

ADVANCING SUPPLY-CHAIN RESILIENCE FOR CANADIAN HEALTH SYSTEMS

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SUMMARY

Every government leader and health-system leader knew, or should have known, that a pandemic was inevitable. Yet, when the COVID-19 pandemic arrived, the Canadian health-care supply chain was not ready.

Critical supplies were held up by lockdowns in China and disruptions in transportation networks. Competition between provinces for emergency supplies meant places with the greatest needs were not prioritized. Health-care professionals were given top-down orders on the supplies they were to use, denied the autonomy to make infection-control decisions applicable to their specific situations. With no direct involvement by health-care workers in procurement decisions, governments bought many unnecessary, poor-quality or counterfeit supplies that were wasted. Shortages drove a “hospital-first” approach, which resulted in supplies being diverted away from non-hospital settings experiencing critical need, such as long-term care homes, sometimes with devastating consequences.

To ensure a more resilient health-care supply chain that will withstand future disruptions, shortages and crises, policy-makers need to learn from the problems encountered during the COVID-19 pandemic. A more sustainable supply chain requires data standards and digital infrastructure that enable the tracking of supply inventories and product usage in near real time. It is critical that this information is consistent across all provinces, and at the federal level, to provide true visibility that monitors supplies and needs, while identifying risks of shortages early. It is also vital that the health-care workforce is involved

in the management and maintenance of supplies, so that they can inform decisions that serve patients and feel confident in the safety of their own workplaces.

Canada also needs to ensure it no longer pursues a supply-chain strategy that prioritizes lowest-cost producers, which resulted in our overdependence on a single region. Resilience in the supply chain will require diversification of product sources. It will also benefit from policies that support domestic manufacturers, including by providing them privileged access to provincial health-care markets, allowing Canadian suppliers to grow to sufficient scale so they can become reliable sources for the domestic market and also profit from international sales.

The fragility of the supply chain that was exposed by the COVID-19 pandemic revealed just how important the supply chain is. Human lives depend on 100-per-cent supply availability. Accurate, timely, automated and interoperable supply data, and the involvement of frontline health-care workers in procurement decisions, make data-driven and collaborative leadership possible, while mitigating the risks of future supply disruptions. The COVID-19 pandemic will not be the last health-care supply crisis that Canada will face, but the lessons learned from this crisis about supply-chain fragility will allow us to become much better prepared for the next one.

AMÉLIORER LA RÉSILIENCE DE LA CHAÎNE D'APPROVISIONNEMENT DES SYSTÈMES DE SANTÉ AU CANADA

Anne W Snowdon

RÉSUMÉ

Tous les leaders du gouvernement et tous les responsables du système de santé savaient, ou auraient dû savoir, qu'une pandémie était inévitable. Pourtant, lorsque la pandémie de COVID-19 est apparue, la chaîne d'approvisionnement canadienne des soins de santé n'était pas prête.

Des fournitures essentielles ont été retenues par les blocages en Chine et par la perturbation des réseaux de transport. La concurrence entre les provinces pour le matériel d'urgence a fait en sorte que les endroits où les besoins étaient les plus grands n'étaient pas prioritaires. Les professionnels de la santé ont reçu des ordres quant aux fournitures qu'ils devaient utiliser, les privant ainsi de l'autonomie quant aux décisions de contrôle des infections propres à leurs situations particulières. En l'absence d'implication directe des travailleurs de la santé dans les décisions d'achat, les gouvernements ont acheté de nombreuses fournitures inutiles, de mauvaise qualité ou contrefaites qui ont été gaspillées. Les pénuries ont conduit à une approche préconisant « l'hôpital d'abord », ce qui a entraîné le détournement du matériel des milieux non hospitaliers ayant des besoins particuliers, comme les foyers de soins de longue durée, parfois avec des conséquences dévastatrices.

Pour garantir une chaîne d'approvisionnement plus résiliente qui résiste aux perturbations, aux pénuries et aux crises, les décideurs politiques doivent tirer leçon des problèmes rencontrés pendant la pandémie de COVID-19. Une chaîne d'approvisionnement plus durable nécessite des normes en matière de données ainsi qu'une infrastructure numérique qui permettent le suivi des stocks d'approvisionnement et de l'utilisation des produits en temps quasi réel. Il est essentiel que ces informations soient cohérentes dans toutes les provinces et au niveau fédéral, afin d'offrir une véritable visibilité qui permet de surveiller l'approvisionnement et les besoins, tout en repérant rapidement les risques de pénurie. Il est également essentiel que les travailleurs de la santé soient impliqués dans la gestion et l'entretien des fournitures, afin qu'ils puissent prendre des décisions éclairées au bénéfice des patients et qu'ils aient confiance dans la sécurité de leur lieu de travail.

Le Canada doit également s'assurer de ne plus poursuivre une stratégie de chaîne d'approvisionnement qui accorde priorité aux producteurs les moins chers, ce qui a entraîné une dépendance excessive à l'égard d'une seule région. La résilience de la chaîne d'approvisionnement nécessitera une diversification des sources. Le Canada bénéficierait également de politiques qui soutiennent les fabricants nationaux, notamment en leur offrant un accès privilégié aux marchés provinciaux des soins de santé, ce qui permettrait aux fournisseurs canadiens de croître à une échelle suffisante pour devenir des sources fiables pour le marché intérieur tout en profitant des ventes internationales.

La fragilité de la chaîne d'approvisionnement, laquelle a été révélée par la pandémie de COVID-19, démontre toute son importance. Les vies humaines dépendent de la disponibilité d'un approvisionnement qui fonctionne à 100 %. Des données d'approvisionnement précises, opportunes, automatisées et interopérables, de même que l'implication des travailleurs de la santé de première ligne dans les décisions d'approvisionnement, rendent possible un leadership collaboratif tout en atténuant les risques de ruptures d'approvisionnement. La pandémie de COVID-19 ne sera pas la dernière crise d'approvisionnement des soins de santé pour le Canada, mais les leçons tirées de cette crise nous permettront de mieux nous préparer à la prochaine.

GENERAL INTRODUCTION

In 2017, the federal government took a new approach to that taken in the early 2000s to move forward on health system priorities. The government worked with the provinces and territories (PTs) to identify shared health priorities for federal investments, develop common areas of action within these priorities through an FPT framework, and then negotiated bilateral agreements with each PT. COVID-19 has highlighted the need for resilient health care systems that will continue to meet the needs of Canadians today and in the future.

It is in this context that in April 2021, the School of Public Policy convened a group of health policy experts to develop research papers on various aspects of the evolution of health care in consultation with Health Canada. These experts have a diverse range of perspectives on issues related to Canadian health systems. Health Canada was consulted on the list of topics, but the orientation of each paper, the methodology, as well as the substance of the recommendations were left entirely to the discretion of the authors.

We are proud to share the result of this process. Each paper in this series of eight was subject to the intense scrutiny, and discussed extensively following detailed roundtable presentations. Two eminent health policy experts were also asked to conduct a careful double-blind review of the papers, with a special focus on rigor, readability, and relevance. We believe these policy briefs offer a rare combination of original thinking, deep subject expertise, and technical feasibility: a perfect balance between the very practical needs of the end users of the research and the independent and innovative spirit that pervades all the work originating from the School of Public Policy.

INTRODUCTION AND BACKGROUND

The COVID-19 pandemic has exposed significant fragilities in the current capacity and function of global health-care supply chains. During the first wave of the pandemic, long, undiversified, and lean global supply chains were destabilized by a massive surge in demand for care that required high volumes of critical health products for care delivery (Snowdon, Saunders and Wright 2021). China, the primary manufacturer of a number of critical health products, and the first site of a COVID-19 outbreak, temporarily shuttered its manufacturing capacity. As a result, there were severe product shortages across every global health system. Manufacturers were unable to rapidly scale-up their production capacity to meet the sudden and dramatic increase in the demand for critical products, which resulted in a destabilizing “ripple effect” across global health-care supply chains. The COVID-19 pandemic, and the surge in supply demands it created, exposed the fragility of global health-care supply chains. The destabilization of health-care supply chains impacted every jurisdiction in Canada and touched the lives of health-care workers, patients, citizens, and non-permanent residents (such as temporary foreign workers).

During the pandemic, issues concerning personal protective equipment (PPE) came to exemplify the essential linkages between health-care delivery, the health-system workforce and patient safety, and the health-care supply chain’s capacity to respond to unexpected surges in demand and significant supply interruptions. Supply issues were not limited to PPE: bed capacity, ventilators, testing kits, swabs, syringes, pharmaceutical products, vaccines (including all of the components and logistical processes involved in vaccination) and many other products were all impacted by the COVID-19 pandemic.

The health-care supply chain includes the infrastructure and processes necessary to manufacture, source, procure, distribute, and track products used in the delivery of health-care services. The health-care supply chain therefore extends from the manufacturer of the product to the point-of-care delivery for patients and to the outcomes achieved. In disrupting health-care supply chains, the pandemic exposed their crucial role in the health system’s capacity to deliver health services to Canadians. At the same time, the exposure of the structural fragility of health-care supply chains through their destabilization by the COVID-19 pandemic revealed their necessity.

There is a long history of supply-chain disruptions in the health sector that have occurred due to natural disasters and public-health crises, resulting in severe consequences that have put health workers and patients at significant risk. One example was Hurricane Maria in 2017, where electrical grids were wiped out in Puerto Rico, which disrupted the production of intravenous therapy products, (e.g., IV bags) manufactured by Baxter (Wong 2018). The resulting shortage of IV bags spread globally, causing an increase in cost by 600 per cent (Wong 2018). Similarly, a flood in 2012 impacted Sanofi Pasteur, the supplier of the cancer drug ImmuCyst. The result was significant delays in cancer treatment for patients, as manufacturers could not increase production of the drug rapidly enough to meet demand (Mostafid, Redorta, Sylvester and Witjes 2014). The SARS epidemic also put extreme pressure on health-

system supply chains, due to an increase in demand for the critical products required to keep health workers and patients safe from transmission of the SARS virus.

Not only do these crises put the physical health of essential workers at risk — three of the 44 Canadians who died from SARS were health-care workers (Low 2004) — emerging evidence also identifies significant impacts on the mental health of those in the health-care workforce. In the current COVID-19 pandemic, the inadequate supply of PPE, and the uncertainty these supply shortages created among Canada’s health-care workers, resulted in high rates of mental health issues, such as anxiety and depression (Smith 2021). As Aldrighetti et al. (2019) note, given that the end of the health supply chain is human life, the standard by which health-care supply-chain capacity is measured, or the required service level of a health supply chain, is different from that of industrial supply chains:

“In the context of HSCs [health-care supply chains], such disastrous events [as disruptions] can potentially have devastating effects because human lives are on the table: these networks cannot afford to register missing drugs in the hospital, i.e., it should always perform with service level equal to 100%.”

This need for the capacity of a health supply chain to maintain a “service level equal to 100 per cent” helps to contextualize the urgency of the development of leadership strategies for health-care supply-chain resilience. When the health-care supply chain breaks down, the result is a direct impact on human life (Aldrighetti et al. 2019; Mandal 2017; Snowdon and Saunders 2021). The COVID-19 pandemic has highlighted the urgent need for research focused on the health-care supply chain in order to further understand the nuances evident in this sector and to develop strategies specific to health-care supply-chain management. The significant fragilities in the current capacity and function of the health-care supply chain suggest that foundational leadership strategies, within and across health-care organizations and systems, will need to prioritize supply-chain resilience. Indeed, leadership strategies to advance a resilient health-care supply chain, which are delineated next, are the first step toward enabling innovation uptake in the health-care supply chain.

SUPPLY-CHAIN VISIBILITY SUPPORTED BY STANDARDIZED DATA AND DIGITAL INFRASTRUCTURE

Advancing supply-chain visibility is a foundational leadership imperative to advance supply-chain resilience in Canada. Specifically, visibility can only be achieved by advancing data standards and digital infrastructure that transform data into knowledge and insights within and across health-care systems. It allows data to be safely captured from multiple sources, where data are stored securely, and flow seamlessly across health systems to enable visibility across the entire health system in near real time. Digital infrastructure integrates patient, clinical and supply-chain data in real time, across all levels of the health-care system, and must have the capacity to connect interoperably with other health systems within or across jurisdictions. Data standards and digital infrastructure are among the most foundational features of a resilient health-care supply chain, enabling health-system capacity to respond to and manage

unexpected shortages and surges in the demand for care. Data standards and digital infrastructure are also areas where most Canadian provinces are lacking, with very high variation within provincial and territorial health systems and no evidence of interoperability across provinces and territories.

Data standards and digital infrastructure are foundational to a resilient supply chain and are critical first steps to advancing visibility of agile supply-chain capacity to respond to unexpected shifts in demands for care. There are three features of supply-chain visibility: 1) point-of-care data capture to accurately capture utilization rates and care demands; 2) interoperability of data systems within and across jurisdictions to enable visibility into supply utilization and supply inventories; and 3) advanced analytics and modelling for accurate forecasting. These three features of data and digital infrastructure enable leaders to advance supply-chain resilience to support national co-ordination and managerial direction to ensure every health system has the capacity to respond to unexpected supply disruptions or surges in demand.

Point-of-care data capture to create visibility of utilization. Point-of-care capture of data captures product use during care-delivery procedures for every individual patient. Point-of-care data capture offers granular data that identify rates of product utilization relative to patient-care volumes in every care-delivery organization in a health-care system. However, this micro level of data is not sufficient. Point-of-care data capture must be supported by data-exchange infrastructure across organizations to support visibility of product utilization across the entire health system. Global standards offer visibility of product-supply utilization relative to product inventories to enable co-ordination of supply-chain efforts across provincial and territorial health systems. Global standards also create a common language between manufacturers, distributors and health organizations to digitally track demands for care, location and quantity of supply inventory, while ensuring that the right products are available in care settings when and where needed, to ensure safe use during patient care.

A leadership priority to enable supply-chain visibility in Canada requires a policy framework that mandates adoption of global standards (ex. GS1). Currently, Canada has not required the adoption of global standards for health products, which has resulted in significant challenges in accurately identifying products and many instances of counterfeit or poor-quality products being procured. In order to advance supply-chain resilience, senior leaders across federal, provincial and territorial health systems must require the adoption of global standards to enable visibility, co-ordination and effective management of supply inventories across the country.

When products and pandemic inventories are managed using global standards, every region, province and territory has a common data language that creates supply-chain visibility across health systems and jurisdictions. This high level of visibility enables leaders to accurately identify products, mitigating the risk of sourcing counterfeit, or poor-quality products. Supply visibility offers accurate data on product utilization, product inventory available and risks of product shortages for entire health systems. Such accurate and detailed product data create a robust and highly visible supply-chain data infrastructure, able to generate data in near real time to track utilization and identify risks of product shortages. During times of crisis, such as a pandemic, global

standards enable teams at the provincial and territorial level to accurately identify products, prevent procurement of fraudulent products and accurately track utilization rates for critical products. This enables them to identify required inventory volumes and ensure that clinician teams have access to the products required, when and where they are most needed, for the safe delivery of quality care. At the federal level, global standards enable visibility into the sources and attributes of products, to inform decisions on prioritization of product sourcing for provinces and territories that are most in need. Global standards further support the accurate identification and approval of safe and high-quality products for Canadian health systems.

The supply scarcity during early waves of COVID-19 resulted in leaders being “blind” to the inventory levels and utilization rates of PPE, unable to know who needed critical supplies and where priorities for workforce safety required urgent intervention (Snowdon and Forest 2021). Regional and provincial decision makers had little or no data on inventory volumes, location, or utilization rates, which created chaotic and competitive sourcing approaches to manage the uncertainty of demand, with little insight into where products were most urgently needed across provincial and territorial health systems. The lack of visibility of supply-chain data across each of the provinces and territories disadvantaged federal agencies and precluded accurate tracking of utilization rates. Supply-chain visibility, afforded by adoption of global standards and data infrastructure that enables accurate and seamless tracking of supply utilization, offers the significant opportunity to advance supply-chain resilience across Canada.

Interoperable digital infrastructure. Interoperable digital infrastructure enables not only the capture of data, but also the exchange of data across organizations, regions and provincial and territorial health systems. Interoperability enables the capture and mobilization of data across information systems (e.g., supply chain, finance, human resources, patient care), to exchange data seamlessly in a co-ordinated manner across teams, organizations, regions and jurisdictions (HIMMS 2021). Interoperability enables data to flow seamlessly and securely across health systems, to create visibility of activity (e.g., emergency-department volumes across regions, contact tracing and testing, pharmacy, workforce) and data flows in near real time to inform leadership decisions (HIMSS 2021). Interoperability was identified as a significant challenge by the provinces throughout the pandemic. Leaders shared their experiences with overlaps in contact-tracing datasets between the province and the federal Public Health Agency due to the lack of interoperability. Interoperability enables visibility to inform leaders and decision makers at all levels of the health system to support and inform collaborative management across provinces, territories and federal agencies.

Data-driven decisions rely on access and visibility of data, mobilized across all organizations, to create a system-level view of supply resources and utilization for every jurisdiction. From hospitals to health-care specialists to public health units, interoperability enables data sharing in real time to ensure that supply-chain inventories and demand forecasting are accurate and data-driven. Interoperability enables decision makers, clinical leaders and operational leaders to make informed decisions in managing day-to-day operations, as well as managing crises, in a manner that is equitable, data-driven and prioritized based on needs and risks. Interoperability of

data systems across provinces and federal jurisdictions fuels collaboration and the co-ordination of efforts to strengthen supply-chain resilience and health-system outcomes, supported by leadership priorities that establish critical data infrastructure to create supply-chain visibility across the country.

Advanced analytics to inform proactive strategies to mitigate risk. Visibility of supply-chain data linked to patient-care processes makes it possible to accurately forecast utilization rates and anticipate risks related to supply shortages. A robust digital infrastructure enables accurate tracking of critical supplies and resources (e.g., workforce capacity, equipment such as beds and ventilators). However, advanced analytics assumes a critical role in transforming leadership strategies from “reactive” decisions based on events that have already taken place, to proactive decisions that anticipate events, to enable planning, co-ordination and optimization of resources within and across jurisdictions. Visibility of supply data, linked to patient-level data across regions and provinces, offers real-world data that enables accurate forecasting to anticipate and reduce risks of shortages or supply disruptions. For example, tracking and modelling vaccination data, linking public-health, primary-care, hospital and community data, would inform effective and proactive vaccination programming, prioritized to highest-risk communities. Federal programs that source critical products would have exceptional clarity of population risk across jurisdictions to inform the distribution of products based on highest risk, equity and greatest need.

During events such as pandemics, analytics assume a critical role for leaders at the federal level to ensure the most critical products are made available to the highest-risk jurisdictions and communities. Proactive modelling was a strategy leveraged by many provinces throughout the pandemic. However, during the pandemic, the accuracy of modelling was limited by the lack of standardized data or complete lack of any data, and the individualistic approaches to pandemic management in every jurisdiction resulted in high variation and inequities for unique populations, such as people living in long-term care settings. System-level visibility of data to inform decisions offers visibility to events as they unfold, and analytics offer proactive insights into risk to inform leadership decisions on risk-mitigation strategies. Advanced analytics offers a way forward to analyze critical lessons learned, identify provinces and territories with the greatest needs, and may inform accountability frameworks to ensure every Canadian has access to care when and where it is needed.

EMPOWERED HEALTH WORKFORCE CONNECTED TO SUPPLY DECISION-MAKING

Supply-chain teams that work collaboratively with clinician teams are able to ensure that supply-management decisions are informed by the knowledge and expertise of safe patient-care delivery and clinician workflows informed by evidence-based practices and principles of infection prevention and control. During the COVID-19 pandemic in Canada, the health-care workforce had no such engagement in supply-chain decisions or strategies, despite a number of professional associations and unions advocating for their members to be included. A critical outcome of this lack

of engagement of the health workforce in pandemic-management decisions resulted in the use of allocation frameworks that prescribed access and use of critical supplies to clinicians, essentially removing clinician autonomy to make decisions on the use of protective equipment, informed by principles of infection protection and control (Snowdon and Saunders 2021). Clinical integration and engagement in supply-chain management is a critical feature of a resilient supply chain that considers and is informed by clinical knowledge and best practices. An empowered health workforce advances and strengthens supply-chain resilience, which requires two key elements of leadership strategy: 1) the integration of clinical insight and expertise into supply-management decision-making; and 2) the alignment of the health-care supply chain with health-system priority needs and utilization demands.

Integration of clinical insight and expertise into supply decision-making. Decision-making at the level of provincial, territorial, or federal jurisdiction was led primarily by both political leaders (e.g., the provincial premier) and chief medical officers of health, with significant engagement and support from bureaucratic leaders across ministries. Although every provincial leadership strategy was different, there were no jurisdictions that actively engaged the health workforce (e.g., clinician leaders, unions or professional associations) as a strategy to ensure clinical insights and expertise-informed decisions. This lack of clinician engagement resulted in decisions that prioritized hospitals during the initial waves of the pandemic, which had devastating consequences for other health-care settings, such as long-term care, and resulted in the cancellation of health services, such as surgeries and diagnostic imaging services for patients with cancer. Health-workforce leaders were not engaged to inform leadership decisions, resulting in widespread challenges that compromised the health and safety of the health workforce and Canadian citizens. In almost every province, clinicians experienced high levels of uncertainty, anxiety and fear, as they were not at decision-making tables and had no choice but to manage the best way possible in implementing leadership decisions, which, many times, diminished their confidence in the safety of their workplace and the quality of patient care. Fear that there was insufficient protective equipment to be safe at work, and the fear of becoming infected or transmitting infection to their families, plagued many members of Canada's health workforce, which has been associated with high rates of resignation and absenteeism in many jurisdictions.

Crucially, the engagement of the health workforce in supply management and decision-making empowers the health workforce to co-design solutions that not only manage supply shortages, but also manage workflows to accommodate new infection-control practices and ensure quality and safety of patient-care delivery. Engagement of the health workforce protects and supports the autonomy of the clinician workforce and acknowledges the critical role it assumes in the capacity of health systems to deliver care. This approach conveys the value of the health workforce and builds confidence among clinicians as they collaboratively manage the impact of critical supply shortages and the risks to safe patient care. Federal agencies and provincial and territorial leadership tables require the expertise and insights of the health workforce to ensure that decisions are informed by clinical knowledge and expertise of best practices. Empowering and enabling the clinician voice at decision-making tables must extend

throughout health-system governance structures and senior decision-making tables. At regional, provincial and federal levels, clinical leaders and health-professional organizations must inform health-care supply-chain decisions and supply-management strategies, particularly insofar as they concern the creation of the capacity to effectively respond to health-care supply-chain challenges and disruptions.

In the majority of Canadian provinces, clinicians had no access to supply-chain data and did not know what products were available to enable them to deliver care at any given time. Moreover, supply-chain teams made decisions on purchasing products that appeared to be safe and support quality care, however, when made available to clinicians these products were not adopted or used, for a variety of clinical-care-quality reasons. In the early waves of the pandemic, federal, provincial and territorial governments were procuring significant quantities of products, with no knowledge or insight into whether clinicians would accept and work with new products. As a result, significant waste of products was commonplace across many provinces and federal agencies. Engagement of clinician leaders at decision-making tables advances supply-chain resilience, as every product sourced and procured is informed by clinician expertise and is thereby readily adopted and used by clinicians to optimize pandemic outcomes.

Alignment of health-care supply-chain capacity and health-system needs across provinces and territories. A critical role of clinician leaders in supply-chain decisions is ensuring that the most critical products are available when and where they are needed to support care delivery. Health-care supply-chain capacity must anticipate and account for clinician decision-making informed by the precautionary principle, whereby clinicians make decisions on the protective products required to mitigate risks of infection during outbreaks. At the time of the pandemic, there was no province with reserve inventory of critical products to support clinician use of protective products based on infection prevention and control principles. There was no Canadian province that had established and maintained a pandemic stockpile, despite recommendations to do so following the SARS event in 2006 (Campbell 2004). Essentially neither health-system leaders, nor government leaders had prioritized supply stockpiles despite evidence that a global pandemic was inevitable. Thus, health-system leaders had not prioritized pandemic readiness, nor had they considered unexpected supply shortages, leaving every health system in Canada at substantial risk at the time the pandemic unfolded. Despite historical “lessons learned” from SARS, Canada has struggled to support and maintain pandemic preparedness and must prioritize health-system capacity and needs more actively to advance supply-chain resilience.

A resilient and agile supply-chain strategy accounts for a service level of 100-per-cent supply availability to meet patient-care needs. The endpoint of the health-care supply chain is the health and safety of both the health-care worker and the patient, which entails that the workforce is fully protected when the need arises and patients are fully protected from any possibility of exposure to risk of infection. A health-care supply chain must always be able to maintain 100-per-cent capacity to deliver the products required to meet patient-care demands. In order to achieve this goal, clinicians are uniquely qualified to determine the level of reserve product to support quality and safety of care delivery in such situations.

AGILE AND BALANCED SUPPLY-CHAIN CAPACITY

A critical feature of supply-chain resilience is its *agility* to draw upon multiple and diverse sources of critical medical supplies in order to respond to unexpected disruption in product supply. A characteristic of health-care supply-chain fragility is a *lack of diversification*, which was evident in the configuration of health-care supply chains prior to the COVID-19 pandemic, when global health supply chains were lengthy, lean and undiversified, prioritizing lowest cost and often relying on a single geographical region for the supply of critical products (Snowdon, Saunders and Wright 2021). A consequence of relying on geographically limited and lowest-cost sourcing and inventory-management models was the elimination of surge capacity across the health-care supply chain.

However, the health-care supply chain, unlike industrial supply chains, needs to be able to maintain a service level of 100 per cent. Disruptions to health-care supply-chain capacity can result in a diminished capacity for health-care workers to safely and effectively deliver care, which put the lives of both health-care workers and patients at risk. Human life is the endpoint of the health-care supply chain, and health-care supply-chain management must be organized by management principles and strategies that work to maintain a 100-per-cent service level, particularly in the event of a severe disruption or surge in demand.

Lack of diversification of supply sources has led to a constrained, rigid and fragile supply chain. During a severe product shortage, a fragile supply chain lacks the adaptive capacity to pivot to multiple, sustainable sources of supplies, which leads to reactivity, employing product conservation strategies to compensate for the inability to proactively pivot to alternative sources of supplies. A health-care supply chain with critical adaptive capacity is able to adapt to disruptions and maintain a service level of 100 per cent. There are three strategies that enable agility of supply to manage unexpected disruptions to supply: 1) supply diversification across geographic regions; 2) supportive strategies for domestic manufacturers of critical supplies; and 3) stockpile strategies that provide surge capacity.

Supply diversification across geographic regions. If the single-sourcing of critical products is a characteristic of supply-chain fragility (Snowdon, Saunders and Wright 2021), then health-care supply-chain resilience requires a flexible and adaptive diversification of product sources, one that strengthens confidence in multiple and diverse geographic sources of supply. The supply of critical products is global and no country in the world has the raw materials to be fully self-reliant to manufacture all the critical supplies required for quality care delivery. Supply diversification is a key strategy to enable agile capacity to supply products during unexpected disruptions. Supply diversification secures contracts with suppliers in multiple regions. This guards against the overreliance on single countries or regions, which increases the risk of disruptions due to unexpected events such as pandemics and natural disasters (e.g., floods, hurricanes, earthquakes).

Supportive domestic manufacturing strategies. A crucial component of supply diversification is the cultivation of a sustainable domestic source of critical supplies.

Although no country can manufacture all critical supplies, supporting critical manufacturing capacity in Canada offers agility and flexibility in Canada's health-care supply-chain capacity. The cultivation of domestic manufacturing capacity enables a fully diversified health-care supply chain — one that is flexible and can adapt to sudden, unexpected changes in demand or supply shortages. In order to strengthen supply agility, domestic manufacturers must be able to access multiple provincial and territorial health systems, supported by collaborative procurement models across provincial, territorial and federal agencies, to achieve the economies of scale needed to sustain and grow domestic-supplier revenues. Domestic supply-chain sourcing relies on sales volumes to be sustainable and achieve economic growth. Sourcing and procurement strategies must incentivize and support domestic suppliers to ensure supply diversification for Canadian health systems, while at the same time achieving a sustainable domestic supplier network. As Canadian manufacturers achieve sustainable revenue growth across Canadian jurisdictions, domestic manufacturers will be better able to pursue access to global markets to drive economic growth for Canada.

Stockpile strategies to support agility in surge capacity for critical products.

Strategies that enable health-care supply chains to tolerate surges in demand include stockpiles of critical products, supported by digitally enabled automation, to ensure supplies do not expire and result in product waste that is very costly. Pandemic stockpiles across jurisdictions have been established in the past, however they were not adequately managed and rotated to ensure supplies are not wasted and adequate supplies are maintained at all times, so that critical supplies are available when and where they are needed. Pandemic stockpile management includes tracking inventories using automated data capture (e.g., barcode scanning; QR codes; radio-frequency identification, aka RFID) that supports advanced inventory management to ensure products are circulated within a health system to prevent waste due to expiration. Maintaining a source of additional supplies throughout the health supply chain would increase health-care supply-chain resilience and the ability of the health-care supply chain to maintain a service level of 100 per cent. However, pandemic stockpiles across jurisdictions would be further optimized by collaborative stockpile management across jurisdictions to ensure all stockpile supplies are effectively managed and rotated and visible to health-system leaders across the country in the event of future pandemics.

COLLABORATIVE LEADERSHIP ACROSS PROVINCIAL, TERRITORIAL AND FEDERAL JURISDICTIONS

Canada accounts for less than two per cent of the global market for health products, with a relatively small population spread across one of the largest land masses in the world. At the onset of the pandemic, every jurisdiction in the country acted competitively with each other to source and procure products to meet the rapid surge in demand for care. This competitive approach not only made sourcing and procurement a challenge for every health organization and jurisdiction, it drove intense price competition in the market. In order to overcome this competitive approach to managing supply challenges, a more synergistic approach must be advanced to support collaboration and co-ordination of efforts across jurisdictions. The federal

government has a critical role to play in establishing data standards and interoperability across every jurisdiction to make collaboration and co-ordination possible. A common language to support supply management (e.g., the adoption of data standards) and interoperable flow of data across provinces, territories and federal agencies can create visibility of supply management, to inform collaborative approaches to decision-making across jurisdictions. Moreover, the visibility of supply-chain and health-system data across jurisdictions creates the conditions to build and sustain trust and openness among leaders across every provincial, territorial and federal jurisdiction. Collaborative leadership has three critical features: 1) collaboration and co-ordination of government strategy, policy and processes that engage every jurisdiction; 2) co-ordinated and data-driven communication; and 3) responsive and equitable decision-making.

Collaboration and co-ordination of government strategy, policy and processes. The COVID-19 pandemic has highlighted the importance of the health-care supply chain and illustrated the opportunity for co-ordination and collaboration across jurisdictions. A co-ordinated and collaborative approach to management of health is synergistic with collaborative approaches to government strategy, policy and process. In this strategy, federal and provincial partners have visibility into health-care supply-chain capacity, informed by data, and jurisdictions work collaboratively, with clearly established roles and responsibilities, respecting one another's mandates and accountabilities.

A collaborative health-care supply-chain leadership strategy strives to ensure that every jurisdiction has the critical supplies needed to ensure the safety and health of every Canadian. For example, during the early waves of the pandemic, every province and territory, as well as every hospital system, created pandemic stockpiles to ensure products would be available for future waves of the pandemic. Yet, currently there is no single jurisdiction or leadership team in the country that knows the location and size of the many pandemic stockpiles in Canada. Collaborative leadership approaches establish a management infrastructure and framework to accurately identify the size and contents of every pandemic stockpile in the country, with clear roles and responsibilities to enable co-ordination of stockpile management (e.g., rotation and maintenance of each stockpile). This ensures that every jurisdiction has access to stockpiles when needed and that every stockpile is well managed to avoid waste due to expired products.

A lack of co-ordination and collaboration was a significant challenge for most every global jurisdiction. In Canada, every province identified the need for a stronger co-ordinating role from the federal government to manage supplies much more transparently so that every jurisdiction would receive equitable and timely access to products during critical shortages. A managerial strategy at the federal government level would offer greater centralization of pandemic stockpile management with visibility of stockpiles, inventory volumes and logistics infrastructure to inform decisions on optimizing pandemic stockpile management and reduce waste due to expiry of products.

To date, multiple policy opportunities have begun to emerge to strengthen collaboration and co-ordination between federal, provincial and territorial governments to advance supply-chain resilience. For some provinces, the roles and functions assumed by federal,

provincial and municipal government teams overlapped at times and were unknown or unclear at other times, creating barriers or confusion among leaders. For other provinces, key informants reported well established co-ordination and collaboration with the federal agencies, which was considered a strength in supporting capacity to manage the impact of the pandemic on health systems. The working relationships between provinces, territories and federal agencies varies widely, with many diverse teams, agencies and organizations all engaged in health-care supply-chain management (e.g., sourcing, procurement, logistics and distribution), but doing so with no access to accurate supply data and with limited degrees of collaboration and co-ordination across jurisdictions.

Co-ordination of effort and collaborative leadership approaches offer transparency of information and data, which builds trusting relationships across jurisdictions that can overcome administrative redundancy. It ensures that there are collaborative approaches to supply-chain processes such as sourcing, procurement and distribution of products to where they are most needed.

Co-ordinated and data-driven communication. Communication during the pandemic has varied widely both within and across provinces, territories and federal agencies. Communication was, and is, an issue for every jurisdiction in Canada. Constantly changing public-health protocols varied widely across regions and provinces, which at times were often conflicting and ambiguous. For example, a lack of communication between public-health leadership and supply-chain teams in one province contributed to the delayed implementation of public-health protocols (e.g., masking protocols), due to the perception among public-health officials that the supply of protective equipment was inadequate to support the protocols. The lack of consistent and accurate data to inform decisions and communication resulted in communication not being clear and consistent across provinces, nor was communication aligned between provincial health-system leaders, public-health leaders and federal agencies.

A significant outcome of the lack of data and infrastructure was the limitation in clarity of communication within and across provinces and inconsistency in communication between federal agencies and provinces. Inconsistency in communication as well as rapid changes and shifts in messaging were common occurrences throughout the pandemic, which eroded confidence in leadership decisions. When communication is clear and co-ordinated, accounting for jurisdictional differences and nuances, decisions and directives can be more clearly articulated and made simple to understand and easy to follow for every Canadian citizen.

Communication that is not only co-ordinated, but also data-driven, ensures that all health-care organizations, regions, provinces and territories are explicit and clear when communicating with their respective populations, and consistency across jurisdictions instils a sense of confidence and competence in managing pandemic situations. Citizens have relied heavily on news and social media to understand the progress of the pandemic and how it is being managed. The outcome of so much reliance on social-media sources has been an erosion in the confidence citizens have in health-system leaders. This has been linked to increased levels of non-compliance with public-health directives and a lack of confidence in the vaccines, and in some cases has sparked protests. Co-ordinated and data-driven communication efforts may achieve

a more clearly defined “single source of truth,” which can support the credibility and confidence among citizens in all jurisdictions.

Responsive and equitable decision-making. During the COVID-19 pandemic, many at-risk populations (specifically people in long-term care and community care, essential workers, and racialized and impoverished communities) did not have the resources, supplies, knowledge and services needed to protect them from transmission of the COVID-19 virus. This led to disproportionate outbreaks in high-risk groups and in the frontline workforce, which was unnecessarily exposed to infection (Snowdon and Saunders 2021).

Provincial strategies surrounding high-risk groups was executed differently by each of the provinces. Some, such as Manitoba, Ontario and Quebec, intervened to provide products or equipment to mitigate outbreaks only once significant outbreaks had unfolded. In other provinces, a “hospital-first” strategy prioritized supply management and distribution for acute-care organizations, leaving other high-risk settings (e.g., long-term care) or communities with little or no protection. In many of the provinces, there was an inequity in product access, leaving high-risk groups more vulnerable than others.

Inequitable access is influenced by the lack of visibility of supply inventories and a lack of expertise in supply management across several health organizations. Responsive and equitable decision-making leverages data and analytics to predict risks that inform proactive and preventive strategies to ensure every Canadian is protected during disruptions. Equitable decision-making relies on data to proactively identify populations at the highest risk (e.g., seniors residing in long-term care facilities) and high-risk communities (e.g., high-density communities, essential-workforce workplaces). This informs prioritized decisions that are responsive and highly effective in preventing widespread outbreaks, supported by proactive supply management strategies to enable testing, vaccination and other health-system interventions.

Responsive and equitable decision-making is enabled when there is transparency of data (e.g., supply inventory, utilization rates, testing outcomes), collaborative leadership strategies that engage all jurisdictions, and an empowered health workforce to inform decisions that prioritize need, which creates visibility into the needs and risks of every population across Canada. Responsible and equitable decision-making is a collective effort across jurisdictions, with data visibility to create transparency that ensures decisions are data-informed, and supported and implemented by an empowered health workforce, to ensure equitable and responsive pandemic management.

CONCLUSION

The COVID-19 pandemic has made clear the essential relationship between health-care supply-chain management, the capacity of health systems to respond to a sudden surge in demand for, or supply disruption of critical products, and the ability of the health-care workforce to safely and effectively deliver care. The health-care supply chain is the material, structural and logistical foundation of care delivery. If this foundation is compromised — as it was during the COVID-19 pandemic — then

health-care workers and patients are placed at risk of experiencing devastating outcomes, such as illness and death. Given the fragility of pre-pandemic health-care supply chains (Snowdon, Saunders and Wright 2021), and the impact of this fragility on the health-care workforce during the COVID-19 pandemic (Snowdon and Saunders 2021), the post-pandemic renewal and strengthening of health-care supply chains is an urgent priority required to advance and strengthen health-system capacity and responsiveness to the health needs of Canadians.

RECOMMENDATIONS

- The exposure of the structural fragility of health-care supply chains through their destabilization by the COVID-19 pandemic revealed their necessity. Far from being two distinct and separate areas of health-system capacity, health-care supply-chain management and processes and health-system functioning are fundamentally interwoven.
- Data standards and digital infrastructure are foundational to a resilient supply chain and are the first steps toward a national strategy to strengthen and optimize health-care supply-chain resilience. Lack of data compromises clarity of communication within and across provinces, and contributes to inconsistency in communication between federal agencies and provinces. Data standards and digital infrastructure create transparency and support data-driven leadership that is collaborative across jurisdictions.
- Accurate, timely and automated product-utilization tracking based on global standards offers significant opportunity to augment transparency of supply-chain capacity across health systems to support and inform data-driven leadership decisions. Responsive and equitable decision-making leverages data and analytics to predict risks that inform proactive and preventive strategies to ensure that the health of every Canadian is protected.
- The empowerment of the health workforce to engage in and support supply-chain management and decision-making creates the transparency needed for Canada's health workers to be confident in the health and safety of their workplace, and confident they will have the protective supplies and equipment to deliver safe and effective quality care.
- Interoperability of data systems across provinces and federal jurisdictions fuels collaboration and the co-ordination of efforts to strengthen supply-chain resilience and health-system outcomes more broadly. There is a clear need for federal and provincial collaboration to co-ordinate and harmonize health-care supply-chain strategies and approaches, to support a unified approach across jurisdictions, and more effectively respond to crises and supply-chain disruptions.
- If the single-sourcing of critical products is a characteristic of supply-chain fragility (Snowdon, Saunders and Wright 2021), then health-care supply-chain resilience requires a flexible and adaptive diversification of product sources that balances domestic and global supplier networks to strengthen self-reliance across the country. Supply-chain resilience requires a diversification of sources and a shift in priorities towards sustainable supply-chain capacity, rather than prioritizing lowest-cost product sources. Health-care supply-chain strategies must prioritize supplier diversification and domestic manufacturing capacity to advance self-reliance and stimulate economic growth.

SELECT REFERENCES

- Abdulsalam, Y., M. Gopalakrishnan, A. Maltz and E. Schneller. 2015. "Health Care Matters: Supply Chains in and of the Health Sector." *Journal of Business Logistics* 36 (4): 335-39. doi:10.1111/jbl.12111.
- Aldrighetti, R., I. Zennaro, S. Finco and D. Battini. 2019. "Healthcare Supply Chain Simulation with Disruption Considerations: A Case Study from Northern Italy." *Global Journal of Flexible Systems Management* 20 (1): 81-102. doi.org/10.1007/s40171-019-00223-8.
- Campbell, A. 2004. "The SARS commission interim report: SARS and public health in Ontario." *Biosecurity and Bioterrorism: Biodefense Strategy, Practice, and Science* 2 (2): 118-26. <https://www.liebertpub.com/doi/10.1089/153871304323146423>. doi: 10.1089/153871304323146423.
- Dixit, A., S. Routroy, and S. K. Dubey. 2019. "A Systematic Literature Review of Healthcare Supply Chain and Implications of Future Research." *International Journal of Pharmaceutical and Healthcare Marketing* 13 (4): 405-35. doi:10.1108/IJPHM-05-2018-0028.
- Ebel, T., K. George, E. Larsen, K. Shah and D. Ungerman. 2013. *Building a New Strength in the Healthcare Supply Chain*. McKinsey and Company.
- Health Canada. 2015. *Unleashing Innovation: Excellent Healthcare for Canada. Report of the Advisory Panel on Healthcare Innovation*. Ottawa.
- HIMMS. 2021. "Interoperability in Healthcare." HIMSS Analytics. <https://www.himss.org/resources/interoperability-healthcare>.
- Kumar, S. J. T. and Blair. 2013. "U.S. Healthcare Fix: Leveraging the Lessons from the Food Supply Chain." *Technology and Health Care* 21 (2): 125-41. doi:10.3233/THC-130715.
- Kwon, I.W.G., S. H. Kim and D. G. Martin. 2016. "Healthcare supply chain management; strategic areas for quality and financial improvement." *Technological Forecasting and Social Change* 113 (Part B): 422-428.
- Low, D. E. 2004. "SARS: Lessons from Toronto." In S. Knobler, A. Mahmoud, S. Lemon, A. Mack, L. Sivitz and K. Oberholtzer (eds). *Learning from SARS: Preparing for the Next Disease Outbreak*. pp. 63-70. Washington, D.C. National Academies Press.
- Mandal, S. 2017. "The influence of organizational culture on healthcare supply chain resilience: moderating role of technology orientation." *Journal of Business and Industrial Marketing* 32 (8): 1021-1037.
- Mostafid, A.H., J. P. Redorta, R. Sylvester and J. A. Witjes. 2015. "Therapeutic Options in High-Risk Non-Muscle-Invasive Bladder Cancer during the Current Worldwide Shortage of Bacille Calmette-Guérin." *European Urology* 67 (3): 359-60.

- Smith P. M., J. Oudyk, G. Potter and C. Mustard. 2021. "The Association Between the Perceived Adequacy of Workplace Infection Control Procedures and Personal Protective Equipment With Mental Health Symptoms: A Cross-Sectional Survey of Canadian Health-Care Workers during the COVID-19 Pandemic." *Canadian Journal of Psychiatry* 66 (1): 17-24. doi:10.1177/0706743720961729.
- Snowdon, A. and C. Alessi. 2016. Visibility: The New Value Proposition for Health Systems. World Health Innovation Network. https://issuu.com/worldhealthinnovationnetwork/docs/full_paper_-_win_visibility_thought/1. Retrieved December 1, 2020.
- Snowdon, A. and P. G. Forest. 2021. "'Flying Blind': Canada's Supply Chain Infrastructure and the COVID-19 Pandemic." *Healthcare Quarterly* 23 (4): 12-16. doi:10.12927/hcq.2020.26386.
- Snowdon A.W., M. Saunders and A. Wright. 2021. "Key Characteristics of a Fragile Healthcare Supply Chain: Learning from a Pandemic." *Healthcare Quarterly* 24 (1): 36-43. doi: 10.12927/hcq.2021.26467. PMID: 33864439.
- Snowdon, A. W. and M. Saunders. 2021. "COVID-19, Workforce Autonomy and the Health Supply Chain." *Healthcare Quarterly* 24 (2): 16-26.
- Wong, J.C. 2018. "Hospitals Face Critical Shortage of IV Bags due to Puerto Rico Hurricane," *The Guardian*, January 10. <https://www.theguardian.com/us-news/2018/jan/10/hurricane-maria-puerto-rico-iv-bag-shortage-hospitals>.

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