Blue Planet Studio / Shutterstock.com

Considerations on pandemic resilient healthcare facilities

ANNE BROUWER
MSc, Royal HaskoningDHV, Nijmegen, the Netherlands
anne.brouwer@rhdhv.com

ROBERTO TRAVERSARI
PhD, The Netherlands Organisation for Applied Scientific Research TNO, Delft, the Netherlands

FRANS SAURWALT
MSc, Association Contamination Control Netherlands, Woerden, the Netherlands

MENNO HINKEMA
MA, The Netherlands Organisation for Applied Scientific Research TNO, Delft, the Netherlands

WIM MAASSEN
MSc, PDEng, Royal HaskoningDHV, Rotterdam, the Netherlands, Eindhoven University of Technology, Eindhoven, the Netherlands

Summary

The healthcare response to the current COVID-19 pandemic has required marshalling nearly all available capacity in the system. The peak months of the pandemic have seen an almost complete cessation of all but the most urgent regular care. Healthcare systems and facilities must be made more resilient to future outbreaks to avoid large and damaging social, economic and health impacts from missed care. Since it was established in March 2020 in the Netherlands, the Corona Expert Panel has collected evidence, drawn up guidance and provided practical advice to help care institutions cope with unprecedented and very challenging circumstances. Through its work, the Expert Panel has identified a number of intervention areas and strategies in design and management of facilities that healthcare providers can pursue to achieve a higher level of resilience in dealing with future pandemics. This paper zooms in on these areas and strategies and issues a call to action.

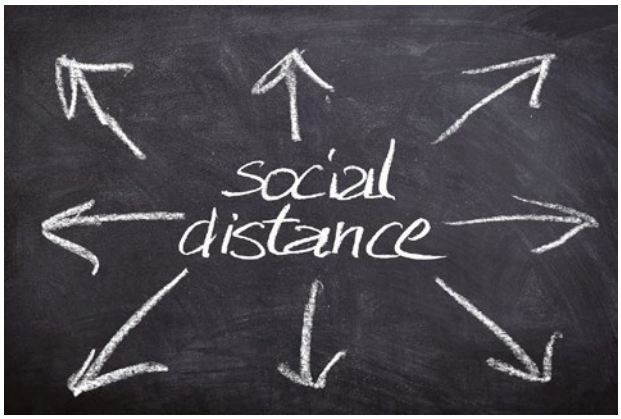


Image by Gerd Altmann from Pixabay

The Corona Expert Panel

In March of 2020, The Netherlands Organisation for Applied Scientific Research TNO, Eindhoven University of Technology (TU/e), the Association Contamination Control Netherlands VCCN and Royal HaskoningDHV (RHDHV) jointly established the Expert Panel on corona care. The objective of the expert panel was to collect evidence, issue guidance and provide practical advice to help healthcare organisations to minimize the risk of airborne contamination in their care facilities. While efforts have understandably been focused on short-term issues and operational responses, over the course of its activities the expert panel has identified a number of design and organisational strategies that healthcare organisations can pursue to be better able to cope with demand from future outbreaks or other large-scale acute events without unnecessary disruption to regular care processes. Since COVID-19 is the first large-scale global pandemic in modern times but very probably not the last, it is advisable to start preparations now in order to avoid negative impacts in the future.

Problems in short-term response

The expert panel found that three main issues contributed to problems in coping with COVID-19 demand and exacerbated the negative impacts of the pandemic.

A lack of scale-up or "surge" capacity meant that crucial facilities for dealing with patients – intensive care units and isolation rooms – quickly became overloaded. Alternative arrangements had to be made, pulling into temporary service regular inpatient wards or even non-patient care areas such as convention centres and concert halls. Since intensive care and isolation capacity are crucial to all complex acute care, responding to COVID-19 meant a very substantial reduction in capacity for regular hospital care. Such capacity for non-COVID-19 care as remained was underused: patients were very reluctant to come to hospital facilities, out of fear of contracting the virus there. Essential diagnoses were missed and crucial treatments postponed, resulting in avoidable adverse health effects.

Although yet unproven, airborne transmission is a suspected route by which Sars-Cov-2 spreads. As a precautionary measure it is advisable to provide care to infected or suspected infected patients in environments with controlled airflow and air treatment. However, most HVAC systems have not been designed to allow continuation of regular care while providing this type of care environment for large numbers of patients. For instance, in most hospitals HVAC systems do not employ zoning or segmentation with the appropriate air flow direction which would allow separation of COVID-19 and non-COVID-19 logistical streams. Climatization issues were also apparent: cooling capacity was often insufficient to prevent overheating in staff wearing airtight protective clothing.

Where conditions in hospitals were and are very challenging, the situation has proven substantially worse in long-term and elderly care facilities and rehabilitation centres. While many of these turned into infection hot spots and consequently needed to provide care to large numbers of very vulnerable patients, HVAC systems in these facilities are generally very limited and do little to protect residents and staff from airborne infection. Logistical lay-outs are generally very basic and do not allow for separation of care for infected and non-infected residents.

How can we do better?

It seems clear that improvements in technical and functional design are required if we are to deal with future pandemics without incurring the level of adverse social, economic and health-related impacts we have seen in the current crisis. On the basis of the evidence and practical experience that the expert panel has collected, several avenues for improvement have been identified. These centre on the functional lay-out of care facilities, on design and operation of installations, and on organisational measures.

In this paper, measures are discussed for hospitals. Most of them are also applicable to long-term care and rehabilitation facilities. Getting it right in these latter facilities is especially important, to combine protecting vulnerable people from infection with safeguarding quality of care and quality of life.

Lay out of health care facilities

Lay-out related options for improving outbreak preparedness while leaving normal operational capacity and efficiency relatively untouched, focus on: lay-outs for inpatients wards; design for physical distancing in indoor areas; logistics, specifically the presence and positioning of staff and visitor changing areas; and on segmentation and redundancy of critical facilities such as ICUs.

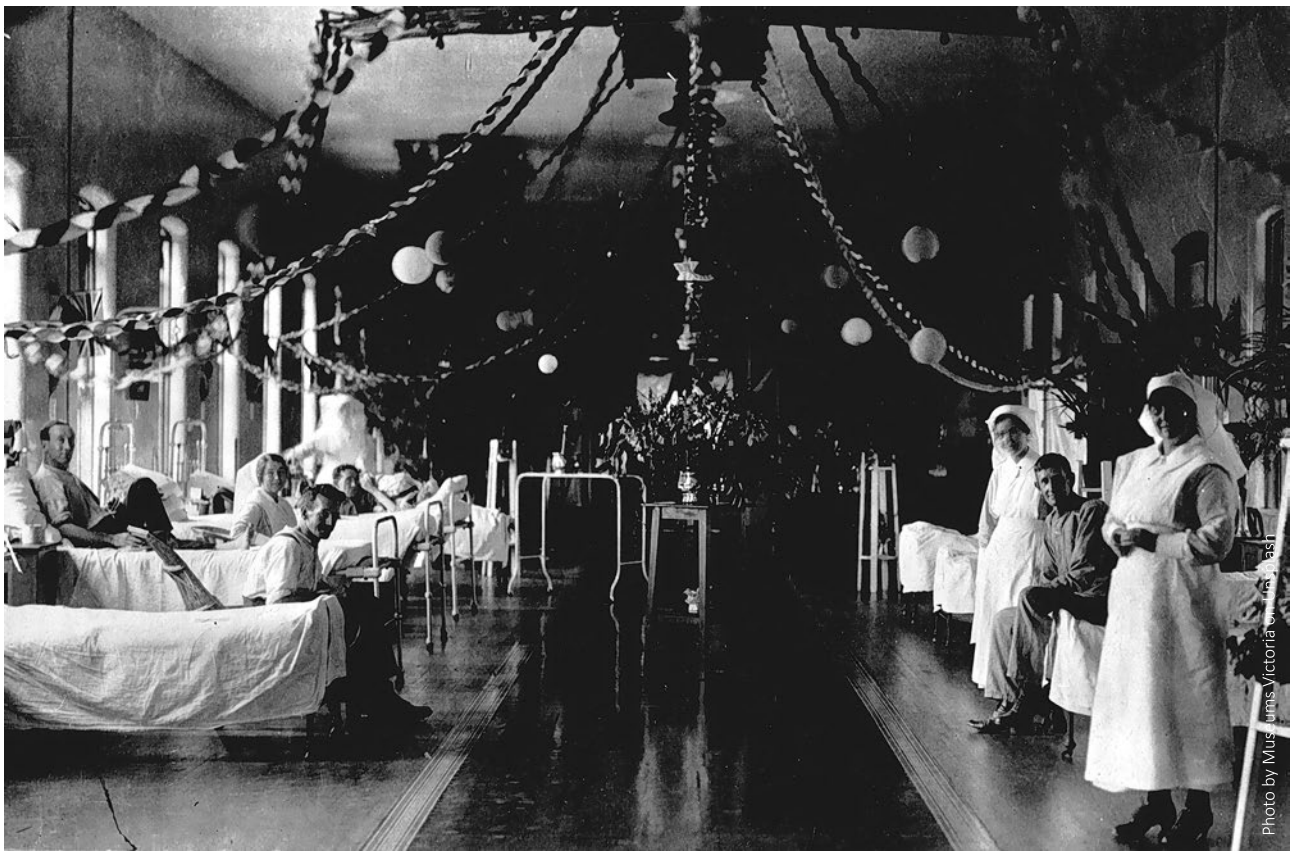
Inpatient wards

Inpatient wards in hospitals typically contain a mixture of single rooms, 2-person rooms and 4-person rooms, with variants such as 3-person rooms occasionally encountered. This type of lay-out is suboptimal in terms of conditions required for effective COVID-19 response, or indeed for

responses to any major outbreak of communicable disease with airborne transmission. Multi-patient rooms increase the risk of patient-patient and patient-staff transmission, while not offering a working environment where scarce staff can be deployed with maximum efficiency. To reduce contamination risks, spatial concepts employing single rooms exclusively or predominantly are known to be effective. If fitted with appropriate ventilation systems, single rooms can be repurposed as emergency isolation rooms. Lay-outs where all single rooms are fitted with airlocks – which could be activated to provide full-scale isolation when needed –are possible, though such lay-outs would come with substantial consequences in terms of spatial requirements (and, accordingly, costs), and might not perform too well from the viewpoint of patient experience and patient-staff interaction requirements in normal circumstances.

The increased level of demand associated with pandemic conditions puts particular strain on available staff capacity. Open plan wards, traditionally known as "Nightingale wards", potentially allow more efficient deployment of nursing staff, through reducing transfer distances and transfer times between patients. Open plan wards are generally not considered acceptable under normal circumstances, for reasons including infection prevention, privacy and personal dignity. However, research findings collected during the present pandemic suggest that their collective space characteristics may actually help to mitigate traumatic psychological effects of hospitalization for COVID-19. Patients report experiencing feelings of isolation, neglect and anxiety when hospitalized for COVID-19 in single rooms. These adverse effects would logically be much less pronounced if patients receive care in a communal setting.

However, advanced the adaptability features included in the functional design of the care facility, transforming single room wards into open plan wards and back again would be unfeasible both in terms of technical complexity and cost. In existing hospitals, this would require major renovation; for new hospitals it would mean designing all interior walls as movable partitions or to incorporate in new to build hospitals having flexible walls. A sensible strategy could be to include buffer inpatient capacity in the form of open plan wards. This type of capacity is not deployed under normal conditions, but is pulled into service during scale-up. This way, in a pandemic, each patient could be cared for in an environment most suited to their individual needs.



Design for physical distancing in indoor areas

Where people are in intensive contact, defined as physical proximity during a short time (e.g. exceeding 10 minutes), personal protective equipment (PPE) is the preferred method to reduce the risk of infection. However, there are areas in healthcare facilities where this type of contact occurs, but where PPE measures cannot be assumed to be in place: waiting areas and public and commercial spaces such as main halls and food courts. In these areas physical distancing is a necessary precautionary measure to reduce the risk of infection through airborne transmission. Waiting areas in most hospitals are currently too cramped relative to patient turnover to allow the relevant departments to function at anything like full capacity. To counter this, functional briefs for hospitals should adopt both a higher overall ratio for waiting area space relative to total floor space, and increased baseline and production-related dimensions for individual waiting areas. Additionally, centralized waiting zones, and ICT-enabled "just in time" planning could reduce crowding in individual waiting areas. Also alternating physical consults and digital consults gives relief on the occupation of the waiting rooms.

Though there is no firm evidence base in the literature, in practice physical distancing requirements are often also imposed for areas that see a high volume of shorter interactions: entrances, circulation areas such as corridors, and vertical transport points. To allow physical distancing in these areas, more spacious dimensioning is required and/or control measures must be put in place to limit throughput.

Logistics

When providing patient care in a pandemic, strict adherence to PPE and other safety protocols is crucially important. To stimulate compliance and support staff and patient safety, hospital floor plans should include changing areas where staff can change clothing and put on PPE. These areas should be positioned in such a way as to allow separation of clean and contaminated logistical streams. For emotional and psychological well-being, it must be possible for patients and visitors to be in close physical contact for longer periods of time. Ideally, patients and visitors should be free to choose timing and duration of contacts. Effecting this without unacceptable compromises to safety, presupposes that visitors wear special-purpose clothing and use PPE. Accordingly, hospital floor plans should include changing areas and

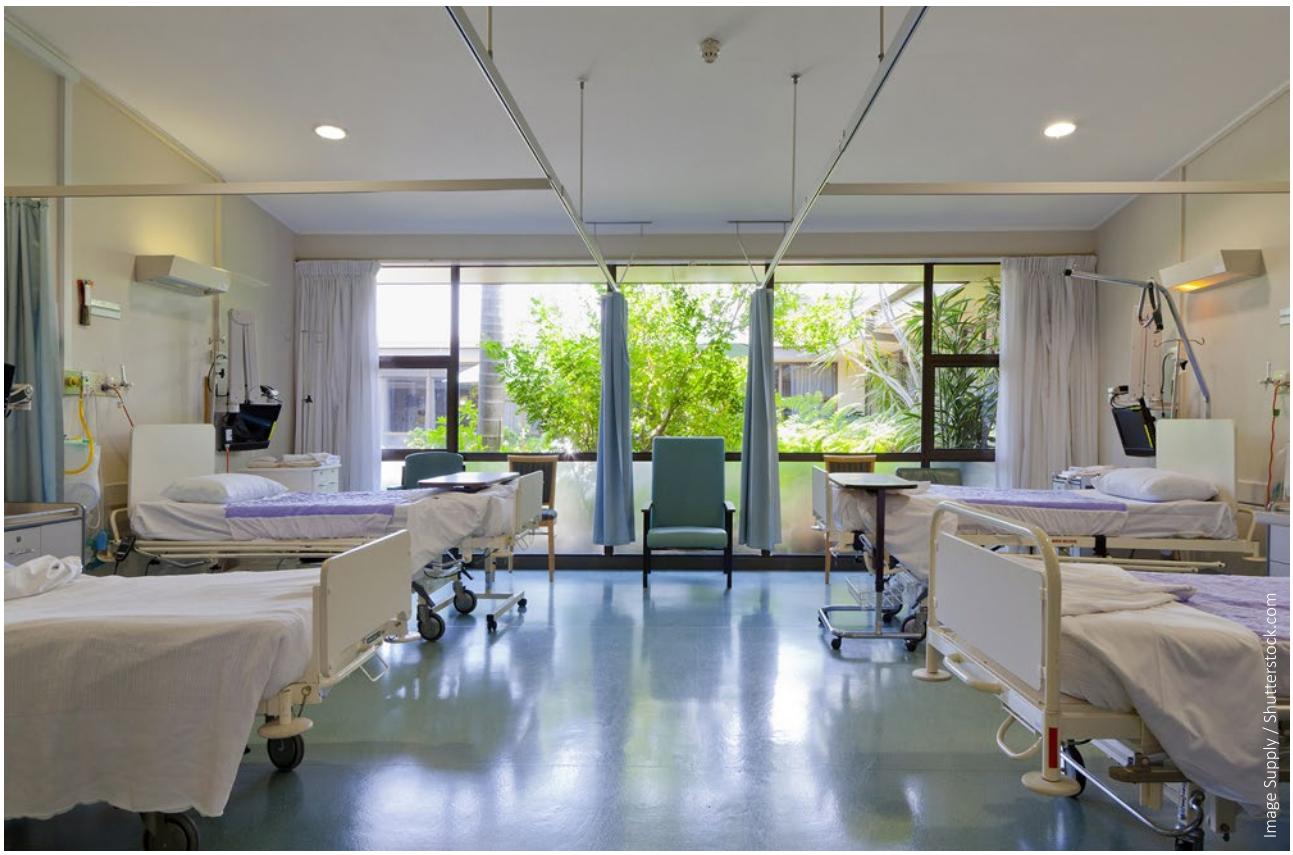


Image Supply / Shutterstock.com

storage facilities for visitors. These spaces, too, must allow separation of clean and contaminated materials, with a proper separation between clean and contaminated, should be incorporated in the floor plan.

Segmentation and redundancy

During the severe early phases of the COVID-19 pandemic, regular patient care came to an almost complete standstill. Critical departments such as the intensive care wards and imaging diagnostics were entirely turned over to care for COVID-19 sufferers. Except at the peak of the pandemic, this was not primarily due to operational capacity as such. Rather, the fact that COVID-19 care took place in these departments meant that the whole department had to be considered a high-risk, potentially infected area and hence could no longer be considered safe areas for regular care. Even where such safety risks were not objectively present, subjective risk perception on the part of patients and staff meant they were reluctant to come in for treatment or for work in these departments.

Segmentation of critical departments into independent smaller units can reduce this problem. It opens up the possibility of dedicating part of the capacity to handling COVID-care (or care related to other outbreaks), while keeping the rest available for regular care. This presupposes that these smaller units are functionally and technically independent of each other and have distinct access and egress routes for patients, staff and goods.

Installations

Installations-based options for outbreak preparedness cover ventilation, air locks, and redundancy and over-dimensioning of fixed and mounted technical equipment.

Ventilation

Current technical hospital designs favour centralized air handling systems. Diversification of systems at building block, floor or even room level is perfectly feasible technically, and would offer much greater flexibility in tailoring ventilation levels to changing needs for smaller areas or individual rooms. This could even take the form of room-specific ventilation systems taking in air from outside directly through the façade. Such systems could also reduce the risk of interference between ventilation systems operating in different zones. Additionally, recirculation of air must be considered a risk factor for transmission of airborne viruses in centralized air systems, but is not an issue at room level, provided sufficient outdoor air is added to the mixture to reduce the concentration of harmful viruses.

Care delivery in outbreak situations creates peak demands for ventilation and cooling capacity. Designing and dimensioning installations so they provide this peak level on a structural basis would create an increased level of energy demand and run contrary to the directive to move towards more sustainable HVAC systems, where reducing demand is one of the pillars supporting the transition, along with improving efficiency of systems performing and a switch towards renewable energy sources. Control systems that only produce peak level airflows and cooling when these are specifically needed are available on the market and could contribute to tackling this issue. Another option worth considering is maximising the potential for natural ventilation, by the simple expedient of making sure that windows can be opened. Care is needed though to avoid introduction of unwanted airflows from outside.

Air locks

Depending on the transmission route of the outbreak, department-level aerogenic air locks may be a useful means to prevent the spread of contaminants from one area to another. Aerogenic air locks aim to prevent airborne spread as much as possible and separate the contaminated area from the rest of the hospital. When properly designed and positioned, changing rooms for staff and visitors, and logistic locks can double as aerogenic air locks and can also be applied on department or building block level. To prevent spreading of contaminated air through apertures between rooms above false ceilings, realizing all interior walls as airtight floor-to-structural ceiling partitions could be considered. This is most likely only feasible in new built care facilities and would only be proportionate in areas to be assigned as containment areas.

Redundancy and over-dimensioning

It is sensible to equip all patient rooms with a level of fixed and mounted technical supplies that allows scaling-up of these rooms for more complex treatment. This includes oxygen and other medical gases, wall sockets, water, drainage and disposal facilities (especially for medical and hazardous waste), as well as data hook-up points for ventilator equipment, monitoring, and CVVH dialysis.

Organisational measures

Opportunities to improve organisational preparedness focus on use of online and remote care; rostering of staff to support segmentation of critical departments; adequate supplies of protective equipment and protocol adherence; and regional scale-up and care distribution contingency planning.

Online and remote care

An unforeseen, but largely positive outcome of the current crisis has been the acceleration in adoption and upscaling of online consultation and diagnostics, as well as remote support of care givers in primary care and long-term care. Technically, this has been possible for some time, but implementation has lagged, due in large part to issues around acceptance and trust. As traditional alternatives became unavailable in the crisis, care providers and patients were forced to switch to online alternatives, and found the transition surprisingly unproblematic. Structural implementation of the change would bring obvious advantages in "normal" times: it would obviate the need for patients to travel to and from hospitals for routine appointments, reduce spatial requirements for outpatient care, and allow medical professionals to use their sparse time more efficiently. Increased familiarity with and use of online modes would also allow a smoother shift towards the sort of online-first paradigm that is required to keep regular outpatient care going under pandemic conditions. Even where patients still come to the hospital for appointments, it makes sense to handle part of their patient journey online. For instance, checking in digitally, with a digital card, e-ticket or any other smartphone-based method would avoid possible contamination through touch screens and would reduce waiting lines and crowding. Special opening hours for persons vulnerable to the virus could also be an option.

Rostering of staff to support segmentation of crucial departments

Above, we have argued for hospital designs that allow segmentation of crucial departments such as intensive care and radiology into independently functioning smaller units. To have an effect in practice, this physical segmentation must be supported by rostering of staff. Dedicated teams working only in one of the units must be established and maintained. Crucially, this also includes support and logistics staff to avoid cross-contamination through e.g. goods delivery and cleaning activity. Additionally, each unit should have its own distinct routing for supplies and waste. In summary, each unit should be physically, logistically and organisationally self-contained.

Adequate supplies of protective equipment and protocol adherence

Capacity problems during the current pandemic have been compounded by the frequent unavailability of sufficient supplies of protective equipment. As a result, staff members became infected and operational capacity of healthcare providers was reduced. Infections among staff also occurred because no adequate protocols for self-protection were in place (at least in the early phases of the pandemic). Even where these were available, unfamiliarity in combination with peak levels of pressure meant they often were not adhered to. Lessons learned during the current pandemic should be used by healthcare organisations to ensure a higher level of organisational preparedness for future outbreaks.

Task differentiation at regional level

Although design, technical and organisational measures can be taken to better allow continuation of regular care under pandemic conditions, providing the two types of care on a single hospital site remains inherently challenging and is likely to affect quality and efficiency of care. Better results might be obtained if regional contingency and distribution plans could be drawn. In these regional configurations, during large-scale outbreaks some hospitals would switch entirely to care for infected patients, while other sites in the region would be dedicated to keeping regular care going. This presupposes triage and allocation of patients through a pooled regional system.

The complexity of implementation regional contingency plans must not be underestimated. For instance, they also involve temporary allocation of staff to other hospitals and/or hospital sites. Also, sites not slated to deal with infected patients cannot allow themselves to drop their guard. It has been shown that COVID-19 patients can be infectious while still asymptomatic or presymptomatic. Systematic testing of patients, visitors and staff will be essential. Even then, centres dealing with regular care must be prepared for occasional occurrence of infections and must have emergency protocols in place to respond.

Regional distribution works best if hospital sites in the region are of similar scale and versatile enough to adapt to provision of different types of care.

Conclusions and call to action

It is obvious that functional, technical and organisational options are available to minimise adverse social, economic and secondary health impacts during future outbreaks. But all of these need advance planning. We cannot wait until the next epidemic is upon us. We must act now to plan, design and develop healthcare facilities that are resilient to future adversity. This calls for concerted and coordinated action by public authorities, healthcare providers and contractors, as well as architects, engineers and builders.■