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Assessment of Supply Chain Management Resilience within Saudi Medical Laboratories during Covid-19 Pandemic

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Abstract

Covid-19 pandemic has affected global supply chains disrupting local inventory management. Multiple studies have shed light on the scarcity of personal protective equipment. Still, not much data was seen on how this crisis resulted in the disruption of other health care sectors. This paper studies how this crisis affected supply chains and inventory management on the laboratory commodities during the Covid-19 pandemic within Saudi Arabia. A cross-sectional qualitative study targeting laboratory personals and suppliers in Saudi Arabia is conducted to evaluate laboratory material inventory management. Our sample includes twelve hospitals and ten suppliers.

The study revealed that the supply chain functions resilience was moderate to mildly affected during the pandemic. The higher effect in the supply chain functions was in the lead time (58%), followed by purchasing (33%), then the inventory (25%). The actual lab supply was significantly affected in 2 hospitals only, moderately affected in 7 hospitals (58%), and mildly affected in 2 hospitals. The unavailability of reagents was the highest result of the disruption (50%) besides the price change and lack of alternatives. Almost (86%) of suppliers reported that their service was partially affected in most supply chain functions although they claimed having reasonable resilience measures/processes to sustain their operations. The highest risk mitigation process were the backup supply, recovery plan, and emergency/disaster agreements coverage. This leads us to conclude that both laboratory and supplier inventory and supply chain management had reasonable resilience processes in Saudi Arabia. Those measures were clear in minimizing the disruption effects caused by the pandemic and having a moderate impact on the laboratory operations.

1. Introduction

Inventory management is a series of events or processes being done in a systematic fashion. It is a main part of supply chain management [1, 2], concerned with having the proper amount of stock in the right place and time. The healthcare supply chain doesn't differ much from the usual definition of the main supply chain management, except that the key outcome saves patients' lives [3]. As it is well known that the healthcare organization is a major part of the industry, any improper or inadequate inventory management will affect the whole population and business. Hospitals are the main part of this healthcare system and are not only a link between partners in the healthcare supply chain but have a more complex framework [4, 5].

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Challenges of the healthcare supply chain differ from other industries; hospitals must balance between cost with the correct amount of inventory while providing high quality patient care. Having "stock out" of materials might affect the patients’ quality of care and might lead to risking patients’ lives [6]. The Covid-19 pandemic outbreak has affected the global supply chain in general but most specifically the health care supply chain since the start of the year of 2020. This crisis brought attention to the weaknesses of the health care supply chain management [7]. Most of the published papers focus on the personal protective equipment. Looking at the pandemic in a broad medical view, having shortage in the protection gear affects the healthcare system but also having shortage in other products results in a challenging care management, including shortage in physicians and nurses, dialysis material, medication, testing supplies and other commodities that are essential for daily care. Laboratory facilities are an important sector of the health care and have a critical role to play starting from the diagnosis till patient recovery [8, 9]. Purchasing and inventory management is considered one of the main processes for laboratories planning and quality management. Having clear instructions and guidelines to provide high quality management for laboratories is one of the Clinical Laboratory Standards Institute (CLSI) essentials. Quality management system is one of the main sections of CLSI. It represents a model for the laboratory services known as QMS-01. The main target of adopting such system is to ensure that the laboratory has planned sufficiently to meet the promised requirements to assure that patients care is always maintained [10]. The laboratory department should develop a well-established inventory management and control system that consists of planning, monitoring, and forecasting.

In this perspective, this paper will shed light on the inventory and supply chain performance for laboratory commodities during the Covid-19 pandemic within the Kingdom of Saudi Arabia. No previous research was found on this topic in the Kingdom making it the first of its kind. The contributions of this paper are twofold: (i) to study the effect of the pandemic on supply chains and inventory management of the laboratory commodities and (ii) to assess the different resilience actions implemented by Saudi hospitals and medical suppliers. The remainder of the paper is as follows. Section 2 describes how the study is conducted. Section 3 presents the results and discussed the findings. Section 4 is devoted for conclusions and suggestions.

2. Methodology

This is a cross-sectional study using primary data via a survey questionnaire that has been constructed to assess the hospital’s inventory management. The respondents involve hospitals or laboratory inventory management within governmental or private hospitals, and the suppliers in Saudi Arabia. The survey excludes everyone not working in the hospital or the laboratory department and their suppling companies. Two different surveys were developed, each targeting a different sector, one for the suppliers within the Kingdom of Saudi Arabia, the other for the hospital or laboratory inventory personals. The survey questions were divided into three parts: (i) assessment of the effect of Covid-19 pandemic on the availability of the supply, (ii) assessment of the depth of the pandemic impact on patient care, and (iii) the type of inventory processes established to enhance the supply chain resilience.

Twenty questions were designed using an electronic online survey platform, Survio.com. The questions were a mix between open ended questions and multiple-choice questions that offer the possibility to evaluate the measured attribute from “extremely affected” to “no effect” scale. The series of response options presented in the scale are defined at the beginning of the survey. A blank part is provided to elaborate on the answers that differ from the ones provided if needed. In some questions multiple answers can be selected while in others a limited choice of one item is allowed. A single survey answer was provided by each hospital and supplier to gather the general data of each organization. The electronic survey was distributed among the targeted group within the Central, Eastern and Western regions of the Kingdom via email or WhatsApp. The study was conducted between October 30th till November 23rd, 2020.

3. Results and discussion

3.1 Hospitals

Table 1 presents the detailed characteristics of the hospitals surveyed. Nine out of the twelve hospitals (75%) had supply chain resilience processes, four of them consider all of risk mitigation inventories, backup supply, recovery plan and emergency/disaster agreements coverage as their chain resilience measure. Direct purchase was acquired by a single hospital that didn’t have any resilience process, but the hospital mentioned that direct purchase is limited and cannot cover their emergency supply deficiencies.

The second section of the survey is devoted to assessing the efficiency of the supply chain during the pandemic. More that 30% of the respondents were impacted by all operations management functions (inventory, transportation, lead time and purchasing). The others were influenced by only one or two functions at a time. Figure 1 summarizes the impact of each function on the hospitals’ supply chain. The inventory management was extremely affected in 25% of the cases and
moderately affected for almost 60% of the cases. Whereas transportation function was extremely affected in 17%, moderately affected in 33%, and not affected in 25% of the cases. Fifty percent of the hospitals were extremely struck down with their lead time function, while four hospitals were moderately affected. Finally, the purchasing function was extremely and moderately affected in four and five hospitals respectively.

Table 1: General characteristics of the surveyed hospitals.

| General hospital characteristics | Frequency |
|---------------------------------|-----------|
| Type of institution:            |           |
| Governmental Hospital           | 6 (50%)   |
| Private Hospital                | 6 (50%)   |
| Organization size:              |           |
| Less than 100 beds              | 1 (8%)    |
| 100-500 beds                   | 5 (42%)   |
| More than 500 beds              | 5 (42%)   |
| Other (Private lab)             | 1 (8%)    |
| Supply chain structure:         |           |
| All (Demand management,        | 7 (57%)   |
| acquisition, logistics, disposal management and Inventory management). | |
| Demand management, logistics and inventory management. | 2 (17%) |
| Logistics and inventory        | 1 (8%)    |
| management                      |           |
| Inventory management only.      |           |
| Supply chain management:        |           |
| Automated                       | 4 (34%)   |
| Partially automated             | 7 (58%)   |
| Manual                          | 1 (8%)    |
| Have an inventory management software: |       |
| Yes                             | 10 (83%)  |
| No                              | 2 (17%)   |
| Have a supply chain resilience measure: |     |
| Yes                             | 9 (75%)   |
| No                              | 3 (25%)   |
| Type of supply chain resilience measure: |       |
| All (Risk mitigation inventories, backup supply, recovery plan and emergency/disaster agreements coverage). | 4 (34%) |
| Risk mitigation inventories, backup supply and emergency/disaster agreements coverage. | 1 (8%) |
| Backup supply and recovery plan. | 1 (8%)    |
| Backup supply                   | 2 (17%)   |
| Risk mitigation inventories      | 2 (17%)   |
| Direct purchase                 | 1 (8%)    |

The third part of the survey focuses on specific pandemic questions. Most of the hospitals (83%) have an automated inventory management system to monitor their laboratories’ inventory. These organizations use some inventory methods such as ABC analysis, minimum safety stock and some inventory management software applications e.g., NGHA Oracle, AlinIQ -IMS ABBOT, etc. The supply chain of most of the participants has been moderately affected at a percentage of 58% and 17% being mildly or extremely affected and only one hospital was not affected. The reason behind is due mostly to the unavailability of reagents, price change and lack of alternatives. Eleven hospitals were performing Covid-19 testing during that time, four of them were getting their supplies from one reliable supplier and four hospitals received it from either reliable suppliers or from excess stock exchange between hospitals. Indeed, during that time four hospitals’ laboratories suffered from shortage in core lab testing only, while three laboratories experienced shortage in specialized testing only and one hospital has shortage in both reagents. Two laboratories suffered from shortage in all reagents (collection sets, core lab testing, specialized and microbiology testing). Only one hospital was not affected at all while another hospital had shortage in other reagents such as Fibrinogen and D-Dimer. The strategy implemented to face these challenges is to collaborate with other institutions that have an emergency supply storage.

3.2 Suppliers

The electronic survey considers 10 valid submissions. The first part of the survey was about general institution characteristics as presented in Table 2. Eight out of the ten suppliers have supply chain resilience measures, 70% of them have all these resilience measures (risk mitigation inventories, backup supply, recovery plan and emergency/disaster agreements coverage).

The second part of the survey demonstrates that the efficiency of supply chain organizations was influenced by all the following functions: inventory, transportation, lead time, and purchasing in 70% of the organizations. Figure 1 shows that 30% and 60% of the suppliers’ inventory was extremely and moderately affected respectively while the transportation as well as the purchasing functions was extremely and moderately affected in 50% and 40% of the cases. Similarly to hospitals, the lead time function for suppliers was extremely affected in 60% of the cases. All the suppliers use automated inventory management software with seventy percent use the Minimum Safety Stock software, and the remaining organizations use either the ABC analysis method or the Fast Slow software’s to manage their stocks. During Covid-19 the suppliers supply chains got affected in 40% of the cases and moderately affected in 50% of the cases. This is due to many reasons including the unavailability of reagents, the price change, and the lack of alternatives.

With regards to reagents shortage, 60% of the suppliers are affected in all of collection sets, core lab tests, specialized and microbiology testing. As a remedy to face these challenges, 40% of the suppliers tried to enlarge their suppliers base and signed contracts with new companies, 20% of them relied on...
their emergency stock and 40% worked on improving their transportation strategies. The suppliers supply chain management is affected mainly by the inventory disruption (70%). The results of this disruption are the loss of contracts and getting bad reputations.

Table 2: General characteristics of the surveyed suppliers.

| General supplier’s characteristics | Frequency |
|-----------------------------------|-----------|
| **Type of institution:**          |           |
| Manufacture                       | 1 (10%)   |
| Supplier                          | 9 (90%)   |
| **Supply chain structure:**       |           |
| All (Demand management, acquisition, logistics, disposal management and Inventory management) | 7 (70%) |
| Demand management, logistics and inventory management. | 1 (10%) |
| Logistics only.                   | 1 (10%)   |
| Inventory management only.        | 1 (10%)   |
| **Supply chain management:**      |           |
| Automated                         | 5 (50%)   |
| Partially automated               | 4 (40%)   |
| Manual                            | 1 (10%)   |
| **Have an inventory management software:** |     |
| Yes                               | 7 (70%)   |
| No                                | 3 (30%)   |
| **Have a supply chain resilience measure:** | |
| Yes                               | 8 (80%)   |
| No                                | 2 (20%)   |
| **Type of supply chain resilience measure:** | |
| All (Risk mitigation inventories, backup supply, recovery plan and emergency/disaster agreements coverage) | 7 (70%) |
| Risk mitigation inventories and emergency/disaster agreements coverage. | 2 (20%) |
| Risk mitigation inventories and recovery plan. | 1 (10%) |

3.3 Observed Impacts of SC disruption

In this project, we studied the pandemic disruption on laboratory supply inventory using two different surveys. One was directed to laboratories, and the second was sent to suppliers operating as manufacturers or vendors in Saudi Arabia. The impact of the pandemic on laboratories inventory management and the disruption level is strongly related to the supply chain strategies implemented individually, nationally, and globally and has bad consequences. Indeed, the survey showed that more than 60% of the respondents confirmed that patient care was adversely afflicted by the disruption in inventory. The effect took a form of test cancellation or delay (routine testing and diagnostic testing related to Covid-19 patient management), which could endanger patient care and affect reputation. More specifically, the direct effects observed are:

- Some routine testing was vital for Covid-19 patient care, which created extra demand above the usual expected number of tests. That put a strain on the operation. The list of laboratory tests for Covid-19 patient's management such as (complete blood cells, coagulation profile testing, liver function) was essential to indicate other medical problems such as respiratory distress, organ failure, or thrombosis. Almost half of the surveyed laboratories confirmed that their operation experienced a lack of reagents in this category, which led them to borrow from other hospitals to cover that shortage.
- The cancellation of all elective admission or surgeries and the remarkably low outpatient visitation due to the enforced lockdown caused low utilization of most basic laboratory testing.
- Almost all specialized testing - such as genetic testing - was ceased.
- Many labs faced wastage of reagents due to short expiry date and low utilization.

3.4 Solutions and recommendations

As a remedy, the ministry of health has limited the license to perform the molecular or screening Covid-19 diagnostic tests to MOH regional laboratories to ensure dealing with reliable suppliers and to avoid supply interruption. Also, as mentioned above, the lead time, which is the period between placing the order and receiving the order, was the most important impact of the pandemic for 70% of suppliers and 54% of hospitals. It is the main reason behind the supply chain disturbance as the ceased air fright internationally played a factor in influencing refilling the stocks, mainly from American and European manufacturers. Other than that, the impact was not that drastic.

Figure 1. The extent of the pandemic effect on the hospital supply chain efficiency
in other inventory management areas; despite the inconsistency of our respondents in defining clear measures of SC resilience. This indicates that there is a proper inventory planning in all laboratories surveyed. This is due to the fact that most healthcare facilities have a mandatory Accreditation of the Saudi central board for accreditation of healthcare institutions (CBAHI). The Collage of American Pathologists-(CAP) must establish clear processes to comply with CLSI guidelines in terms of inventory management and to mitigate risk when it occurs.

In addition, 85% of licensed laboratories report that the molecular diagnostic tests for Covid-19 was not interrupted and that they have a reliable supplier following the MoH’s initiative. The remaining 15% of hospitals indicate that molecular testing was not done in house. On the other hand, 70% of the suppliers answered that they have implemented a system to support the supply chain's resilience, including risk mitigations, recovery plans, backup safety supplies, disposal management, and emergency/disaster agreement coverage. The use of inventory software can also save a great deal of time and increase data storage & data analysis capabilities.

4. Conclusions

Despite the disruption in inventory management in both laboratories and suppliers, they both demonstrated reasonable resilience. The laboratories showed ownership in taking all measures to sustain inventory for in-house diagnostic testing. It was also necessary for some tests to be shifted to other institutions, whether as part of the approved protocol, such as in Covid-19 testing sent to Ministry of Health (MOH), or other tests not available in-house due to lack of reagents. Although no one could predict the disruption's onset, it appears that suppliers and manufacturers alike were able to cope with the demand created by unprecedented disruption. Based on Saudi direction toward technology and infrastructure enhancement we suggest to create a central inventory management system that will help healthcare sector to avoid and overcome any future challenges and risks. If this system is implemented, it might improve the Saudi health care supply chain resilience from moderately to mildly effected to none.

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References

[1] Chopra, S. Supply chain management; strategy, planning and operation. 6th ed; 529. (2013).
[2] Neale, J. Tomlin, B. Willems, S. The role of inventory in superior supply chain performance in the practice of supply chain management: where theory and application converge. 1st ed; 31-59. (2004)
[3] Conceição,J. Spiege,T. De Vasconcelos Silva, A. Da Cunha Reis, A. Issues in Healthcare Supply Chain Management: From Literature to Practice. International Journal of Supply Chain Management 9 (2): 2050-7399. (2020).
[4] Abdulsalam, Y. Gopalakrishnan, M. Maltz, A. Schneller, E. Health Care Matters: Rs in and of the Health Sector. Journal of Business Logistics, 36(4): 335-339. (2015).
[5] Ravkovsla, A. Stratieva, S. A taxonomy of healthcare supply chain management practices. Supply Chain Forum: An International Journal, 19(1): 4-24. (2018).
[6] Moons, K. Waeyenbergh, G. Pintelon, L. Measuring the logistics performance of internal hospital supply chains. A literature study Omega, 82: 205-217. (2019).
[7] Miller, F. Young, S. Dobrow, M. Shojania, K. Vulnerability of the medical product supply chain: the wake-up call of COVID-19. BMJ Qual Saf, 0:1-5. (2020).
[8] Office of Inspector General of the Department of Health and Human Services US. Hospital experiences responding to the COVID-19 pandemic: results of a national pulse survey March 23-27, 2020. Washington, DC: US Department of Health and Human Services, Office of Inspector General, (2020).
[9] Ranney, M. Griffeth, V. Jha, A. Critical Supply Shortages - The Need for Ventilators and Personal Protective Equipment during the Covid-19 Pandemic. N Engl J Med, 41 (1): 382. (2020).
[10] Quality Management System: A Model For Laboratory Services; Approved Guidelines- Fourth Edition, 31(5). (2019).