Jarrett [39] also focuses on identifying whether regulatory policies, industry policies or procedures have hindered the implementation of supply chain management practices. By analytical reasoning, he also compares the estimated healthcare industry benefits with that of other industries.

Another stream of studies considers the performance of supply chains. Aronsson and Abrahamsson [40] argue that when the production processes and flow of patients are in focus, applying an interdisciplinary systems approach is the challenge of designing, integrating and implementing cost-effective and, at the same time, flexible healthcare systems. Their results show how supply chain performance can be improved when lean and agile process strategies are used. Lee et al. [41] also propose a model to describe the impact of supply chain innovation and efficiency and study supplier cooperation and quality management practices on organizational performance. Their results are obtained using structural equation modeling based on data collected from numerous hospitals. In his thesis, DeScioli [42] argues that a hospital needs to implement more than one supply chain policy in order to achieve its objective of maximizing patient care while preventing excessive costs. Their research further proposes that a hospital should develop its supply chain for a specific product based on that product's unit cost, demand, variability, physical size, and criticality.

4.2. *Healthcare logistics*

Because of continuous change in needs of healthcare customers, logistics in healthcare is a complex issue. This complexity is also caused by the very large number of stock items that are used and handled by the industry [43]. The need of maintaining or improving customers service levels along with the focus on cost effectiveness in the healthcare setting has resulted in new and innovative approaches to manage the healthcare logistics. In this section these new approaches and studies are reviewed.

Some of the studies focus on developing framework and ideas to better understand and integrate logistics activities. Harland [44] proposes a conceptual framework and process for healthcare logistics strategies with a case study. Landry and Philippe [45] propose management ideas to better understand the role of logistics in healthcare. Their ideas are based on case study of several leading international practices and show how to better integrate logistics activities through a unique combination of reengineering and activity-based costing.

An important issue in an efficient pharmaceutical supply chain designing is where to locate the warehouses/inventories and how to route distribution vehicles. A good solution to problems of facility location and vehicle routing can guarantee that a rapid distribution of medical supplies can be achieved. Dessouky et al. [46] discuss the requirements and characteristics of large-scale emergencies for the problems of facility location and vehicle routing in the context of a particular emergency situation of an anthrax attack. They mention that emergencies of other types, such as chemical incidents, dirty bomb attacks, and contagious disease outbreaks, may have different characteristics and therefore may result in different requirements on the problem formulations and solutions. Oliveira and Bevan [47] develop a mathematical programming model based on two location-allocation models. Their aim is to redistribute hospital supply using different objective functions under various assumptions about the utilization behavior of patients. Rossetti and Selandari [48] try to enable a better understanding of the delivery and transportation requirements of middle to large size hospitals and describe how a fleet of mobile robots can meet these requirements. They also propose a methodology to evaluate automation in a hospital environment. Fiegl and Pontow [49] develop an algorithm for scheduling pick-up and delivery tasks in hospitals. Based on the identified needs from the viewpoint of patients, Jin et al. [50] define four critical-to-quality parameters namely the fill rate, accuracy rate, efficiency and expiration or spoilage rates and present a case study of applying the principles and procedures of Six Sigma and Lean Thinking in designing and operating a healthcare logistics center.

Some other studies have their main focus over the procurement process. By coordinating the procurement and distribution operations considering inventory capacities, Lapierre et al. [51] present an innovative approach in order to improve hospital logistics. Their approach concentrates on the scheduling decisions such as when to buy a product, when to deliver to each care unit, and when each employee should work with what tasks instead of focusing on multi-echelon inventory decisions. They also propose a tabu search metaheuristic to solve their model and use a real case from hospitals to validate their model. Danese et al. [52] focus on collaboration process that supply chain partners implement coordination mechanisms between parties to plan for key supply chain activities together. These activities range from delivery of raw materials and production to delivery of finished goods to end customers. Their particular collaboration process is called Collaborative Planning, Forcasting and Replenishment (CPFR). They also present a case study of implementing CPFR in supply networks of the pharmaceutical industry. King and Muckstadt [53] try to evaluate how the efficacy of the distribution network would be affected by a specified collection of planned resource availabilities. The efficacy is measured in terms of the number of patient-hours waited during the emergency response. To conduct this evaluation they develop a linear programming model where model's constraints describe the physical system, including the relationships between the parties, the regional distribution warehouse and the medical supply distribution clinics.

Other studies in this class include comparison of different healthcare systems. Aptel and Pourjalali [54] investigate supply chain management or logistics differences between large hospitals in the U.S. and those in France and report that there exist important differences in logistic operations. The reported differences include degree of collaboration between hospitals and other organizations that could be other hospitals or suppliers. This collaboration is observed more in U.S. compared to France.

5. Technology management Related to Healthcare Supply Chain Management

As technology advances the efficiency of supply chains can increase significantly. This increase of efficiency may be even greater for perishable goods as in the healthcare section. One example of technology application in healthcare supply chain is the implementation of Radio Frequency Identification (RFID), which has a great impact on supply chain. RFID could affect important decisions such as pricing decisions especially when the perishable goods are about to reach their expiry dates [55]. While RFID is generally used as a method for inventory control to prevent out-of stock situations, in the pharmaceutical industry it is also known and used as a tool of preventing counterfeit drugs from being circulated and used in the supply chain, as well as increase control in the reverse direction due to expiration or recalled products [56]. Chao et al. [57] show the increased number of publications on RFID as a technological tool from 1991 to 2005. This trend is illustrated in Fig. 1- and shows a big jump from 2003, which implies the importance and impact of this technology in industries. As another example, advances in storage and packaging facilities and equipments increase the lifetime and freshness of products [55].

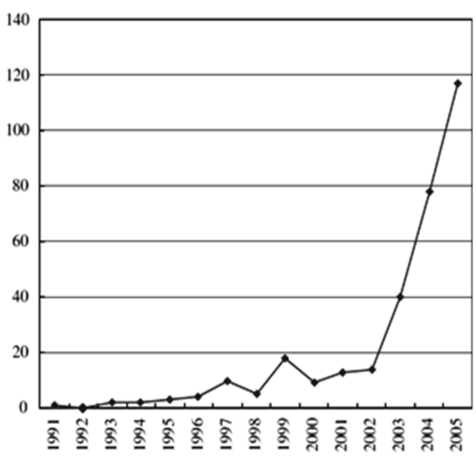

Fig. 1- Number of publications on RFID [57]

Table 2 shows the major applications of RFID in healthcare [58]. Most studies on the impact of technology advances on the healthcare section address the implementation of RFID as a tool to enable the flow of information among different parties in the supply chain as well as detecting and recording expiry possibility of the products in storages (e.g. [56, 59-60]). Bendavid and Boeck [60] describe a system that uses RFID to manage high value products with the aim of consignment and item level traceability. As a result of redesign of the replenishment process, Bendavid and Boeck [60] conclude that three main categories of potential savings can be derived, productivity gains for logistics processes, inventory shrinkage, and non-recurring inventory-related savings. Potential productivity gains are related to time savings of material management tasks operated by nurses and personnel and has a direct impact on patient care quality. Inventory shrinkage is related to the products that can become very costly with a small discrepancy (such as expired products, unused products in the operating room, products no longer used, etc.). The reduction in inventory levels is a result of RFID implementation, which provides better visibility of consumption. They also mention some other benefits of electronically data exchanges including efficient transmission of business data between healthcare supply chain members, increased accuracy of data in the entire supply chain processes, and improved time spent on administrative processes, allowing more time for the main operations (e.g., patient care).

Kumar et al. [56] develop a process improvement approach for the reverse logistics in a recall to avert the possibility of harm to consumers. Kumar et al. [59] tries to address three main challenges of determining the most efficient and cost-effective part of the RFID-implemented healthcare supply chain, providing examples of RFID implementation to show its effectiveness in the healthcare supply chain, and finally describing the current state of RFID technologies in the healthcare section.

Table 2-. Major applications of RFID in healthcare [58]

	Dispensation	Security	Geolocalization	Inventory
People	Patient/blood	Newborns	Alzheimer patients	Operations
Assets	Drugs	Preoperative	Bottle of oxygen	Drugs
Places	Distance control	pharmacy	Doctors	Emergency

Archer et al. [61] develop a conceptual model of the ordering/logistics process to evaluate supply service policy options that could optimize supply management. They also develop a system that supports mobile wireless devices for visiting nurses, in place of an existing paper-based system.

There are several studies that compare different inventory tracking technologies. Table 3 shows an example of comparison reported by Cakici et al. [62]. Cakici et al. [62] discuss the benefits of the RFID technology compared to the barcode technology for managing pharmaceutical inventories. They also develop models to analyze the periodic and continuous review policies in order to monitor the inventory. They show that inventory management can benefit more from continuous review by RFID technology compared to periodic review by barcode technology.

Table 3-. comparison between Barcode and RFID technologies [62]

Feature	Barcode	RFID
Line of sight	Need	Not needed
Simultaneous multiple reads	No	Yes
Unique Id	No	Yes
Data Storage Capacity	Low	High
Security	Low	High
Durability	Low	High
Tracking	Periodic	Real-time
Human error	A Concern	No
Inventory counting and reordering	Manual	Automatic
Update on expiration date	No	Yes

Along with studies that show the advantages of RFID, Bureau et al. [58] question the promises of using RFID and challenges that may be associated with this technology. They state that many RFID specialists and researchers consider RFID as a tool that should improve the tracking of patients, medical personnel, drugs, and equipment, decrease medical errors, provide positive identification of patients and medications, secure the access of sensitive places in hospitals, provide patients with safer medications, and facilitate better information management. However, Bureau et al. (2008) discuss that there are myths related to either misunderstanding of how RFID can make improvements or incorrect or incomplete definitions of what RFID capabilities and business solutions are. They mention seven myths and discuss each with a healthcare case. The myths are RFID as the solution for all your logistics tracking issues, RFID as a tool to deal with the new identification challenge, RFID as a new Big Brother that can spy consumers, RFID as a cost killer, RFID as a tool to reduce medical errors, RFID as a new bar code, and finally RFID as a simple tag.

As the rules of the healthcare delivery game that continues to change rapidly, the players are primarily interested in reducing the cost and increasing efficiency. Managed care organizations (MCOs) use e-business to interact with other parties' and also to access, store and analyze large amounts of information about their interactions. Electronic communication makes it possible for the healthcare providers and payers to exchange rapid feedbacks with the expectation that more information sharing could reduce variations in practice and improve overall quality and efficiency. E-technology also provides effective and efficient means for MCOs to achieve the operational standards, set by accrediting and regulatory bodies [63]. Among the studies of technology management in healthcare, Tzeng et al. [64] have a broader perspective toward the application of IT in the healthcare section. They study the strategic and organizational impacts of RFID technology and develop a theoretical framework rather than just focusing on the real-time applications. By analyzing the data obtained from five hospitals as their case studies and practical evidence, Tzeng et al. (2008) state two major value categories that are shown in Table 4.

Table 4-value categories of RFID application [64]

Value created	Source
Refine	Effective Communications Increase asset utilization Enhanced asset utilization
Extend	Active patient management Virtual integration of the supply chain New service Strategy New business opportunities

6. Conclusion and remarks

In this paper we review the literature of the healthcare supply chain management including inventory management and information technologies used. We classify the existing studies in literature according to three different perspectives: inventory, supply chain design and operation, and related technology management. In each category we further classify studies into subclasses. These subclasses include critical and non-critical for inventory management studies, network design and logistics management for supply chain management studies, and RFID and other information technologies for healthcare management. In each class we review the related studies in Sections 3 through 5.

Based on the review, we can see increased studies of healthcare supply chain management in addition to the traditional blood inventory management. With the implementations of advanced information technologies, better supply chain management in the healthcare sector becomes possible. We expect more quantitative models and case studies will appear in this area, including both operational management at individual locations and the coordination along supply chains. This review is expected to facilitate the tracing of studies and published work in relevant fields of interest and help readers identify potential areas for future research.

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