PEER REVIEWED

The Challenge of Global COVID-19 Vaccine Distribution Demands a New Approach

Safely and expeditiously supplying COVID-19 vaccines to the majority of the world's adult population of more than five billion will be the most formidable logistics challenge ever tackled in peacetime. Are we ready?

It is clear that the first COVID-19 vaccines will be produced in relatively low volumes with the early output being immediately transported to point of need by road and air. The priority, of course, being to protect first responders and vulnerable groups. Some of this initial distribution is likely to be fairly localised because, despite the leaders of countries knowing that this pandemic is not observant of state borders, national interest and political pressures mean that 'me first' policies and approaches are almost inevitable amongst the high-income countries that are the leading vaccine developers. While morally questionable and scientifically irrational, this 'vaccine nationalism', as it has been termed, is understandable: governments want their own people to be protected first.

However, the lesson we can learn from prior mass vaccination efforts is that comprehensive administration in just a few countries is not enough. The response must be collective, with equitable distribution to all countries at the same time. After the initial 'emergency' consignments, and as the production of different COVID-19 vaccines ramps up for mass immunisation programmes, volume-related pressures are going to emerge accompanied, no doubt, with another cost explosion in freight rates. In these circumstances, and with so much at stake, it is patently myopic not to be considering supplementing road and airfreight with a more resilient transport mode.

Weighing up the Options

Airfreight has traditionally been the default mode of transport for high-value and high-risk medicines. There are a number of reasons for this; the most obvious one being, of course, speed. But speed of delivery is only important if it does not come at an unacceptable cost, either financially or in terms of safety and performance. As one pharmaceutical executive put it: "Speed of delivery doesn't matter if we can't fully secure the requested quality of the medicine"[1]. The problem is that, in a globalised world, pharma airfreight is a highly complex process with products travelling thousands of miles en route to market, during which they may be exposed to widely varying ambient environments and passed between as many as twenty or more links in the supply chain.

With its multiple hand-offs, its absence of failsafe protection and its direct exposure to different environments, airfreight for medicines is well-documented as being a risky process. And, as any risk analyst or insurer will tell you, it is at interfaces and handover points where the greatest risks invariably lie. Blurred responsibilities, lack of co-ordination, incompatible quality standards, inconsistent training and many other factors conspire to create endlessly recurring supply chain issues.

Resilience

"The resilience of a transportation network rests in its capacity to absorb the effects of a disruption and to quickly return to normal operating levels"[2]. There is little doubt that a lack of resilience lies at the heart of the perilous situation that the pharma industry is facing ahead of its biggest-ever logistics challenge. One area of obvious concern rests in the fact that airfreight has experienced a significant loss of freight capacity as a result of the pandemic-induced travel collapse and the concomitant loss of belly freight services. According to IATA, belly capacity for international air cargo shrank 75% in April 2020 compared with the previous year, though this was partially offset by a 15% increase in capacity through expanded use of freighter aircraft[3].

While strenuous efforts have been made since then to bolster cargo capacity, at the end of November 2020 the overall shortfall remains at 25% of 2019 levels and the industry is not expected to return to pre-pandemic capacity levels until passenger services recover[4].

Sea freight, on the other hand, has a surfeit of capacity largely on account of its historic focus on volume and the fact that, whilst not immune to disruption, has been much less affected by the pandemic. As a recent article in the Financial Times reported[5], the sea freight sector has weathered the pandemic storm in much better shape with its impact being more transient than structural. Ocean carriers are in a position to relatively swiftly and effortlessly adjust to the new normal.

Staggering Deliveries

Not all COVID-19 vaccines are the same. This means deliveries will need to be phased in line with vaccine type/stability, the availability of suitable cold-chain transport and local storage, and the preparedness and readiness of trained health staff. For these reasons it will often be necessary to conduct staggered delivery regimes.

This is something that can be very effectively achieved through the use of GDP-compliant refrigerated ocean containers as temporary and mobile storage units. By adopting a 'floating warehouse' strategy, it is possible to achieve a sequence of phased vaccine deliveries while minimising, or even eliminating, the need for surge capacity at local cold-chain storage depots.

A floating warehouse strategy is where you have product on the high seas that is spread amongst different containers on different vessels, and even on different lines. This simple expedient provides a remarkable degree of flexibility in the shipping process at the heart of a systematic replenishment cycle.

A much less attractive alternative is to invest heavily in temperature-controlled warehousing and/or third-party storage, particularly for ultra-low temperature storage. But, in addition to its attendant time, cost and availability penalties, this carries a huge risk that the vaccines simply cannot be supplied safely or end up being in sub-optimal locations.

Vaccine Visibility

Continuous consignment tracking and monitoring is a vital part of the pharma-logistics process. In airfreight, both passive and near real-time data-logging solutions have their adherents, with the choice often

coming down to cost, reliability and cellular network coverage.

In the case of ocean freight, a series of large-scale sea trials, conducted in 2018 and 2019 by the Poseidon network, established, conclusively, that satellite communications are necessary for reliable data exchange at sea[6]. This is because GSM and other terrestrial transmission systems have limited reach and quickly lose connection with offshore devices. For land-based monitoring and in air cargo situations in which the data connection is disabled in flight, this isn't much of a problem. However, with the longer durations and remoteness of sea travel and the inability of battery-powered devices to continuously transmit for prolonged voyage durations, reliable ship-to shore satellite communications are necessary.

Satellites may seem like an expensive option but in fact this can be a relatively inexpensive option due to the fact that many reefers are equipped with inbuilt telematics. For example, the entire 270,000-strong reefer fleet of shipping line Maersk is equipped with remote container management (RCM) technology. Satellite systems, including those that automatically switch to GSM when within cellular range, such as those fitted to the range of reefers from Klinge Corporation, provide door-to-door data transfer including ambient temperature, cargo temperature, running condition, alarm status, fuel levels, and power source, all in near real time.

Risky Business

Estimates of the drug losses attributable to temperature excursions are in the billions of dollars with some sources reckoning that up to 5% of pharma shipments involve a notifiable temperature event[7]. One recent survey reported nearly 45% of respondents experiencing multiple temperature excursions, with 16% having monthly occurrences[8].

Reefer Model NMF-372 from Klinge Corp with dual refrigeration units and integral generator-set.

This scale of detriment is breathtaking for an industry that is tasked with saving lives, and vaccines are not exempt.

One of the reasons for these extra-ordinary logistics failures is the fact that, despite its sustained efforts, airfreight for temperature-sensitive vaccines and pharmaceuticals remains a very risky business compared to other modes of transport. One recent paper suggests that airfreight is responsible for no less than 79% of all temperature excursion occurrences compared to 19% for road and a tiny 1% for ocean[9].

Some observers contend that pharma airfreight has become just too complex a process to ever be consistently reliable in practice. "Simplicity is a prerequisite for reliability", as the celebrated Dutch mathematician and computer scientist Edsgar Dijkstra famously said.

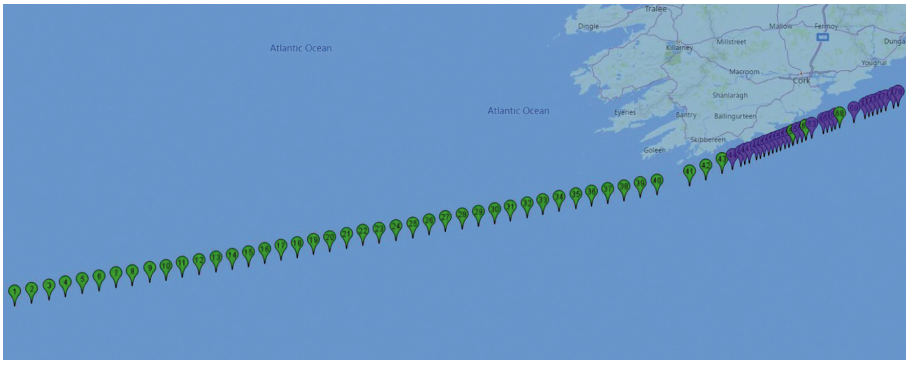


Image shows a reefer connected via satellite when crossing the Atlantic (green symbols) then a switching to GSM near Ireland (purple symbols). When GSM connection is lost it automatically reverts to satellite.

Inherent Advantages

On the other hand, ocean freight comes with a number of inherent advantages which account for its much lower rate of thermal excursions. Firstly, the sea freight process involves significantly fewer touchpoints than airfreight and, crucially, vaccines and other pharma merchandise remain in a temperature-managed, GDP-compliant, storage environment all the way from the point of production to the place of delivery. Once the reefer doors are closed at the manufacturer's premises there is no interference with the vaccines during transportation, there is practically no opportunity for opportunistic theft, and there are virtually no interruptions to the storage conditions throughout the journey.

Reefers have several technological features which further render them highly advantageous for vaccines and other sensitive medicines. Reefers are available with built-in redundancy options in the form of dual refrigeration units and models such as the NMR-262 from Klinge Corp. come with in-built power generation to provide the ultimate peace of mind when shipping vaccines and other medicines.

Refrigerated reefer containers are highly reliable units that are built to take the rough and tumble of many years of continuous use. Adjustable to one-tenth of one degree Celsius, the technical performance and reliability of these containers is legendary,

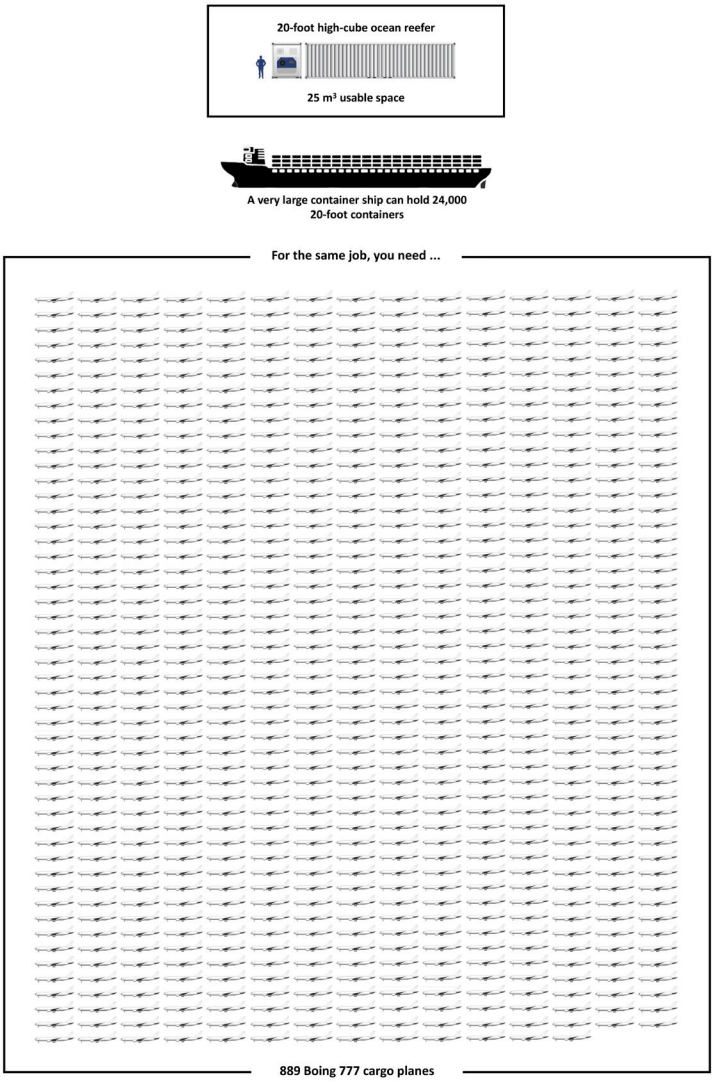
with properly serviced units typically operating for fifteen years or more without breakdown.

By combining active reefer refrigeration with qualified passive pallet protection and other qualified system components, a 'belts and braces' transport environment can be created that is thermally stable for indefinite periods in practically all conceivable ambient conditions. This 'duplex protection' is highly fault-tolerant and has been successfully field-trialled by the Poseidon network over more than 50,000 reefer-kilometres in severe summer and winter conditions. Such a system is proof against the vast majority of cold-chain breakdown scenarios including temporary power-loss, ambient extremes, customs inspections, unexpected delays, deferred power hook-ups, unplanned door opening events and equipment malfunctions.

20-foot and 40-foot refrigerated containers are easily moved by road to place of need.

Storage Boxes

In theory, one very large container ship has a volumetric freight capacity equivalent to more than 800 Boeing 777-200F wide body freighters, which means that just a dozen ships could easily hold sufficient COVID-19 vaccine doses to double dose every adult in the entire world. By comparison, it will need something like 10,500 Boeing 777F Freighters to carry the same volume of vaccine. At the other end of the scale, a single 40-foot high-cube ocean reefer has the capacity to accommodate something between 350,000 and 3,800,000 individual vaccine vials depending on presentation[10]. So, from a capacity perspective it is easy to visualise how the ocean mode of transport can be the mainstay of a viable global logistics solution for COVID-19 vaccines.



The volumetric capacity of a modern container ship is prodigious compared to a dedicated widebody airfreighter.

For COVID-19 vaccine distribution purposes, refrigerated containers can be uplifted from the seaport and easily transported by road to vaccine distribution points and, as we have seen, used as GDP-compliant temporary/mobile storage units. Such moveable cold stores mean that there is no need to find, rent or build expensive fixed storage facilities. Employing a leasing strategy means there is no need to tie up huge amounts of capital. and this highly flexible approach addresses one of the biggest issues with the entire global COVID-19 vaccination programme – the availability of suitable vaccine storage in remoter locations. The only requirement is an electrical power source which, if/when necessary, can be supplied from generators or other standby sources.

Cold Comfort

Reefers can maintain stable cargo temperatures in temperatures from plus 30°C all the way down to minus 70°C and in ambient temperatures up to plus 50°C. Tests are currently underway to qualify even lower

reefer operating temperatures. A major benefit with reefers rests in the fact that, having mechanical refrigeration, they are not dependent on CO_2 "dry ice", for cooling, with all its associated availability, top-up, training and safety issues. Classified as a 'hazardous cargo' and with current regulations restricting the maximum total volume of dry ice on board a single wide-bodied flight to "around 1 tonne"[11], dry ice presents a serious limitation to the volumes of very cold vaccines that can be handled by airlines.

In many regions, and in fact in some entire countries, there is little, or simply no, availability of dry ice in commercial volumes. Talking about mRNA vaccine, Dr Jarbas Barbosa, assistant director of the Pan American Health Organization, recently told broadcaster CNN: "The rural and the urban areas in any country in the world are not ready to manage this vaccine today".[12]

However, the majority of COVID-19 vaccines will not need ultra-cold storage conditions. In fact, where adjuvants are used, some vaccines will almost certainly require protection against freezing which can result in loss or destruction of potency. Most COVID-19 candidate vaccines will require plus 2°C to plus 8°C and a smaller number minus 15°C to minus 25°C. These are much less challenging compared to ultra-cold temperature handling.

In cases where there is a risk of freeze-sensitive vaccines being exposed to sub-zero ambient temperatures, it is worth noting that, unlike many active airfreight containers, refrigerated reefers come equipped with reliable heating as well as refrigeration equipment.

Cost Matters

Finally, we come to cost. It is easy to say that you cannot put a cost on life, but it is a hard fact that the distribution of COVID-19 vaccines needs to be performed in the most cost-efficient manner possible. Only in that way will it be possible to reach every eligible adult in every country in the world in a timely manner.

The airline industry's loss of belly capacity has not only resulted in curtailed freight services, it has provoked an inevitable surge in airfreight rates to record highs. Ocean freight rates, on the other hand, although having been volatile recently, are historically a fraction of the equivalent airfreight levels and, for now, even lower.

A 2019 study[13] indicated that those pharmaceutical companies that have made a serious transition from airfreight to ocean freight are consistently realising cost savings in the order of 70% or more. An even more recent (post-pandemic) analysis comparing airfreight and sea freight rates over a typical Asia to Europe freight lane, showed that temperature-controlled ocean freight for vaccines is now less than 8% of the equivalent airfreight rate. This suggests that, with its lower risk factor, ocean freight will be much more effective for vaccine distribution on a price/performance basis.

Turbulence Ahead

To expect airfreight to cope with the volumes concerned, while at the same time continuing to maintain an uninterrupted flow of non-COVID-19 related drugs, is wholly unrealistic. The ramping up of air cargo capacity may be a visceral reaction from an airline industry facing existential pressures but it is not a sustainable solution to the challenges being faced going forwards. A sole reliance on airfreight for large-scale vaccine distribution is not only physically and financially unrealistic, it will perpetuate the "all in one basket" gamble that created much of the current freight turbulence in the first place.

Finally, it is important to bear in mind that where COVID-19 vaccines are being flown into place, this might be at the expense of other life-saving medicines and vaccines which will remain in demand but are potentially delayed or clinically impaired through sub-optimal distribution. This displacement of vital medicines might be a frightening 'robbing Peter to pay Paul' consequence of ignoring alternative distributions modes and the bigger picture.

In Conclusion

There is little doubt that the long-haul transportation of COVID-19 vaccines and other vital pharmaceuticals needs to be conducted in a manner that is coordinated, integrated, multi-modal, affordable, sustainable and reliable. Practically speaking, this will require a shift from airfreight to sea freight for a proportion of COVID-19 vaccines and other medicines.

Already some governments are indicating that they may have to defer their vaccination programmes pending the arrival of vaccine types that are easier to store and transport[14]. If so, this will leave huge expanses of the world exposed to the pandemic. As WHO chief Tedros Adhanom Ghebreyesus emphasised recently: "No-one is safe until everyone is safe"[15].

Disclaimer

The mention of specific companies or of certain manufacturers' products does not imply that they are endorsed or recommended by the authors in preference to others of a similar nature that are not mentioned.

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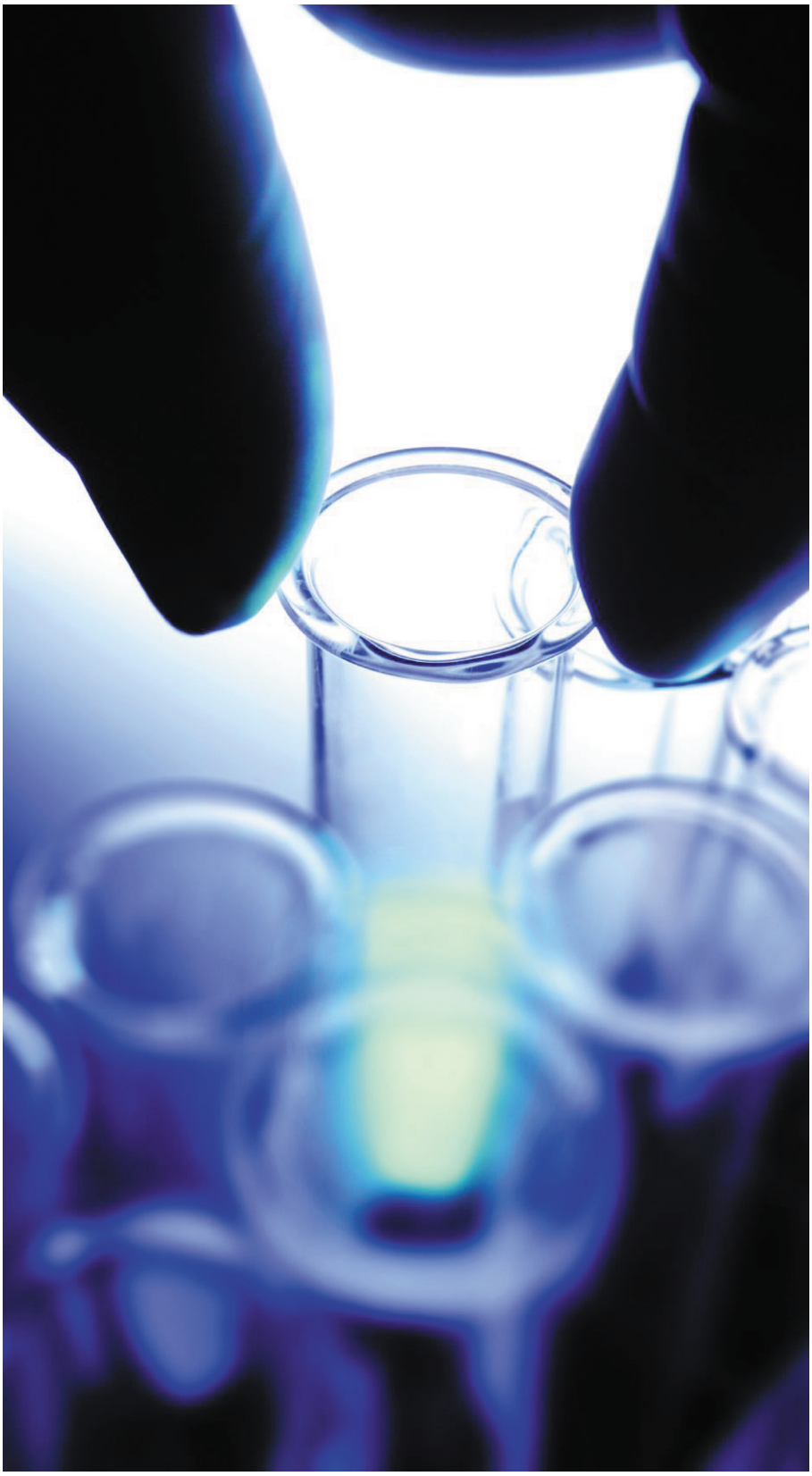

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