Product and process variation in the operating theatre: How to innovate supply chain management?

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Abstract

While clinical procedures are becoming more standardized in healthcare, the product variability in the OR still seems high. This study aims to investigate how supply chain strategies should be adopted taking the level of product variability into account. Using a case study design, this study outlines current supply chain processes in a first phase. In a second phase, the level of variability in product consumption is illustrated. Based on the insights of the process description and the level of variability, an innovative solution is described combining the insights of two supply chain strategies.

Keywords: Product variation, supply chain innovation, Operating Theatre

Introduction

In the quest for a high-performing healthcare supply chain in the operating theatre, a major challenge is to manage the variability and even unpredictability in demand and processes (Green, 2004). Operating Room (OR) scheduling (Cardoen et al., 2010) and standardisation (Lega et al., 2013) have been mentioned as important critical success factors. Although a large number of studies have been performed on OR scheduling (Cardoen et al., 2010) the operating room department still faces many ad-hoc changes of the schedule which introduces variation in the demand for products and materials used. The OR planning is partially determined by unpredictable incidents such as emergency operations, incomplete information of preoperative examinations or patient characteristics and complications that lead to a delay. Hence, it is impossible to predict the exact need for products and equipment necessary to perform an operation.

Nonetheless, since the introduction of clinical care pathways, standardisation has been on the agenda of hospital administration. Clinical pathways are integrated management plans that display goals for patients, and provide the sequence and timing of actions necessary to achieve such goals with optimal efficiency (Pearson et al., 1995). Clinical pathways have extensively been used in surgical procedures such as knee and hip replacement (Kim et al., 2003). Notwithstanding the major efforts of hospitals to implement clinical pathways, there is still a considerable variation in the processes and products used during these surgical procedures (Koenig and Bozic, 2015). Healthcare professionals still prefer to select their own way of working and their own selection of products and equipment (Schneller et al., 2006). This leads to a rather low level of standardisation of the processes and products used, resulting in huge challenges to implement well-known materials management systems such as MRP II (material resource planning)(Nguyen et al., 2014).

Hospital managers are looking with bigger interest to materials management techniques such as MRP II to improve healthcare supply chain practices (Hans et al., 2012). The basic idea of MRP II is that the essential quantities of goods required by the hospital can be calculated considering the existing stock, the demand forecast, and the materials reservation stock. The MRP II system is used to estimate the required quantities of medicines and materials that will be ordered to vendors. Hence, the orders of clinics and departments influence dynamically the MRP II system and a certain level of standardisation should be available in order to install MRP II practices (Stefanou and Revanoglou, 2006).

Since product use in healthcare is highly variable but at the same time clinical procedures are becoming more standardized, we want to investigate how supply chain strategies should be adopted taking the level of product variability into account. This paper first decribes two different supply chain strategies. Second, current supply chain processes are mapped in order the identify problems in the current supply chain practice in hospitals. Third, we aim to investigate the variability in products and materials used in the procedure of total hip replacement (THP). Since THP is known as a more standard procedure in which clinical pathways and Evidence Based Medicine have commonly been used, one could expect that variability will be limited in this process. Fourth, we want to indicate new opportunities for supple chain innovation practices taking the results of the variability in material use into account. Based on the insights of the process description and the level of variability, an innovative solution is described combining insight of two supply chain strategies.

Theoretical framework

An increasing interest has been devoting to Lean Management (LM) in academic and managerial literature to improve supply chain practices in healthcare. Lean is often used in supply chain management (Melton, 2005) as a method to reduce variability, increase the standardisation of processes and improve productivity and quality. Following the lean thinking, standardisation of processes is vital so that operational problems can be corrected based on evidence. However, a middle ground must be reached as too much standardisation will limit patient focus (Boyer and Pronovost, 2010). The key challenge is to design and manage systems with appropriate levels of flexibility to cope with the natural and unanticipated variability in complex systems such as healthcare (Frei, 2006).

The requirement for organizations to become more responsive to the different and variable needs of patients can be explained by the concept of “agility”. Christopher (2000) makes a clear distinction between leanness (doing more with less) and agility (responding quickly to changes in demand in terms of both volume and variety). The notion of agility is therefore recognized to be holistic rather than functional, and of strategic rather than tactical importance. 'Agility' is a concept that needs to be extended beyond the traditional boundaries of the individual organization to encompass the operations of the supply chain within which the organization works. The effectiveness of an organization to provide a flexible response to variable demands is principally determined by the capabilities of trading partners and suppliers. In this context reliability of supply becomes a critical issue that can best be facilitated by the sharing of accurate, timely information with suppliers. The availability of materials is crucial in a hospital setting, since a patient's life can depend on it. At the downstream end of the supply chain, suppliers find it hard to operate in this highly variable environment of demand since distribution channels are unable to respond due to physical or information flow related issues. Towill (1997) expresses this in terms of creating a ``seamless supply chain" where territorial boundaries between trading partners are eliminated and they effectively operate as if part of one organization.

In this study we aim to investigate whether supply chain management practices in healthcare should be managed using a lean or an agile approach. Following the trend of clinical pathways and standardisation, a lean approach might be suitable when the variation of demand can be decreased. However, building further on the fact that patients and surgeons increase the level of variability, we hypothese that an agile approach is more applicable since this method enables responding quickly to the variability in demand.

Design/methodology/approach

A case study research design was used to study the product and process variability in a standardized healthcare process, i.e. the procedure of total hip replacement. First, we identified the different supply chain processes used in the hospital to replenish the stock in the OR. Five group interviews with head nurses, nurses, logistics personnel and external logistics service deliverers were performed identifying different processes in one hospital. We did a walk through and performed observations of each process flow.

In order to get a better understanding of the product variance, in a first phase several observations at the hospital were carried out (four surgeries). Thereafter, in a second phase, empty packages were gathered of the products consumed in 50 surgeries for total hip replacement (THP). Surgeries were performed by 3 different surgeons. Empty packages were collected by two nurses. The number of products was listed for each surgery, per physician and per material process type. Next, we classified products using the classification of the different supply chain processes. The results of the data collection were reviewed by the OR manager, logistics manager and a head nurse. Possible causes for variation were discussed and identified. We only outline the processes for non-reusable products, equipment and skills were out of scope.

Findings

<u>Process type identification</u>

Thirteen different material flows for the delivery from supplier to the OR room were identified in one hospital (see table 1).

Table 1 – Number of different material supply chain processes

1	Medication infusion therapy
2	Medication (general)

3	Medication opiates
4	**Prosthesis components (consignation)**
5	Prosthesis components (borrowed from supplier)
6	**Sterile products (registered)**
7	**Sterile products (non-registered)**
8	**Sterile products (custom packs)**
9	**Stitching material**
10	**Consumables not-registered**
11	Disinfectant products
12	Non storage materials
13	**Biopsy material**

The process of non-registered sterile materials is discussed as an example (fig. 1). The supplier delivers materials to a central distribution point of an external company. A min/max SAP warehousing management system is used to supply the platform. From the platform, non-registered sterile materials are delivered to the OR. Replenishment is based on a Kanban system. The replenishment of the OR-rooms is ordered by filling in hand written order lists. These process characteristics indicate the complexity of the process.

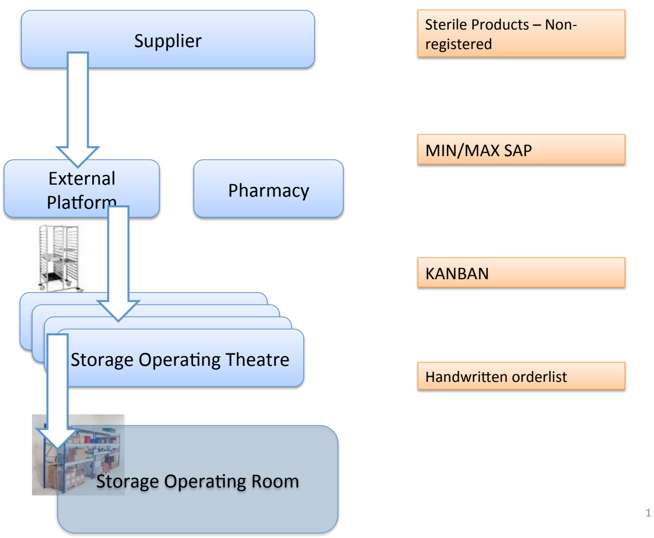

Figure 1 – Supply chain process of the sterile products

This is not only the case in this process but also in the other thirteen material processes. A different number of intermediate storage locations and processes to supply the several storages in the process exist. For example, sometimes the supplier delivers directly to the OR, this is the case for the infusion therapy, prosthesis in consignation and borrowed prosthesis, stitching materials, non storage materials and sterile products (custom packs). Processes of general medication, opiates, and registered sterile products go through the pharmacy and the external platform is used as an intermediate storage for sterile non-registered materials and disposables. Automated data collection of supplies, consumption and storages are limited to two programs in the hospital, infohos and SAP. SAP is used for the processes that pass the external platform and for the processes of stitching material and sterile products (custom packs). Infohos is used when the intermediate storage is performed by the pharmacy. Replenishment of the pharmacy and the external platform can be managed using the data of consumed materials of the stock levels. However, SAP can only register processes and costs until products leave the intermediate storage place. The replenishment of medication is based on the number of registered consumed products through infohos. Consumed medication is registered by hand in infohos directly or on a paper file. The traceability in these processes is very low.

These examples illustrate that the supply chain of the OR is a very complex and costly operation that includes different and intermediate suppliers. We examined these material processes for traceability, obsolescence, availability, patient safety and supply chain cost following the GS1 standards (Process, 2010). We used a 5-point Likert scale to identify whether statements involving these criteria were true (5) or false (1). The higher the number in the table, the better the product scores on one of the criteria. The table indicates the complexity and the high supply chain cost for the processes. The variability in processes and low performance scores indicate that there is need for health care supply chain innovation practices.

Table 2 – Performance of material processes

5=good	Traceability Patient	Obsolescence	Availability	Patient Safety	SupplyChainCost
	Which Product/Lot/SN has be used at a specific surgery?	How many inventories has not been used during their lifetime?	How many shortages have occured in the OR room?	How many incidents, threathening the patient safety have occured?	How much is the supply chain cost to ensure availability in the OR room?
Drugs	1	1	4	3	3
Medication Drips	1	3	4	3	2
Medication Stitching Materials	1	5	4	4	1
Medication Opiats	1	3	4	4	1
Prothese Components - Consignation	5	5	4	5	2
Prothese Components - "On Loan"	5	4	4	4	1
Sterile Products - Registered	5	4	4	4	1
Sterile Products - Custom Pack	1	4	4	5	1
Sterile Products - Non-registered	1	1	3	4	3
Consumables - Non-registered		2	3	4	3

Empty packages could only be gathered for seven of the thirteen process types (see bold items in table 1). In total 255 different stock keeping units (SKUs) in seven materials process types were identified. The SKUs have been used during one or more of the 50 surgeries. The biggest material process type group are the non-registered sterile materials for which 106 SKUs were identified. The 106 SKU's of non-registered sterile materials are supplied by 30 different suppliers. All of the 106 SKU's have an individual packaging with a readable Product Identification Code. Only 59% have a barcoded identification code on the individual packaging, which makes the treacability of these type of products difficult.

Variation in products consumed

Product variance between surgeons

First we aim to identify whether there is a difference between surgeons. In the following graphs, the usage of products per surgery and material process type has been represented in a graphical manner for each surgeon. The variance in the consumption of the number products used per individual surgery for each surgeon is not that large. The mean number of products used per surgeon ranged from 23 to 28. The number of SKUs ranged from 18.5 to 19.4.

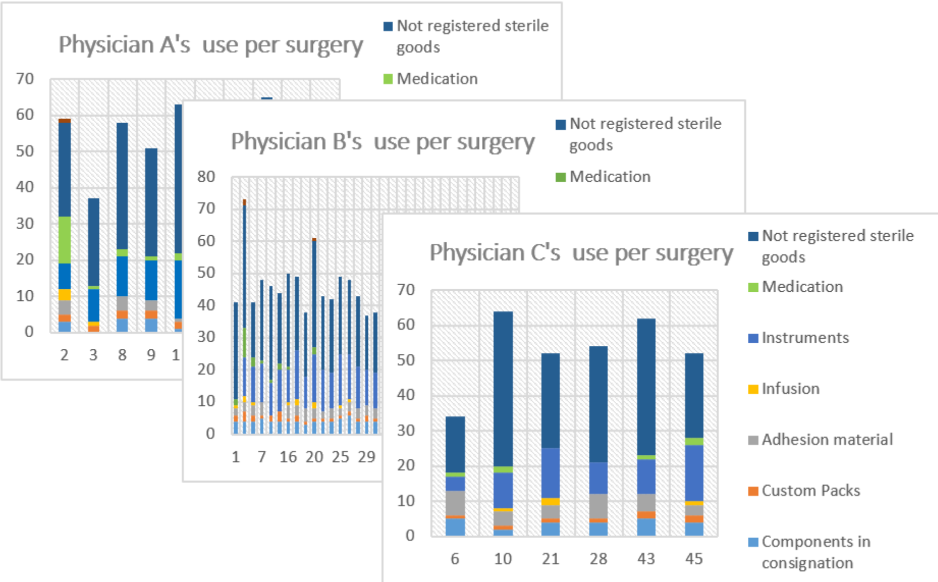

Figure 2 – Use per physician/surgery

Table 3 – Variance between physicians for number of products used

Physician	Number of surgeries	Mean number of products used per surgery	Std. Dev of products used per surgery	SKUs/ surgery	Std. Dev of SKUs per surgery
Physician A	10	27,8	8,4	19,2	5,1
Physician B	33	22,5	6,2	19,4	9,3
Physician C	6	28,2	11,3	18,5	6,0

There is not a lot of variance for the number products used. However, there is a lot of variation in the type of products used. In table 4 the average consumption of sterile products has been listed per individual surgeon, ranked from high to low for surgeon A. As the data sheet indicates, some products with high consumption of surgeon A are not or less used by other surgeons and vice versa. These graphs and data indicate that, with exception of a limited number of sterile products, the consumption per individual surgery varies importantly. This is partially due to the individual preferences of surgeons and the way they proceed and learned how to perform a surgery. All surgeons use different techniques and use different companies for their equipment, although they are working the same department of 1 hospital. This has an impact on the type of products used.

Table 4 – Variance between physicians for type of products used

Gemiddeld aantal stuks p	Dr A	Dr B	Dr C
Protexis Latex Micro handsch	3,20	2,42	1,33
Steri-Drape - Afdeklaken - 20	2,20	0,88	0,50
Flyte Hood	2,10	1,64	0,00
Desinfectiedepper foam	1,60	0,70	1,00
Steri-Drape - Zelfklevend lak	1,50	0,06	0,33
Protexis Latex Micro handsch	1,10	0,82	0,33
Sterile Disposable Electrical	1,00	1,06	0,33
IOBAN 2 Anti-microbiële inci	1,00	0,91	0,17
Steri-Drape - Schouderdrape	1,00	0,00	0,00
Surgical Gloves with Aloë Ve	1,00	0,00	0,00
Bair Hugger - Temperature M	0,80	0,70	0,33
Sagittal Blade	0,70	0,91	0,67
Protexis Latex Micro handsch	0,60	2,15	0,17
BD Plastipak Spuit 20ml	0,60	0,27	0,17
BD Whitacre Needle 27GA 3.	0,60	0,24	0,17
BD Emerald Spuit 10ml	0,60	0,21	0,33
Adult Nasal Cannula	0,60	0,09	0,00
Fluoroscope Drape 91*76cm	0,60	0,00	0,00
BD Microlance 3 1,1*40mm	0,50	0,18	1,00
Steri-Drape - Afdeklaken - 20	0,50	0,15	0,00
Protexis Latex Micro handsch	0,40	0,85	4,33
Surgical Blade Carbon Steel 2	0,40	0,73	0,00
Protexis Latex Micro handsch	0,40	0,24	1,83
IVD MEDICAL DIAGNOSTIC IN	0,40	0,24	0,17
Operatiejas voor eenmalig g	0,40	0,21	1,33
5 Telasorb 45cm*45cm - Tela	0,40	0,09	1,00
Leukoclip FD	0,30	0,30	0,33
BD Emerald Spuit 3ml	0,30	0,12	0,17
Schaar scherp/stomp 14cm	0,30	0,03	0,00
Protexis Latex Micro handsch	0,20	1,39	1,83
Suction Bag 2000 ml + Suction	0,20	0,30	0,00
Stella Crepe S	0,20	0,12	0,83
Stella Crepe S 10cm*4m	0,20	0,06	0,17
Disposable Scalpel	0,20	0,00	0,00
Mepilex Border Post-Up 6*8c	0,20	0,00	0,00
Disposable Skin Stapler with	0,10	0,64	0,50
Mepilex Border Post-Up 10*2	0,10	0,58	0,33
Klassieke electrochirurgische	0,10	0,18	0,33
Sterile Transport Swab	0,10	0,18	0,17
Mepilex Border Post-Up 10*3	0,10	0,09	0,00
BD Emerald Spuit 5ml	0,10	0,06	0,00
Infusiesysteem 175cm	0,10	0,06	0,00
Suction Bag 2000 ml + tube 1,	0,10	0,06	0,00
Infusiesysteem	0,10	0,03	0,00
Surgical Blade Carbon Steel 2	0,10	0,00	0,83
Blade Electrode 6,5"	0,10	0,00	0,00
Dual Cut Sagittal Blade	0,10	0,00	0,00
Sagittal Blade 25*90mm	0,10	0,00	0,00
Surgical Gloves with Aloë Ve	0,10	0,00	0,00
Tegaderm Transparante folie	0,10	0,00	0,00
Iso-Betadine Uniwash 7,5% 1	0,00	0,30	0,00
Protexis Latex Micro handsch	0,00	0,30	0,00
Operatiejas voor eenmalig g	0,00	0,24	0,17
Steri-Drape - Kleefstrip - 55*	0,00	0,21	0,00
Medipore + Pad Steriel Wind	0,00	0,09	0,17
Steri-Drape - Zelfklevend lak	0,00	0,09	0,17
Large Adult Face Mask	0,00	0,09	0,00
Telacomp 10STUKS 10*20cm	0,00	0,06	0,67
Kocher 14cm	0,00	0,06	0,17
Portex Tracheal Tube 7.5mm	0,00	0,06	0,17
BD Insyte-W	*0,00*	*0,06*	*0,00*
BD Whitacre Needle 25GA 3.5	*0,00*	*0,06*	*0,00*
Instruo Protector Small	*0,00*	*0,06*	*0,00*
Medium Adult Face Mask	*0,00*	*0,06*	*0,00*
Steri-Drape - Zelfklevend lake	*0,00*	*0,06*	*0,00*
Tegaderm Transparante folie	*0,00*	*0,06*	*0,00*
Versterkte operatiejas voor e	*0,00*	*0,06*	*0,00*
IOBAN 2 Anti-microbiële inci	0,00	0,03	0,50
Mepilex Border Post-Up 10*2	0,00	0,03	0,50
Mayotafelsloop 80*142cm	0,00	0,03	0,33
Gaaskompres 10*10cm 12LAC	0,00	0,03	0,17
ARGYLE	*0,00*	*0,03*	*0,00*
*BD Microlance 3 0,7*30mm*	*0,00*	*0,03*	*0,00*
FH+Freeze Flex with elbow m	*0,00*	*0,03*	*0,00*
Flexibele Yankauer	*0,00*	*0,03*	*0,00*
IOBAN 2 Anti-microbiële incis	*0,00*	*0,03*	*0,00*
Mallinckrodt Adult Oxygen M	*0,00*	*0,03*	*0,00*
Portex Tracheal Tube 8mm	*0,00*	*0,03*	*0,00*
*Steri-Drape - 60cm*85cm*	*0,00*	*0,03*	*0,00*
Sterile Polyisoprene PowderF	*0,00*	*0,03*	*0,00*
*SteriSets - Bulkgaas 45*45cm*	*0,00*	*0,03*	*0,00*
Suction Bag	*0,00*	*0,03*	*0,00*
Surgical Blade Carbon Steel 1	*0,00*	*0,03*	*0,00*
Surgical Skin Marker Standar	*0,00*	*0,03*	*0,00*
Tegaderm Transparante folie	*0,00*	*0,03*	*0,00*
BD Plastipak Catheder Tip sp	0,00	0,00	0,83
Steri-Drape Ioban 2 Patiënt I	0,00	0,00	0,67
Steri-Drape Overzettafelsloc	0,00	0,00	0,67
Surgisite Reinigingssponsje v	0,00	0,00	0,33
Absorbent Wound Dressing	0,00	0,00	0,17
BD Q-Syte Verlengset 15cm	0,00	0,00	0,17
Cohesieve fixatiezwachtel	0,00	0,00	0,17
Connect-A-set3	0,00	0,00	0,17
Hospi-Flow B Debietregelaar	0,00	0,00	0,17
Main Pump Tubing	0,00	0,00	0,17
Steri-Drape Isolatielaken me	0,00	0,00	0,17
Stockinette 121*30cm	0,00	0,00	0,17
Surgical Blade Carbon Steel 1	0,00	0,00	0,17
Tensoplast 2,5cm*4,5m	0,00	0,00	0,17

Product variance between surgeries per surgeon

We describe products consumed by surgeon B as an example to identify the product variance between surgeries for one surgeon. Table 5 represents the number and type of materials used for all surgeries. Some products consumed are repetitive per individual surgery, for example the flyte hood. Other products are only a few times used i.e. the tracheal tube. The repetitive materials are part of the bill of material which is a list of products per surgeon that should be available and prepared before the surgery starts. These products are highlighted in table 5. The non-repetitive materials, which is the largest part of the materials collected, are mostly stored in the OR-room. A lot of the product variation within the operations performed by one physician can be explained by the differences in patient characteristics and unpredictable events that occur during the surgery. It was found that these variations where caused by many different and unpredictable reasons. The variations can be caused by patient specific conditions (hardness of bones, comfort of the patient, reaction of patient on specific treatments), by specific circumstances during the surgery (the largeness of the incision, the amount of bleeding during incision,…) or by the availability of alternative products. This shows that the consumption of products does not only vary from one surgery to another, the consumption also largely depends on patient characteristics.

Table 5 - the number and type of materials used for all surgeries for one surgeon

ProductName	1	4	5	7	14	15	16	18	19	20	22	23	25	26	27	29	30	31	32	33	35	36	39	38	40	41	42	44	46	47	48	49	50
Flyte Hood	1	2	2	1	1	1	2	1	1	1	1	2	2	2	1	1	2	2	2	2	1	2	2	2		2	2	1	3	3	3	2	1
Iso-Betadine Uniwash 7,5% 10r	1											1	1	1			1	1	1	1	1	1											
Portex Tracheal Tube 7.5mm				1						1																							
Portex Tracheal Tube 8mm							1																										
Mallinckrodt Adult Oxygen Mask - Medium Concentration		1																															
Adult Nasal Cannula	1				1	1																											
Tegaderm Transparante folie 7*8,5cm		1		1																													
Protexis Latex Micro handschoenen 6					3				2	3	4		3	3	3						3	1				1				1			
Protexis Latex Micro handschoenen 6 1/2		4	3				4												3	2		3	2	3	4	1	1	2	2	4	2	3	3
Protexis Latex Micro handschoenen 7											2						4	2															
Protexis Latex Micro handschoenen 7 1/2	3	3	3	3	3	1			2							4		1					2			1						2	
Protexis Latex Micro handschoenen 8	3	2		3	4	1	2	5	3	3	4	2	3	3	3	4	3	3	2	2	3	2	3	2	2	1	1		3		3	2	3
Protexis Latex Micro handschoenen 8 1/2	2	2	1	2			4	2	2	1	1	2	1	1	1	1	2	1	2	2	2	3	4	4	3	3	1	4	4	4	3	3	3
Protexis Latex Micro handschoenen 9																							1		1	1	1			1	2	1	2
Sterile Polyisoprene PowderFree Surgical Glove 8																			1														
BD Plastipak Spuit 20ml	3	1			2		1			2																							
BD Microlance 3 0,7*30mm										1																							
Sterile Transport Swab	1															1			1		1				1					1			
BD Microlance 3 1,1*40mm	3	2								1																							
BD Emerald Spuit 3ml					3		1																										
BD Emerald Spuit 5ml							1			1																							
BD Emerald Spuit 10ml	2	1			2	1	1																										
Medipore + Pad Steriel Windverband						1		1																			1						
Tegaderm+Pad 5*7cm																											1						
BD Insyte-W	1	1																															
Instruo Protector Small													1		1																		
BD Whitacre Needle 27GA 3.50IN C		1			1	1		1													1			1			1			1			
BD Whitacre Needle 25GA 3.50IN		2																															
Infusiesysteem 175cm							1																						1				
Infusiesysteem		1																															
Telacomp 10STUKS 10*20cm																													2				
5 Telasorb 45cm*45cm - Telatrast Modul System										2																							
5 Telasorb 45cm*45cm - Telatrast Modul System						1																											
Mepilex Border Post-Up 10*20cm																																	1
Mepilex Border Post-Up 10*25cm						1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1		1						1		1	
Mepilex Border Post-Up 10*30cm	1			1																							1						
Bair Hugger - Temperature Management Blanket		1	1	1	1	1	1	1		1	1	1		1	1				1	1	1	1	1	1			1	1	1	1		1	
Disposable Skin Stapler with 35 Wide Staples												1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2		1	1		1	1
Kocher 14cm										1																		1					
Schaar scherp/stomp 14cm	1																																
SteriSets - Bulkgaas 45*45cm	1																																
Desinfectiedepper foam		3	1	1	2	2	2	2	2	2					1			2						1		1	1						
Sagittal Blade	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1	1	1	1	1	1		1	1	1	1	1
Leukoclip FD	1	1	1	1	1		1	1	1	1	1																						
IOBAN 2 Anti-microbiële incisiefolie 35*35cm																													1				
IOBAN 2 Anti-microbiële incisiefolie 60*60cm																											1						
IOBAN 2 Anti-microbiële incisiefolie	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1	1	1	1
Gaaskompres 10*10cm 12LAGEN 10STUKS						1																											
Operatiejas voor eenmalig gebruik							1				1							1						2		1					1		
Operatiejas voor eenmalig gebruik XXL																							1		1			1	1	1	1	1	1
Versterkte operatiejas voor eenmalig gebruik - XL																														2			
Mayotafelsloop 80*142cm																											1						
Flexibele Yankauer																		1															
Steri-Drape - Afdeklaken - 200*150cm	2	1	1			1	2				2	1	1	1	1	1		1			1		1	2		2	1	3	1	1	1		1
Steri-Drape - Afdeklaken - 200*228cm					1	1								1									1				1						
Steri-Drape - Zelfklevend laken - 183*183cmm																											1				1		
Steri-Drape - Zelfklevend laken - 250*152cmm										2																							
Steri-Drape - Zelfklevend laken - 300*228cmm						1				1																						1	
Steri-Drape - Kleefstrip - 55*10cm											1												1	1		1	2		1				
Sterile Disposable Electrical Irrigation Unit	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1
IVD MEDICAL DIAGNOSTIC IN VITR(		1	1			1				1			1		1																1		1
Surgical Blade Carbon Steel 11										1																							
Surgical Blade Carbon Steel 20		3		1		1				1		3	1						3			3						1		4	2	1	
ARGYLE																		1															
	30	38	17	19	28	20	29	18	17	31	21	17	19	18	18	17	17	20	20	15	19	21	23	24	16	18	23	16	24	30	23	22	20

Relevance/contribution
Supply chain management in hospitals is a very complex and costly issue. In this case study we found thirteen different processes to supply the OR with materials needed to perform a THP. The variability and the complexity of the processes indicate a high cost for the supply chain management. Following the lean thinking, a higher level of standardisation of processes is vital so that operational problems can be corrected based on evidence. Hence we suggest that the variability in processes can be reduced using a lean strategy. Hospitals should try to minimize the number of different processes to supply the OR and other departments.

However, not all variation can be eliminated in this OR context. Even though clinical pathways and standardisation in healthcare are cornerstones of evidence-based practice, the product variation of procedures is still large. Physicians tend to use different products to perform a THP. Moreover, there is not only variation between physicians but also within the procedures performed by one physician. This indicates that it is hard to minimize the variation in consumables used because of the variability in patients' needs. Since product demand is highly variable, even for one surgeon who works each time with the same methods, the demand cannot be completely anticipated or predicted. Saurin et al. (2013) recognize that Lean Management is not designed to deal with unanticipated variability and unexpected events and that theories and practices should be developed to make the workforce more resilient, i.e. to respond quickly to unanticipated changes in demand in terms of both volume and variety. This indicates the necessity for a more agile strategy to develop new supply chain practices. Replenishment should be carried out based on real product consumption since this is hard to predict beforehand.

Our supply chain innovation is built on both lean and agile practices. Following the results of the process description, a lean strategy to minimize to variability in processes is appropriate. This is in line with Håkan et al. (2011), who state in their conceptual paper that a combination of lean and agile sub-processes should be applied in supply chain management. We aim at minimizing the number of supply chain processes for products to one supply chain process only. However, since the variability in product use cannot be predicted, we are unable to use MRP II planning tools to optimize supply chain strategies in healthcare. The findings of this case study presume that a methodology to replenish stock should be based on the real consumption of materials. To respond to the fluctuating demand both in volume and variety, agile strategies should be applied. A TO BE solution should be based on the replenishment by collecting data evaluating the real consumption of materials. This method was tested in this research since we were able to gather data by registering the empty packages. However, this worked for only 7 of 13 material processes. How to handle and count dangerous empty packages such as glass should be further investigated in the future. Moreover, data was collected by registering product' packages by hand, which was time consuming. Registration of products consumed should be handled in a more automated way. RFID registration or visualizing scans can be used to register the products used. Crucial products such as prosthesis components should be tagged using RFID, in order to immediately start replenishment after consumption. Other products, such as stitches can be scanned within 24 hours after an operation is preceded.

Agile strategies indicate the necessity to collaborate and communicate with external service deliverers and suppliers. A more agile strategy to deal with the complexity of supply chain in hospitals could be described as follows: after products are registered, an automatic signal can be sent to the supplier or internal deliverer that the stock has to be replenished. This means that an integrating IT-platform should be implemented since suppliers, hospitals and logistics service providers do not use the same technologies and systems. An IT-integrator should be able to provide an integrated platform. In sum, the suggested supply chain management innovation entails detecting and capturing the types of variability, reduces it were possible and copes with the remaining (unpredictable) variability using both lean and agile approaches in a healthcare environment.

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