Chapter 18
The Challenges of Hospital Supply Chain Management, from Central Stores to Nursing Units

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1 Introduction

In the vast majority of countries, the healthcare sector is the focus of a great deal of attention from public decision makers and media alike. Although healthcare is by definition a clinically driven environment, the practice of patient care is supported by a range of activities that notably include purchasing, inventory management, and the distribution of supplies to the point of care. These activities are associated with healthcare supply chain management, also referred to by many as healthcare logistics. Improving the efficiency of such logistics can provide opportunities for healthcare institutions and health systems to increase the quality of care and reduce costs.

This chapter will describe the challenges of healthcare supply chain management with a focus on the hospital's internal supply chain and more specifically on the distribution of medical supplies from the central storeroom to nursing units (point of care). Section 2 provides background information on healthcare supply chain management, with particular reference made to the efficient healthcare consumer response (EHCR) report, the first industry-wide report on healthcare supply chain integration. Section 2 goes on to discuss the complexities of the internal hospital supply chain and addresses how the materials management function overseeing this activity is structured. Section 3 covers the challenges and methods of distributing medical supplies to nursing units. Sections 4 and 5 identify best practices and future research opportunities. Section 6 concludes the chapter.

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2 Background on Healthcare Supply Chain Management

Hospitals are much more than simply a link in the healthcare supply chain. They are on the receiving end of a wide range of supplies that support the delivery of care. This section will address the challenges of the internal and external supply chain and will examine how these activities and processes within the hospital are structured.

2.1 Efficient Healthcare Consumer Response

Publication in the USA of the EHCR report in 1996 marked a turning point in healthcare supply chain management. This analysis presented a global vision of the supply chain in the sector by placing particular focus on medical and surgical supplies and pharmaceutical products (CSC Consulting 1996). The document followed on the heels of studies conducted previously in other sectors, such as those in the apparel industry supply chain in 1986, which led to the Quick Response movement (Blackburn 1991; Hunter and Valentino 1995) and in the (nonperishable) food industry in 1993, which prompted the Efficient Consumer Response (ECR) report (Kurt Salmon Associates Inc. 1993). The EHCR report was largely inspired by the ECR report; however, healthcare issues are much different from those faced by retail businesses, if only in the identification of the consumer, who may be the patient (to whom the supplies are directed and in certain cases charged), the healthcare professional (who prescribes or uses the products or supplies), or the taxpayers, employers, government programs, or insurance companies (who pay).

The vision put forward in the EHCR report brought to light supply chain inefficiencies shared by manufacturers, distributors, and healthcare providers, including duplication of tasks, multiple storage areas, a fragmented information flow, delays of all types, and substandard service. The study itself led to the creation of a number of committees and expectations for changes in the strategies deployed by the stakeholders [providers, distributors, manufacturers, group purchasing organizations (GPOs), etc.]. In turn, substantial savings were expected—savings that at the time were estimated at $11 billion across the US health system or almost half of the costs associated with documented logistics process. However, once the new strategies had been drafted, the corporate priorities of the stakeholders involved, many of them competitors, led a large number of decision makers to take isolated action and dissolve the EHCR committees a few years after their creation (Landry and Beaulieu 2008).

In 2009, a team of researchers from the University of Arkansas Center for Innovation in Healthcare Logistics (CIHL) published a report on the advancement of healthcare logistics practices since the EHCR. The report stated that “despite this effort, a lack of clear and measurable cost and quality improvements is evident within the industry” (Nachtmann and Pohl 2009). Almost half of the respondents, most of whom were employed by hospitals or health systems in director-level

positions, indicated that their organization's supply chain was at a low level of maturity (i.e., neither linked nor integrated/extended). Moreover, the report concluded that the healthcare supply chain was starved for accurate and accessible data, the lack of data standards being a major hurdle. However, there was evidence of implementing the strategies recommended in the 1996 report. Indeed, according to this report, 41% of respondents had attempted at least half of the suggested EHCR strategic initiatives, such as e-commerce implementation and supply chain automation, and had achieved performance improvements.

2.2 Hospital Supply Chain Management Challenges

Although the trend is moving toward the establishment of a continuum of care among multiple healthcare providers, such as outpatient clinics, acute care hospitals, and nursing homes within a health system or an integrated delivery network (IDN), hospitals remain the backbone of these systems and present multifaceted supply chain management challenges. In 2009, for example, the just under 6,000 hospitals in the USA (AHA 2010) accounted for close to one third of the national health budget and were the primary expenditure item (California Healthcare Foundation 2011). The challenges these institutions face pertain to the integration of the external supply chain as defined in the EHCR report, that is, manufacturers, distributors, and healthcare providers, as well as the integration of hospital's internal supply chain (Fig. 18.1).

The hospital is much more than simply a link in the supply chain (Landry and Beaulieu 2007), and its internal supply chain is highly complex. Hospitals are generally structured around clinical departments such as emergency, intensive care, oncology, cardiology or coronary care, the catheterization laboratory or cath lab, and surgery [performed in operating rooms (ORs)], with inpatient beds organized in wards or nursing units averaging two dozen beds each. These departments and nursing units must have on hand pharmaceutical products and medical supplies to support patient care, and these products and supplies go through a series of steps before they reach the end user (clinical staff or patient) for consumption. Medical supplies tend to come under the responsibility of the materials management department and most often must be processed by receiving and central stores before being delivered to end users. (An exception is pharmaceutical Thitchie et al. 2000 products, which are processed and managed by the pharmacy and are discussed in Vila-Parish and Ive and therefore fall outside the scope of this chapter.)

Nursing units generally have a main storeroom where medical supplies are kept. However, this room is rarely the final storage position, as secondary storage points located closer to the point of use throughout the unit cater to the specific needs of clinical staff. These points, which are replenished with supplies drawn from the main storage room, may take several forms, from mobile carts that transport supplies from patient to patient to stationary storage units in patient rooms.

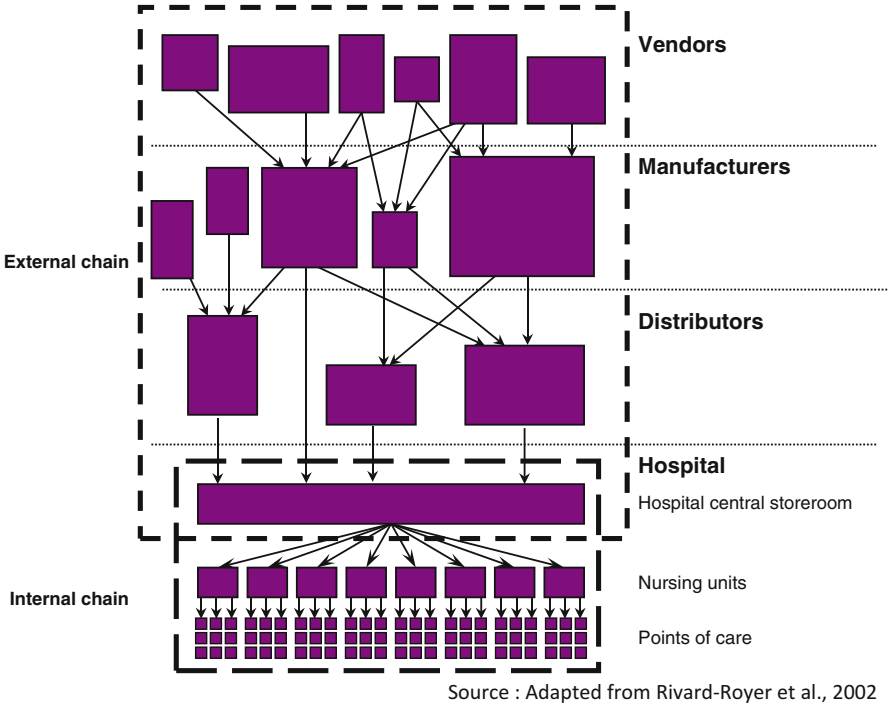

Fig. 18.1 Healthcare sector supply chain

In addition, certain supplies commonly known as nonstock items (or direct purchases) are, as their name implies, not stored in central stores but rather delivered directly to a specific nursing unit shortly after being received, often because the unit is the sole user of these supplies. Other supplies, such as food, linens, and surgical instruments, must go through a "transformation" process before being delivered to users (e.g., cooking, washing, or sterilization). After use, certain supplies must go through what is called reverse logistics to be transformed once again (e.g., linens), while other supplies become a waste management issue (e.g., cardboard). Hospitals produce a variety of waste matter (biomedical, chemical, metal, etc.) (Tudor et al. 2009), which often must be managed according to regulatory standards (Tyagi et al. 2010). For ecological reasons, hospitals also develop practices to reduce environmental impacts, such as unpacking and recycling cardboard boxes in central stores to promote paper recuperation and prevent boxes from accumulating in nursing units (Tudor et al. 2008).

Hospitals therefore receive a wide range of supplies that support the delivery of care, either directly (medical supplies, pharmaceutical products) or indirectly (linens, meals, stationery, cleaning products). In most cases these supplies carry a high level of awareness as to the risks of stocking out. Moreover, the many different flows of information and material in a hospital have resulted in a range of clinical

staff contributing to the logistics activities associated with the various supplies used. This means that within a hospital, almost everyone is involved in the supply chain, although few realize it (Landry and Beaulieu 2002). Among the professionals involved, clinical staff often have neither the expertise nor resources to efficiently manage logistics activities. And, considering that most industrialized countries are facing nursing shortages, it is vital to find ways to ensure that all of the efforts of clinical staff are channeled toward patient care. Instead, many of these employees currently spend more than 10% of their time on logistics tasks (Chow and Heaver 1994; Rivard-Royer et al. 2002; Fereng 2010). Added to this is the fact that nurses are often interrupted in their work because of supply shortages and other logistics problems (Tucker and Edmondson 2003).

The diversity of flows and the dispersal of logistics activities among the various departments and nursing units in a hospital tend to inflate the costs associated with these activities. In fact, North American studies have found that more than 40% of a hospital's expenses are related to supply chain activities (Chow and Heaver 1994; Nachtmann and Pohl 2009; AHRMM 2010). Similar studies conducted in France and Holland have revealed that 30–35% of a hospital's operating budget is spent on logistics (Bourgeon et al. 2001).

Not all products are alike; their cost or the impact of a shortage will vary (Schneller and Smeltzer 2006). In some cases, the material manager must change strategies to take advantage of any savings that may be available. Tendering strategies and the consolidation of suppliers are primarily used for commodity products (Pedersen 1996). It remains that physicians' preference items (PPI), that is, supplies and expensive disposable items used during surgical procedures, hold the greatest potential for savings in hospitals (DeJohn 2005). Indeed, surgeons' decisions are frequently based on factors unrelated to cost, such as their experience with a particular product, their sense of what is in the best interests of a particular patient, or their relationship with a manufacturer's representative (Montgomery and Schneller 2007). Savings on these products can be generated through supply standardization strategies or utilization management (Governance Committee 1997). However, such strategies ultimately depend on physician participation (Montgomery and Schneller 2007; Aston 2010).

The hospital, due to the particularities of its internal supply chain, consequently merits greater attention, and solutions are needed that address its unique situation. The benefits that can be generated through sound management of the hospital supply chain are equally unique. Whereas using effective logistics in the industrial and retail sectors can lead to reduced costs and increased customer service, efficient logistics in the healthcare sector can yield other substantial gains. For example, improved logistics in this sector can become a tool to enhance job satisfaction among clinical staff. To this end, given the complexity and challenges being faced by the healthcare sector, it is important to integrate the internal supply chain in order to fully benefit from its integration with the external chain (Schneller and Smeltzer 2006).

2.3 Organizational Structure of the Materials Management Function

In North America, as reported by Landry and Beaulieu (2002), the emergence of the materials management or logistics department in its current form is the result of many changes that have taken place over a 100-year period within the hospital environment. Indeed, "in the early 1920s, the American College of Surgeons endorsed the concept of standardized surgical dressings and the centralized preparation and handling of all surgical supplies" (Thorsfeldt 1988, p. 64). By the 1940s, W.R. Underwood and others were paving the way for a central service organization (Thorsfeldt 1988), and in the 1970s, analysts became proponents of a centralized system to manage purchases, inventory, and distribution in hospitals (Driscoll 1981). During the same decade, this central department evolved further, integrating new functions and becoming the materials management department; one of the functions rolled into it was purchasing, although this emerging organizational structure varied from hospital to hospital (Thorsfeldt 1988).

Prior to 1950, few hospitals had a centralized purchasing department; each department managed its own purchases and inventory. However, this approach was feasible only when a limited assortment of products was involved. The technological evolution that followed the Second World War brought with it a surge in the range of products available as well as an increase in deliveries, further complicating the management of supplies. To eliminate duplication and labor costs, hospitals turned to a centralized purchasing approach (Burnette 1994).

The consolidation of a central service and purchasing unit within a new materials management department responded to a need for greater efficiency and productivity by eliminating waste and duplication in the management of material flows (Thorsfeldt 1988). It also put responsibility for purchasing supplies into the hands of professionals, which in turn led to an increased knowledge of the markets (Fearon and Ayres 1967). These centralization efforts gave birth to what we know today as healthcare supply chain management or healthcare logistics, which take concrete form through these various terms and the different roles that logistics play within a hospital. Yet, despite the clear benefits of assigning an increasing number of activities to the materials management, logistics, or supply chain department, as noted above, we continue to see many hospitals dealing with fragmented logistics activities and a host of players (Parker and DeLay 2005), which can impede the emergence of a single, credible entity to handle supply chain activities.

Moreover, in many sectors, including healthcare, the purchasing function is largely ignored by senior management (Bales and Fearon 1993; Cammish and Keough 1991). Often, responsibility for this department is assigned to a middle manager, whose authority is by definition limited (Janson 1985). In more than half of the hospitals in the USA, the materials management department reports to the financial director or CFO, which means that the manager must negotiate with decision makers in other departments as well as with his or her own internal clients (Kowalski 1993; AHRMM 2000; HFMA 2010). Chow and Heaver (1994)

agree, stating that this situation initially leads to an inability to implement solutions that involve both the hospital and its suppliers and goes on to disrupt operational activities, as the department is left to find its own solutions.

Recent developments in the healthcare sector demonstrate the extent to which supply chain management is gaining the attention of leaders. In Canada and the USA, healthcare reforms are prompting a number of materials management departments to outsource a portion of what were once their traditional activities. Most departments, for example, turn to a group purchasing organization (GPO) to find suppliers and negotiate contracts; others use the stockless approach, calling on medical supply distributors to deliver products directly to nursing units (Arthur Andersen 1990; Souhrada 1998; Rivard-Royer et al. 2002). In recent years, we have also seen the emergence of consolidated service centers (AHRMM 2010), which use a shared services or 3PL approach to serve many institutions in the same province or state or indeed in several states. More and more hospitals are also creating materiel/materials management or supply chain departments and in some cases, the position of Chief Resource Officer. This shift is not unique to North America; in France, for example, the first such platforms made their debut in the late 1990s (Landry et al. 2000).

3 Distribution of Supplies to Nursing Units

As mentioned above, the distribution of medical supplies to nursing units represents a key component of the hospital's internal supply chain, given the many nursing units found in a hospital, the large quantity of items replenished on a daily basis, the number of clinical staff impacted, and the cost of these items. Methods of distributing supplies to nursing units can be classified according to whether decisions regarding the quantities to be replenished are centralized in the materials management/logistics department or decentralized in the nursing units themselves, and, on another level, according to whether supplies are managed in nursing units as perpetual inventory (online real-time inventory status) or as periodic inventory (where items on hand have to be counted to establish reordering quantities).

In most cases, supply purchases are charged to the nursing unit (or user department) at the time of delivery and no longer appear on the hospital's books as an asset. This "unofficial inventory" can represent up to ten times the value of the official inventory, that is, the supplies kept in central stores and managed through a perpetual inventory management system (Berling and Geppi 1989).

Based on the literature on this subject (primarily Perrin 1994) and our own field experience, we note that the methods most commonly used to distribute supplies to hospital nursing units have ranged from clinically driven requisition-based systems (decentralized-periodic inventory), exchange carts (centralized-periodic), and periodic automatic replenishment or par level system (centralized-periodic) to the more recently introduced two-bin system (centralized-periodic), RFID-enabled two-bin system (centralized-perpetual), weight control bins (centralized-perpetual), and

user-driven unitary demand capture systems (centralized-perpetual). See Table 18.1 for a detailed description of these different types of inventory management systems.

The order in which the above replenishment systems are presented is not random; it follows the same sequence as their introduction into the healthcare sector. This evolution has come in three waves. In the 1970s, the exchange cart system began to overtake the requisition system in popularity (Perrin 1994). Although rarely used today, the exchange cart concept nevertheless introduced a key objective that subsequent replenishment systems only served to reinforce: transfer responsibility for replenishment from clinical personnel to a centralized administrative body [e.g., hospital central stores or, in the case of stockless materials management, distributors (Rivard-Royer et al. 2002)], which would perform this task for all of the hospital's nursing units. To a certain degree, this is a sort of "internal" vendor managed inventory (VMI) system. This division of duties allowed for greater specialization of functions, with clinical personnel now able to focus on their core mission of patient care. It also allowed staff in the centralized administrative unit to spend time establishing minimum and maximum thresholds for the various supplies kept in stock and identifying the optimal replenishment frequency—in short, managing the inventory, a task that clinical personnel were often forced to neglect (Landry and Philippe 2004).

In the 1980s, the par level system proved itself more efficient than the exchange cart system by delivering appreciable gains through reductions in stock and storage space in central stores, as it eliminated the need to manage duplicate mobile supply carts. Par level was also more flexible, in that it could be used with any and all storage equipment in the nursing unit (fixed carts, fixed shelving, cabinets, etc.), while enabling staff to manage a wider range of products than with the exchange cart system, as the process was no longer limited to using a particular type of mobile cart. Moreover, it permitted the use of portable readers to enter quantities in stock or scan label barcodes. However, these gains were achieved at the expense of additional contact between the material handler (a stores clerk who is part of the materials management department) and clinical staff (mainly nurses or nursing aides), as the handler now had to spend more time in the nursing unit to count the supplies requiring replenishment and put away delivered products. It was nevertheless possible to diminish the disruption by conducting rounds to scan barcodes and put away supplies during the evening or night shifts, when there was less activity on the unit.

The third development came at the end of the 1980s, when the two-bin or kanban system emerged from Denmark and Holland (early 1990s in France; late 1990s in North America) and delivered significant gains over its predecessors. During scanning rounds (order taking), rather than material handlers drawing on their experience only and "eyeballing" the materials as with par level (Leone and Rahn 2010), they could now simply scan labels that had been removed from empty bins and affixed to a wall-mounted board within each nursing unit storage area. It is important to note that the gains generated by the two-bin system did not come at the expense of increased inventory. In fact, compared to the par level system, the two-bin method did not double the quota of supplies, but rather divided it between each

Table 18.1 Description of distribution methods (adapted and expanded from Landry and Beaulieu 2010)

Method	Description
Requisition	Nursing or clinical support staff conduct regular inventory counts combined with consumption estimates (a form or fixed-interval periodic review system). Products identified as low in inventory are noted on a requisition form that is forwarded, either manually or electronically, to the materials management department. Based on this requisition, required supplies are picked or ordered from external vendors and sent to the nursing unit in question. With this mode, it is often clinical personnel who are assigned the task of putting away the delivered products in the storage units
Exchange carts	Medical supplies are placed on a cart positioned in a storage area on the nursing units. Products are taken from the cart and consumed, with the cart being exchanged according to a predetermined schedule by an identical, fully stocked replacement cart (fixed-interval periodic review system). During the replenishment period, the first cart is returned to central stores to be restocked. According to the set schedule, the newly replenished cart will later be exchanged for the cart on the nursing unit
Par level	Rounds of the nursing units to be replenished are conducted according to a predetermined schedule. During the rounds, a material handler identifies items that need replenishment on the nursing unit through a visual evaluation or a more formal inventory count. Normally, a product is identified by scanning a barcoded label on the shelf, bin, or packaging, and the quantities counted are entered into a handheld computer. The information is then downloaded to the materials management information system, which compares the quantities counted with established quotas and generates a pick list or requisition in the case of nonstock items (fixed-interval periodic review system). The picked or ordered products are then delivered to the nursing units and put away by a material handler. Some hospitals use a min/max variation of the par level system
Two-bin/kanban	Each quota of medical supplies is divided between two compartments. When the first of the two compartments is empty, clinical staff remove the label identifying the product from the front of the compartment and affix it to a wall-mounted kanban board (with rails). Rounds of the nursing units to be replenished are conducted according to a predetermined schedule. Thus, two conditions must be satisfied to trigger the replenishment process: the bin must be empty, and the replenishment process must be underway (hybrid inventory management system, which combines both fixed-order and fixed-interval characteristics). During the rounds, a material handler scans the labels on the board. The replenishment information is then transferred to the materials management information system, which generates either a pick list for items stored in the central warehouse or a requisition for items sourced externally (direct purchase). The medical supplies are delivered to the nursing unit and put away in the empty compartments by a material handler after having rotated the stock Some hospitals have implemented this system using individual plastic bins. In this case, each supply is divided between two labeled plastic bins that are either stacked or placed end to end on a shelf. When a bin is empty, it is set aside and collected by a material handler to be brought back to central stores for replenishment (Graban 2009)

Table 18.1 (continued)

Method	Description
User-driven unitary demand capture systems	With these automated systems, items are stored in the nursing units in closed cabinets or open bins. Each unit removed is recorded by the employee (through various means such as pushing buttons or scanning transponders or barcodes), thus capturing consumption. At any point in time (generally at fixed intervals), communication is established with the materials management information system to enable replenishment based on this on-hand quantity. The collected data is also transferred to the hospital's billing application to charge patients for the supplies used to treat them
Weight control bins	This system stores the various items in bins and maintains a perpetual inventory in the nursing unit based on the weight of these items. Replenishment is triggered when the bin reaches the preset weight for each product type. Communication is established with the materials management system to enable a request to be generated
RFID-enabled two-bin/kanban systems	In this version of the two-bin system, the bin's label looks like any other but is equipped with a passive (no battery) high-frequency (HF) RFID transponder. A reader is installed behind each of the replenishment boards where labels from empty bins are affixed. This board is connected to the hospital's information technology network. The moment an RFID label enters the reading range of the antenna, communication is established with the materials management system to enable a request to be generated at fixed intervals or according to preestablished replenishment rules. In addition to being used with compartments, RFID transponders can also be affixed to the individual plastic bins, thus representing another way to automate the two-bin system. RFID technology eliminates the necessity of conducting rounds to scan the labels of empty bins. The system also maintains a perpetual inventory of bins (i.e., plastic bins or compartments)

bin. The two-bin system also brought with it greater control over the quantities to order (a fixed quantity per bin). In addition, the two-bin system forced stock rotation and in doing so reduced the risk of products expiring. It could also be combined with a high-density storage system, which enabled a greater variety of products to be stored in the same storage area, including direct purchases that could be managed with this system (Landry et al. 2004).

In the early 1990s, the USA saw the introduction of automated storage cabinets in nursing units, the first user-driven unitary demand capture systems to provide perpetual inventory management. Used primarily for medical supplies and pharmaceutical products, these systems emerged in the American healthcare sector as a result of private hospitals seeking to better reconcile the supplies consumed by patients with those invoiced to them. A few years later, less expensive point-of-use technologies using open bins with transponders were introduced. However, the challenge with these systems, both closed and open, has been compliance by users to record consumption, with one notable consequence being inventory inaccuracies. In the case of the automated cabinets, once the door of a closed cabinet is opened, clinical staff can remove items without accounting for them. Indeed, in a study that targeted the dispensing of pharmaceutical products, Klibanov and Eckel (2003) found that 19.5% of 2,895 drawers contained incorrect inventory. Moreover, in certain countries, such as the USA, the practice of invoicing patients or insurance companies for individual items used is gradually changing to a diagnostic and treatment-related system. For this reason, some are questioning the ongoing practicality of using such sophisticated permanent inventory systems in nursing units.

In the early 2000s, in an effort to reduce compliance issues, some vendors introduced RFID transponder technology, thus eliminating the requirement for nursing unit staff to record transactions (Bendavid et al. 2010). Still, the deployment of this technology has been limited, as each item must be conditioned by affixing an RFID transponder to it, an activity that can become cost-prohibitive given the relative low cost of most medical supplies (Bendavid et al. 2010). The use of this technology has therefore been restricted to a small group of products, such as implants, in specialized areas (operating rooms, cath labs, etc.).

In the mid-2000s, in a further effort to reduce compliance and demand capture issues, a weight control bin solution for general supplies was adapted from the industrial sector and introduced in the US healthcare sector. The solution automatically triggers the replenishment process using order point logic. However, the solution is challenging from a space utilization point of view; not only is it a wall-mounted system, but in many cases the walls used must be reinforced. The offering has a limited assortment of bins and can also be unreliable in a live environment (technology failure, recalibration, items returned to the wrong bin, monitoring of expiry dates, etc.).

The mid-2000s also saw the development of the RFID-enabled two-bin replenishment system. Initially developed in Canada (Beaulieu and Landry 2010; Bendavid et al. 2010), this replenishment system has since become popular in Europe, particularly in France and Spain. In 2011, a computer vision-enabled

version of the two-bin replenishment system (video capture) was introduced in North America at the annual AHRMM conference (Association for Healthcare Resource & Materials Management). Using video cameras, the new application is capable of recognizing empty bins and generating replenishment orders. This further reduces human intervention while maintaining the benefits of the two-bin system. Building on the gains delivered by the two-bin system, both RFID and video capture technology allow for the elimination of data collection through preestablished rounds and provide real-time, remote visibility of inventory levels and replenishment needs. At the bin level, the periodic review model has thus evolved into a perpetual inventory model.

All of these inventory management systems use a fixed-interval reordering process (periodic review system), order point logic, or a combination of both (hybrid system). This means that the review period duration, maximum inventory level, order point, reordering quantities, and safety stock can all be calculated using various stochastic inventory models to try to find the right balance between ordering costs and inventory carrying costs. Research has shown that keeping these inventory management parameters up to date can lead to improved performance (Landry et al. 2004). Unfortunately, in many hospitals, the rule of thumb prevails; too often demand is not tracked, and parameters are not kept up to date.

Over and above what has been presented for a typical nursing unit, the operating room presents unique challenges, as a large proportion of the items it carries are nonstock (direct purchase) and consignment items. Moreover, these supplies are often very expensive, with inventory costing five to six times more than that stocked in the hospital's central stores and with an inventory turnover rate of 2.5, compared to 12 in central stores (Park and Dickerson 2009). However, the OR offers a rare opportunity in healthcare, as material usage could theoretically be planned days or sometimes weeks in advance by taking advantage of the forward visibility of the OR schedule and surgeons' preference lists (bills of materials). Material requirements planning (MRP) systems, common in the manufacturing sector for dependent demand items, could then be used (Steinberg et al. 1982; Lafond and Landry 2001). To our knowledge, however, very few examples of such utilization exist in practice in the OR. Currently, forward visibility is restricted to using OR schedules and preference lists (for predictable items) to enable the preparation of case carts before a surgical procedure. Rather than having OR staff pick supplies and instruments from OR storerooms right before the operation, the ability to prepare in advance also paves the way for automating of charge capture, with data collection greatly streamlined for patient charging where applicable.

And finally, the OR has recently seen the introduction of RFID technology to manage high value items via a number of applications, such as RFID shelves, cabinets, and receptacles (Bendavid and Boeck 2011). Although they use the same technology to collect data, RFID-enabled shelves and cabinets manage the process differently from RFID receptacles: shelves and cabinets read tags on product packages when within the field of the antenna and therefore in inventory, and removing a product from a shelf will deplete this product from inventory. In the case of the receptacle, data is read when a product is consumed, with its RFID-tagged

packaging disposed of in an RFID-enabled receptacle. The logic here is that a product recorded in the conditioning process is in inventory until its packaging is disposed of in the receptacle, thus requiring less technology per item managed. As for the RFID-enabled shelves and cabinets, these are used to track the usage of unpredictable high value items—usually consignment products—such as orthopedic prostheses (Philippe and Beaulieu 2010).

4 Best Practices in Medical Supply Distribution Methods

In many situations, the two-bin/kanban replenishment method has proven to be a better inventory management system for medical supplies and common drugs, office supplies, etc. than clinically driven requisition-based methods, exchange carts, par level, or more expensive automated cabinets (Landry et al. 2004; Black and Miller 2008; Graban 2009; Landry and Beaulieu 2010; Leone and Rahn 2010).

As mentioned above, generally speaking, the two-bin system offers the following advantages over other periodic review systems:

- No-count replenishment system (built-in decision rule; no "eyeballing," as is often the case with other systems)
- Reduces the average inventory level, because it increases the quality of information at the point of use
- Reduces the time taken for the ordering process (four to seven times faster than par level systems, Landry et al. 2004) and thus reduces the time spent by material handlers in the nursing unit (less chance of disruption to clinical activities)
- Reduces product handling and increases event-related sterility (infection control)
- Reduces the risk of products expiring (built-in stock rotation)
- Manages products with different replenishment cycles in the same storage units
- Leads to better ergonomics when implemented with high-density storage systems
- Integrates a number of lean healthcare features (visual management, standardized process, kanban; Landry and Beaulieu 2010)

The addition of RFID technology has further improved the two-bin system. It has eliminated the need to conduct rounds of the nursing unit to scan the labels of empty bins, thus doing away with movements with little or no added value (elimination of waste) and disruptions on the nursing unit, particularly in hard to access areas (Landry and Beaulieu 2010). Moreover, RFID technology, combined with a materials management information system, can immediately alert the materials management department via pager or other device that there is a stockout in the nursing unit (i.e., that the label from the second bin has been affixed to the board; Landry and Beaulieu 2010). The emerging application of voice technology used in conjunction with portable RFID readers also improves the put away process by locating labels on the board faster and reducing the risk of errors.

While we consider the RFID-enabled two-bin system a better way to manage supplies in nursing units or specialty areas such as the OR, one must remain open

minded about using other systems or techniques in specific circumstances. For example, we have seen the exchange cart work well in dialysis, with sourcing directly from the vendor. Indeed, according to Szulanski (1996), best practices are replicated organizational routines where "practice refers to the organization's routine use of knowledge and often has a tacit component, embedded partly in individual skills and partly in collaborative social arrangements." Winter (1995) states that these organizational routines intuitively rely on behaviors that generate a predictable result. On a more conceptual level, these routines "can be conceived as a web of coordinating relationships connecting specific resources" (Winter 1995). A practice is therefore not limited to technology and work processes. Under these circumstances, a practice can qualify as "best" based on the environment where it is deployed (Moore 1999).

For example, Hôpital du Sacré-Cœur de Montréal, a hospital in Montreal, Canada, transformed the secondary storage locations in its emergency department examination rooms into more than 30 primary storage points replenished by the hospital's central stores. These storage locations had previously been replenished by clinical support staff from a central storage area in the emergency department itself. The change gave material managers a greater awareness of the replenishment process of a very busy area of the hospital (Beaulieu and Landry 2010). It also generated substantial clinical productivity gains that could then be refocused on patient care.

This transformation was supported by the implementation of an RFID-enabled two-bin application housed in a high-density storage system, a solution perfectly suited to the challenges at hand. But, in keeping with the above account of the impact of combining resources, behaviors, and a practice, it was also supported by a revamping of the working methods of materials management employees and the training of clinical personnel. In this example, not only was a technology deployed that offered intrinsic advantages, but the hospital implemented it within a perspective of optimizing the entire logistics process in terms of who does what at each step of the process. The hospital also moved away from replenishing nursing units during the busy day shift, when there is a greater likelihood of disrupting clinical flows and when access to elevators is more challenging (Beaulieu and Landry 2010). With respect to putting away supplies, Sacré-Cœur opted to have two designated teams deliver supplies to nursing units and put the supplies away in each bin while performing stock rotation. This further illustrates what we cited about best practices earlier in the section and the fact that better practices become "best" in real-life situations and in a specific context that integrates both hard and soft dimensions.

We can therefore define best practices as a set of organizational characteristics that produce superior performance. A best practice may take the form of a technology, work method, work organization, or a combination of all of these elements (Landry et al. 2000). During its 10-year initiative, Sacré-Cœur has demonstrated the importance of patience, continuous improvement, and innovation while maintaining a clear vision of what it means to have an integrated internal supply chain. Today, the logistics department is considered as playing a strategic role within the hospital

(Amaya et al. 2010). Its involvement goes beyond the simple transferring of supplies in response to the needs of clinical staff; it has become a major stakeholder in developing solutions to the various logistics problems faced by the hospital, for example, patient movements and the positioning of medical equipment. This department has demonstrated its ability to coordinate resources in order to produce new organizational routines. In short, when it comes to best practices, perhaps W. Evert Welch said it best: "There are no bad techniques [. . .] just bad applications" (cited in Plossl 1994, p. 288).

5 Future Research Opportunities

Due to the real-time visibility of inventory status associated with the two-bin replenishment concept, RFID technology and more recently video capture have made it possible to proactively manage supplies by triggering replenishment rounds based on a range of criteria (number of labels on the kanban board, time elapsed since a label has been on the board, stockout situation, etc.) (Landry and Beaulieu 2010). These innovations open the door to a large number of research avenues. For example, when deciding on replenishment triggers, what criteria might help optimize the management of inventory? Also, in terms of transport, this makes possible a field of research on deterministic or stochastic inventory-routing problems in the world of medical supply distribution. Currently, the replenishment of nursing units is for the most part done according to a predetermined schedule that is rarely updated (e.g., a hospital may decide to replenish a nursing unit every day, on Mondays and Thursdays, or once a week). This schedule can remain unchanged over a number of months or even a year and beyond. Increased knowledge of the stock status in the nursing units can enable staff to plan replenishments according to a variable schedule based on one or more criteria, while optimizing the transport route in consideration of the supplies being delivered, the location of the deliveries (nursing units), the hospital configuration (corridors and elevators), and the capacity of the transport cart (capacitated vehicle routing problem).

In addition, when combined with the implementation of a warehouse management system, the RFID-enabled two-bin system offers the possibility of tracing each medical supply lot from the moment it enters the hospital, through the receiving area, until the moment it is used in a nursing unit, by linking each lot to specific storage bins. This opens yet another research avenue. Simulation may constitute a way of approaching these questions and addressing issues that include, for example, whether secondary storage locations in the nursing units should be replenished by clinical staff from primary locations or whether central stores should replenish these directly. In other words, what should the key drivers be in defining a primary vs. secondary storage location? Simulation also offers the possibility of weighing different options during a major renovation project or the construction of new nursing units or even a new hospital.

The emergence of centralized distribution platforms also generates interesting research possibilities. For example, does a better model exist between shared services and third party logistics (3PL) providers, or under what conditions should one or the other organizational mode or governance structure be selected? Does a third option exist? Given the emergence of distribution platforms, which often are region-wide, what impact might these platforms have on upstream partners in the supply chain, primarily GPOs and distributors?

Change management also offers interesting research opportunities, as the implementation of the innovative systems discussed in this chapter (e.g., two-bin system, RFID-enabled two-bin system, or the preparation of case carts using surgeons' preference lists) introduces varying levels of transformation to the organization.

6 Conclusion

We have demonstrated the important role of supply chain management in a hospital setting and the various ways of structuring the associated activities, and we have emphasized the main challenges of distributing medical supplies to nursing units. Operational excellence is thus achieved through the use of "best" inventory management and distribution systems, combined with continuous supply chain process improvements and better integration with the patient care process. With respect to the latter, dramatic clinical advancements have been made in recent years. However, generally speaking, the management processes supporting the delivery of care have not moved at the same pace (Spear 2009). Emerging healthcare supply chain innovations, many of which, such as RFID technology and the lean approach, originated in the industrial sector, offer an opportunity to fill the gap. The implementation of best practices in the distribution of medical supplies to nursing units is a good illustration of how improving the healthcare supply chain releases clinical staff from the frustrations associated with managing inventory at the nursing unit level and provides them with the time to focus on problems that more directly involve them and that they have been trained to resolve.

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