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## **COVID-19 outbreak: implications on healthcare operations**

### **Abstract:**

**Purpose** - The COVID-19 pandemic is considered a major disruptive event of this decade, raising unforeseen socio-economic implications worldwide. This novel virus has increased the influx of patients in hospitals, and healthcare organisations are facing unprecedented constraints in their operations to deal with increased demand and pressed capacity. Thus, this article evaluates the impact of the COVID-19 pandemic on healthcare systems' demand, resources and capacity, and provides research directions.

**Design/methodology/approach** - This is a viewpoint article, and uses timely information on healthcare operations from both scholars and managers, published by diverse sources during the COVID-19 outbreak.

**Findings** – We discuss the focus on ‘flattening the curve of infection’ as a measure to protect healthcare, delay the impact of increased demand, and reorientate healthcare supply chain practices. Furthermore, **we evaluate** the role of lean practices on managing demand and capacity, and improving quality across healthcare operations and supply chain. Finally, we suggest research directions on modern operational issues that emerged during this pandemic, such as discussions around the sustainability of lean post-pandemic, ‘just in time’ practices, inventory trade-offs, and lack of **organisational** responsiveness during untenable events.

**Originality/value:** In this article, we provide a contemporary assessment of the implications of the COVID-19 pandemic on healthcare operations, underscoring main economic and operational elements that can be affected, such as unforeseen demand, resources and capacity shortage. Therefore, we assess that healthcare **organisations**, practitioners and governments have to

anticipate operational and economic impacts, and ultimately, to reassess their plans to deal with such adverse events.

**Article Classification:** Viewpoint

**Keywords:** Capacity; COVID-19; Coronavirus; Demand; Infection Curve; Healthcare System; Healthcare Operations; Lean Healthcare; Pandemic; Resources.

## **Introduction**

Bohmer *et al.* (2020) argue that a pandemic generates an untenable demand shock for healthcare systems constrained capacity. In low and middle-income countries, the pandemic might result in increasing poverty and reducing access to healthcare far beyond COVID-19 (Evans and Over, 2020).

Since the outbreak of COVID-19 in China, the world has learnt that this pandemic is disruptive, affecting governments, healthcare organisations, citizens, and economies. Whilst COVID-19 has driven some healthcare systems beyond their limit, the financial implications of the virus is also a mutual concern amongst world leaders. As a result of many countries adopting social distancing, lockdown/shelter in place measures and accepted the cost of an economic pullback, it is raising uncertainties for the global economy (Singhal *et al.*, 2020). For instance, a discussion about the cost of ‘flattening the curve’ for COVID-19 (Thunstrom *et al.*, 2020) provides data from Goldman Sachs that predicts a gross domestic product shrink in the US, around 3.8% in 2020. Indeed, there is also an economic impact on healthcare. The concerns are related to the cost that this pandemic will add to public healthcare systems, and especially the cost of private healthcare insurance premiums in the consecutive year, which could rise from 4% to 40% (Adams, 2020). Beyond the economic damage, the lockdown may impact on the mental health and well-being of citizens, which will further put pressure on ailing healthcare organisation post-COVID-19 period.

### ***Protecting healthcare – flattening the curve***

When COVID-19 was officially acknowledged as a pandemic by World Healthcare Organization (WHO), a focus to ‘flatten its curve of infection’ has been endorsed globally to save lives (Anderson *et al.*, 2020). The key reasons for flattening this curve is to avoid casualties, delay the pandemic impact on healthcare operations (i.e. trying to follow level loading principles) and ‘buy

time' for healthcare and other manufacturing and service organisations to reorient their supply chain practices. Nonetheless, when geographic and temporal clustering of the outbreak becomes an epicentre of the virus infection, healthcare capacity has to deal with unbearable demands (Carvalho *et al.*, 2020). The pandemic has an unforeseen impact on healthcare operations; directly affecting resource utilisation, capacity and patient demand. In terms of healthcare preparedness, governments and public healthcare organisations are learning from experiences in China, Germany, South Korea and Italy about how to deal with COVID-19. International agencies have also published recommendations for strengthening healthcare system responses, considering patient impact and hospital capacity and resources (CDC, 2020; WHO, 2020a).

Therefore, supported by a range of contemporary sources published during the outbreak, this article discusses the implications of the COVID-19 pandemic on healthcare operations, including consideration of 'flattening the infection curve' in controlling demand to support a delayed impact on constrained healthcare operations. Further considerations are paid to the potential for maximising lean application in healthcare, and how prepared governments are, in terms of resources and capacity post-COVID-19 period.

### **Implications for demand, resources and capacity**

There are uncertainties about the size of demand for healthcare treatment for COVID-19, as well as when 'waves' of infection will come, but there are indicators emerging from other countries experiences. WHO (2020b) expect that 80% of infected patients will be mild cases without the need for specialised care. However, when patients with severe COVID-19 symptoms require intensive care, considerable strain is evident on healthcare operations. The continually increasing number of patients creates an operational 'bottleneck'. In classic terms of Factory Physics (Hopp

and Spearman, 2011), at high capacity utilisation in healthcare organisations, there will be a long queue of patients who have to wait to receive treatment (e.g. as viewed in Italian healthcare system due to limited availability of ventilators to treat COVID-19 patients).

Public healthcare capacity, defined as ability to deal with a considerable influx of patients during the COVID-19 pandemic, is measured by the availability of hospital facilities, beds (including ICU), financial and human resources. To cope with the untenable rise of infected patients, hospitals are considerably increasing their capacity. For William *et al.* (2020), bed capacity plays an important role in managing the COVID-19 demand; it is recommended to cease all non-emergent care across hospitals (Hare *et al.*, 2020), move appointments to telemedicine when possible, and to commission the use of private hospitals to increase responsiveness (Leite *et al.*, 2020).

Going back to the basics of Factory Physic (Hopp and Spearman, 2011), increased demand directly impacts healthcare's limited resources (e.g. equipment, materials and medications) and the ways to maximise utilisation of healthcare facilities are either to address the issue of arrival rate variability at patient end (e.g. by testing and treating citizens in local communities as done by Germany, Iceland, and South Korea) or minimise process variability issues within healthcare supply chains.

Many countries have flirted with applying lean in healthcare (Costa and Godinho, 2016; Improta *et al.*, 2019; Leite *et al.*, 2019). We use the term 'flirted with' as there has been challenges of having consistency in the approach to lean implementations and sustainability over the longer-term (Jabbal, 2017; Hines *et al.*, 2018; Lindsay *et al.*, 2020). However, lean offers the opportunity to manage demand and capacity, improve quality and safety of care and reduce costs (Womack

and Jones, 1996). Given the fiscal demand and economic implications from COVID-19, there remains wider opportunities for lean to be implemented beyond the current crisis.

Elements of lean are already visible in the COVID-19 responses within healthcare. Pathways have been redesigned for flow, staff redeployed and new multi-disciplinary teams created (NHSTayside, 2020). The focused nature of field hospitals for specifically treating COVID patients in the UK and Italy, clearly draw on lean in their design with considerations of flow, 5S and standardised processes to support non-specialists delivering Covid-19 specific care (Locke, 2020; Marsi, 2020). The challenge will be sustaining lean in the pandemic and post-pandemic eras. This focus on COVID-19 capacity comes at the expense of ‘business as usual’ in the provision of preventative screening programmes and routine (non-emergency) surgeries. By late April 2020, two million operations had been cancelled in the NHS in England, and there is a real fear that the cancelling of ‘routine’ procedures will have wider and more severe mortality implications later (Sample, 2020). Given that COVID-19 is expected to remain with us for some time (Gullard, 2020), it will be critical that COVID-19 care and treatments and full healthcare services are offered in parallel. Lean can be applied to manage and increase capacity (LaGanga, 2011; Ricciardi *et al.*, 2019) and support staff in redesigning processes and sustaining meaningful change that breaks down hierarchical barriers (Poksinska and Swartling, 2018; Mårtensson *et al.*, 2019; Lindsay *et al.*, 2020).

An example of applying Lean principles and tools could be the UK NHS starting to offer full healthcare services and use the ‘Nightingale’ hospitals to treat COVID-19 patients. There are several illustrations available where care home or non-COVID patients admitted to the hospital catch COVID19 symptoms during treatment process. This can be the result of poor layout in the hospital in segregating infected from non-infected patients, or it could be due to transfer of

infection from clinical staff (where care has not been taken to isolate clinicians treating COVID-19 patients). Here techniques borrowed from lean lexicon such as clear communication, careful planning, using visual management and standard operating procedures followed during admission, treatment, and post-treatment by patients and clinicians could help in minimising spread of infection. Even in the procurement of Personal Protective Equipment (PPE), either nationally or internationally, having clearly defined PPE specifications would have helped to avoid wastes generated or significant delay caused due to PPE supplies not meeting the healthcare quality standards. After a significant delay to collect 400000 of PPE (gowns) from Turkey to help the NHS staff treat COVID 19 patients, it was identified that the supplied PPE does not meet the UK quality standards (Rawlinson, 2020). This is a classic example of the failure of material management and not having clearly defined specifications (Regattieri *et al.*, 2018), leading to creation of several types of wastes including transportation, motion, inventory, waiting, extra processing, and defects. This mistake could have been avoided if precise specifications were provided to suppliers of the PPE. One of the key tenets of Lean Production System is close collaboration between buyers and suppliers to maximise value delivery to end consumer. This principle was seen to be widely followed during the manufacturing of ventilation equipment globally. Close collaboration between public, private, and third sector in the UK resulted in design and manufacturing of ventilators within 5-6 weeks which would have taken multi-year development cycle (TTP, 2020).

Where lean has been particularly challenged is in the inventory management of PPE. A highly infectious virus requires intensive use of this and other specialised equipment and drugs. However, healthcare supply chains in the Western world (Italy, Spain, UK, and USA), were not prepared to deal with disruption on this scale that impacts daily services (NPR, 2020). The increased demand

for PPE, equipment (e.g. ventilators), and drugs, exposed the fragility in the healthcare supply network (UN NEWS, 2020) due to a reliance on Just-in-Time (JIT) approaches and failure to effectively manage inventories. In the complex and multi-layered UK healthcare system with more than 200 Trusts, even the centralised model for the distribution of supplies, could not facilitate rapid responses to fast-changing ground reality due to multi-layered communication channels, between clinicians and suppliers. The fear of a late 2020 ‘more deadly wave’ means inventories must be built now as lockdown measures begin to ease, to mitigate against issues seen in this period (Leung *et al.*, 2020; Gulland, 2020). The lack of resources will ultimately lead to process variability, affecting healthcare capacity utilisation and disrupt operations.

We understand that these operational and supply chain management issues are not new during critical events, as history shows that similar outbreaks (such as Ebola in West Africa 2014 - 2016), also suffered from issues over PPE, overwhelmed healthcare operations, and resulted in increased numbers of deaths of patients and healthcare workers (Elston *et al.*, 2017). However, we have not experienced this level of global impact and disruption in our lifetimes. Pandemics raise awareness of the future risks we might face, highlight the fragility of global healthcare infrastructures, and reinforces the role and impact of healthcare operations in the management of demand, capacity and resources, as well as constraints from the wider supply chain.

### **Operatuions Manamegement Contributions**

Countries around the globe have seen collaboration between public, private, and charitable organisations to address the operations management (OM) dilemma of ‘demand vs capacity’. The timing and appropriateness of those OM-related decisions now have severe implications for the economy, citizens, and public healthcare organisation of many countries. This ‘black swan’ pandemic

has forced organisations to reorient their supply chain model for short-term survival. There are examples of proactive supply chain collaborations to meet the needs of healthcare organisations where companies, (e.g. Airbus, Diageo and Rolls-Royce) have realigned their product offerings, processes, and supply chain to manufacture essential items for healthcare operations, such as PPE, hand sanitisers and ventilators (Davies, 2020). The healthcare organisations faces significant challenges in the post-COVID-19 period, but at the same time, there are opportunities to restructure and realign its operations. If the pandemic created unprecedented impact on healthcare operations, it also accelerated the changes in policies, disaster plans, and the use of technology (Salamon, 2020). For instance, Kaiser (2020) observes that the healthcare systems will have to adapt and reorganise its structural care focus, and already attention to remote medical services and cross-vertical and industrial cooperation is seen as a way forward.

Demand for healthcare provision is expected to increase, either by a possible second wave of infection, or postponed medical services during the pandemic, such as surgeries and treatments. There are also post-pandemic side-effects that create an influx of patients seeking healthcare services, for instance, post-traumatic stress disorder (PTSD), healthcare professionals burnout, and increasing birth rates (e.g. baby boom post-pandemic) (McBain *et al.*, 2016; Hollander and Sites, 2020; Marston *et al.*, 2020; Segers, 2020; Wang, 2020). These challenges, together with a suggested response plan and recommendations, are presented in table 1.

Table 1 – Healthcare Operational Challenges during COVID-19 and Beyond

Healthcare challenges during COVID-19 and beyond	Response plan	Reflections of the authors and recommendations for future unforeseen events
Low bed capacity (including ICU)	<ul style="list-style-type: none"> <li>- Level loading principles by using lean practices such as redesigning flow and process (VSM)</li> <li>- Move non-urgent appointments to telemedicine;</li> <li>- Delay non-urgent surgeries and treatments;</li> <li>- Use of private hospitals to increase responsiveness;</li> </ul>	<p>Bed capacity is crucial in responding to critical events, and we believe that it is possible to increase healthcare capacity by redesigning flows and redirecting non-urgent medical needs to telemedicine, cancelling elective work, and if necessary using temporary healthcare facilities. These elements should be part of a major disaster response plan, to enable proactive rather than reactive measures.</p>
Supply chain constraints: Lack of medical resources, PPE and equipment	<ul style="list-style-type: none"> <li>- A robust disaster plan that includes inventory of key resources;</li> <li>- Reorientation of SCM practices by working closer to suppliers;</li> <li>- Cross-vertical and industrial cooperation for key equipment and PPE's;</li> </ul>	<p>The lack of resources, PPEs and equipment exposed the healthcare supply chain fragility and dependency. Moving forward, healthcare managers should consider inventory of key resources for unforeseen events, establish closer collaboration between buyers and suppliers, and develop projects in collaboration with local industries.</p>
Healthcare staff shortage	<ul style="list-style-type: none"> <li>- Redirect staff from non-priority areas;</li> <li>- A plan to bring back retired staff;</li> <li>- Medical and nursing students early graduation;</li> <li>- Effective collaboration between primary and secondary care to share capacity; Collaboration with social care sector and provide required support in care homes</li> </ul>	<p>If during ‘normal’ circumstances the healthcare system already operates under staff shortages, when a pandemic begins this is an extra constraint to healthcare capacity. Therefore, we suggest a focus on building staff capacity for the intake of COVID-19 patients, including redirecting staff from non-urgent areas, calling upon retired staff and providing early graduation for final year students from healthcare programmes. These measures combined with use of technology and prioritization of healthcare for the pandemic and critical services, might considerably increase staff capacity.</p>
Increased demand vs low capacity	<p>Implementation of lean practices:</p> <ul style="list-style-type: none"> <li>- Management of demand and capacity;</li> <li>- Improve quality and safety;</li> <li>- Reduce costs;</li> </ul>	<p>Lean practices have been widely used in healthcare to manage demand and increase capacity (e.g. Burgess and Radnor, 2013; D’Andreamatteo <i>et al.</i>, 2015). During unforeseen events, lean approaches might guarantee the stability of the operation, support management of excessive demand and limited capacity as well as improve patient safety. However, it is important that lean is applied as continuous improvement practice, otherwise it will not be sustained during such critical events.</p>

A second wave of infection or increased demand

- Adoption of the response measures above;
- Use of technology to wider healthcare coverage and enable contact tracing;
- Continue essential screening services/Cancer care Provision;
- Active collaboration between public, private and third sector;
- Broader investments in healthcare;

There is a growing fear amongst healthcare managers that the second wave of demand will hit public healthcare (Leung *et al.*, 2020; Gulland, 2020), either by a new rise in cases of Covid-19 infection; influx of patients that had their non-urgent procedures postponed; emerging mental health issues (PTSD; staff burn-out) and increasing birth rates (baby boom). What we recommend is to implement the response plan above, combined with technologies to provide remote medical services, and enable contact tracing to halt the spread of the virus. Finally investment in public healthcare systems are critical for readiness and preparedness that will increase healthcare capacity and save lives.

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Due to postponement or cancellation of services like cancer treatment during COVID19 lockdown period, we may see an influx of deaths in several months' time because of discontinuity of important treatment or services. These are unintended consequences that healthcare will face due to lack of systems thinking in decision making process. The mental health hospitals may also see influx of patients as more people will be affected because of unemployment, substance misuse, bereavement, physical illness and lack of support. To address this issue in the long-term, active collaboration between public, private and third sector is required. Other option will be to invest resources to increase the capacity in the mental health units which are already struggling due to staffing issues including less number of clinical and managerial staff, staff sickness, leaves, unwillingness to work due to safety concerns.

### **Future Research Directions**

This pandemic also forces healthcare organisations, such as the NHS, to rethink their operations and supply chain model of procurement, capacity planning, demand management and patient-centric care at a community level to address the operational dilemma of 'demand vs. capacity'. Thus, based on the impact of the COVID-19 pandemic on healthcare operations, we raise some important OM challenges to be addressed by further empirical research. For instance, will lean initiatives be sustained and support healthcare operations to deliver safe and effective care in the new COVID-19 world? Wider supply chains decisions that result in a lean inventory, such as 'just in time', are questioned during the pandemic; perhaps future approaches to inventory will consider cost as a trade-off to increase resource and capacity responsiveness during untenable events (Bohmer *et al.*, 2020). This might influence how disaster plans are developed by public organisations, and how key players in the healthcare supply

network are developed locally to avoid dependency and disruption related to critical products and services (Economist, 2020).

The impact of postponing medical procedures and treatment is expected to result in an influx of patients seeking healthcare services, at primary or secondary care, in the post-pandemic period (William *et al.*, 2020). This requires an innovative way of demand management without compromising on the quality of care, which will require effective collaboration between primary and secondary care and other social care sectors. We encourage research that investigates several areas of demand management in healthcare. Firstly, given the global impact of the pandemic, studies on healthcare resilience, including comparative country studies for benchmarking best practices in the lockdown period, would be welcomed. Another interesting area to research is how healthcare organisations collaborated with other industries in public and private sectors to develop customised solutions for the treatment of COVID19 patients and supporting healthcare workers. In healthcare, critical resources are staff, and these staff will be essential in the management of demand and capacity. As it is already being reported about the potential for mental distress, there is scope for research on how extreme events such as wars and pandemics, impact human resources and create distress and mental health debilitation as a side-effect in managing excessive demand (Segers, 2020; Wang, 2020). Lastly, we advocate that COVID-19 is a modern disruptive case study for OM teaching, and it brings a new perspective of operations and supply chain management subjects, that might be introduced for the advantage of student learning.

### **Concluding Remarks**

In this article we discussed the implications of COVID-19 pandemic on healthcare demand, resources and capacity, and provided research directions. We argued that this pandemic has an economic and operational impact on countries and their healthcare systems. This novel virus has

already claimed a considerable number of lives, and governments around the world are fighting to ‘flatten the infection curve’ to thwart further casualties. Flattening the curve to prepare for increased demand has seen a renaissance of lean in healthcare which is positive, but adaption is necessary to manage inventory and the wider supply chain. Countries around the world have already been advised to start preparing now for a second, deadlier wave by the WHO (Gulland, 2020). Therefore, we suggest governments and healthcare organisations to assess the current COVID-19 impacts, and to reevaluate their contingency plans to improve how they deal with critical events. Finally, we hope that this article motivates future research on this subject and beyond, especially on healthcare operations and sustainability of improvements, including challenges raised by our research agenda.

## References

- Adams, K. (2020), “Will the pandemic mean higher health care costs in the future?”, <https://www.marketplace.org/2020/03/31/will-the-pandemic-mean-higher-health-care-costs-in-the-future/>, (Accessed 5 April 2020).
- Anderson, R.M., Heesterbeek, H., Klinkenberg, D. and Hollingsworth, T.D. (2020), “How will country-based mitigation measures influence the course of the COVID-19 epidemic?”, *The Lancet*, Vol. 395 No. 10228, pp.931-934.
- Bohmer, R. M. J., Pisano, G. P., Sadun, R. and Tsau, T.C. (2020), “How Hospitals Can Manage Supply Shortages as Demand Surges”, *Harvard Business Review*.
- Burgess, N. and Radnor, Z. (2013), "Evaluating Lean in healthcare", *International Journal of Health Care Quality Assurance*, Vol. 26 No. 3, pp. 220-235.
- Carvalho, J.J., Donoho, D.A., Forman, H.P. (2020), “Hospital Capacity and Operations in the Coronavirus Disease 2019 (COVID-19) Pandemic—Planning for the Nth Patient”, <https://jamanetwork.com/channels/health-forum/fullarticle/2763353>, (Accessed 23 March 2020).
- CDC (2020), COVID-19 Module. <https://www.cdc.gov/nhsn/acute-care-hospital/covid19/index.html>, (Accessed 9 April 2020).
- Costa, L. B., and Godinho, M. F. (2016), “Lean Healthcare: Review, Classification and Analysis of Literature”, *Production Planning & Control*, Vol. 27 No. 10, pp. 823–836.
- Davies, R. (2020), “Ventilator Challenge UK to start production in Covid-19 fight”, <https://www.theguardian.com/world/2020/mar/29/ventilator-challenge-uk-to-start-production-in-covid-19-fight>, (Accessed 21 April 2020).
- D’Andreamatteo, A., Ianni, L., Lega, F. and Sargiacomo, M., (2015), “Lean in healthcare: A comprehensive review”, *Health Policy*, Vol.119, No.9, pp.1197-1209.
- Economist (2020), “The changes covid-19 is forcing on to business”, <https://www.economist.com/briefing/2020/04/11/the-changes-covid-19-is-forcing-on-to-business>, (Accessed 22 April 2020).

- Elston, J. W., Cartwright, C., Ndumbi, P., Wright, J. (2017), “The health impact of the 2014–15 Ebola outbreak”, *Public Health*, Vol. 143, pp. 60-70.
- Evans, D. and Over, M. (2020), “The Economic Impact of COVID-19 in Low- and Middle-Income Countries”, <https://www.cgdev.org/blog/economic-impact-covid-19-low-and-middle-income-countries>, (Accessed 5 April 2020).
- Gulland, A. (2020), “Exclusive: Second more deadly wave of coronavirus 'to hit Europe this winter'”, [https://www.telegraph.co.uk/news/2020/05/18/second-wave-winter-coronavirus-europe-uk/?li\\_source=LI&li\\_medium=liftigniter-rhr](https://www.telegraph.co.uk/news/2020/05/18/second-wave-winter-coronavirus-europe-uk/?li_source=LI&li_medium=liftigniter-rhr), (Accessed 18 May 2020).
- Hare, S.S., Rodrigues, J., Nair, A., Robinson, G. (2020), “Lessons from the frontline of the Covid-19 outbreak”, *The BMJ Opinion*, <https://blogs.bmj.com/bmj/2020/03/20/lessons-from-the-frontline-of-the-covid-19-outbreak/>, (Accessed 14 April 2020).
- Hines, P., Taylor, D. and Walsh, A. (2020), “The Lean journey: have we got it wrong?” *Total quality management & business excellence*, Vol. 31 No. 3-4, pp. 389-406.
- Hollander, J.E. and Sites, F.D., (2020), “The transition from reimagining to recreating health care is now”, *NEJM Catalyst Innovations in Care Delivery*, Vol.1, No.2, Pp. 1-8.
- Hopp, W.J., and Spearman, M.L. (2011), “Factory Physics”, 3rd ed., Waveland Press, Illinois, USA.
- Improta, G., Balato, G., Ricciardi, C., Russo, M.A., Santalucia, I., Triassi, M. and Cesarelli, M. (2019), “Lean Six Sigma in healthcare: fast track surgery for patients undergoing prosthetic hip replacement surgery”, *The TQM Journal*, Vol. 31 No. 4, pp. 526-540.
- Jabbal, J. (2017), “Embedding a culture of quality improvement”, <https://www.kingsfund.org.uk/publications/embedding-culture-quality-improvement>, (Accessed 10 January 2020).
- Kaiser, F., 2020, “Future of health care in post-Covid-19 world”, <https://asiatimes.com/2020/05/future-of-health-care-in-post-covid-19-world/>. Accessed 6 July 2020.
- LaGanga, L. R. (2011), “Lean service operations: reflections and new directions for capacity expansion in outpatient clinics”, *Journal of Operations Management*, Vol. 29 No. 5, pp. 422-433.
- Leite, H., Bateman, N., Radnor, Z. (2019), “Beyond the ostensible: an exploration of barriers to lean implementation and sustainability in healthcare”, *Production Planning and Control*, Vol. 31 No. 1, pp. 1-18.
- Leite, H., Hodgkinson, I. R., and Gruber, T., (2020), “New development: “‘Healing at a distance’—telemedicine and COVID-19””, *Public Money & Management*
- Leung, K., Wu, J.T., Liu, D. and Leung, G.M., 2020. First-wave COVID-19 transmissibility and severity in China outside Hubei after control measures, and second-wave scenario planning: a modelling impact assessment. *The Lancet*. Vol. 395 No. 10233, pp. 1382-1393.
- Lindsay, C. F., Kumar, M., Juleff, L. (2020), “Operationalising Lean in Healthcare: the Impact of Professionalism”, *Production Planning and Control*, Vol. 31 No. 8, pp. 629-643.
- Locke, T. (2020), “UK COVID-19 Daily: 4000 Capacity London Field Hospital Announced”. <https://www.medscape.com/viewarticle/927352> (Accessed 4 April 2020)
- McBain, R.K., Wickett, E., Mugunga, J.C., Beste, J., Konwloh, P. and Mukherjee, J., (2016), “The post-Ebola baby boom: time to strengthen health systems”, *The Lancet*, Vol.388, No.10058, pp.2331-2333.
- Marsi, F. (2020), “Coronavirus: Italy’s worst-hit region builds new hospital in 10 days” from The Independent at: <https://www.independent.co.uk/news/world/europe/coronavirus-italy-hospital-milan-lombardy-cases-deaths-a9438761.html> (Accessed 18 May 2020)
- Marston, H.R., Musselwhite, C. and Hadley, R.A., 2020. COVID-19 vs Social Isolation: the impact technology can have on communities, social connections and citizens. [https://www.academia.edu/download/62420979/COVID-19\\_vs\\_Social\\_Isolation\\_the\\_Impact\\_Technology\\_Ageing\\_Issues20200320-17623-1v0k1bl.pdf](https://www.academia.edu/download/62420979/COVID-19_vs_Social_Isolation_the_Impact_Technology_Ageing_Issues20200320-17623-1v0k1bl.pdf), The British Society of Gerontology. (Accessed 5 July 2020)
- Mårtensson, A., Snyder, K. and Ingelsson, P., (2019), “Interlinking Lean and sustainability: how ready are leaders?”, *The TQM Journal*, Vol. 31 No. 2, pp. 136-149.

- NHSTayside (2020), "A look inside the Covid-19 assessment unit at Ninewells Hospital", [https://www.nhstayside.scot.nhs.uk/News/Article/index.htm?article=PROD\\_336314](https://www.nhstayside.scot.nhs.uk/News/Article/index.htm?article=PROD_336314), (Accessed 18 May 2020).
- NPR, (2020), "As The Pandemic Spreads, Will There Be Enough Ventilators? there-be-enough-ventilators", <https://www.npr.org/sections/health-shots/2020/03/14/815675678/as-the-pandemic-spreads-will>, (Accessed 28 March 2020).
- Poksinska, B. and Swartling, D., (2018), "From successful to sustainable Lean production—the case of a Lean Prize Award Winner", *Total Quality Management & Business Excellence*, Vol. 29 No. 9-10, pp. 996-1011.
- Radnor, Z. J., Holweg, M. and Waring, J. (2012), "Lean in healthcare: The unfilled promise?", *Social Science & Medicine*, Vol.74, No.3, pp. 364-371.
- Rawlinson, K., (2020), "Coronavirus PPE: all 400,000 gowns flown from Turkey for NHS fail UK standards", <https://www.theguardian.com/world/2020/may/07/all-400000-gowns-flown-from-turkey-for-nhs-fail-uk-standards>, (Accessed 19 May 2020)
- Regattieri, A., Bartolini, A., Cima, M., Fanti, M.G. and Lauritano, D. (2018), "An innovative procedure for introducing the lean concept into the internal drug supply chain of a hospital", *The TQM Journal*, Vol. 30 No. 6, pp. 717-731.
- Ricciardi, C., Fiorillo, A., Valente, A.S., Borrelli, A., Verdoliva, C., Triassi, M. and Improta, G. (2019), "Lean Six Sigma approach to reduce LOS through a diagnostic-therapeutic-assistance path at AORNA Cardarelli", *The TQM Journal*, Vol. 31 No. 5, pp. 657-672.
- Salamon, M. (2020). A Decade of Telemedicine Policy Has Advanced in Just 2 Weeks. <https://www.medscape.com/viewarticle/928038?src=rss>. Accessed 6 July 2020.
- Sample, I. (2020), "More than two million operations cancelled as NHS fights Covid-19" from The Guardian, at: <https://www.theguardian.com/society/2020/apr/26/more-than-two-million-operations-cancelled-as-nhs-fights-covid-19>, (Accessed 18 May 2020)
- Segers, C., (2020), Psychological Resilience, Burnout Syndrome, and Stress-related Psychiatric Disorders among Healthcare Professionals during the COVID-19 Crisis. *Psychosociological Issues in Human Resource Management*, Vol. 8, No.1, pp.7-12.
- Singhal, S., Finn, P., Kumar, P., Craven, M., and Smit, S. (2020), "Critical care capacity: The number to watch during the battle of COVID-19", <https://www.mckinsey.com/industries/healthcare-systems-and-services/our-insights/critical-care-capacity-the-number-to-watch-during-the-battle-of-covid-19>, (Accessed 7 April 2020).
- Thunström, L., Newbold, S.C., Finnoff, D., Ashworth, M. and Shogren, J.F. (2020), "The benefits and costs of using social distancing to flatten the curve for COVID-19", *Journal of Benefit-Cost Analysis*, pp.1-27.
- TTP, (2020), "Cambridge companies unite to meet the COVID-19 ventilator challenge". <https://www.ttp.com/news/cambridge-companies-unite-to-meet-the-covid-19-ventilator-challenge>, (Accessed 14 April 2020).
- UN News, (2020), "Coronavirus: demand for face masks creates shortfall for those in real need". <https://news.un.org/en/story/2020/02/1056942>, (Accessed 14 April 2020).
- Wang, C., Pan, R., Wan, X., Tan, Y., Xu, L., McIntyre, R.S., Choo, F.N., Tran, B., Ho, R., Sharma, V.K. and Ho, C., (2020), "A longitudinal study on the mental health of general population during the COVID-19 epidemic in China", *Brain, behavior, and immunity*. Vol. 87, pp. 40-48.
- WHO, (2020a), "Strengthening the health system response to COVID-19" [http://www.euro.who.int/\\_\\_data/assets/pdf\\_file/0003/436350/strengthening-health-system-response-COVID-19.pdf?ua=1](http://www.euro.who.int/__data/assets/pdf_file/0003/436350/strengthening-health-system-response-COVID-19.pdf?ua=1), (Accessed 7 April 2020).
- WHO, (2020b), World Health Organization: "Coronavirus disease 2019 (COVID-19) Situation Report-41". [https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200301-sitrep-41-covid-19.pdf?sfvrsn=6768306d\\_2](https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200301-sitrep-41-covid-19.pdf?sfvrsn=6768306d_2), (Accessed 28 March 2020).
- William, J., King, A.J., Jeffery, K., Bienz, N. (2020), "Fractured European response to the pandemic". *BMJ*, Vol.368, No.1117

Womack, J.P. and Jones, D.T. (1996), “Lean thinking—banish waste and create wealth in your corporation”, *Journal of the Operational Research Society*, Vol. 48 No. 11, pp.1148-1148.