CAN LOCKER BOX LOGISTICS ENABLE MORE HUMAN CENTRIC MEDICAL SUPPLY CHAINS?

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Introduction

There are a range of non-clinical support services within hospitals, such as catering, linen / laundry and supply logistics, which are widely considered to have a significant effect on the delivery and quality of patient care. Supply chain activities are regarded as one of the most important owing to the potentially fatal consequences of 'stock-outs' (Özkil *et al.* 2009; Costantino *et al.* 2010) where key inventory becomes temporarily unavailable. As a result, hospitals typically employ inventory buffers but in spite of such practices, stock-outs still occur due to disparities in inventory requirements between the hospital and suppliers; the presence of unusual demand for specific items (Jarret 2006); and, receipt of goods which are faulty, contaminated or otherwise unfit for purpose. In such events, the supply chain needs to be agile, responding quickly in order to cater for demand. However, due to the structure of the healthcare supply chain which consists of an external chain (delivering goods to the hospital) and internal hospital chain (distributing delivered goods to end users throughout the hospital), the fast flow of goods is often stalled by the interface between the two (Aronsson *et al.* 2011).

This paper critically assesses the current supply chain practices implemented at Great Ormond Street Hospital (GOSH) NHS Trust in London in relation to those that could be utilised, whilst presenting a new concept of supply for key lines and items to the trust using unattended electronic locker boxes to create a more individualistic human-centric service for users, with the overall aim of improving the speed of the distribution of goods both internally (between players once inventory has arrived at the hospital) and externally (for inventory being delivered into the hospital from outside).

Great Ormond Street Hospital

GOSH is a tertiary care NHS Trust for children, with the majority of patient cases being referred to the trust by general practitioners and specialists. The hospital comprises of 29 NHS wards and 8 private healthcare wards which provide more than fifty different clinical specialities, treating more than 192,000 patients per annum.

A recent survey of the goods yard undertaken by the author at GOSH, (November 2011) quantified the delivery and servicing activities during day time hours of operation (07:00 – 17:00). Conducted over a 5-day period, it found that 403 deliveries were made by 223 vehicles, on behalf of over 300 suppliers. Many of these deliveries were received through a single receipts area located within the yard. All goods were sorted into cages for delivery to their respective departments in rounds performed by materials management staff / porters. This delivery structure has been identified as a significant issue in respect of the speedy movement of urgent items for laboratory testing, patient treatment and care.

Hospital Supply Mechanisms

Hospital logistics are typically complex, involving the movement of materials and significant quantities of related data (Rivard-Royer *et al.* 2002) across a fragmented management structure. This typically comprises numerous functional silos representing different medical services and professions, each of which require tailored supply chains to provide for both planned and un-predictable emergency medical care (Aronsson *et al.* 2011). In this sense, the healthcare industry is set apart from other businesses considered able to estimate or predict consumer demand with relative certainty and manage the supply chain accordingly (de Vries *et al.* 1999). Much of the variability experienced in healthcare is attributed to at least three different factors:

1) Clinical variability related to the numerous different ailments, severity levels and responses to treatment;
2) Demand variability due to the unpredictability of patient requirements (i.e. emergency medicine and referred treatment); and,
3) Variation in the approaches to care and levels of care delivered by independent clinicians and care providers (Lega *et al.* 2012).

Given such uncertainties in demand, industrial and manufacturing techniques such as Just-In-Time (JIT) are deemed unsuitable for hospital supply considering the high cost of stock-out situations such as patient illness or death (de Vries and Huijsman 2012; Stanger *et al.* 2012). As a result, healthcare supply chains focus on the provision of inventory buffers to prevent long queues and stock-outs (Stanger *et al.* 2012). These are managed using either an 'Inventory oriented approach', (employed by GOSH and most NHS Trusts, whereby hospitals and medical departments place orders upon meeting pre-established reorder levels (Lapierre and Ruiz 2005)); or, a 'Scheduling oriented approach', (developing accurate schedules to handle purchasing operations, replenishments and supplier deliveries to ensure resource availabilities are respected and stock-outs avoided (Costantino *et al.* 2010)). A study of Singapore hospitals conducted by Pan and Pokharel (2007) found this approach be successfully practiced by small hospitals (100 beds or less) due to their low demand. Of the two methods, inventory approaches typically incur more man power, greater amounts of inventory space and higher operational cost; however, scheduling approaches require regular reviews of stock usage to ensure all schedules are accurate and up-to-date (Pan and Pokharel 2007).

In addition to the physical flow of supplies within hospitals, there are large quantities of time-sensitive data connected to the material services (Singh 2006), much of which are indicators of hospital demand; and, numerous stakeholders such as manufacturers, distributors, GPs, materials management professionals, doctors and other clinicians (McKone-Sweet *et al.* 2005). The large number of stakeholders and vast amounts of data generated by each raises issues regarding the sustainability of the supply chain operation. A common cause of this is misalignment/miscommunication of the required and achievable service levels and performance indicators to the hospital (Costantino *et al.* 2010).

Issues surrounding accurate and comprehensive flows of information internally within the hospital are particularly pertinent within GOSH. Whilst most orders are procured via an electronic ordering system, a lack of visibility of information pertaining to current- / processed- / back- orders has been noted. This can result in situations where consignments which have not been checked-in to the receipts area go un-noticed for some time after their actual delivery. This stalls the supply process and potentially affects the timely delivery of medical treatment and research within the hospital.

In contrast to the issues associated with the nature of supply and the flow of inventory related information, internal factors such as the speed of goods distribution, the transfer of information between wards and the procurement of items are also recognised as having an equal / greater effect on effective hospital supply. Healthcare institutions are not the end-consumer within the chain of supply on account that their role is the delivery of supplies to patient care units (PCUs) and to the users, via their own logistics network (Rivard-Royer *et al.* 2002). This role results in the presence of two chains: one external and the other internal. Disparities between the two chains can create issues which propagate backwards and forwards between and through them, causing delays in the delivery of items to their final destinations within the hospital and the return of items in the opposite direction.

Structure of Hospital Supply

Due to the presence of two supply chains, the management of hospital logistics is more complex, requiring the maintenance of the external supply chain whilst maximising the service levels of the internal chain (Pan and Pokharel 2007). Management of the interface between the external and the internal chains can often present challenges due to inadequate procedures and information systems operating within a fragmented structure leading to increasing costs and inefficiencies (Poulin 2003; Dembiríska-Cyran 2005).

There are three basic models for the distribution of supplies within hospitals:

1) "Conventional Model", delivery to medical departments via a central warehouse (illustrated in Figure 1);
2) Semi-Direct, delivery via each medical departments' warehouse; and,
3) Direct delivery, daily replenishment of small medical departments' storage facilities (Aptel and Pourjalali 2001).

GOSH currently employs a system of direct delivery via weekly replenishment for each medical department or bi-weekly for theatre departments (see Figure 1). All goods are received to the hospital via receipts / materials management who are responsible for taking deliveries of items, sorting and

delivering them to each ward; and, the management of stock levels within each ward store. From this point, goods are sorted and then forwarded to their respective ward / department destination where they are stocked within a dedicated store. Due to the nature of this model and the size of the stores available within each ward / department, no more than two weeks provision for each item is stocked, with the exception of low use, high cost items (e.g. OxyTip sensors, used to monitor blood oxygen saturation levels) which are ordered in bulk to achieve the necessary economies of scale. Such items are stored within a special store within materials management.

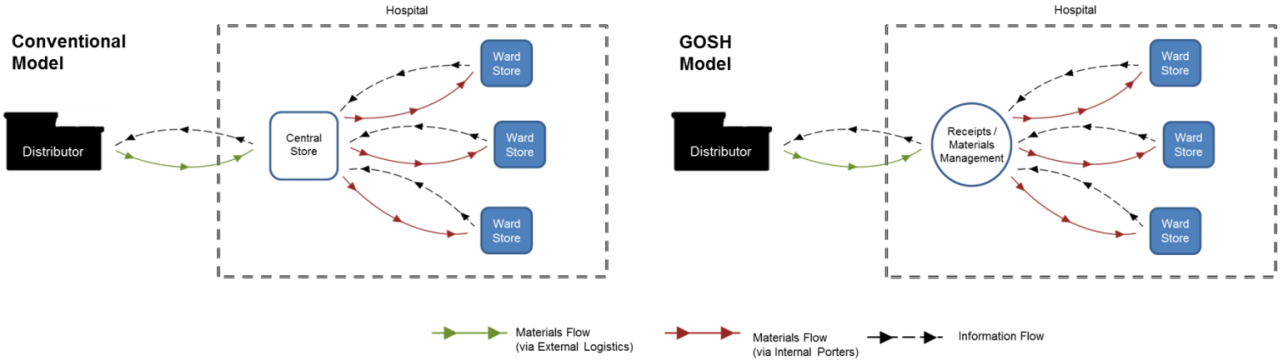

Figure 1 Conventional and GOSH Supply Chain Structures [derived from (Rivard-Royer *et al.* 2002) Figure 2 pp.415]

Attempts to overcome these issues regarding the presence of the external and internal supply chains have been made. A key example of this was the implementation of a stockless inventory approach within the U.S. during the 1970s-1990s, which aimed to eliminate the need for an internal chain. The stockless materials management approach to hospital supply emerged in the 1970s within the U.S. healthcare sector (Kowalski 1991). Its aim was to eliminate the presence of the internal hospital supply chain by outsourcing the management of supplies within hospitals over to the suppliers. This method required consolidation of a hospital's suppliers to one or two, and maintenance of high levels of visibility and transparency of demand / inventory usage between the point of use and the supplier.

The stockless method of supply was found to yield a higher frequency of supplier deliveries, with greater fill rates and a higher turnover of inventory, resulting in fewer materials management staff and fewer clinical staff required to be involved in daily materials management (Nicholson *et al.* 2004). Whilst the stockless method provided many benefits, an imbalance in the benefits gained by the hospital against those gained by the distributors was found to render stockless methods unattractive to suppliers (Rivard-Royer *et al.* 2002). Furthermore, with regards to GOSH, due to the specialist nature of many of the products which are supplied, rationalisation of suppliers becomes impracticable.

More recent studies including those of the stockless materials management approach have demonstrated that supply chains within hospitals operating without intermediate tiers can perform better than those with a multi-tier supply chain (Zhang and Zhang 2007). In consideration of this, an electronic locker box system has been identified as a potentially viable solution to removing a number of agents involved in the delivery of urgent medical items, thereby improving the flow of supply to the end-users.

Locker Box Concept

The locker box concept proposed for GOSH, (illustrated in Figure 2) is designed to provide a direct route from the point of delivery to the point of use. The aim of the unit is to enable a more human-centric supply chain by linking key personnel in hospitals who can act quickly when stock announces its arrival. In its simplest form, items can be delivered via the suppliers' traditional delivery route, with special instructions for the items labelled to be delivered to the locker box unit within the hospital. The driver enters a unique code on the locker box unit for each item, which opens a specific box into which the parcel can be deposited. Once the door is shut, confirmation of the item's delivery is made via a text or email sent using either a hard-wire or wireless (3G) internet connection. More advanced systems are equipped with sensors to detect the parcels presence using RFID. The box then sends a confirmation notice via text and / or email to the recipient informing them that their parcel is ready for collection, providing them with a unique code required to open the box.

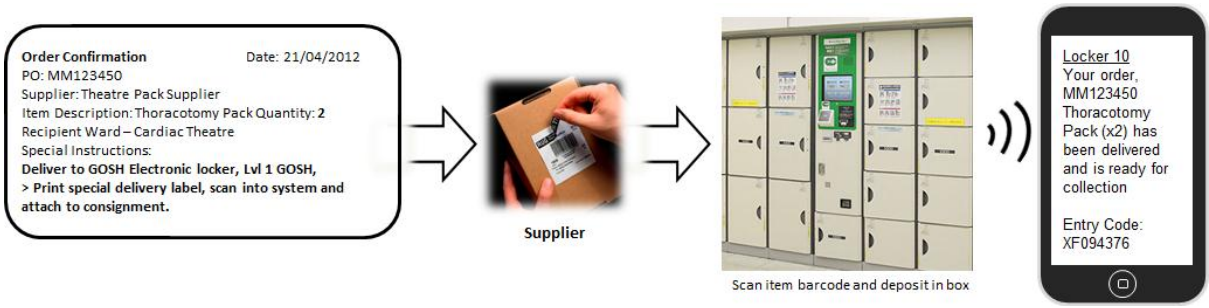

Figure 2 Locker Box Concept and Process of Operation

This system may mitigate against lost / misplaced packages and enable a separate dedicated storage location for urgent consignments, accessible only by the recipient who has received the unique code. It may also provide some benefits in the return of items to suppliers.

The unattended locker box concept differs significantly from intelligent medicine cabinet storage systems. Locker boxes are used only as a means of temporary stock holding (1-day maximum), informing a member of staff that a single specialist order is ready for collection; whereas intelligent medicine cabinets are designed to store and manage inventory stock holding by monitoring the amount of stock within the cabinet, automatically ordering stock to replenish items removed for use.

Methodology

This study is based on both quantitative and qualitative assessments of the feasibility and practicality of the locker box concept within the hospital environment at GOSH. It identifies the departments which indicate the greatest benefits from the use of such a system and examines the potential demand for use of the unit.

The primary sources of data for the quantitative assessments have been derived from: i) 14 wards 'usage statistics reports', and 're-order level reports' for wards where the former are either absent / incomplete; and, ii) the November 2011 deliveries and servicing survey, conducted by the University of Southampton.

The quantitative assessment used information pertaining to supplier / manufacturer, item description and recipient department captured from 18% of the 403 deliveries recorded during the survey. This was used to identify the departments within the hospital which received the highest proportions of day-time deliveries, and the specific items within those which potentially constitute urgent / high priority deliveries. Urgent deliveries were identified as items which are typically ordered for a specific patient or procedure, with a required lead time between 18 and 48 hours.

An additional analysis of the departments identified the monthly average volume of orders for medical consumables (excl. gloves, drapes and gowns) aggregated from the individual monthly averages made for each product line derived from ward usage statistics or re-order level reports. Monthly averages were calculated according to the total quantity of an item supplied to the department over an annualised period, divided by 12.

The quantitative assessment also explored the number of urgent items observed during the survey which are considered suitable for a locker box system according to requirements (i.e. ambient temperature products) and the type and dimensions of the packaging used by suppliers. Box dimensions were obtained from the manufacturers / suppliers of each urgent item, however this information was not obtained for all products due to manufacturer / supplier company policies.

The qualitative assessment comprises results from interviews and discussions with clinical members of staff such as the "Head nurse, clinical equipment, products and practices", members of the supply chain team and corporate facilities. Information gained was used to validate the findings of the quantitative assessment and provide further insight into the potential uses and siting of the locker box within the hospital.

Results

Potential Main Users of the Locker Box

To assess the feasibility of implementing the locker box concept into the hospital, it was necessary to establish the departments likely to be the main users of the unit and by extension, the products. Identification of the main users was established according to the departments which received the highest proportions of deliveries during the survey week. These figures were derived from data captured during the survey week pertaining to individual item descriptions, order quantities, manufacturer / supplier and recipient department.

Department	**Deliveries*** (by volume)
VCB Theatres *(incl. Ear, Nose and Throat surgeries; Anaesthesiology, Orthopaedics, Shared, Ophthalmology and Urology)*	31
Ocean Theatres *(incl. Spinal and Neurology)*	29
XMR *(Interventional Radiology)*	28
Cardiac Theatres	24
Parrot Ward VCB**	18
Total	130
* A delivery denotes an individual product line ** During the study, Parrot Ward VCB operated as a Neuro Surgery recovery ward.	

Table 1 Departments / Ward according to number of deliveries

The Results (Table 1) indicate that VCB Theatres, Ocean Theatres, XMR, Cardiac Theatres and Parrot Ward VCB receive the most deliveries. These results are consistent with qualitative data, which identified all theatre departments as the departments which receive the highest proportion of goods than any other department / ward. Higher proportions of deliveries are typically observed within theatres due to the standard route of supply being used to stock the standard size range of items only. Therefore special orders of items such as guide wires and stents used within XMR interventional radiology are required for unusual cases / demand. In addition to theatres, Pharmacy, Laboratories, Haemodialysis and the Intensive Care wards were perceived to also potentially benefit from the locker box concept.

Potential Frequency of Use for a Locker Box Unit

The list of items delivered to the departments (including: surgical procedure packs, synthetic surgical grafts, tubing for heart and lung bypass operations, surgical catheters and guide wires) were presented to the “head nurse, clinical equipment, products and practices”, who identified the products on the list which are commonly ordered as urgent for specific patients or procedures. Classification of urgent items was made based on their importance / the unique functions which they perform. For example, Perfusionist theatres use cardiopulmonary bypass machines for surgery, therefore stock-outs of items such as tubing packs would prevent bypass operations being performed.

Table 2, indicates that XMR received the most urgent deliveries, followed by Cardiac Theatres, Perfusionist Theatres, Angio Reception and Cochlear Implant. This data indicates that:

- Within Cardiac Theatres, 8 product lines are considered urgent, with 1 item required for 7 of the lines and 2 items for 1 additional line. Each individual item is packaged within a box 320 x 165 x 63 mm. /The average monthly issue indicates that a single item from each line will be issued to Cardiac Theatres 6 times within a single month.

- On this basis, a single item for each of the 14 lines for XMR, and each of the 8 lines for Cardiac may be ordered approximately 8 and 6 times a month, respectively. Therefore, a combined total of 160 separate orders may be made between the two departments. From this it may be inferred a locker box unit would require at least 160 separate boxes to cater for the two departments.

However, such a scenario may be unlikely given that the data in Table 2, suggests that multiple units of each line are often ordered within a single consignment and therefore may be packaged within a single larger locker box inside the unit. Further analysis of the box dimensions presented in Table 2, indicates that the required minimum locker box dimensions, based on the largest single unit, are 380 x 390 x 580 mm.

Department	**Urgent Product Lines** (by volume)	**Quantity Issued per Line***	**Box Dimensions per Line** (mm) [L x W x H]**	**Average Monthly Issue**
XMR Theatres	**14**	**1**	300 x 370 x 170	7.693
Cardiac Theatres	*7*	*1*	320 x 165 x 63	6.132
	1	*2*		
Total	**8**	**3**		
Perfusionist	*4*	*6*	380 x 490 x 580	-
Theatres	*2*	*8*		
Total	**6**	**14**		
Angio Reception	**2**	**160**	Delivered on a pallet	-
Cochlear Implant	**2**	**1**	225 x 152 x 27	-
** All lines excluding a single line delivered to XMR (supplied in a box of 50) are delivered as single units.*				
*** Box dimensions per line represent standardised packaging in which lines are delivered.*				

Table 2 Departments / Wards according to urgent deliveries

Based on a unit with 160 boxes and the minimum locker box dimensions required, an approximate minimum locker unit size of 1,560 x 15,200 x 580 mm (H x L x W), may be inferred. However, assuming a more conservative figure of a separate box for each of the 23 items ordered for XMR and Cardiac during the survey week and the minimum box dimensions, a locker box unit measuring 1,560 x 2,185 x 580 mm (H x L x W) would suffice.

Discussion

The locker box concept has been presented as a method for reducing the number of agents within the medical supply chain for orders of urgent items, which under "normal" operations can become delayed within the receipts area. The key reasons for this have been identified as, urgent items becoming lost / hidden within deliveries of large consignments and / or a disparity in the information provided to the receipts team otherwise instructing the expediting of such items. Interviews with clinical and non-clinical (supply chain / materials management) members of staff provide insight into the contextual and operational uses of a locker box within GOSH. These have yielded a number of scenarios and operational structures in addition to that which has been proposed for urgent items.

Contextual Scenarios:

Faulty / Incomplete Items

On rare occasions the hospital experiences issues with the condition of supplies such as faulty batches. Under these circumstances the hospital materials management staff may be required to contact NHS Trusts within London to source replacement items. These items can be collected by numerous couriers and delivered to the hospital in separate consignments. In such situations the locker box would provide a point of consolidation for all goods which are being sourced, providing a greater level of track and trace for the items within each consignment. This would also avoid such items, which under such circumstances are often required for immediate use, being delayed within the receipts area.

Delivery and Collection of Laboratory Samples

The testing laboratories situated within the hospital often have samples which require sending to specialist facilities for further testing. This often requires the scheduling of a specialised courier to collect the samples from the receipts area. Utilisation of a locker box system for the collection / delivery of samples, whereby the courier is issued with instructions on use of the locker box unit, would make collection and delivery of samples more straight forward and secure.

In addition to this the locker box unit may also be used for the return of incorrect / faulty goods supplied to the hospital.

Inter-departmental Transfers and Personal Deliveries

The concept of using the locker box unit for inter-departmental transfers and delivery of personal staff deliveries received negative responses from interviewees. Although person-to-person inter-departmental transfers, of which there are approximately 60 per week, create difficulties with regards to the management of inventories and individual ward / department budgets, the perceived benefits of improved recording or use and track-and-trace, afforded by the use of a locker box unit for inter-

departmental transfers were outweighed by the speed at which a transfer can be made when conducted person-to-person.

Personal staff deliveries being made to the hospital exacerbates the issues observed within the receipts area given that it artificially increases the through-put of items. The concept of personal deliveries made via the proposed locker box unit was presented as a means to reduce / remove such demand on the receipts area. However, both clinical and non-clinical staff perceived this to have potentially negative effects on the available capacity of the locker box unit and staff habits within the hospital, encouraging larger numbers of personal orders to be made to the hospital.

Operational Use:

Next-Day Delivery

The lead time between ordering and the time of delivery to the hospital is a common issue raised by clinical members of staff, suggesting that could it be reduced it would improve the delivery of treatment to patients. A locker box unit would facilitate this, enabling out-of-hours deliveries to be made over-night providing next-day delivery of vitally urgent items. Non-clinical management and support staff perceived this to be of great use in rare circumstances. However, adoption of faster lead-times for all goods is generally regarded as unattractive on the same basis that JIT inventory management within healthcare is considered unsuitable. Whilst enabling quicker delivery times on goods is largely feasible for many manufacturers, a lead-time of 24-48 hours is agreed with the hospital to encourage staff to order products with a 'safe' buffering period to prevent life-threatening stock-out scenarios.

Delivery Notification and Collection

The current proposal for notification of an items delivery to the recipient comprised the unit sending a personal message to the recipient's mobile phone / email address. However, clinical members of staff within GOSH are issued with hospital bleepers, not mobile phones. Therefore, notification of an items delivery would be sent to a centralised communications location such as the switchboard / help-desk, who may then forward the message and necessary security information onto the intended recipient for collection. However, implementation of smartphone technology with the locker box concept would enable the agile / urgent supply chain to become more human centric, providing greater levels of visibility for urgent items to the ward sister or surgeon. This would allow for collection of items as soon as they are delivered, or whenever they are required, whilst providing visibility of the items exact location.

It is assumed that the collection of an item, given that it is urgent would be performed by any member of staff which is available at the time. If an item is not collected before 08:00 the next day, materials management staff collects the item and deliver it to its final destination. This however presents issues of security and their correct and intended use, given that there is no method of identifying the member of staff collecting the item. Therefore incorporation of an I.D. system onto the locker unit may be beneficial.

Issues

The main issue to consider with regards to implementation of a locker box unit within a hospital environment is the physical location of the system, with regards to security and convenience of delivery and collection. Whilst the electronic locker box units which are currently available are secure, the unit needs to be situated within a secure area to ensure the time during delivery and collection, when the items are most exposed to theft and tampering, are safe. In addition to this the unit needs to be located at a site which does not inhibit the movement of staff and patients / obstruct fire exits, within the hospital easily accessible to couriers, within a public area of the hospital; whilst also being close to the areas of use, within semi-sterile environments so that staff in sterile clothing are not required to change in order to collect the item. Solutions to this problem require significant amounts of planning and coordination between non-clinical and clinical members of staff likely to use the unit; and may also require a re-design of the locker box concepts with dual-entry, so that deposits may be made from one side within a public area, and collections by staff made on the other side within sterile environments.

Conclusion

This paper has assessed the application of electronic locker boxes within hospital environments, designed to overcome the current issues at the interface between the external and internal supply chains. Quantitative assessment of the concept at GOSH, found that theatre departments are likely to

benefit the most from a locker box system for urgent deliveries with an estimated 160 boxes per month diverted through lockers for XMR and Cardiac Theatres. These findings were validated by interviews and discussions with clinical and non-clinical members of staff. Analysis of the volumes and frequencies of urgent deliveries to theatre departments suggests implementation of the concept is feasible.

The concept of the locker box unit for urgent deliveries yielded further positive results in the qualitative assessment, indicating benefits for stock-out scenarios and un-predictable events such as sourcing items from local hospitals in the event of GOSH being provided with faulty or incomplete batches of products and equipment. However, staff perceptions regarding improved lead-times on orders were found to be counter-intuitive to hospital operating procedures. Further issues regarding how a member of staff is notified and appropriate siting of the locker box were also identified owing to operational and practical issues.

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