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Application of a hybrid selective inventory control technique in a hospital: a precursor for inventory reduction through lean thinking

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Abstract

Purpose – The cost of providing healthcare is spiralling up in recent times. On the one hand, patients expect the highest quality of service, while on the other hand, the managers of the healthcare services want to minimise the total operating expenses. Hence, healthcare organisations implement lean thinking (LT) to achieve these twin objectives. LT reduces the eight wastes that are prevalent in the healthcare processes and functions. In particular, if the wasteful inventories related to expensive medical supplies are reduced, the resulting cost savings can help in providing affordable and accessible healthcare.

Design/methodology/approach – Hence, in this paper, a case study of a hospital is presented where LT is implemented. One of the projects was related to inventory reduction in the store of the catheterisation laboratory (cath lab). A hybrid methodology called multi-unit selective inventory control (MUSIC) that combined these three dimensions (3D), namely, consumption value, criticality and lead time or ease of availability was used to classify the medical supplies into different categories.

Findings – Based on the results obtained, various inventory systems and the associated tools and techniques of LT were proposed. For example, a deep dive into the A-class items revealed that some of the medical supplies fell under both vital and scarce categories. Hence, it was recommended that the case hospital should follow the economic order quantity (EOQ) with safety stock approach as these items were to be shipped from other states in India. Subsequently, the focus should be on developing a local supplier and attempts should be made to establish a *kanban* system with adequate information sharing.

Practical implications – This study demonstrates the step-by-step methodology of MUSIC-3D which would guide the procurement managers to apply the same in their organisation. It also helps them in identifying appropriate elements of LT for inventory reduction before the actual deployment.

Originality/value – None of the papers has utilised the MUSIC-3D methodology as a precursor for inventory reduction, specifically within the domain of LT. Similarly, identifying and proposing different type of inventory systems and various LT practices based on this unique method is a novel attempt.

Keywords Lean thinking, Selective inventory control, MUSIC-3D, Cath lab, Multi-speciality hospital, Case study, India

Paper type Research paper

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1. Introduction

Gebicki *et al.* (2014) noted that the average annual drug expenditure per hospital in the United States of America (USA) was about $4.8m and the average value of medications stored at any given time in 5795 US hospitals would be $2.9bn. In the case of the hospitals in Myanmar, Than *et al.* (2017) estimated that the cost for the medicines and medical suppliers represented one of the most significant cost components (about 28.78% and 26.60%, respectively) at Magway Teaching Hospital (MTH) and Pyinmanar General Hospital (PMNGH). They also mentioned that the studies from Pakistan and Vietnam also reported similar results. Jacobs *et al.* (2019) too highlighted that salaries and wages made up the most significant proportion of costs (44–50%), followed by medicine and materials (37–44%) in Cambodia. A similar situation was seen in India too. The recent report by the Association of Healthcare Providers of India (AHPI) showed the following distribution of operations costs: doctors' salary: 18–22%; wages for allied healthcare workers including nursing staff: 23–30%; drugs and medical consumables: 28–32%; administrative cost: 18–20%; cost of marketing and advertisement: 5–7%; power and utilities: 4–5%; repair and maintenance: 2–3%; quality and regulatory compliances accounting for about 2–3% [1]. A cursory analysis indicated that the expenses related to drugs and consumables and the administrative costs alone constituted to about 40% of the total cost of hospital operations. These pieces of evidence reinforce that problems due to inventory are perennial in the hospitals irrespective of the countries. Hence, if the procurement managers in a hospital can focus on these heads by implementing lean thinking (LT), it can lead to significant cost reduction, which in turn helps in offering accessible and affordable healthcare.

LT has been frequently implemented in healthcare to address various problems. For example, Barnabè and Giorgino (2017) discussed a case study in a healthcare setting about how the lean strategy (Hoshin Kanri) can be operationalised using the *X*-matrix reporting tool and simulation techniques involving role play. Baldassarre *et al.* (2018) presented a case study of reducing the bottleneck and waiting through process improvements in the surgery department of an Italian hospital. Gijo and Antony (2014) too addressed the issue of longer patient waiting time in the outpatient department (OPD) of a super-speciality hospital in India using the Lean Six Sigma (LSS) methodology. Most of these studies also described how the seven wastes identified by Ohno (1988) were eliminated through various tools of LT. Amongst these wastes, inventory is considered the "mother of all wastes" as it hides all other problems in the organisation. Besides, inventory tends to lock in the most valuable "working capital" for an organisation. Hence, reducing inventory levels is one of the significant objectives for the hospitals that are implementing LT. However, Nicholson *et al.* (2004) commented that inventory and supply chain management systems had not received as much attention from management in healthcare organisations. The reason being that one of the most common wastes in the hospital is the "waste due to waiting or delay", which affects patients' satisfaction directly. Also, the issues of inventory problems are internal to the hospital, and the patients may not be bothered as it may not affect them directly. Hence, in this paper, the multi-unit selective inventory control (MUSIC) methodology incorporating the three dimensions (3D) of dollar volume/consumption value, criticality and lead time or ease of availability is used as a precursor for reducing the inventory waste within the domain of LT in healthcare.

Generally, inventory in hospitals can be of three types: perishable (such as blood, plasma and medicines), non-disposable (such as equipment, instruments, etc.) and disposable items (such as gloves, masks, cotton bandages, to name a few) (Bijvank and Vis, 2012). The stock of these disposable and non-disposable items is held in multiple places of the hospitals such as the centralised stores or warehouse, OPD store, OP pharmacy, inpatient stores, inpatient pharmacy, etc. Landry and Beaulieu (2013) called this as an internal supply chain of the hospital. Machada Guimarã *et al.* (2013) commented that it was common to find high levels of safety stocks in such internal supply chains due to poorly implemented inventory management practices. Second, hospitals have a large number of stock keeping units (SKUs) as they procure similar products from multiple companies to comply with the requirements of the consultants and surgeons. Venkateswaran *et al.* (2013) observed that Ochsner Health System had three different central warehouses and each of them stored over 1,100 types of medical supplies to supply various departments and other clinics. Khorajia *et al.* (2009) mentioned that a hospital in Texas, the USA, held more than 5,000 different items (SKUs) in the sterile supply room alone. Naturally, it becomes cumbersome for the hospital administrators to monitor and ensure the availability of right items in the right quantity at the right place at the right time. If there is a deviation in these objectives, then it makes the difference between life and death of a patient. Hence, front-line employees tend to ensure adequate stock of medical supplies in their work areas. So, it may not be a surprise to find a "hidden treasure of stocks" that can last for months in areas such as nursing stations and inpatient care. However, this practice increases the cost of hospital operations.

To reduce the same, most of the hospitals tend to follow various inventory systems such as fixed order quantity (*Q*) models, fixed time period models (*P*), par systems, etc. They also use multiple inventory reduction practices such as two-bin and kanban systems, visual control mechanisms, etc. that are part of LT. Landry and Beaulieu (2013) noted that these different inventory distribution mechanisms have evolved over the years in hospitals. But the problem for the materials/procurement manager is to choose between these inventory systems and methods for every individual SKUs. Major questions they may have to answer are

(1) Which of the SKUs should follow the *Q* or *P*-model?

(2) Which of them should be monitored using two-bin and par systems, etc.?

(3) When to implement elements of LT such as kanban, supermarkets, vendor-managed inventory (VMI), etc.?

It is in these contexts that this paper attempts to classify the medical supplies and materials of a case hospital based on various parameters, so that the following objectives are achieved:

(1) Suggesting ways to reduce the inventory levels based on the tools and techniques of LT and thereby can achieve adequate cost savings.

(2) Improve the efficiency of stores and purchase executives by ensuring strict monitoring and control of a few critical items and thereby facilitating the timely delivery of medical supplies to various departments.

In manufacturing, one of the commonly used selective inventory control technique is the ABC (colloquially called "Always in Better Control") analysis. This methodology also finds application in healthcare (Beheshti *et al.*, 2012). The main limitation of this method is that some critical material that demonstrates low usage value will not receive priority attention (Al-Qatawneh and Hafeez, 2011). Some of the medical items might be very critical (for performing surgery or carrying out treatment), while another set of medical supplies have to be imported from other countries which might have a very high lead time for delivery. Hence, the following three essential dimensions: criticality, lead time/ease of availability and the consumption value of each item are to be considered simultaneously. In particular, various selective inventory control techniques such as (1) ABC (focussing on consumption value), (2) vital, essential and desirable or VED (addressing the criticality) and (3) scarce, difficult and easy or SDE (accounting for lead time or ease of availability) are to be combined to develop the MUSIC-3D approach. The step-by-step algorithm of MUSIC-3D is demonstrated using a case study of a catheterisation laboratory (cath lab) of a multi-speciality hospital from India, where

LT is deployed as a significant amount of inventory is held in the stores of the cath lab. Hence, to reduce the same and ensure effective control, the available materials are classified based on the MUSIC-3D approach and various inventory control policies and methods were proposed as part of deploying LT. Thus, it is suggested that the proposed MUSIC-3D methodology should be used as a precursor by the implementing team of LT before establishing LT practices such as kanban system, supermarkets, two-bin system, etc.

The rest of the paper is organised as follows: Section 2 presents a literature review on inventory systems in hospitals to identify the research gaps. Section 3 explains the research methodology and provides an overview of the case organisation. Section 4 describes the step-by-step application of the MUSIC-3D, Section 5 deals with the results and discussion and finally, Section 6 concludes by describing the potential contributions of this work.

2. Literature review

Eissa and Rashed (2020) evaluated suppliers in a healthcare facility by applying statistical process optimisation tools in managing the inventory of products' quality. They selected random records of container deliveries from three different suppliers and analysed products' characteristics using statistical process control (SPC) tools. The results indicated that most dominant manufacturers supplied the product having specifications close to the target values, whereas the least contacted vendor revealed the highest precision. The study provided a direction for improvement in product monitoring characteristics and helped for corrections of any product specifications deviation. They also performed two-dimensional data stratification, which was useful in recognising data pattern and clustering. They commented that a unique quantitative measure for determining inventory weight could be adopted, which will help in decision-making related to material stock movement. On the other hand, there are papers which address this inventory reduction problem through the implementation of management philosophies such as LT. For example, Venkateswaran *et al.* (2013) compared two different implementation approaches of housekeeping practices called 5S by experimenting them in three warehouses of a case hospital. Thus, the existing literature can be reviewed, synthesised and classified into two streams:papers that address the healthcare inventory problems from a mathematical modelling perspective and those from a non-mathematical modelling perspective. A similar approach was followed by Ahmadi *et al.* (2019). They reviewed the studies related to inventory management of surgical instruments and supplies and discussed the issues related to service levels, costs, storage area limitation, surgeon satisfaction, lack of information and limited human resources. They suggested that future studies should deal with the development of stochastic models for surgical supplies.

2.1 Healthcare inventory problems from a mathematical modelling perspective

A brief review of articles dealing with inventory management from a mathematical modelling perspective is shown in Table 1.

These papers utilise the models based on simulation and optimisation to address a variety of issues related to inventory by considering additional information/parameters such as the number of prescriptions, expiry date, space availability, etc. These models attempted to maximise service level, minimise operating cost, reduces shortages, etc. by considering uncertainties in the form of demand, global drug shortages due to supply chain issues, outsourcing, etc. Similarly, the inventory problems faced in different parts of the hospital, such as pharmacy, central stores, blood bank, etc. are also addressed.

2.2 Healthcare inventory problems from a non-mathematical modelling perspective

The papers in this category are devoid of complex mathematical models but are deeply rooted in the best managerial practices implemented within the hospitals, as shown in Table 2.

Table 1.
Review of papers on inventory management in healthcare from a mathematical modelling perspective

S. No.	Author/year	Problem addressed	Applied in	Methods used	Remarks
1.	Bijvank and Vis (2012)	Inventory models considering space constraints/capacity limitations and service levels	Within the hospital comprising stores, nursing station, etc.	Optimisation	Used two types of models: capacity and service models
2.	Gebicki *et al.* (2014)	Comparison of different inventory policies	Internal supply chain comprising one central store, main pharmacy and dispensing machines	Simulation	The policies performed differently for various drugs as it depends on the criticality, expiration date, etc.
3.	Rosales *et al.* (2015)	Analyse the performance of RFID- based two-bin system at the point of use	Hospital in general but focus is on the point of use	Optimisation models based on semi-Markov decision chain	Comparison of periodic and continuous review for the replenishment of bins in RFID-based 2-bin systems based on long-run average cost per unit and optimal empty bin
4.	Hafnika *et al.* (2016)	Compare the ideal and actual amount of the average inventory level	Hospital in general, but focussed on pharmaceutical materials	Probabilistic inventory model and continuous review policy	Concluded that the hospital would be able to reduce almost 830 m Indonesian rupiah or 57% from the current inventory level
5.	Stecca *et al.* (2016)	Improving efficiency and service level	Pharmaceutical purchasing and distribution within a hospital	Optimisation model based on holding and ordering costs	The model consists of two agents: central pharmacy and wards with centralised decision-making by pharmacy
6.	Saedi *et al.* (2016)	Minimise drug shortages	Hospital – typically for the centralised stores	Continuous chain Markov model	The model considers both drug shortages and substitution for a given drug
7.	Dillon *et al.* (2017)	Minimising operating cost, shortages, wastages of red blood cells	Blood bank or blood supply chain	A two-stage stochastic programming model	Optimal period review system for blood, based on the daily demand and standard deviation of demand
8.	Maestre *et al.* (2018)	Continuous re-planning policy based on unexpected consumption peaks, variation in prices, etc.	Laboratory in the hospital	Model predictive control (MPC)	Stock levels of ten drugs that belong to the same laboratory have been controlled by using an MPC policy. The results were better than the adopted approach of the hospital
9.	Saha and Ray (2019)	Inventory planning based on the demand along with the different types of beds, LOS, etc.	Pharmacy in the hospital	Markov decision process with backward induction algorithm	Used a case study in a multi-speciality hospital in Kolkata, India, to validate the proposed model

(*continued*)

S. No.	Author/year	Problem addressed	Applied in	Methods used	Remarks
10.	Rajendran and Ravindran (2020)	Minimising platelet wastage and shortage based on procurement and holding cost	Hospital	A multiple criteria mathematical programming (MCMP) model	Compared three MCMP techniques; preemptive goal programming (PGP), non-preemptive goal programming (NPGP) and weighted objective methods (WOM) to model the daily demand data of platelets
11.	Priyan and Mala (2020)	Optimise the customer service level by considering the deteriorating rate as well as the expiration date of the product	A two-echelon supply chain between a hospital and pharmaceutical company	Game-theoretic approach	Used numerical results to explain their models
12.	Galli *et al.* (2020)	Inventory management of drug supplies using prescriptive analytics	Hospital wards	K-Nearest neighbour, random forests, XGBoost and decision trees	Developed a stochastic model by defining the features related to daily ward conditions. They used innovative scoring function to train machine learning models which helped in handling multi-objective problems. Also, *ad- hoc-* featured engineering was developed to extract the data required for the machine learning model. The results developed from random forest and XGBoost method dominated other methods and found a reasonable settlement amongst two objectives of decreasing emergency replenishment order and order quantities
13.	Duong *et al.* (2020)	Development of decision framework for inventory management of perishable products	Hospital blood centre	Discrete event simulation (DES), analytic hierarchy process (AHP) and data envelopment analysis (DEA)	Defined replenishment policy for perishable health products. A decision framework was developed based on non-financial measures to improve inventory management. Prioritised the performance measure of the simulated supply chain model using AHP. Further, each scenario of supply chain model was studied and ranked using the DEA

Table 1.

Table 2.
Review of papers on inventory management in healthcare from a non-mathematical modelling perspective

S. No.	Author/year	Problem addressed	Applied in	Hospital	Benefits
1.	Khorajia *et al.* (2009)	Inventory reduction through rough-cut kanban with no past data and less knowledge on inventory management	Sterile supply room for the operating rooms (ORs)	A 500-bed community hospital located at Abilene, Texas, the USA	8% reduction in storage space capacity and 28% improvement in the case picking time
2.	Landry and Beaulieu (2010)	Implementing two-bin RFID-based kanban system	Nursing stations, point of use areas	Not mentioned but used examples from hospitals in Canada	Improved standardisation, reduction in staff movements, improved job satisfaction for nurses
3.	Vries (2011)	Issues in reshaping the inventory system	Pharmacy of the hospital	A 400 bedded medium-sized hospital with 1,500 employees	Dynamics of the relationships and interactions between the stakeholders affect the reshaping
4.	Bendavid *et al.* (2012)	RFID-based internal traceability for high-value items	Operating rooms	A public 246-bed Canadian hospital	Better item-level traceability, service levels and reduced inventory shrinkage
5.	Venkateswaran *et al.* (2013)	Implementation of 5S to improve visibility and inventory control	Central warehouses/ stores	Ochsner Health System, the USA	Reduced delays, mixups of supplies and an increase in inventory turn
6.	Machado Guimarães *et al.* (2013)	Exploring vendor-managed inventory (VMI)	Central stores of pharmacy	Public, multi-site hospital	Improved stock visibility, reduced stock-outs, delivery errors, "secret" safety inventory, etc.
7.	Regattieri *et al.* (2018)	Inventory control through the operator's confidence and capability	Central stores and point of use in the surgery department	A 1,500-bed hospital in Bologna (northern Italy)	Accounted for the behaviour of the ward personnel for material management. Used LT practices such as visual control, discipline, two-bin system, etc.
8.	Yıldız and Khan (2018)	Inventory monitoring through a web-based tracking system	1,100 public hospitals in Turkey	The Ministry of Health, Turkey	A web-based information system as part of the Health Transformation Programme (HTP) of Turkey to lower the expenses associated with inventory held by hospitals
9.	Shiau (2019)	Inventory control based on daily patient prescriptions and drug flows	Central stores (not mentioned explicitly)	National Health Insurance in Taiwan	Around 480,000 data were extracted from Taiwan's National Health Insurance files and utilised 19 association rules to mine the treatments data to derive prescription-oriented association rules for improving inventory management

(*continued*)

S. No.	Author/year	Problem addressed	Applied in	Hospital	Benefits
10.	Chila and Susi (2019)	Lean principles to explore an out-dated process	Radiology department	The MetroHealth System, Cuyahoga County, Ohio, United States	Established a web-based inventory tracking system to control the supplies in the radiology department
11.	Taddele *et al.* (2019)	Inventory management of pharmacy store and identification of drugs requiring stringent management control	Pharmacy store	Arbaminch General Hospital, Ethiopia with a total of 450 beds	Used the ABC–VED matrix and identified the drugs requiring stringent management control. The study revealed that medicines pertaining to category 1 require strict inventory control and that of categories 2 and 3 need control by middle and lower managerial levels
12.	Bialas *et al.* (2020)	Improvement of hospital pharmacy inventory management	Pharmacy store	A 700 bedded Greek public hospital	Established easy to implement a practical framework for improving inventory management of pharmacy story of the hospital using data segmentation. The results confirmed a substantial improvement for all critical performance parameters and transformed into inventory cost savings

Table 2.

Table 2 reveals a variety of managerial and technical practices such as radio-frequency identification (RFID), 5S, two-bin systems, stakeholder analysis, etc. which are used to reduce inventory. These mechanisms are also used in diverse areas such as operating room, nursing stations, stores, pharmacy, etc.

2.3 Research gaps

Although the papers based on operations research and optimisation models are highly relevant, they are based on multiple assumptions. For example, Nicholson *et al.* (2004) modelled the problem of outsourcing inventory by considering only a single-period review for single items. Also, some of the models were so complex. For example, Saedi *et al.* (2016) had numerous prepositions and theorems, while Rosales *et al.* (2015) concluded that the long-run average cost per unit is quasi convex. Not many of the purchasing executives may be able to appreciate such impressive mathematical results. Moreover, before utilising such mathematical models under continuous or periodic inventory system, it is essential to understand which of the medical items have to follow which of these inventory models and mechanisms. The proposed approach MUSIC-3D would help in addressing this issue and hence would be appropriate in the planning stage of developing inventory systems during the implementation of LT.

On the other hand, the review of papers that are non-mathematical modelling based revealed that many of the works were from developed countries such as the USA, Canada, Italy, etc. Not many reports were available from emerging countries such as India, where the healthcare sector is far behind. Although, many articles utilised qualitative approaches such as case study to enumerate a practical application of the inventory problem, hardly any paper reported about the utilisation of MUSIC-3D approach as a precursor for LT implementation.

As mentioned earlier, the three factors for managing inventory – the dollar volume or consumption value (to reduce cost), criticality (for ensuring the quality of service) and lead time (to ensure timely availability of materials) – are paramount. These three dimensions help the procurement managers in the hospitals to achieve these objectives of reducing cost, providing a high-quality of service through timely availability of materials without any stock-outs in tandem by utilising the MUSIC-3D approach. Although Antonoglou *et al.* (2017) employed a hybrid method comprising ABC and VED analyses to manage the medical inventory in a military hospital in Greece, they did not account for the lead time. They did not perform any SDE analysis. In the case of the manufacturing sector, Sanjeevy and Thomas (2014) used ABC, VED and fast-, slow- and (FSN) non-moving analyses to monitor the spare parts for a chemical company. None of the authors had integrated ABC and VED with SDE, which is essential for the context of the hospital. Hence, an attempt is made in this paper to fill up these gaps.

3. The research methodology

A case study approach is utilised in this study. This method enables the researcher to collect insightful data, where an explanation is required rather than statistical measurement (Bryman and Bell, 2011). For example, to demonstrate the MUSIC-3D methodology, real-life data about the list of items, quantity stocked, the dollar value of these items, suppliers, etc. are collected from the case organisation. These data are not meant for any statistical measurement but to demonstrate the utility of the proposed method. Moreover, a case study method is suitable to answer "how" and "why" questions and also to investigate a contemporary phenomenon in its real-life context when the boundaries between phenomenon and context are not evident recurring to several data collection techniques and different evidence sources (Yin, 2009). In particular, if the objective is not to produce causality statements but to achieve a logical sequence of connection between empirical data, problem/

research questions and findings/conclusions, then the case study approach is highly suitable. In this study, a detailed step-by-step methodology of MUSIC-3D would be demonstrated using the obtained data to highlight that it can help in identifying the appropriate tools and techniques of LT for inventory reduction. Finally, this qualitative research method is also commonly used in the domain of management and especially in operations management (Voss *et al.*, 2002). Hence, an exploratory case study method is employed.

3.1 An overview of the case organisation

The authors have signed a confidentiality agreement with the case hospital. Hence, the name of the hospital is camouflaged as ABC Hospital (ABCH). ABCH is a leading hospital in Kerala, a state located in the southern part of India. It is one of the few multi-speciality hospitals accredited to the National Accreditation Board for Hospitals and Healthcare Providers (NABH). It has also obtained various other certifications such as ISO 9001:2000 and ISO 14001:2004. This hospital was established in 1987 as a 52-bed hospital. It has been growing steadily for the past 23 years and currently has a capacity of about 800 beds. The case hospital consisted of over 40 medical and surgical departments, 21 operation theatres, 18 fully equipped ICUs with 210 intensive care beds and a 24 h accident and trauma care unit. Nearly 200 doctors and 1500 medical, nursing, paramedical and administrative staff members were employed. The case hospital provided four types of healthcare services, namely, outpatient, inpatient, emergency and intensive care.

The hospital started the implementation of LT early in 2015 as the vision and mission of the hospital is to make the healthcare services more accessible and affordable. Also, it faces fierce competition from more than ten multi-speciality hospitals, which are located within the radius of 10 km from the case hospital. The initial application of LT was in the non-core functions such as dietary, laundry, housekeeping, electrical and civil maintenance, etc. They implemented various elements of LT, such as 5S, colour coding, periodic maintenance, work standardisation, etc. Slowly on gaining experience and the support from other employees, they started implementing LT in the core functions. They started with the project on inventory reduction in the core areas such as inpatient and outpatient stores, inpatient and outpatient pharmacies and other stock holding points in the hospital. The reason was that the employees in the purchasing and stores departments of the hospital started feeling that their work was stressful. They said that they were spending most of the time in a fire-fighting mode on the following:

(1) Arranging, storing and counting the wide variety of drugs, consumables and equipment such that it is easy to identify, pick and deliver the required items on time;

(2) Trying to arrange for quick replenishment of medical needs that are out of stock by coordinating with suppliers;

(3) Carrying out other administrative activities such as raising purchase orders, negotiating with suppliers for prices, following up with suppliers for ensuring timely delivery, etc.

The daily work became highly stressed not just for these executives but also for the pickers and billers in the pharmacy as the demand for healthcare services was also increasing. If they made a mistake in ordering or delivering the required materials, then it might have affected the treatment and diagnostics, which would further jeopardise the satisfaction of both the employees as well as patients. Hence, as a pilot project, the implementing team decided to focus on inventory reduction in the cath lab as part of the LT deployment in the core areas of the hospital. A cath lab is an examination room in a hospital or clinic with diagnostic imaging equipment used to visualise the arteries of the heart and the chambers of the heart and treat any stenosis or abnormality. The reasons for selecting the cath lab as the pilot project for inventory reduction are as follows:

(1) It is the key revenue generator for the hospital as there is a significant demand for cardiology services.
(2) Equipment and consumables used in this department are usually expensive.
(3) Any stock of unnecessary items or high inventory of necessary items is also tying up significant working capital.
(4) Most of these equipment, medicines, devices and consumables in this department should not be out of stock as it would make the difference between life and death of a patient.

Naturally, better stock management of these items is imperative. Moreover, the success of this project can also give the implementing team the necessary confidence to implement LT in other areas too.

4. Application of multi-unit selective inventory control incorporating three dimensions

MUSIC-3D is a hybrid selective inventory control technique. It amalgamates three different methods – namely the ABC, VED and SDE analyses. As mentioned earlier, the ABC analysis works on the principle of Pareto analysis to develop categories of medical supplies based on the total dollar volume or consumption value. The VED analysis classifies them based on the criticality, and the SDE analysis focusses on the lead time and ease of availability of materials and thereby ranks each item as scare, difficult and easy. Since all these objectives are critical for the case hospital and in particular to the cath lab, it is essential to integrate these three different selective inventory control techniques. Hence, it is abbreviated as multi-unit selective inventory control (MUSIC) incorporating three dimensions (3D) – consumption value, criticality and lead time. The detailed step-by-step methodology is explained as we move along the case study.

4.1 The step-by-step methodology

(1) Stage 1: data collection

Step 1: Details regarding items in stock such as the name, quantity available, its value, suppliers, etc. are collected from the hospital information system by filtering out the SKUs for the cath lab. The detailed data about the items in stock in the cath lab are enormous; hence, they could not be included with the paper due to strict word limitations. Therefore, they are provided as a supplementary file (see Appendix).

From Appendix, it can be found that there were multiple SKUs for the same item. Some of the SKUs were the same items but supplied by a different supplier. Some of the SKUs were the same items but they differed by their size. For example, GUIDEWIRE 0.035 X 260CM J TIP (TERUMO) is a product supplied by a company called Terumo, while Cordis also provided the same product. Similarly, there existed multiple sizes of guidewires with different diameter and length. Due to this, there was an increase in the number of suppliers, shelf space, search time, etc. Also, the monitoring and other processes such as ordering and follow-up too were very high.

(2) Stage 2: performing the ABC analysis

Step 2: Due to space limitations, detailed computations are not shown. Readers can refer to Beheshti *et al.* (2012) and Narang *et al.* (2018) for the exact steps of ABC analysis.

Step 3: Based on the cumulative relative contribution of consumption value, items under A, B and C classes were identified. Appendix shows the detailed results of the ABC analysis, while Table 3 shows a summary of the result of ABC analysis.

From Table 3, it can be inferred that the stock of the items in the cath lab store is worth INR 57 lakhs. Out of which, 12% of the total items (i.e. 17 out of 140 items) contributed to approximately INR 40 lakhs – i.e. 69.81% of the total dollar volume or consumption value. These A-class items were expensive and required strict monitoring and control. Similarly, around 62% of the total items (i.e. 87 out of 140 items) merely contributed to just 10.22% of the total dollar volume or consumption value. These were C-class items. The supplies with a cumulative relative contribution of dollar volume or consumption value ranging from 70% to 90% fell under the B-class items (about 36 items). This classification helped the procurement executives to minimise the amount of monitoring and control, which in turn made their work less stressful.

(3) Stage 3: integrating the VED analysis with the ABC analysis

Since the ABC analysis does not account for the criticality and ease of availability of items, other selective inventory control techniques were to be used. Additional data regarding the criticality were collected by interacting with various employees of the case organisation.

Step 4: The executives in the purchasing department, the materials incharge, the nurses and the doctors working in the cath lab were consulted to understand the criticality of each item. The list of materials used in the cath lab was shared with them and they were asked to classify each item as vital, essential and desirable by marking V, E and D. Based on the mode value for the responses, their criticality was identified. Appendix shows the detailed VED analysis for each of the supplies, while Table 4 shows the summary of VED analysis.

Step 5: The results obtained from ABC and VED analyses were integrated to account for the criticality. Table 5 shows a summary of the classification of materials based on the integration of ABC and VED analyses.

There were five desirable A-class items, while about 13 C-class items which were vital. If these two analyses are used separately, then one cannot identify these 13 C-class items, which also requires constant attention from the procurement team.

(4) Stage 4: integrating lead time with VED and ABC analyses: the MUSIC-3D approach

Step 6: The next step is to integrate the lead time/ease of availability with the above-mentioned analysis. Details regarding the lead time, type of suppliers (local or outside the state), etc. were provided by the purchasing executives. When the lead time of the product was high (greater than seven days) and it had to be shipped from far-away states (say, a distance of about 2000km), then it was marked as "scarce (S)". If the lead time of the product

Description	Category A	B	C	Total
Total annual consumption (%)	69.81	19.97	10.22	100.00
Value of annual consumption (INR)	4,021,844.00	1,150,678.00	588,712.00	5,761,234.00
Number of items (nos.)	17	36	87	140
Percentage of items (%)	12.05	25.71	62.14	100.00

Table 3. Summary of the results obtained from the ABC analysis

Category	No. of items	% of total items
Vital (V)	22	15.71
Essential (E)	49	35.00
Desirable (D)	69	49.29
Total	140	100.00

Table 4. Summary of the results obtained from the VED analysis

was less (lesser than two days) and it was available in the domestic market, then it was marked as "easy (E)". Finally, if the lead time of the product was between two to seven days and was transported from the nearby state (say, Tamil Nadu), then it was marked as "Difficult (D)". Appendix shows the details of the SDE analysis, while Table 6 shows a summary of the same.

Step 7: The results obtained from ABC, VED and SDE analyses were integrated. Table 7 shows a summary of the classification of materials based on the MUSIC-3D approach.

There are 27 different categories of materials. However, in this case, there were no materials available in some of the groups such as A-class, vital and difficult (AVD), A-class, desirable and scarce (ADS), etc. for the cath lab. Each of these categories had some unique characteristics. Based on the same, various inventory policies and systems had to be established and appropriate tools and techniques of LT were to be deployed by the team responsible for implementing LT.

5. Results and discussion

The outcome of this study revealed that cath lab alone has locked in about INR 57.6 lakhs worth of capital in inventory. For the whole hospital, the money locked in stock would be worth several crores of rupees, which might be a significant proportion of the working capital. The results reinforce the decision of the hospital administrators to implement LT for inventory reduction. Applying the standalone classification techniques such as the ABC analysis alone would have missed out of many of the medical supplies, which are critical as well as scarce. The MUSIC-3D approach helped in identifying a few more categories to ensure effective monitoring and establishing suitable inventory policies that were listed by Landry and Beaulieu (2010).

5.1 Policies for A-class items and its subcategories

The ABC analysis revealed 17 A-class items which warranted immediate attention from the top management and required stringent control with effective transaction monitoring. All the

	V	E	D	Total
A	AV (2 items) 1.42% INR 321,525 (5.58%)	AE (10 items) 7.14% INR 1,376,330 (23.89%)	AD (5 items) 3.57% INR 2,308,073 (40.06%)	17 items (12.14%) INR 4,005,928 (69.53%)
B	BV (7 items) 5% INR 189,443 (3.29%)	BE (12 items) 8.57% INR 445,708 (7.74%)	BD (18 items) 12.85% INR 547,442 (9.50%)	37 items (26.42%) INR 1,182,593 (20.53%)
C	CV (13 items) 9.28% INR 99,367 (1.72%)	CE (27 items) 19.28% INR 172,564 (2.30%)	CD (46 items) 32.85% INR 300,782 (5.47%)	86 items (61.42%) INR 572,713 (9.94%)
Total	22 items (15.71%) INR 610,335 (10.60%)	49 items (35%) INR 1,994,602 (34.62%)	69 items (49.28%) INR 3,156,297 (54.78%)	140 items (100%) INR 5,761,234 (100%)

Table 5. Summary of the results obtained from integration of ABC and VED analyses

Category	No. of items	% of total items
Scarce (S)	4	2.85
Difficult (D)	25	17.85
Easy (E)	111	79.30
Total	*140*	*100.00*

Table 6. Summary of the results obtained from SDE analysis

Table 7. Summary of the results obtained from the MUSIC-3D analyses

		Total dollar volume/consumption value								
		A			B			C		
Criticality	Availability	S	D	E	S	D	E	S	D	E
V	No. of items	2					7	1	1	11
	% of total items	1.43					5.00	0.71	0.71	7.86
	Value of the items in INR	321,525.00					189,443.50	12,200	14,470	72,696.77
	% contribution to the total value of the items	5.58					3.29	0.21	0.25	1.26
E	No. of items		2	7		1	12		8	19
	% of total items		1.43	5.00		0.71	8.57		5.71	13.57
	Value of the items in INR		150,461.00	1,162,239.00		20,498	488,390.00		52,098.14	265,735.8
	% contribution to the total value of the items		2.61	20.17		0.36	8.48		0.90	4.61
D	No. of items			6	1	4	11		9	38
	% of total items			4.29	0.71	2.86	7.86		6.43	27.14
	Value of the items in INR			2,387,619.00	31,500	118,630.52	301,765.60		51,045.92	265,735.8
	% contribution to the total value of the items			41.44	0.55	2.06	5.24		0.89	4.61

transactions of these items were to be strictly updated in the hospital management system. Similarly, a 100% service level should be ensured. A deep dive into these 17 items in Appendix, along with the results from Table 7 revealed the following:

(1) A-class, vital and scare (AVS): The following two items fall under this category: HepaSphere and fractional flow reserve (FFR) pressure wires. The suppliers were located far away and hence, the lead time was very high. Therefore, these items were to be managed using the EOQ model with safety stock approach.

(2) A-class, essential and difficult (AED): This category comprises two items, Guidewire Transend and PVA Particle 500 that contributed to 2.61% of the total inventory. Since these items have an average lead time of two to five days and have to be transported from a supplier in the nearby state, the EOQ model with discounts can be used to overcome the lead time variability. The procurement team also can negotiate with the existing local suppliers and develop a strong supplier relationship with whom a long-term contract for the overall annual requirement can be established.

(3) A-class, essential and easy (AEE): Strict managerial control has to be maintained for the items in this category as it contributes to approximately 20.17% of the total inventory value. Simple EOQ models with reorder point can be used. It ensures that items are replenished based on their consumption as they are readily available from the domestic suppliers. However, the procurement manager should explore the use of a kanban system with just in delivery in the future.

(4) A-class, desirable and easy (ADE): These items were available easily from local suppliers and hence could be procured based on fixed order quantity with a fixed time interval between orders. More importantly, it contributed to 41% of the total inventory value. Hence, practices such as VMI could be explored as the local supplier can check the stock of the items and deliver the same within a day or two through proper information sharing. Necessary actions could be taken to enable multiple items to be supplied from a single supplier. This would result in supplier rationalisation and consolidation too.

5.2 Policies for B-class items and its subcategories

Although medical suppliers in the B category contribute to just 20% of the total inventory value, some of them are vital, while some of them are essential. Hence, suitable inventory policies have to be followed. These can be monitored by the purchasing executives every week but a strict discipline related to transaction update has to be carried out by the front-line employees.

(1) B-class, desirable and scarce (BDS): There is only one item in this category that contributes to 0.55% of the total inventory value. Since it is rare due to longer lead times, it is better to employ a periodic review mechanism – such as ordering every week based on the quantity getting consumed along with stipulated safety stock of about 15–20% more. Over the long run, the materials manager should find a local manufacturer/supplier for items under this category.

(2) B-class, essential and difficult (BED): Again, only one item is present, which contributes to about 0.36% of the total inventory value. It is better to maintain a "par level" system. Irrespective of the consumption, the material should always be filled to the pre-defined level such that no stock-outs happen.

(3) B-class, desirable and difficult (BDD): This category includes four items that contribute about 2.06% of the total value of the inventory. Since the materials are available locally, a periodic inventory model with ordering every fortnight can be used. Safety stock of about 10% can also be maintained as it can be delivered quickly within a day.

(4) B-class, vital and easy (BVE): About seven items in this category contribute to about 3.29% of the total inventory value. 100% service level should be ensured as it is vital. Hence, the two-bin system can be explored. As one bin gets consumed, it indicates the need for replenishment, which can be made within a day as the suppliers are locally available.

(5) B-class, essential and easy (BEE): This category contains 12 different supplies contributing to 8.48% of the total inventory value. These items should be ordered using a fixed period model by ordering every three days. A minimal safety stock of about 3% can be maintained as it is essential and the delivery too can be made quickly.

(6) B-class, desirable and easy (BDE): A monthly review and purchase are sufficient to take care of these 11 items, contributing to 5.24% of the total value. These items are readily available from the local suppliers and are of medium importance.

5.3 Policies for C-class items and its subcategories

Monitoring of these items can be relegated to the storekeeper or store incharge who would make the order and the same can be approved by the purchasing executives. A routine visual check would be carried out and the amount to be ordered can be based on approximate values that are forecasted using the naïve method or previous experience. Based on the results from the MUSIC-3D analysis, the following inventory policies and mechanisms are recommended:

(1) C-class, desirable and easy (CDE): These items should be eliminated or their use should be minimised if possible. This can happen if there is re-designing of a product due to new technology or a new vendor supplies a product with integrated features. In our case, 38 different entities fall under this category. The conventional arms-length relationship between suppliers can be practised to deliver immediately, although it may lead to variation in the quality of the products.

(2) C-class, vital and scarce (CVS) and C-class, vital and difficult (CVD): A periodic inventory system with a review period of about seven days can be used with necessary safety stock included. In this case, both these categories include just one item with an inventory value of only 0.45% together.

(3) C-class, essential and difficult (CED) and C-class, essential and easy (CEE): The items in these categories can follow similar patterns. A two-bin system can be established so that frequent monitoring can be avoided. More number of items are available in these categories and hence sole sourcing – i.e. a vendor who can supply multiple items from these categories can be explored.

(4) C-class, desirable and difficult (CDD): The item in this category can follow a periodic review model with a review period of about 15–20 days. Since it is difficult to get, one needs to stock items for about two to three weeks with adequate safety stock of about 10–15%. Although there can be significant physical stock, it may not increase the total inventory value. About nine items fall under this group, contributing to less than 1% of the entire inventory value (0.89%).

5.4 Managerial implications

A detailed step-by-step methodology of MUSIC-3D was presented. Hence, the practitioners can benefit by applying the same in their work setting. Also, the classification of items by the MUSIC-3D approach can help them in identifying suitable inventory control policies and systems apart from identifying appropriate tools and techniques of LT before the actual deployment. For instance, VMI, kanban, two-bin system, visual control, supplier relationship, etc. were suggested in addition to the conventional inventory management system. These policies and mechanisms can help in reducing the inventory level as well as the cost of inventory if successfully implemented. For instance, it was found that some of the items are obtained from two different suppliers. Hence, the cost, time and effort for coordinating and carrying out administrative tasks can be reduced through suppliers' rationalisation or sole sourcing, which is also a practice followed as part of LT. It can reduce the level of monitoring to be carried out by the purchasing executives and relegate some of these tasks to the store incharges and front-line operators such as nurses. Thus, MUSIC-3D can be considered as a pre-planning tool for reducing inventory for LT implementation.

5.5 Research implications

Since a hybrid methodology for classifying the medical supplies is proposed as a precursor for the actual implementation of LT, a comparison with similar studies was made to highlight the unique contribution of this work. Table 8 shows the comparison of this study with the existing literature.

As evident from Table 8, it has been used to categorise medical supplies in pharmacy, medical stores of the hospital, etc. Most of the researchers have attempted to use the ABC–VED analysis. None of the reviewed works has demonstrated the application of MUSIC-3D, which integrates ABC, VED and SDE methodologies. Sandeep *et al.* (2017) and Mehrotra *et al.* (2015) claimed to have used the MUSIC-3D approach. A critical reading of these articles would reveal some lacunae. They have suggested only eight categories for classification by having

S. No.	Author, year	Applied in	Healthcare institution	Country	Methods employed
1.	Narang *et al.* (2018)	Anti-cancer drugs	Tertiary care hospital of ESI, Delhi	India	ABC
2.	Hazrati *et al.* (2018)	Pharmacy	Imam Reza Educational Hospital	Iran	ABC, VED, ABC–VED matrix
3.	Fitriana *et al.* (2018)	Pharmacy store	Veterinary Hospital	Yogyakarta, Indonesia	ABC, VED, ABC–VED matrix
4.	Kanyakam (2018)	Medical stores	Secondary care unit service-level hospitals	Northeast of Thailand	ABC, VED, ABC–VED matrix, forecasting methods, EOQ, reorder point
5.	Antonoglou *et al.* (2017)	Medical technological products	401 hospital	Greece	ABC, VED, ABC–VED with other financial analyses
6.	Hlaing *et al.* (2017)	Pharmacy	A public teaching hospital	Thailand	ABC and FSN analyses
7.	*This study*	*Stores of the cath lab*	*Private, tertiary care, multi-speciality hospital*	*India*	*ABC, VED, SDE, ABC–VED, ABC–SDE and MUSIC-3D approach*

Table 8.
Comparison of this study with the existing studies in the literature

only two levels (high and low) instead of three for consumption value, criticality and lead time, respectively. In this study, a complete SDE analysis was done that considered both the lead time and the ease of availability. A total of 27 different categories were identified and inventory policies and procedures for most of these categories were suggested, apart from identifying various tools and techniques of LT for inventory reduction. Thus, this study is unique and different in terms of the application of MUSIC-3D. Moreover, this methodology was used within the context of a hospital implementing LT, which is also unique.

5.6 Limitations

Since a single case study was utilised, the results related to the classification of medical supplies cannot be generalised. Some of the categories in Table 8 were empty without any items for the cath lab. It may not be the case with the implementation of this technique in other hospitals or departments. Moreover, the classification of materials by the practitioners while doing VED and SDE analyses was subjective. It depended on the experience of the participating team, availability of suppliers, etc. Finally, this methodology only proposed various inventory systems and multiple tools and techniques of LT for the case organisation before the actual deployment of LT for inventory reduction. The same has to be implemented and the benefits obtained have to be documented.

6. Conclusion

In this study, the problems due to inventory in the healthcare sector were highlighted. A literature review revealed that hardly any work reported about the utilisation of a hybrid selective inventory control mechanism that integrated ABC, VED and SDE analyses in the context of implementing LT. The step-by-step approach of the MUSIC-3D approach was demonstrated using a real-life case study. The outcome of this study helped the purchasing executives in the case hospital to critically focus on A-class (17 out of 140 items) and B-class items (36 out of 140 items) by developing suitable inventory systems. This would reduce the workload and complexity of their jobs. It would also enable the procurement managers to install appropriate elements of LT and thereby ensure the availability of the right material at the right time in the right quantity. Finally, it is suggested that this methodology should be used as a precursor for identifying suitable inventory systems and other tools and techniques of LT during the planning stage of implementation itself.

Note

1. http://www.newindianexpress.com/nation/2018/jun/16/private-hospitals-spend-50-per-cent-of-operational-costs-on-salaries-of-medical-staff-including-doc-1829098.html (accessed on 18 April 2020).

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Appendix

Details regarding the list of materials, cost, quantity and their classification in terms of ABC, VED and SDE

S. No.	Item code	Item description	Qty (in nos.)	Unit price (INR)	Total amount (INR)	SDE	ABC	VED
1.	1002123	Coil Embolization Hilal MWCE 18-2-4 (Cook)	2	8,478.75	16,957.50	E	B	V
2.	1002516	Catheter guiding 6f guide liner (Vascular)	1	37,800.00	37,800.00	D	B	D
3.	1002570	Coil Embolization Hilal MWCE 18-3-4 (Cook)	3	8,479.00	25,437.00	E	B	V
4.	1002870	Pressure monitoring line 200CM BL	50	32.55	1,627.50	E	C	E
5.	1003721	Catheter bipolar electrode 6F	5	4,200.00	21,000.00	E	B	D
6.	1003728	Catheter diagnostic 4F head hunter (Cordis)	4	2,100.00	8,400.00	E	C	E
7.	1003731	Catheter diagnostic 5F head hunter (Cordis)	5	2,100.00	10,500.00	E	C	D
8.	1003741	Catheter diagnostic 5F radial tiger (Terumo)	165	1,089.07	179,697.00	E	A	E
9.	1003745	Catheter diagnostic 6F JL 3.5 (Cordis)	25	1,250.00	31,250.00	E	B	E
10.	1003749	Catheter diagnostic 6F JR 3.5 (Cordis)	40	1,250.00	50,000.00	E	B	E
11.	1003755	Catheter export aspiration 6F	10	34,000.00	340,000.00	E	A	E
12.	1003767	Catheter guiding 6F EBU 3.0(M edtronic)	3	4,650.45	13,951.35	E	C	E
13.	1003768	Catheter guiding 6F EBU 3.5(M edtronic)	45	4,650.42	209,269.00	E	A	E
14.	1003769	Catheter guiding 6F EBU 4.0(M edtronic)	6	4,650.17	27,901.00	E	B	E
15.	1003770	Catheter guiding 6F (Envoy)	10	8,610.00	86,100.00	E	A	E
16.	1003772	Catheter guiding 6F JL 3.0(Medtronic)	4	4,650.50	18,602.00	E	B	E
17.	1003773	Catheter guiding 6F JL 3.5(Medtronic)	3	8,217.00	24,651.00	E	B	D
18.	1003776	Catheter guiding 6F JR 3.5(Medtronic)	23	4,215.61	96,959.00	E	A	E
19.	1003780	Catheter guiding (Medtronic)	6	4,650.00	27,900.00	E	B	D
20.	1003802	Catheter guiding 8F MPA 1.0(Cordis)	1	3,570.00	3,570.00	E	C	D
21.	1004374	Coil Embolization MReye IMWCE	6	3,987.50	23,925.00	E	B	D
22.	1004388	Coil Embolization Hilal MWCE	2	8,479.00	16,958.00	E	B	V
23.	1004390	Coil Embolization Hilal MWCE 18-3-3 (Cook)	5	8,479.00	42,395.00	E	B	V
24.	1007463	Guidewire 0.035 X 260 cm J TIP (Terumo)	16	1,982.81	31,725.00	E	B	E

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S. No.	Item code	Item description	Qty (in nos.)	Unit price (INR)	Total amount (INR)	SDE	ABC	VED
25.	1007473	Guidewire 0.032 X 150 cm straight tip (Cordis)	5	1,100.00	5,500.01	E	C	E
26.	1007476	Guidewire 0.035 X 150 cm J TIP (Cordis)	50	1,100.00	55,000.00	E	B	E
27.	1007477	Guidewire 0.035 X 150 cm J TIP (Nipro)	2	950.00	1,900.00	E	C	D
28.	1007481	Guidewire 0.035 X 260 cm J TIP (Cordis)	5	1,100.00	5,500.01	E	C	D
29.	1007487	Guidewire PTCA BMW 190 cm (Abbott)	20	4,500.00	90,000.00	E	A	D
30.	1007491	Guidewire PTCA DOC extension (Abbott)	1	4,500.00	4,500.00	E	C	E
31.	1007492	Guidewire PTCA fielder FC 0.014 X 180 cm (Asahi)	13	5,091.54	66,190.00	E	A	E
32	1007495	Guidewire PTCA run through floppy hypercoat (Terumo)	30	12,211.50	366,345.00	E	A	D
33.	1007496	Guidewire PTCA fielder XT (Asahi)	1	7,848.75	7,848.75	E	C	E
34.	1007498	Guidewire transend EX 0.014	7	12,107.43	84,752.00	D	A	E
35.	1007957	Kit inflation device	48	3,833.83	184,024.00	E	A	E
36.	1009095	Y-connector set (Push Pull)	80	1,139.69	91,175.00	E	A	D
37.	1009130	Particle PVA 700	3	6,982.67	20,948.00	D	B	E
38.	1013815	Sheath radial 6 F(Terumo)	105	757.58	79,546.00	E	A	D
39.	1013816	Sheath radial 5 F(Terumo)	10	1,050.00	10,500.00	E	C	D
40.	1013820	Sheath femoral 5 F(Cordis)	20	800.00	16,000.00	E	C	D
41.	1013821	Sheath femoral 6 F(Cordis)	40	800.00	32,000.00	E	B	D
42.	1013822	Sheath femoral 7 F(Cordis)	70	800.00	56,000.00	E	B	D
43.	1013823	Sheath femoral 8 F(Cordis)	15	800.00	12,000.00	E	C	D
44.	1013844	Sheath femoral 10 F 11 cm (Cordis)	5	800.00	3,999.98	E	C	D
45.	1017336	Catheter guiding 6 F JR 3(Medtronic)	5	4,650.45	23,252.25	E	B	D
46.	1017342	Catheter micro finecross	2	25,200.00	50,400.00	E	B	E
47.	1017344	FFR pressure wire certus	9	25,725.00	231,525.00	S	A	V
48.	1017353	Guidewire 0.032 X 150 cm J TIP (Terumo)	10	819.00	8,190.00	E	C	D
49.	1017355	Guidewire 0.035 X 150 cm J TIP (Terumo)	65	978.92	63,630.00	E	B	E
50.	1017358	Guidewire PTCA grand slam (Asahi)	13	4,830.00	62,790.00	E	B	E
51.	1017359	Guidewire PTCA miracle 4.5 (Asahi)	2	6,279.00	12,558.00	E	C	E
52.	1017360	Guidewire PTCA miracle 6 (Asahi)	8	6,279.00	50,232.00	E	B	E
53.	1017363	Manifold	10	346.50	3,465.00	D	C	E
54.	1017370	Puncture needle 18 gauge IS IT (needle introducer biomed)	700	63.00	44,100.00	E	B	V
55.	1017372	Sheath femoral 11 F(Cordis)	5	800.00	3,999.98	E	C	D

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S. No.	Item code	Item description	Qty (in nos.)	Unit price (INR)	Total amount (INR)	SDE	ABC	VED
56.	1017375	Sheath balkin 7 F(Cook)	2	5,900.00	11,800.00	E	C	D
57.	1021818	Guidewire PTCA sion blue 0.014 (Asahi)	160	5,186.33	829,813.00	E	A	D
58.	1021945	Catheter guiding 6 F JL 4.0(Medtronic)	2	4,650.00	9,300.00	E	C	E
59.	1022328	Catheter corsair 2.6 F X 135 cm	1	40,330.50	40,330.50	D	B	D
60.	1024969	Neff set naps -100-RH (Cook)	2	6,100.00	12,200.00	S	C	V
61.	1024971	Guidewire superstiff 035/ 260 (Boston)	2	4,900.00	9,800.00	E	C	D
62.	1024972	Cather diagnostics 5 F-C1 (Boston)	2	2,200.00	4,400.00	E	C	D
63.	1025198	Cather diagnostics pigtail marker	1	8,400.00	8,400.00	E	C	E
64.	1025265	Sheath long 7 F 45 cm (Arrow)	2	3,885.00	7,770.00	E	C	E
65.	1025309	PVA particle 300	1	6,982.50	6,982.50	D	C	E
66.	1025310	PVA particle 500	10	6,570.90	65,709.00	D	A	E
67.	1025475	Catheter guiding 7 F MPA (Medtronic)	2	4,650.45	9,300.90	E	C	E
68.	1025583	Needle biopsy bone DBBN-13-10.0-M2 Cook	1	2,756.25	2,756.25	E	C	V
69.	1025609	Chiba biopsy needle –DCHN-22-15.0– Cook	5	690.40	3,452.00	E	C	V
70.	1025611	Micropunture transitional introducer MPIS-501-NT-SST	2	2,711.50	5,423.00	E	C	D
71.	1025619	Catheter utrine roberts SCBR5.0 X 35 X 90 PNS RUC – Cook	1	2,656.08	2,656.08	D	C	E
72.	1025703	Tip beacon torcon HNBR 5.0.-38-40-PNS-KMP– Cook	2	1,426.32	2,852.64	D	C	E
73.	1025705	Tip beacon pig flush catheter HNR 5.0-38-70-P-10S– Cook	2	1,426.32	2,852.64	D	C	D
74.	1025706	Tip beacon torcon HNBR 5.0.-38-100-PNS-JB1– Cook	3	1,426.32	4,278.96	D	C	D
75.	1025738	Check flow introducer mullince sheat RCFW–8.0-38-63-RB-MTS	1	5,251.68	5,251.68	E	C	D
76.	1025739	Check flow introducer mullince sheat RCFW–9.0-38-75-RB-MTS	1	5,251.68	5,251.68	E	C	D
77.	1025740	Check flow introducer mullince sheat RCFW–10.0-38-75-RB-MT	2	7,275.50	14,551.00	E	C	D
78.	1025741	Coil Embolization IMWCE 35-5-10 (Cook)	2	3,987.65	7,975.30	E	C	V
79.	1025743	Catheter SIM 1 HNBR4.0-35-100-P-NS– Cook	1	1,426.32	1,426.32	E	C	E

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S. No.	Item code	Item description	Qty (in nos.)	Unit price (INR)	Total amount (INR)	SDE	ABC	VED
80.	1025748	Needle biopsy coaxial quick-core QCS-20-9.0-10T–(Cook)	1	2,948.40	2,948.40	E	C	V
81.	1025749	Needle biopsy coaxial quick-core QCS-20-9.0-20T–(Cook)	1	2,948.40	2,948.40	E	C	V
82.	1025750	Needle biopsy quick-core QCS-18-9.0-20T–(Cook)	1	2,948.40	2,948.40	E	C	V
83.	1025751	Guide wire Amplatz Ultra Stiff -THSF-35-260-AUS1–(Cook)	7	2,991.00	20,937.00	E	B	D
84.	1025752	Slip catheter tip beacon hydro SCBR5.0-38-100-SIM 1- Cook	2	2,724.63	5,449.25	D	C	D
85.	1025756	Slip catheter tip beacon hydro SCBR5.0-38-100-SIM 2- Cook	1	2,724.62	2,724.62	D	C	D
86.	1025760	Vert beacon tip HNBR5.0-38-125– (Cook)	3	1,426.32	4,278.96	E	C	D
87.	1025761	Vert beacon tip HNBR4.0-38-125– (Cook)	2	1,426.32	2,852.64	E	C	D
88.	1025762	Biopsy quick coaxial set QCS-18-9.0-10T (Cook)	1	2,948.40	2,948.40	E	C	V
89.	1025763	Ultrathane cope type ULT10.2-38-25-MCL–(Cook)	3	4,823.33	14,470.00	D	C	V
90.	1025779	Catheter diagnostics hydrophilic multipurpose (Terumo)	4	3,465.00	13,860.00	E	C	D
91.	1025782	Catheter diagnostics hydrophilic vertebral 5 FR (Terumo)	2	3,465.00	6,930.00	E	C	D
92.	1025783	Catheter diagnostics hydrophilic vertebral 4 FR (Terumo)	7	3,347.14	23,430.00	E	B	E
93.	1025784	Catheter diagnostics hydrophilic Simmons 100 cm (Terumo)	3	3,410.00	10,230.00	E	C	D
94.	1025785	Catheter diagnostics hydrophilic cobra 4 FR (Terumo)	7	3,347.14	23,430.00	E	B	E
95.	1025789	Guidewire GA18153 single (Terumo)	10	1,050.00	10,500.00	E	C	D
96.	1025799	Slip catheter tip beacon hydro SCBR4.0-38-100-N-PS-VERT- (Cook	1	2,724.62	2,724.62	E	C	D
97.	1025801	Guide wire Amplatz Ultra Stiff -THSCF-35-145-AUS1–(Cook)	1	2,492.78	2,492.78	E	C	D
98.	1025802	Slip catheter beacon tip hydro SCBR5.0-38-65-C2-Cook	1	2,724.62	2,724.62	E	C	D

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S. No.	Item code	Item description	Qty (in nos.)	Unit price (INR)	Total amount (INR)	SDE	ABC	VED
99.	1025807	Slip catheter beacon tip hydro SCBR4.0-38-65-C2 4.0FR–(Cook)	2	2,570.40	5,140.80	E	C	E
100.	1025829	Catheter C2 beacon tip HNBR4.0-35-65-P-NS–Cook	1	1,426.32	1,426.32	E	C	E
101.	1025879	Sheath polyurethane 5FR * 11 cm CP-08503-A (Arrow)	1	847.35	847.35	E	C	D
102.	1025880	Sheath polyurethane 6FR * 7.5 cm CP-08603-P (Arrow)	1	785.40	785.40	E	C	D
103.	1025881	Sheath polyurethane 8FR * 11 cm CP-08803 (Arrow)	1	847.35	847.35	E	C	D
104.	1025882	Sheath polyurethane 6FR * 24 cm CL-07624 (Arrow)	1	2,164.05	2,164.05	D	C	D
105.	1025883	Sheath polyurethane 7FR * 24 cm CL-07724 (Arrow)	1	2,167.20	2,167.20	D	C	D
106.	1025885	Sheath polyurethane 8FR * 24 cm CL-07824 (Arrow)	1	2,209.20	2,209.20	D	C	D
107.	1025886	Sheath polyurethane 8FR * 65 cm CL-07865 (Arrow)	1	4,090.80	4,090.80	D	C	E
108.	1025887	Coil Embolization Platinum Nester MWCE 18-7-8 (Cook)	2	7,465.50	14,931.00	E	C	V
109.	1025890	Guidewire GA25263 double (Terumo)	5	1,900.00	9,499.98	E	C	D
110.	1025891	Catheter diagnostics hydrophilic cobra 5 FR C2(Terumo)	7	3,300.00	23,100.00	E	B	D
111.	1025901	Catheter diagnostics 5 F head hunter (Terumo)	3	3,300.00	9,900.01	E	C	D
112.	1025905	Catheter head hunter 4 F(Terumo)	3	3,465.00	10,395.00	E	C	D
113.	1025908	Guidewire PTCA WINN 200T X 300(Abbott)	3	8,000.00	24,000.00	D	B	D
114.	1025909	Guidewire PTCA WINN 40 O.14 300(Abbott)	2	8,000.00	16,000.00	D	C	D
115.	1025946	Catheter diagnostic Yashiro (Terumo)	4	3,300.00	13,200.00	D	C	D
116.	1026169	Coil Embolization Platinum Nester MWCE (Cook)	3	7,266.00	2,1798.00	E	B	V
117.	1026171	Coil Embolization Platinum Nester MWCE 18-14-8 (Cook)	2	7,266.00	14,532.00	E	C	V
118.	1026172	Coil Embolization Platinum Nester MWCE 18-14-10 (Cook)	2	7,266.00	14,532.00	E	C	V
119.	1026173	Coil Embolization Platinum Nester MWCE 18-7-10 (Cook)	3	7,266.00	21,798.00	E	B	V

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S. No.	Item code	Item description	Qty (in nos.)	Unit price (INR)	Total amount (INR)	SDE	ABC	VED
120.	1026188	Coil Embolization Axium	25	37,229.60	930,740.00	E	A	D
121.	1026329	Guidewire SYNCRO^2 0.014 X 200 cm (Stryker)	2	15,750.00	31,500.00	S	B	D
122.	1026330	Catheter ASAP LP aspiration 6 F (Merit)	1	28,000.35	28,000.35	E	B	D
123.	1026366	Check flow introducer mullince sheat RCFW-14.0-38-75-RB-MTS	1	9,660.00	9,660.00	E	C	D
124.	1026575	Kit inflation device – Merit	4	3,750.00	15,000.00	E	C	D
125.	1026583	Guiding sheath KSAW-6.0-18-38-55-RB-ANL2 HC (Cook)	1	5,856.90	5,856.90	E	C	D
126.	1026625	HepaSphere	2	45,000.00	90,000.00	S	A	V
127.	1026642	Guidewire galeo intermediate 0.014 X 190	5	4,200.00	21,000.00	E	B	D
128.	1026719	Particle PVA 200	1	6,982.50	6,982.50	E	C	E
129.	1026720	Particle PVA 1000	1	6,982.50	6,982.50	D	C	E
130.	1026721	Check flow introducer mullince sheat RCFW-12.0-38-75-RB-MTS	1	7,523.25	7,523.25	E	C	D
131.	1026722	Catheter angiographic torcon NB HNB 5.0-38-100-P-NS-JR4- Cook	5	1,251.20	6,256.00	E	C	E
132.	1026723	Catheter angiographic torcon NB HNB 5.0-38-100-P-NS-JR3- Cook	5	1,240.85	6,204.24	E	C	E
133.	1026724	Guide wire Amplatz Extra Stiff -THSCF-35-260-3-AES-Cook	1	2,446.50	2,446.50	E	C	E
134.	1026755	Micro puncture pedal set MPIS-401-PEDAL-NT-U-SST (Cook)	3	3,176.21	9,528.62	D	C	E
135.	1026795	Catheter foundation infusion 4 FR 45 cm X 20 cm – Merit	1	15,540.00	15,540.00	D	C	E
136.	1026797	Catheter glide RF hydrophilic 05F–100 cm (Terumo)	5	3,300.00	16,500.02	D	B	D
137.	1026841	Angioplasty kit – Merit	3	1,155.00	3,465.00	E	C	D
138.	1026896	Catheter angiographic torcon NB HNBR 4.0-35-100-P-NS-H1- Cook	1	1,426.32	1,426.32	E	C	E
139.	1026897	Slip catheter tip beacon hydro SCBR5.0-38-100-P-NS-JB1– Cook	1	2,724.62	2,724.62	E	C	D
140.	1026898	Slip catheter tip beacon hydro SCBR4.0-38-100-PS-VERT Cook	1	2,724.62	2,724.62	E	C	V
		Total value			*5,761,233.77*			

About the authors

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