Supply chain challenges of personal protective equipment, and methods of mitigation amidst COVID-19 pandemic: a qualitative study from Sri Lanka, a developing country in South East Asia

Ishanka Ayeshwari Talagala (ishankat@uom.lk)
Faculty of Medicine, University of Moratuwa
Keerthi Mahesh Kodithuwakku
Post Graduate Institute of Medicine, University of Colombo

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Abstract

Background

Personal Protective equipment (PPE) are essential for healthcare workers to prevent the disease spread. With COVID-19 pandemic, although demand for PPE increased, its supply chain was adversely affected. This case-study describes the supply chain challenges of PPE and mitigation measures during COVID-19 pandemic in Sri Lanka, a developing country in South East Asia.

Methods

In-depth interviews were conducted among officials (N = 14), who were directly involved with PPE procurement to the Health Ministry of Sri Lanka, at the Medical Supplies Division, State Ministry of Production Supply and Regulation of Pharmaceuticals and State Pharmaceutical Corporation. Study sample was collected until data saturation. A semi-structured interviewer guide was used to assess the PPE supply chain challenges and mitigation measures undertaken by Sri Lanka, during the COVID-19 pandemic. Thematic analysis was done.

Results

It was revealed that the preparation for an un-interrupted PPE supply prior to pandemic hitting the country was unsatisfactory. High cost; unavailability of certified suppliers; unavailability of PPE globally and locally; lack of raw materials; quality failure; delays in procurement procedure; increased demand and its dynamicity; and lack of funds challenged the PPE supply chain. Intergovernmental negotiations; encouraging local production; purchasing from local suppliers; issuing guidelines for PPE usage; and obtaining support from development partners/INGOs were the mitigation strategies that were undertaken.

Conclusions

Sri Lanka, as a country with limited resources, has faced several PPE supply chain challenges during the pandemic. Policy makers need to undertake measures to improve the readiness prior to similar disasters in the future. In addition, encouraging local PPE production, establishing quality assurance mechanisms, development of relevant guidelines and improving staff capacity on the procurement process are recommended to face disasters of such caliber in the future.

Background

The novel Coronavirus disease was first reported in Wuhan, China in December 2019. Considering the burden and the rapid spread of the disease, the World Health Organization (WHO) declared it as a public health emergency of international concern on 30th January 2020 and as a pandemic on 11th March 2020.[1] Accordingly, as of 4th January 2023, there were 655,689,115 confirmed cases and 6,671,624 deaths reported globally.[2] In addition, the pandemic continues to affect the economies[3] and challenges the health systems of the countries across the globe.[4, 5]

Sri Lanka, low income country in the South East Asia, currently is facing the third wave of COVID-19 which occurred following the carefree new year celebrations in 2021 and with the introduction of the delta strain of COVID-19 virus into the country. As of 4th January 2023, Sri Lanka reported 671,903 confirmed cases and 16,817 deaths.[6] Sri Lanka undertook 'whole-of government', 'whole-of-society' approach with urgent and aggressive actions to contain and mitigate the disease within the country. Also, Sri Lanka commenced the vaccination programme against COVID-19 on 29th January 2021.[6]

It is well known that COVID-19 virus is transmitted through aerosols or droplets sprayed by an infected individual through coughing, sneezing, speaking and even during breathing. In addition, the virus gets transmitted if a person comes into contact with an infected individual's respiratory secretions and also via contaminated surfaces and equipment.[7] Health care workers are in constant contact to persons that could be infected with COVID-19 and hence, are at a higher risk of infection, as they are continuously exposed to aerosols produced by patients during medical examination and management.

Personal Protective Equipment (PPE) are generally used by healthcare workers as a universal precaution against infections in their routine work. Thus, use of PPE, including gown, gloves, face mask, face shield, boots and goggles by healthcare workers is essential to protect themselves from being exposed to various diseases including COVID-19. If not properly protected, the healthcare workers who are the front-line service providers against Coronavirus disease, would get infected and will spread the infection to their families, friends and patients. Considering this risk, the WHO recommended the healthcare workers to essentially wear PPE during patient care[8], especially during the pandemic period.

Considering the rapid surge of demand for PPE during the COVID-19 pandemic, the WHO estimated that the requirement of medical masks, gloves and goggles would be 89 million, 76 million and 1.6 million respectively, per month, for COVID-19 response[9] and also emphasized the importance of rapid increase in their manufacturing by the PPE industry. The WHO also urged the governments to quickly act on increasing and securing their PPE supply as well[9].

The mismatch between the demand and the supply of PPE occurred following the rapidly increasing COVID-19 infected persons, due to misinformation; unavailability of raw materials for the PPE production; due to export bans and boarder lockdowns implemented by countries; transport, shipping and freight bans; profiteering; panic buying; stockpiling and limited work force capacity;[8, 10] which collectively overwhelmed the global production of PPE. Also, the local supply chains of PPE were affected due to lockdowns, travel bans and factory shutdowns during the pandemic.[11]

In the Sri Lankan health system, the Medical Supplies Division (MSD) of Ministry of Health (MoH) centrally purchases all PPE required for all healthcare workers at the state sector healthcare institutions across the country. Procurements are done through the State Ministry of Production Supply and Regulation of Pharmaceuticals (for urgent procurements) and the State Pharmaceutical Corporation (SPC) (purchasing entity to the MoH) (Fig. 1). These PPE are then distributed to the regional MSDs in each district of the country (Regional Medical Supplies Division – RMSD). From each RMSD, the PPE will

be re-distributed among the healthcare institutions within the respective district, as per their requested demand.

Considering the importance of PPE in healthcare, especially during the pandemic, MSD thus, so far has distributed a considerable number of PPE for healthcare workers across the country. Nevertheless, it is important to note that reportedly there was a massive gap between the demand and supply of PPE across the globe, due to various reasons during the pandemic. Therefore, this study was conducted with the aim of assessing the supply chain challenges in provisioning PPE to Sri Lanka, and the measures that were undertaken to mitigate these challenges as an economically developing country, during the COVID-19 pandemic. Findings of this study gave an insight to the policy makers of Sri Lanka on the challenges faced in supplying PPE to the healthcare workers in the pandemic and a baseline to plan and implement relevant actions to secure an uninterrupted supply of PPE during such a disaster in the future. In addition, sharing the experience of Sri Lanka would provide baseline information for many such economically developing countries across the world, to plan and face disasters of similar caliber in the future.

Methods

This study was conducted with the aim of identifying the PPE supply chain challenges and the mitigation measures that were undertaken in Sri Lanka during the COVID-19 pandemic. In-depth interviews were conducted by the authors, among the officials at the MSD (n = 5), State Ministry of Production Supply and Regulation of Pharmaceuticals (n = 4) and SPC (n = 5), who were directly involved with the procurement of PPE for the MoH (N = 14). A semi-structured interviewer guide with open ended questions was utilized to obtain details regarding the measures taken by the MoH to ensure an un-interrupted supply of PPE during the preparation phase of COVID-19 outbreak; change in the demand for PPE during the pandemic; challenges faced in the supply chain of PPE during the pandemic and measures undertaken to mitigate and in response to the challenges of the supply chain. The study sample for the interviews was obtained until the point of data saturation. The interviews were conducted during June – August 2022, while the country was facing the third wave of COVID-19 outbreak. Following informed written consent from the study participants, all interviews were recorded and then were transcribed verbatim. Thematic analysis of this transcribed text was conducted. Ethics clearance to conduct the study was obtained from the ethics review committee of the Faculty of Medicine, University of Colombo, Sri Lanka.

Results

Following were the findings of the in-depth interviews following thematic analysis:

1. Preparatory Measures Undertaken For An Un-interrupted Supply Of Ppe Before The Pandemic Hit The Country

Considering the global context of rapidly spread of COVID-19 infection and rapidly increased demand for PPE, the interviewees were initially inquired about the preparatory measures for the supply chain of PPE

that were undertaken by the Ministry of Health before the COVID-19 outbreak hit the country. The participants indicated that the Ministry of Health indeed undertook certain measures to assure the supply chain of PPE:

"The Health Ministry developed a monitoring system for the PPEs. Using all data available, a model was developed to predict the potential requirement of PPE and initiated procurement of PPE closer to that amount, even before COVID was widely spread in the country" (M02).

However, according to the respondents, this preparation at the central level was not satisfactory.

"..just like Ebola, people though that this also will not hit the country. Therefore, although we were prepared to a certain extent, it was not satisfactory" (M03).

"We thought we were ready. But never expected the gravity of the disease to be this high…" (M02).

2. Change In Demand For Ppe During The Pandemic

Generally, MSD prepares the national requirement for PPE (Fig. 1). The respondents indicated that there was a drastic increase in the demand for PPE during the pandemic period compared to the pre-pandemic period.

Considering the PPE kits (single package containing all components of PPE such as masks, apron, gloves, face shield, goggles), it was indicated that the MSD designed and specified the specifications for each component of the PPE kit, since it was not previously used in the country.

"The demand for PPE kits increased especially after the first wave.." (M02).

"We had only the separate PPE components. We did not have all together in one pack. Such kits were not available in the market for us to purchase. Therefore, we had meetings with Physician at the National Institute of Infectious Disease and designed a new PPE kit and made the relevant specifications as well" (M01).

The demand for the N95 masks was also considerably high during the pandemic;

"During the pre-pandemic period, there was a varying demand for N95, with the demand increasing during the flu outbreaks. Therefore, we always had a considerable number of N95s in hospitals. But the demand was not this high. After the pandemic occurred, the demand for N95 went sky high" (M01).

Also, the demand for all other PPE components were drastically increased during the pandemic as well.

"Demand for all the PPE components was already there as these were being used during patient care and management. The quantity however alarmingly increased with the occurrence of the pandemic" (M01).

"… We used to have only one order annually for the surgical face masks before the pandemic. Now we need to procure at a higher frequency and in significantly higher numbers. It is the same for all PPE" (M02).

However, this demand for PPE was found to be unrealistic as per the respondents.

"The numbers they requested were sometimes unrealistic. We realized in some hospitals, while the Doctors wear only the apron to examine and manage patients, certain other staff categories refused to wear only the apron and requested for the whole kit, which has eight components. Of course, the fear psychosis played a role" (M03).

"It was reported initially that the healthcare staff changed PPE kits 2–3 times per day, due to many reasons such as the fear of spreading the infection; difficulty in wearing one PPE kit continuously in our temperate climate; and also, because we did not provide them a guideline on wearing PPE kits" (M02).

3. Challenges Faced In The Ppe Supply Chain During The Pandemic

Several themes were identified as challenges of the PPE supply chain during the pandemic, following thematic analysis.

• High Cost Of Ppe

One of the major challenges faced by the SPC in the supply chain of PPE was the high cost of the PPE kits and PPE components.

"With the demand and scarcity of the PPE in the world, the prices suddenly went up during the pandemic. A PPE kit each costed about LKR.7000/=. Before the pandemic, N95 masks were purchased at a low rate and then its price went up to LKR. 400/= each during the pandemic. Whereas the price of the surgical gloves, which was about LKR. 12/= per pair went up to LKR. 16/=" (S01).

Another respondent stated:

"Prior to the pandemic, we purchased a surgical face masks at a rate of about LKR. 3.50–4.50 each. Then the price went up to about LKR. 45/= during the pandemic" (S02).

• Unavailability Of National Medicines Regulatory Authority (Nmra) Certified Suppliers To Supply Ppe

In order to procure medical supplies and medicines to Sri Lanka, like in any other country, it is essential by law that the product and the supplier is assessed and certified. The NMRA is the institutions which assesses the quality of the medical supplies and issues this certificate in Sri Lanka. Unavailability of

adequate number of NMRA certified suppliers in the country was a challenge faced during the pandemic, to meet the increasing demand of PPE.

"We had an issue initially with getting PPE. As an example, we had only two suppliers at that time who had the NMRA certification for face masks. There were people who had the power to provide PPE but, they were not certified. Therefore, we had to depend only on few suppliers" (P01).

• Unavailability Of Ppe Locally And Globally

Unavailability of PPE locally as well as globally was another challenge in the supply chain. Higher prices and issues related to production as reluctance of people to come to work were few of the reasons behind.

"With the pandemic spreading, there were no PPE available to purchase from anywhere in the world. Countries did not sell as they kept reserves for their needs, as it was highly uncertain" (P01).

"Even we manufactured locally, the workers were reluctant to come for work. Their families did not allow them to come for work especially by public transport. Sometimes, even with the transport being provided and over-time was paid, they were reluctant to come. Therefore, the local production was low. Otherwise, there was no transportation issues regarding the supply of the products" (S04).

• Lack Of Raw Materials For The Local Manufacturers Of Ppe

There was a delay in PPE supply from the local manufacturers as the required raw materials were unavailable for them due to lockdowns of countries and closure of relevant factories.

*"..local manufacturers could not provide PPE as they didn't get the required raw materials due to various reasons such as factory shutdowns and country or area lockdowns in other countries, especially, China" (*S03).

"Local manufacturers had issues in producing as they could not get the raw materials from China to manufacture PPE" (S02).

• Quality Failures Of The Ppe Products Received

As indicated by the respondents, there were several issues related to the quality of the PPE received.

"There were quality failures of the PPE. Sometimes the Zip just broke by a simple pull while testing the samples" (P01).

"There were quality issues with the masks we received" (S01).

• Delays In The Procurement Procedure

Also, there were delays in the procurement procedure, due to failures from the suppliers' side, such as not providing samples as requested, failure to supply certain items, products not in line with the specifications requested.

"..Some did not provide the requested samples for the technical evaluation committee to assess, sometimes all the bids were not on the specifications that we provided, just submitted the bid with the best items they had. This resulted in delays in the procurement process. There were instances we had to re-call the tender" (P02).

"…Once, the supplier said that he cannot provide certain items that was in the list, after we had awarded him the tender. Then we had to call tenders for that particular item separately. All these took additional time" (S03).

Also, respondents reported that certain specifications given were unrealistic.

"The specifications given were unrealistic. None of the products in the market could meet all the specifications. Therefore, either we should have practical specifications, or they should select the best from the available lot in the evaluation, considering the circumstances. But, after the evaluation, they completely rejected the bids and had to re-call tender" (P02).

In addition, there were delays in the procurement process due to the lack of knowledge of the staff on the procurement process as well.

"There were delays due to the lack of knowledge on the procurement process among the staff including higher officials" (P02).

• Dynamicity In The Demand For Ppe

As per the respondents, the demand for PPE was greatly varying, sometimes even daily. This dynamicity in demand for PPE was a challenge in procuring PPE.

"The demand for PPE was changing almost daily. There was no way that we could think of a fixed number of PPE to procure. If it was a fixed number that needed to be procured, things would have been much easier" (S02).

• Lack Of Funds

With the increased cost of PPE and the high demand that needed to be catered, Ministry of Health had to spend a significant amount of funds for procuring PPE. However, there was a considerable difference

between the funds allocated to the MSD and the exact expenditure. The Rupee crisis has made the situation worse.

"…By April 2021, the difference between the expenses and the allocation was about LKR. Mn.1774. We have not yet received this money" (M01).

"Because of the Dollar crisis, people are facing issues with getting raw materials from foreign countries. Because of the Rupee crisis the suppliers have not been paid at the right time. They cannot pay the salaries of the employees on time" (M02).

4.measures Undertaken To Mitigate The Challenges Of Ppe Supply Chain During The Pandemic

Following themes were identified regarding the mitigation strategies:

• Intergovernmental Negotiations For Ppe

When there were no PPE to be purchased in the market due to high global demand, government to government negotiations had been done.

"With the high global demand, we could not purchase PPE. In that case, the hierarchy of the country, spoke to the Presidents of other countries directly and requested for PPE for Sri Lanka. So, the government hierarchy played a significant role" (M02).

"With all the restrictions, the local manufacturers had issues with obtaining the raw materials from China. The government got involved and the products were brought into the country as a government to government negotiation by air freight" (M01).

• Local Production Of Ppe By Local Manufacturers

Encouraging the local manufacturers to produce PPE was another mitigating strategy used. In addition, local textile manufacturers supported the Ministry of Health by producing PPE as well.

"There were local manufacturers who produce and export PPE to other countries. We requested them to produce PPE as per our requirements as well" (M03).

"One of the local textile factories, shifted their textiles orders to their other factories and used on whole factory to produce PPE for us. And most of the consignments were given free, especially during the second wave of COVID" (S01).

"We have a factory producing N95 masks in the free trade zone now and we have another textile factory producing PPE kits for the country" (S03).

• Shift to purchase PPE from local suppliers during the pandemic

According to the respondents, there was a shift from the foreign suppliers to more local suppliers for PPE during the pandemic.

"Earlier we got all PPE from foreign suppliers. Most came from China and India. We also got certain products from European countries including Germany. Especially, goggles and face shields were imported" (S02).

"Gradually, the local manufacturers established the manufacturing plants in Sri Lanka. So, from the foreign supply, we slowly shifted to the local suppliers. Now we get the products mostly from them" (S03).

The respondents stated that the shift to purchase from the foreign suppliers to the local suppliers provided added advantages.

"Procuring from the local suppliers saved a lot of money to the government. It must have saved at least about LKR.3.00 per item. Since the procurements were millions in quantity, it indeed saved a lot of money per consignment. Also, the supply delays were minimum" (S01).

• Measures To Limit The Usage Of Ppe

Considering the demand and supply mismatch, guidelines were issued by the Ministry of Health on rational use of PPE during the pandemic.

"Especially in the initial period of the pandemic, staff was changing PPE from one patient to the other for the fear of spreading the infection. Then we prepared and disseminated guidelines on the rational use of PPE" (M01).

• Support Received By The Development Partners And International Non-governmental Organizations (Ingo)

According to the respondents, the development partners and INGO have supported the Ministry of Health in obtaining PPE during the crisis.

"Due to the high lead time in manufacturing, the lead time for imports and due to quality failures, sometimes we had failed to supply PPE on time. In such instances, we requested support from WHO and certain INGOs. The Sri Lanka Red Cross and WHO country office has supported us in obtaining PPE" (M01).

Discussion

This study was conducted to obtain an insight on the supply chain challenges of PPE and mitigation measures undertaken for these challenges faced by the MoH, Sri Lanka, which is a low resource country in South-East Asia, amidst COVID-19 pandemic.

It is essential that the healthcare staff wear PPE as the frontline workers of COVID-19 response, as they are continuously exposed to the patients with coronavirus disease and hence, were at a higher risk of contracting the disease[12]. In addition, healthcare staff being positive for COVID-19 would add additional pressures on the health system due to the lack of already limited human resources, especially in resource limited settings like Sri Lanka[13].

This led to a drastic increase in the demand for PPE not only locally but also globally[7, 14, 15]. The data obtained from the information management system of the MSD were analyzed by the authors and found that there was a 1.2 times higher demand for surgical gloves; 5.7 times higher demand for Aprons; 3.5 times higher demand for face masks; 23 times higher demand for face shields; and 2.2 times higher demand for surgical hair caps during the pandemic (2020–2021) compared to that of pre-pandemic period (2018–2019), in Sri Lanka. The demand for PPE kits (single package containing all components of PPE such as masks, apron, gloves, face shield, goggles) was originated only after the occurrence of the pandemic. Also, a considerable increase in demand for PPE was seen after October 2020, following the Navy cluster – emergence of the second wave of COVID-19[6] and April 2021, following the carefree new year celebrations and introduction of Delta variant to the country – emergence of the third wave of COVID-19 in Sri Lanka[6].

In order to cater to the increased global demand for PPE, China, being the major PPE producer for the global market reportedly produced about 110 million surgical masks per day compared to the usual 20 million masks during the pre-pandemic period[15]. In addition, UNICEF predicted that the demand for surgical masks, gloves and face shields would drastically increase during the pandemic[16]; while, the WHO estimated that the PPE industry would need to increase the manufacturing of by at least 40% to meet the increasing demand during the pandemic[9]. However, despite the high demand, shortage of PPE was evident in many countries across the globe[14, 15, 17], resulting in WHO Director General Tedros Adhanom Ghebreyesus to state that “the chronic global shortage of personal protective equipment is now one of the most urgent threats to our collective ability to save lives”[13].

According to Cohen and Rodgers, 2020, even though the governments were warned of the gravity of the outbreak, most governments were underprepared to face the pandemic[14]. This lack of preparation was well evident by the increased numbers of health care workers affected by the disease, who either became sick or died[14]. According to the authors as of July 28 2020, there were 1842 healthcare workers including doctors, nurses, physicians’ assistants globally, and 342 in the US died due to the coronavirus disease and another significant number were sick[14]. The picture was the same in Italy, where shortage of PPE resulted in infections and deaths due to COVID-19 among the healthcare staff[15]. It is also reported that, despite the known shortage of PPE across the globe, governments did not respond to the crisis[17] and

had not adequately built or sustained the required PPE stocks to face the pandemic[18]. Nevertheless, the condition was indicated to be the same in Sri Lanka as well, where the preparatory measures undertaken were not adequate. Lack of funds to purchase the required stocks would have been a limiting factor for many countries across the globe especially, the low and middle income countries.

With the rapid spread of COVID-19, the dynamicity of the demand for PPE was increased. Our study indicated that the demand for the PPE considerably changed almost daily, greatly challenging the PPE supply. It was reported that forecasting the demand for the vaccines was easier compared to that of PPE[15]. High cost of PPE, lack of funds and unavailability of PPE globally were some of the major PPE supply chain challenges faced by Sri Lanka. Since the pandemic started, the prices of PPE markedly increased globally where, the price of the N95 masks increased by three times; surgical mask price by six-fold, and surgical gowns price had doubled[15]. This price hike along with the lack of funds limited many economically developing countries in the world including Sri Lanka, in accessing PPE during the pandemic.

Reportedly, China, the major global supplier of PPE, was the major producer of surgical gowns and produced half of the global supply of surgical masks during the pre-pandemic period. However, with the emerge and the wide spread of COVID-19 in China, this production came into a halt, affecting the global availability of PPE[15]. In addition, the national policies to restrict the export of PPE due to sudden significant increase in the domestic requirement for PPE[15, 17] and international travel restrictions made this matter worst[15, 19]. Also, misinformation, price hike, panic buying and stockpiling also contributed to the global unavailability of the PPE[20, 8]. Factory closure, country/area lockdowns, workers being made redundant were other factors that contributed to the global unavailability of PPE[18].

In addition, companies and countries world-wide have been implementing lean supply chain management strategies including Just-in-Time, with the aim of minimizing the cost and as a methodology of inventory efficiency[17]. Thus, leading the production of PPE to become more geographically concentrated[18]. As a result, with the current pandemic, with shutting down of factories and border closures, there was a significant depletion in the national PPE stocks with no buffer stocks to be utilized[10, 19, 18], especially affecting the low and middle –income countries in the world.

On the other hand, it is important to note that although a considerable amount of discussions about the equitable access to vaccines, drugs and diagnostics related to COVID-19 had happened in the world, such attention was not given for PPE[15]. Thus, it is essential that a global healthcare approach and global stewardship is available for combating such pandemic situations in the future[17].

The current study found out that lack of raw materials to the local manufacturers was a major limitation to produce PPE locally. Burki, 2020, reported that inability to obtain the raw materials had resulted in the failure of the local production, resulting in gap between the demand and the PPE production during pandemic[15, 19]. As China has been the major supplier of the raw materials for the production of PPE

globally, with the spread of COVID-19 in China, the companies around the world that had depended highly on China failed to function in their full capacity to produce PPE[19]. Nevertheless, COVID-19 pandemic ultimately surfaced and challenged the fact of medicines and healthcare products being produced by 'globally sourced materials'[20].

With the emergence of novel suppliers into the PPE supply chain, it was evident that there were various quality issues with PPE[21, 18]. Similarly, the current study found out that there were quality failures with PPE. Also, it is reported that certain healthcare systems have purchased PPE from sources without having the capacity and facilities to check for their quality, as this is usually done by the distribution partners[21]. Hence, it is recommended for the health systems to focus on quality assurance, especially during a crisis of this nature in the future[18].

Also, in line with the findings of the current study, it is evident that poor procurement capacities, poor information infrastructure, poor data management, lack of accessibility to real time data on consumables, lack of integration and poor inventory management capacities have also resulted the gap between the supply and the demand of PPE across the globe[18, 17]. These could be major limiting factors especially in Low and middle income countries.

Nevertheless, in the backdrop of these challenges in the PPE supply chain, countries including Sri Lanka have undertaken several strategies to mitigate the impact during the pandemic at least to a certain extent. Exploring the alternatives for PPE and possibility of re-use after sterilization; implementing strategies to reduce PPE use and requesting justifications for shortage of PPE by higher authorities[18, 17] were some of such strategies. MoH Sri Lanka also prepared and disseminated a guideline on the rational use of PPE in hospitals in the context of COVID-19[22].

It is reported that by April 2020, WHO has provided 0.5 million PPE to 47 countries across the globe[10], including Sri Lanka. COVID-19 Pandemic indeed was an opportunity to obtain an insight and experiment with the potential solutions to such emergencies and disasters in the future, especially for low resource settings like Sri Lanka[18]. Production of re-usable medical products, local refurbishment of the supplies and local manufacturing of the medical supplies, prevent depending on limited suppliers for medical products were some of the proactive solutions that several countries across the world including Sri Lanka has undertaken during the pandemic[10, 18]. This shift of enhancing local production and encouraging local suppliers was evidently highly beneficial in Sri Lanka. Hence, would be an important lesson learnt for the developing countries across the world.

Conclusion

Challenges faced in the PPE supply chain by Sri Lanka included high cost of PPE; unavailability of certified suppliers; global and local unavailability of PPE; lack of raw materials for local production; quality failures; delays in the procurement procedure; dynamicity of the demand and lack of funds. Based on the lessons learnt from Sri Lanka, mitigation strategies that could be undertaken to overcome these

challenges by low and middle-income countries across the world would be intergovernmental negotiations for PPE; shifting to local production and suppliers; and obtaining support from the developmental partners.

Abbreviations

HIMS	Health Information Management System
INGO	International Non-Governmental Organizations
MOH	Ministry of Health
MSD	Medical Supplies Division
NMRA	National Medicines Regulatory Authority
PPE	Personal Protective equipment
RMSD	Regional Medical Supplies Division
SPC	State Pharmaceutical Corporation
SPMC	State Pharmaceuticals Manufacturing Corporation
WHO	World Health Organization

Declarations

Ethics and consent

Ethics approval

Ethics approval to conduct the study was obtained from the Ethics Review Committee, Faculty of Medicine, University of Colombo (ID:EC-21-049). The study was conducted in accordance with the Declaration of Helsinki.

Consent to participate

Informed written consent to participate in the study was obtained from each participant prior to interviewing them. The study was conducted in accordance with the Declaration of Helsinki.

Consent for publication

Not applicable. Data leading to identification of the study participants have not been published.

Availability of data and materials

Data will not be shared as prior approval for sharing was not obtained from the study participants. Hence, relevant data used and/or analyzed during the current study are available from the corresponding author, on reasonable request, only for academic purposes.

Competing interests

The authors declare that they have no financial and non-financial conflicting interests.

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Authors' contributions

IA was the principal investigator of the study. IA and MK have made substantial contributions to conception, design and interpretation of data. IA and MK collected data and conducted interviews. IA analyzed the data. IA and MK drafted the manuscript and revised it critically for important intellectual content and IA and MK agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. IA and MK confirm that we had full access to all data and accept the responsibility of submitting for publication.

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Figures

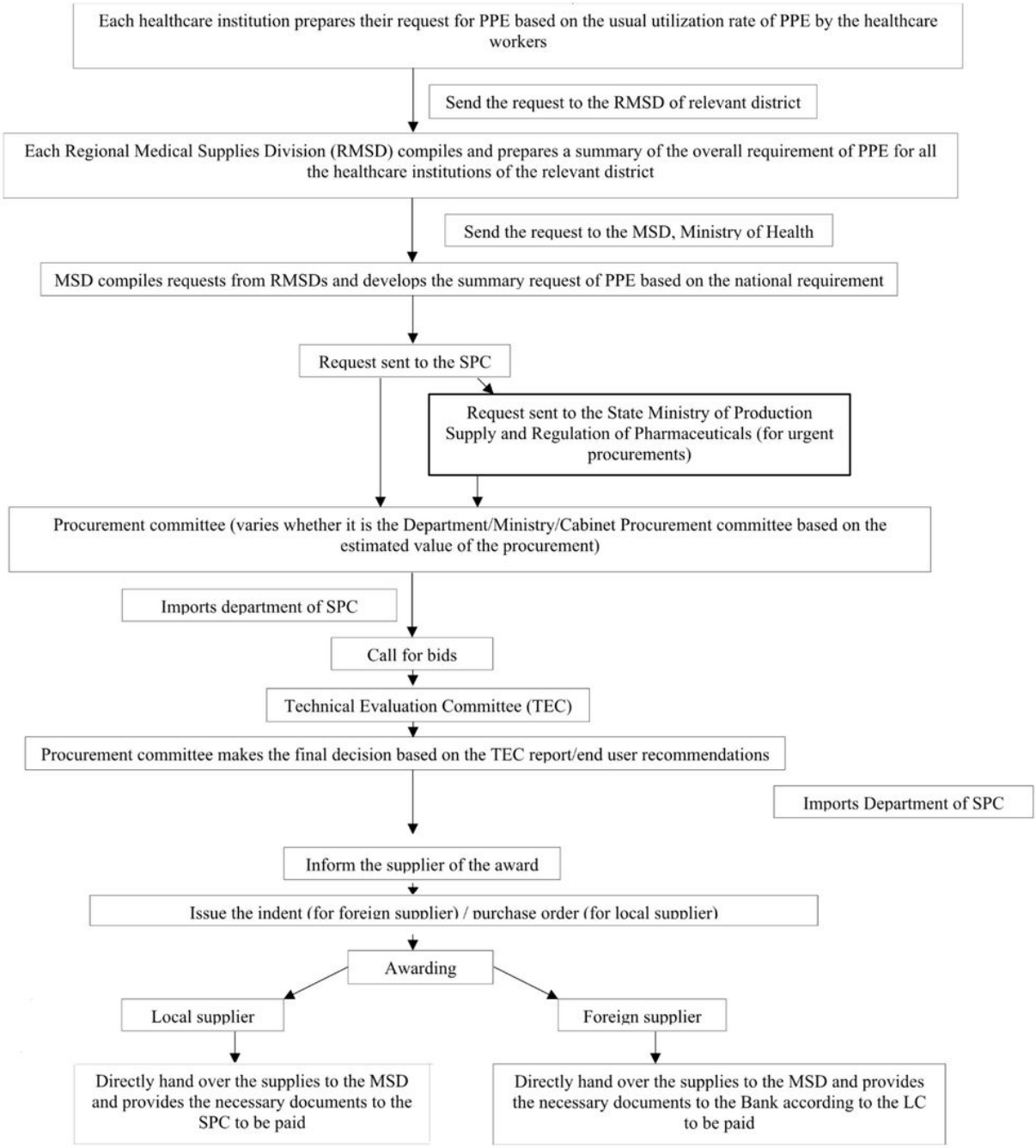

Figure 1

General and urgent procurement process of PPE to the Ministry of Health Sri Lanka