Lessons from the Pandemic
Hospital Design and Planning for Infection Prevention and Control

A Perspective from the European Health Property Network

Introduction

The European Health Property Network (EuHPN; www.euhpn.eu) is a knowledge-sharing organisation, comprising members in a range of European countries with common interests in how best to plan, design, construct, maintain and finance all kinds of healthcare buildings. The corporate and individual members include healthcare architectural practices, health system planning agencies, health estates departments and academic research centres.

In April 2020, as the COVID-19 pandemic began to spread across Europe and the globe, several EuHPN members[1] came together to examine the response of hospitals in Europe and beyond. A series of five webinars, titled *Reorganise, Relocate, Repurpose,* was organised through 2020 and early 2021, to examine case studies that could shed light on what measures were successful, or unsuccessful, in combating the spread of SARS-Cov-2, and what features of the hospital sector response might be of lasting value – for COVID-19, or for future pandemics of infectious disease.

The webinars and accompanying materials (slides, papers, recordings, images) were archived in a purpose-built website[2], and an initial analysis of the documentation resulted in a field guide which focused on four themes: Space, Staff, Systems, and Supply chains. The key questions were:

- How were hospitals adapted, rebuilt, or created, to meet the clinical need for hugely increased ICU, respiratory and recovery capacity? What changes occurred in relation to the physical space of hospital facilities, and were these judged to be successful and sustainable?
- What helped or hindered staff to cope with the rapid transition to pandemic care? How did hospitals ensure support for staff wellbeing? What were the risks that contributed to infection of staff with the virus, and the mitigations that prevented this outcome?
- What changes occurred to the 'normal' systems in place to manage and operate hospitals? What decisions did senior management take, early in the pandemic and thereafter, to ensure that COVID-19 patients, and others, continued to receive the best care possible?
- How did the supply chain to hospitals react? Were there gaps, breakdowns or mistakes? How should supply chains be reconfigured in the future to ensure a more resilient response to future crises?

The issue of Infection Prevention and Control (IPC) was central to each of these themes. Staff wellbeing, and the ability to carry out work, were clearly affected by the presence or absence of measures that could control the spread of the virus. The many systems in place in hospitals - to manage admissions and discharges, diagnosis and testing, supply of equipment, food and consumables, building maintenance and repairs – each had to be reconsidered in light of infection

[1] EuHPN Secretariat (UK, Netherlands); White Arkitekter (Sweden); Ramboll (Denmark); Comentum (Sweden)
[2] https://c.ramboll.com/pandemic-resilience

risk. Every decision about ward reconfigurations and expansion of ICU capacity was similarly constrained by IPC protocols. And even the materials and services provided by supply chains, usually uncontentious, had to be considered as possible sources of SARS-Cov-2 infection.

The final webinar of the series was held in March 2021, more or less coinciding (in many countries in Europe) with the end of the second wave of COVID-19, and as vaccinations were becoming available. Consequently, much of the webinar material concerns the responses that were trialled during the period of greatest uncertainty and highest risk. This is reflected in the 20+ presentations that were given during the webinar series, by speakers who included hospital directors, senior clinicians, health estates and facilities managers, hospital engineering companies, healthcare architecture practices, health system planners, change management professionals, and healthcare system researchers.

EuHPN responses to the Nuffield Trust questionnaire

The Nuffield Trust was commissioned to investigate links between the physical and organisational environments of English NHS hospitals and the spread of COVID-19 among patients and staff. The case study approach to this central question made use of a two-part questionnaire, the first part consisting of high-level, broad-based questions, and the second focusing on details concerning clinical and technical factors.

The work carried out by the EuHPN relates mainly to the high-level questions in the Nuffield Trust questionnaire, for two reasons. First, these questions map well onto the materials obtained during the EuHPN webinar series. Second, the detailed clinical and technical factors are often context-dependent and cannot be easily interrogated in settings in other countries and health systems, at least not without considerable re-working.

There is a further limitation to the analysis of the webinar materials. Most of the contributors to the EuHPN webinar series, and the subsequent field guide document, were focused on factors that helped (or were thought to have helped) to keep infection rates low among patients and staff. The available materials therefore concentrate on primary and secondary drivers of low infection rates, and there was less said about evidence pointing towards high infection rates among patients or staff. Nonetheless, these two facets are somewhat interlinked: for example, if a hospital with a high percentage of single-bedded accommodation had a low rate of nosocomial infection (as in the case of Erasmus MC, Netherlands), this at least suggests that that type of ward environment was effective.

The webinar materials, and the accompanying field guide, also offer some interesting observations concerning the context of each of the EuHPN case studies, and the clinical and organisational policy environment that was present in many of these. These are included in the table below.

Case Study	Country	Primary Drivers: low patient outbreaks	Secondary Drivers: low patient outbreaks
Increasing Healthcare and Emergency Hospitalisation Capacity	Spain (Catalunya Region)	• Versatility of equipment and engineering solutions. • Adaptability of physical space. • Speed of response in relation to making changes to the hospital environment.	• Clear and obvious separation of patient and staff flow • Separation of supply routes Note: view that these factors not only improve IPC, but also build confidence among staff and patients that the hospital is a safe environment that can still be accessed and used even during an infectious disease outbreak.
Tiohundra AB (a hospital operating within the health and social care Nortalje model)	Sweden		• Isolation of elderly care homes was critical in keeping infection to a low level - integration with hospital services was key to this. • Early deployment of a mobile team - doctors and nurses - was used to identify patients who were likely to be admitted to hospital (heart failrure, respiratory problems) were targeted to avoid admissions and possible infections.
Erasmus MC	Netherlands	• 100% single rooms. • Capacity and flexibility to re-purpose 'medium care' wards as surge ICU capacity. • Availability of pressurised isolation rooms on wards, especially in the infectious disease and pulmonary disease wards. • Decision taken in late March 2020 that 10 OR's, 275 MC-beds and 30 ICU-beds must stay operational for non-COVID patients - roughly half the 'normal' capacity.	• The ICU space initially chosen to house COVID infected patients was close to the 'elevator bank', thus minimising movement of patients and risk of cross-infection. • Clear lines of command were established early: a Crisis Management Team, advised by the Local Outbreak Team, was chaired by a board director, with decisions ratified by the Executive Board. • Separate working groups were convened to address: clinical capacity; human resources; equipment and facilities; logistics. • Weekly live-stream sessions set up to give employees

			access to the most up-to-date information on treatment protocols, IPC measures, etc. • Rapid deployment of e-health solutions for out-patient services; patients contacted 2-3 days prior to their appointments and asked whether they have COVID-like symptoms; patients with symptoms are triaged whether they need to come in, or whether the appointment can be postponed. • Patients attending hospital were tested on entry. • Without tests (for whatever reason), all patients were considered as infectious, issued with a medical-grade mouth/nose mask at the entrance, and are directed to an isolation room.
Sheba Medical Center	Israel	• Use of an alternative space (underground car park) allowed for complete physical separation of Covid patients from the rest of the hospital structure. • Absolute division of the space into clean and contaminated zones. • Two separate ICU units with their own 'control rooms' within the clean areas. The control rooms were used to remotely organise the work in each of the ICU wards.	• Israel has a vibrant and well-established med tech sector, and the start-up and existing companies working in telemedicine were well placed to adapt their products to the new Covid reality in hospitals. These were used in 4 areas: monitoring, management, physical examination and communication. E.g. telepresence robots. Often adapted from home care solutions to the hospital environment. The telepresence robots were judged by staff to be a useful and flexible technology, that allowed them to focus on patients at close quarters, and allowed patients to see the face of the clinician treating them. • The remote monitoring equipment had a secondary use in preventing patient-to-patient, or patient-to-staff

			transmission - the senior supervising staff were able to closely monitor the correct use of PPE, spotting, for example, if a staff member forgot to change a glove or had a gap in their gown cover.
Rigs Hospital, Copenhagen Mother-Child Clinic, Slagelse Hospital, Zeeland New Acute Care Hospital, Hjelst	Denmark Denmark Norway	Rigs Hospital, Copenhagen: • New North Wing (57k m2) was due to come into use in 2020, but had been delayed. That space was therefore available for Covid patient treatment - solved the problem of separation. • However, no Danish hospital had facilities available for mass testing, so tented structures had to be created quickly. • Despite the availability of nearly 200 single patient rooms, the hospital lacked the staff to manage patients in individual accommodation, and had to opt for clusters of 10 beds in the operating theatre spaces. Mother-Child clinic, Slagelse Hospital, Zeeland, Denmark: • 173 single bed rooms, connected to the main hospital but in a separate building. • Also needed tent spaces for testing, storage, staff changing areas. New Acute Care Hospital, Hjelst, Norway: • Design already altered to have a 'pandemic entrance' to offer separation of patient flow, located next to an elevator tower. • May also incorporate a new triage entrance, only for use in pandemic situations.	Rigs Hospital, Copenhagen: • Back door to the clinic was important, in that it provided a 'Covid entrance', which kept Covid + or Covid-susptected patients separate from the rest of the hospital. • Recommendation to add more hand-washing sinks should be added to all hospital designs. • Recommendation to provide separate (and more) lab spaces to allow for distinct testing of infectious pathogens of concern. • Smaller, separated waiting areas recommended, instead of larger areas.
Mount Sinai Hospital, New York	USA	• ICUs transformed to include many more low pressure rooms (converted from open ICU wards) with additional HEPA filtration units. Went from 6 negative pressure isolation rooms to 48.	• Mount Sinai atrium converted into a 100-bed 'step down' unit, for recovering Covid patients. • Tented area outside for triage and testing.

Research Group on the Healthcare Working Environment, Post-COVID, Queensland University of Technology	Australia	• Design for control of entrances and exits. • Infrastructure to enable easy virtual health consultations, and their interactions with in-person consultations. • Consideration of a return to the design principles of the TB sanatoria of the early 20th century • Individual and separated workstations for healthcare workers and managers. • Hospital architecture with wide-open spaces, public boulevards, gardens and other outdoor spaces.	
Sahlgrenska University Hospital	Sweden	*Note: Sahlgrenska Hospital has a group structure; estates and facilities are managed by a separate real estate company*. • Triage of patients was conducted exclusively outdoors, at the five hospitals which could accommodate emergency care. • The facilities company organised the tents, barriers, signage, traffic management and waste container provision. • All five hospitals closed their entrances; provided an 'entrance host' 24/7 • All continued to offer in-hospital care to anyone who was symptom-free. • Rapid creation of quarantine reception, adjustments to ventilation, increased oxygen capacity, more local storage, increased mortuary places, some reductions in planned activity. • ICU beds increased by 90 across the 5 hospitals. • One hospital experimented with creating an outdoor 'field hospital' - tented structure.	• Quick extension of lab analysis function. • Red Cross crisis management team embedded (within a tented structure). • Inclusion in regional disaster planning exercises.
Fribourg Canton field hospital	Switzerland	• The 'Forum Fribourg' conference centre was repurposed as a COVID treatment hospital. • Pod structure: standardised and scalable clinical units. • Standardised procedures; decentralised problem solving but	

		centralised critical decision-making. • Designed through a rapid prototyping process.	
The 'O-House', Karolinska Huddinge	Sweden	• To cope with COVID demand, the nearly-ready O-House was quickly repurposed to provide additional ICU support, using the 23 OTs and 44 Pre/Post-op spaces. • Advantages of this arrangement: existing pass-through cabinets; ceiling supply units; prep room between each 2 OTs; relatively large (60m2) OT rooms. • Each OT space converted to house 3 ICU beds. • Lessons learned from the experience of converting the O-House to Covid care include: (1) need for flexibility in building design; (2) importance of an existing 'culture of change'; (3) adaptable working practices; (4) adaptable equipment; (5) importance of a high quality working environment, even in times of crisis.	
Hospital del Mar, Barcelona	Spain	• This project was the adaptation on an existing hospital - the Hospital del Mar - to meet the surge in wave 1 Covid patients. • The expectation was primarily for an increase in ICU beds from 40 to 190. 4 scenarios were explored: (1) use the existing 'day hospital' facility - temporary converstion; (2) occupy the unused 1st floor of the existing hospital building; (3) occupy the sports stadium close to the hospital; (4) use the car parking space as a field hospital. Options (1) to (3) were all used. • Day hospital: recovery spaces converted to 54 bed spaces. 1st floor: fitted out for 70 ICU beds. Sports stadium: converted to accommodate 72 ICU beds.	• The follow up conceptual work, after this project was completed, resulted in the proposal of an 'accordian hospital', comprising three main themes. • First - linear and repeated arrangements of clinical and non-clinical space. • Second - circulation space dedicated to ICU use, with a corridor reserved for patient family use. • Third - inclusion of large spaces (waiting areas, halls) that can be multi-functional.

If there are general lessons to be drawn from the varied experiences of the hospital organisations described in the table above, these might be summarised as follows:

1. Hospitals with a high proportion of single bed patient accommodation found it easier to implement and maintain the IPC measures that led to relatively lower rates of nosocomial infection of patients and staff. Examples include: Erasmus MC (Netherlands); Mother-Child clinic, Slagelse Hospital (Denmark); Rigs Hospital (Denmark).

2. An estate that had some redundancy and/or spare capacity also had IPC and operational advantages: (1) Easier to establish separate physical pathways for patients, staff and supplies; (2) Continuation of a higher proportion of non-Covid activity; (3) More space to accommodate socially distanced working for clinical and non-clinical staff, and to expand areas for staff rest and relaxation. Examples include: North Tees and Hartlepool NHS Foundation Trust (UK), which operates across two sites; Hospital de Mar (Spain), which could make use of an unused floor and convert an existing day hospital facility; Sahlgrenska hospital, which operates as a group structure with acute, rehabilitation and community hospital sites; the O-House Karolinska Huddinge (Sweden), which could repurpose well-equipped, modern surgical OTs and wards as ICU space. Spare capacity might be associated with larger hospitals, but the operational flexibility associated with hospital group organisations could also be advantageous.

3. More recently built hospitals had some advantages in relation to flexibility and adaptability, even if they were not primarily designed with pandemic resilience in mind. These stemmed from adherence to the latest IPC design and engineering guidance. The O-House Karolinska Huddinge (Sweden) and Hjelst Hospital (Norway) provided evidence of this.

4. Field hospitals, whether temporary or permanent structures, or adaptations of other buildings such as sports arenas or conference centres, were only used sporadically and *in extemis*. It was therefore difficult to know whether they contributed positively or negatively to the spread of SARS-Cov-2. Concerns were expressed, however, in several jurisdictions, about safe staffing of these facilities as well as the risks posed by rapid implementation of engineering systems such as medical gas supply and waste management. In addition, where staff did spend significant amounts of time in repurposed or newly constructed temporary facilities, their experience was often poor and psychologically distressing.

Lessons from the EuHPN Field Guide

The EuHPN Field Guide drew on the materials presented in the series of five webinars, as well as supplementary material that was available to the authors. This evidence was used to analyse the response of a variety of hospitals within the four themes of the webinar series: space, staff, systems and supply chains.

Space

In relation to *space*, i.e., the nature and performance of the healthcare built environment, the authors of this section identified four main typologies: transformation of non-healthcare buildings; transformation of existing hospitals (newly completed, or older facilities); plug-in spaces in existing hospitals; implementation of ongoing projects and new initiatives. The advantages and disadvantages of each typology, in respect of IPC, and clinical and operational management, are listed below.

Transformation of non-healthcare buildings

This strategy, mostly used in the first phase of the pandemic, included the creation of field hospitals from modular components, or the adaptation of large commercial or sporting facilities. Six case studies were considered: the Louisa Jordan hospital (Scotland), USACE Novi (USA, Michigan), Stockholm Fair (Sweden), Hospital del Mar sports arena (Spain), Ifema Exhibition Centre (Spain) and Sheba Medical Center parking garage (Israel).

Advantages

Large buildings with several entrances and few internal walls enable high flexibility for arranging suitable flows.

The existing infrastructure around the existing buildings (e.g. conference centres, sports arenas) eases access for both ambulances and deliveries of new systems and supplies.

Possible to control access to the buildings to ensure that only authorised staff can enter and exit.

One of the fastest solutions for a substantial increase in patient beds.

The temporary room layout often includes several patients to be treated in the same area, which eases staff overview of patients.

Disadvantages

Covid-19 care separated from hospitals is a disadvantage for patients who need access to other healthcare services.

Challenging to staff these structures, due to physical distance to hospital buildings.

Risks and challenges inherent in installation of medical gas and energy supplies, in buildings not originally designed for medical purposes.

A temporary environment often lacks basic elements of healing environment, such as daylight, privacy, good acoustics, etc, for both staff and patients.

Adverse psychological impact on patients when being treated so close to others.

Transformation of existing buildings

This strategy was the most commonly adopted, particularly following the first wave of the pandemic, from mid- to late 2020 onwards. Placing Covid-19 care within existing hospital structures offered the immediate benefits of familiarity of staff with the environment, availability of some storage spaces, well established logistical systems and equipment (mostly) known to be fit for use. However, this strategy was also closely associated with pausing or postponing some non-COVID-19 clinical activities, including elective surgery and outpatient care. There was considerable variation in the ease with which ICU environments could be expanded, depending on the age and layout of existing hospital facilities.

Existing but newly completed buildings

During the last 20 years, many hospitals in Europe, especially in northern Europe, have been undergoing major changes with extensive refurbishments, rebuilds or extensions. The Erasmus MC (Netherlands), New Karolinska Solna (Sweden) and several new general hospitals in Denmark (Aarhus, Odense etc) are some examples. Access to *newly completed* buildings made it possible for some hospitals to quickly redirect these facilities to Covid-19 care.

In the cases of recent development of surgical departments at the New Karolinska Huddinge (Sweden) and the Rigshospitalet in Copenhagen (Denmark), it was possible to swiftly convert the surgical environments into ICU wards for Covid-19 patients. The operating theatres and pre- and post-surgery rooms proved ideal for transformation into ICUs, as they already met the appropriate technical standards. These spaces were also larger, compared with standard patient rooms, and could therefore accommodate multiple beds, allowing the clinical teams to oversee several patients at the same time.

Advantages: Good working environment for staff: daylight, views and well-planned staff rooms compared to many newly constructed 'field hospital' solutions.

Staff have access to the latest advanced technology.

Access to all logistics and infrastructure within the hospitals.

Easier to staff due to adjacent hospital.

Disadvantages: Challenges in separating entrances, horizontal and vertical flows within the building.

Partial postponing of normal healthcare provision, such as elective surgeries or outpatient care.

Existing, but older buildings

Hospitals are typically designed to be flexible. Existing hospitals, from recently built structures to those several decades old, were adapted during the Covid-19 pandemic to increase the number of

ICU beds and to separate the flows within the buildings. The latter measure was essential in order to decrease the risk of the pandemic spreading within the hospital environment. In general, these solutions were intensively used and often successful in terms of treating Covid-19 patients. We observed three cases: Mount Sinai Hospital (New York, USA), Mother-Child Clinic at Slagelse Hospital (Slagelse, Denmark) and Hospital del Mar (Barcelona, Spain).

Advantages: Good working environment for staff: daylight, views and well-planned staff rooms compared to many newly constructed 'field hospital' solutions.

Staff have access to the latest advanced technology.

Access to all logistics and infrastructure within the hospitals.

Easier to staff due to adjacent hospital.

Disadvantages: Depending on the flexibility of the building, more or less optimal solutions for Covid-19 care.

New spatial grammar and zoning of the wards can be difficult to understand for staff.

Challenges in separating entrances, horizontal and vertical flows within some buildings.

Partial postponing of the normal healthcare provision, such as elective surgeries or outpatient care.

Plug-in spaces in existing hospitals

Plug-in spaces, within existing hospitals, is another strategy that was widely applied, mostly in combination with the transformation of existing hospital buildings. The plug-ins include tented structures that link to existing entrances and exits, and modular, temporary buildings that occupy unused space in courtyards or atriums. Their use is therefore dependent on the availability of suitable space, which may not be the case on all hospital sites. We considered five different plug-in spaces case studies: the extensions of Sahlgrenska University Hospital (Gothenburg, Sweden), Rigshospitalet in Copenhagen (Denmark), Hospital del Mar (Barcelona, Spain), Mount Sinai Hospital (New York City, USA), Slagelse hospital (Denmark).

Advantages: Provisory modules (triage tents) standing outside emergency entrances have been a successful strategy to keep the untested Covid-19 patients separated from other patients before entering the hospital.

Plug-in spaces can even be a fast means to increase the availability of technically complex environments, such as ICUs (e.g. the Sahlgrenska military tent).

Disadvantages: Temporary spaces such as these lack both good working and healing environment; low standards and limited security for staff, patients and supplies.

Implementation of ongoing projects and new initiatives

Many hospital planners have pursued the challenge of adapting existing hospitals during the pandemic, and in some cases, they were able to do so as construction projects were nearing their final phase. In other cases, they have revised their hospital planning and design protocols, and embarked on entirely new, pandemic-oriented projects.

The changes that took place during the final stage of the design process for the SNR hospital Mordmoere og Romsdal (Norway), led to the following changes being implemented:

- Separated pandemic triage entrance at the emergency department.
- Sinks in all observation rooms.
- Vertical separation – acute/pandemic/other
- Separated labs – pandemic/non pandemic

In Madrid, the General Director of Infrastructure of the Regional Department of Health of the Community, has taken one step further than most other Spanish regions. Madrid has built a new 'pandemic hospital' with the aim of taking care of future emergency situations and of coordinating and engaging medical crises or other catastrophes. The complex will also function as a logistics centre for medical resources.

Conclusions

Based on the foregoing examples from the hospital sector in Europe and beyond, and the details observed concerning the links observed between IPC and hospital design, we conclude that the following design principles should be considered when remodelling or rebuilding hospital infrastructure, to provide the best response to future pandemics.

1. Flexibility. A general key to success in the adaptation and transformation of existing hospitals is the high flexibility of spaces, layouts and technical supplies. In the specific context of the Covid-19 pandemic, larger rooms with a high standard of technical installations, such as operating theatres, pre- and post-operating rooms, have been transformed into ICU rooms for Covid-19 patients. Flexibility for future transformation is a demonstrated best practice principle for future-proof and pandemic-resilient hospitals, although it might implicate a higher capital investment in the short term.

2. Sectionable units. Units and departments could be planned to be divisible in sections, each with separate entrances. The possibility to dedicate part of one department to infectious patients is a design solution that could be prepared in future projects or existing buildings, when possible. It implies, for example, solutions for physical separation through sluices, separation of flows and entrances, separation of technical supplies as well as redundancy in certain functions or rooms.

3. Separation of flows. It is crucial to design for separated flows of patients, staff and goods, as well as in-patients and outpatients or visitors. This separation applies to both horizontal and vertical flows. It has been a general best practice design principle for post-antibiotic hospitals and has become even more decisive during the Covid-19 pandemic

4. Access to multiple entrances. The possibility of separating flows implies that the building and the different units are accessible from multiple entrances. The access to multiple

entrances is not obvious because it requires access to multiple elevators and staircases, as well as proper accessibility from outdoor spaces. It is a solution that might in the future contrast with another relevant trend in hospital design: the concentration of few public entrances due to security risks.

5. Multiple rooms with direct access from the outside. A&E and infections clinics might be planned and re-adapted to have multiple rooms that can be accessed directly from outside. In A&E departments, it has been crucial to separate triage and testing of Covid-19 patients as much as possible from other patient flows. This solution might considerably determine the layout of these units in future hospital projects.

6. Re-think waiting areas. In general, waiting areas should be designed to avoid overcrowding. Different solutions might be implemented such as divisible waiting rooms, several smaller waiting rooms instead of central large ones, as well as designing protected outdoor spaces for waiting purposes.

7. Design for visitors and families. Facilities should be designed to enable safe visits of relatives and loved ones. This has been one of the greatest challenges during the Covid-19 pandemic, due to the lack of protective gear and proper physical solutions.

8. Evidence-Based Design. Healing design has been shown to be highly important, or maybe even more important, during a crisis such as a pandemic. Staff and patients have been affected by a highly stressful and unknown situation. The adaptation of newly built hospitals, with high-quality daylight and views, access to outdoor spaces and well-planned staff areas, have exemplified how flexibility goes hand in hand with healing architecture.

Staff

The workforce in the acute hospital case studies examined by EuHPN – clinicians, scientists, administrators, technicians, support staff, managers and directors – had to confront similar challenges, regardless of the region, the size of the hospital or the operating budget. When analysing these challenges, we concluded that they fell into four distinct areas of concern – effects of dislocation, effects of isolation, changes to working practices, disruption to management practice – and we looked in each of these to identify mitigations.

Effects of dislocation

We know from peer reviewed, published literature [1][2][3] and from our case studies that many hospital staff had to work in very different environments during the course of the first and second waves of the pandemic. They experienced the unfamiliarity of field hospital structures, rapid conversions of emergency departments, ICUs, operating theatres, general wards and public spaces, socially distanced restrictions on rest and social areas, different circulation arrangements (one-way systems), and even the loss of basic amenities such as car parking spaces.

Such rapid and profound changes to familiar environments, and therefore to the usual processes of care, are psychologically dislocating[4]. Furthermore, as widely reported, these physical changes were accompanied by the introduction of robust protocols on infection prevention and control and the steep learning curve needed to understand a new disease and to care for COVID-19 patients. The normal routines of mandatory training and clinical education were often disrupted – troubling for staff who want to maintain their professional accreditation and concerning for organisations that are answerable to regulatory authorities. Many staff members were asked or required to retrain quickly to support colleagues in different specialties and were frequently relocated within the organisation for weeks or months. Multidisciplinary teamwork, which brought together colleagues who were previously unknown to each other, became the norm, and some hospital organisations also rapidly put in place new partnerships with other public and private sector agencies [5].

In the face of these challenges, senior clinicians and managers had to find innovative ways to maintain morale, protect their staff, ensure high professional standards and safe patient care and, crucially, preserve a sense of common purpose. The mitigations varied from hospital to hospital, from region to region and from country to county; the following represents a synthesis of these.

Mitigations

There is no 'one size fits all' approach to resolving the dislocating effects on staff of the hospital response to the COVID-19 pandemic. However, some measures were typical of many of the hospitals in our case studies:

- Strict infection prevention and control protocols to reassure staff, with a particular emphasis on providing the correct personal protective equipment (PPE)
- Limitation of shift hours and provision of rest areas
- Skills workshops and supervision
- Mental health support through multidisciplinary teams, including psychologists
- Psychology Team available to front-line staff
- Rapid deployment of a 7-day specialist palliative care team (to take pressure off staff coping with the increase in sudden deaths from COVID-19)

- Enhanced visibility of senior staff/directors, with regular ward visits
- Innovation in ways and means to communicate with staff, using apps and teleconferencing.
- Communicating to staff that planning was informed by international and local intelligence and active research.
- Optimising patient flow, infection prevention and control, and oxygen provision to build confidence in the whole system.
- Early interdepartmental collaboration and planning.
- Early support for COVID-19 research and clinical trials.
- Upskilling of nursing and medical workforce.
- Rapid assessment and communication of 'what worked and what didn't work'.
- Clarity over triggers for escalation and de-escalation.
- Planning for recovery and restoration.

Effects of isolation

Healthcare is a profoundly social activity. Doctors, nurses and therapists are, by nature and by training, team players who spend much time communicating directly with patients, family members and colleagues, often using warm phrases such as 'ward huddles' to describe their direct interactions with each other. Many healthcare staff, in hospitals and primary and community care settings, speak of belonging to a 'family', and they include in that group all the support, managerial and administrative staff who work alongside them. The pandemic-related outpouring of support from the public – for example, the UK's 'clap for carers' evenings during the first wave of COVID-19 (which even has its own website) [6] – demonstrated a deep, affective bond with health and social care workers.

Literature relating to the effects of changes to 'normal' processes on hospital/healthcare staff has often reflected on the challenges to staff caused by disruption to the usual means of communication and professional and social interaction [7][8]. In many cases, this amounts to a form of isolation: staff left without the means to talk directly with colleagues and patients; mealtimes spent alone; meetings held remotely; messages passed on by text rather than a conversation; seating re-arranged to be distant from colleagues.

Mitigations

- Mental health support through multidisciplinary teams, including psychologists.
- Psychology Team available to front-line staff.
- Rapid improvements to the quality and availability of videoconferencing technologies.
- Reconfiguring social spaces such as restaurants, cafés, gardens and terraces to accommodate socially distanced contacts.
- Proactive buddying and mentoring programmes, using text, phone and video to offer support to staff.
- Increased corporate communications, to present unified messages about support and teamwork.
- Creation, where possible, of staff 'bubbles' – designated groups within which individuals could have closer social and physical contact.
- Public acknowledgement of the isolating effects of changes to work patterns.

Changes to working practices

In confronting the challenges of the pandemic in 2020, 2021 and beyond, all our case examples of hospital organisations were obliged to make rapid, far-reaching changes to working practices. These changes affected all staff, not only those working on the frontline of care. Administrators often no longer had access to a familiar office environment, if working from home. Laboratory staff were asked to work in reduced numbers and cover different shift patterns. Estates and facilities staff had to wear appropriate PPE and follow strict IPC protocols. For clinical and non-clinical staff alike, there were some common challenges, associated with unfamiliar risks:

- New and additional responsibilities.
- Making decisions with limited data and information.
- Implementing new and frequently changing clinical guidance.
- Working at the limits of their professional competence.

Mitigations

Some organsations made explicit use of a variety of **learning systems**, anchored by a multidisciplinary team which filtered and assessed the emerging knowledge concerning SARS-Cov-2 and therapeutic options, cascaded best practice advice and guidance to the rest of the organisation, and acted as a rapid decision-making and response unit. This approach was widely used within the 'field hospital' responses to pandemic pressures.

Structured programmes to **upskill and reassign** staff were widely undertaken. Anaesthetists were retrained to take on clinical responsibilities as intensive care or respiratory physicians. Nurses from varied backgrounds were redeployed and upskilled to work in ICU environments. Administrators and managers with clinical backgrounds were asked to redeploy on wards and clinics, to backfill for staff who were focussing on care of Covid patients.

At local level, significant efforts were made to use **redesign of the environment** to mitigate the emerging risks associated with changes to working practices. If team meetings and training sessions could not be held in person, ICT departments rapidly deployed technologies that allowed staff to access relevant information via screens. Meeting rooms were subdivided to accommodate small groups of socially distanced staff. Information centres sprang up, using any available space - hospital chapels, library facilities or gyms were favoured environments. Virtual outpatient clinics required rapid prototyping of small-scale spaces that allowed for privacy and confidentiality during consultations. It is noteworthy that many hospitals in our sample became community resources and collaborated more intensely with other health and care agencies, during this period. Some neighbourhood health centres, nursing homes and home care services were able to access the IPC and operational expertise of hospital organisations, allowing for common training and knowledge-sharing to take place. Over time, private healthcare, physiotherapy and occupational health organisations also became part of these collaborative consortia.

<u>Changes to management structures</u>

Most of the case studies reported on significant changes to command-and-control structures during wave one of the pandemic and anticipated that similar measures would be required during subsequent surges in infection rates and demand.

Although most health systems, and hospitals, anticipate crises of varying kinds, modelling often focuses on short-term emergencies associated with disasters caused by natural or human factors. The COVID-19 pandemic upended these assumptions and tested the operational and strategic response of public and private sector agencies to the limit.

Mitigations

Two contrasting cases, those of North Tees and Hartlepool NHS Foundation Trust (NTHFT, UK) and Erasmus MC (Netherlands) typify the response of hospital organisations. NTHFT is a medium-sized District General Hospital in the north east of England, serving a population of around 450,000 citizens and operating across two sites, one an acute 'hot' site with urgent and emergency services and an ICU, the other a 'cold' site which focuses on low-risk elective care and frailty services. Erasmus MC is a major tertiary and secondary care centre and teaching hospital, serving the city of Rotterdam and the surrounding region.

As UK national guidance emerged in March 2020, and as the scale of the challenge became apparent, NTHFT rapidly switched operational management to a strategic command model, with tactical cells covering clinical decisions, infection prevention and control, workforce, estates (including an oxygen subgroup), recovery (re-establishing normal operations) and communications. The usual processes of reporting were replaced by a more agile model, and operational decisions were devolved downwards.

This approach closely matched the measures taken in the European countries that were at the forefront of the pandemic response, which in turn relied on the information available from early studies of the response in China. One study from Italy reported on the radical task force–based response to the pandemic, in terms of dedicated COVID-19 ICU spaces, pre-triage and isolation of suspected cases, training staff for work in the ICU, establishment of multidisciplinary units, estates reconfiguration, staff recruitment, logistics and training.

The response from the Erasmus MC, Netherlands, was similar to that of North Tees and the Hartlepool NHS Foundation Trust in that there was early reconfiguration of strategic and tactical measures and decision-making structures. A Crisis Management Team was deployed from the beginning of wave one of the pandemic, supplanted later by a COVID Coordination Team and a series of working groups that were given the tasks of organising clinical capacity, human resources, logistics, equipment and facilities.

Over time, the links between managers and clinical staff became more direct:

- An expert panel was convened to answer questions from employees via livestream sessions
- The hospital's intranet was used as the unifying source of information on infection control protocols and how to correctly put on and remove PPE
- The hospital-wide Quality Management System hosted information and updates that could be directly accessed from the communication devices used by nurses.

The mitigations were generally effective, but an important overall message from the 3R's work on changes to management structures during the pandemics, is that hospitals and health systems were, in the main, under-prepared and under-resourced to ensure a resilient response over a long period. This should be the focus of future considerations in relation to the recruitment, education, training and support of staff, not only in the hospital sector but also across the wider health and care system.

A more comprehensive account of the response of Erasmus MC [9] is available here.

Emerging questions

In early 2021, following the work on case studies and desk research, the 3Rs group put together a set of emerging questions, as described below. The questions were grouped according to the main areas of a typical hospital's activity, as shown below.

Outpatients

- Can hospitals offer virtual appointments, using multidisciplinary teams to manage patient needs, without compromising the quality of care?
- How can infection prevention and control be better implemented in outpatient areas?
- What forms of digital communication are best suited to different patient groups?

Diagnostics

- If infectious disease screening is the 'new normal', how will this impact the time taken to process patients?
- How can hospitals best use available resources, where there are known limitations?

Planned care

- After each wave of the pandemic, how are normal services resumed?
- How do hospitals ensure that there are enough suitably trained staff to offer elective services?
- How can the independent or private sector contribute to the pandemic effort?

Emergency care

- Should operating theatre designs accommodate multi-use functionality?
- How can hospitals flex up and down in relation to emergency response?
- Can digital technologies contribute more to patient flow?
- What is the role of triage services in preventing inappropriate emergency care attendance?

Community care

- What the future contribution of primary and community care to hospital admission avoidance?
- How can hospitals contribute to a 'single point of access' model?

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