Upscaling life-saving equipment in a crisis

Despite the challenges of international shortages of life-saving equipment, huge volumes of medical devices have been commissioned to provide monitoring and support for patients with COVID-19. **Louise Frampton** provides an insight into the extraordinary response by the clinical engineering community, during the coronavirus crisis, and the lessons that can be learned for the future.

New field hospitals and new COVID-19 hospital wards within our current NHS hospitals have been transformed to provide contingency support for many of the thousands of sick patients with the COVID-19 virus. To commission the medical equipment country-wide has required a monumental effort from the clinical engineering community, with many engineers from the public and private sectors teaming up to accelerate the process.

The Nightingale Hospital at Excel, London, was set up in just 10 days, with plans to provide up to 4,000 intensive care beds. The purchasing and commissioning equipment for the equivalent of 10 general hospitals has been a huge undertaking – requiring an estimated 112,500 hours of hands-on time to get the devices to the patients. An international shortage of medical equipment including ICU ventilators, infusion devices and patient monitoring has made this even more of a challenge than could ever have been estimated.

Capacity has expanded even further with six other Nightingale hospitals across England. These are at various stages of planning, development or completion and include sites at Birmingham, Manchester, Bristol, Harrogate, Sunderland and Exeter. Similar facilities have also been created in Scotland and Wales. This is in addition to the extra capacity already created for NHS Hospitals, freeing up more than 33,000 beds – the equivalent of more than 50 new hospitals.

While the nation has given a well-deserved standing ovation to the many healthcare workers that have risked their own lives while delivering frontline care, we should also acknowledge the enormous engineering contribution provided behind the scenes, that has enabled this care to be delivered safely. Scaling up access to intensive care has been made possible by the hard work of clinical engineers, who have worked long hours, away from their families, overcoming significant challenges to turn exhibition halls into emergency field hospitals and operating theatres into ICUs.

Dr. John Sandham has been providing operational advice for commissioning COVID-19 ICU bed spaces, on and off-site in the UK. He explains that an intensive care bed requires much greater volumes of equipment compared to a general bed – including items such as ventilators, patient monitors, defibrillators, syringe pumps, infusion pumps, flowmeters and piped gases. These devices all need to be assembled, checked, and installed into the bed space.

To give an insight into the scale of the effort, each intensive care bed space requires, on average, around 15 pieces of equipment to support a single patient. For London's Nightingale hospital, this equates to over 60,000 pieces of equipment – some of which is highly specialised – such as ventilators, humidifiers and patient warmers.

Dr. Sandham points out that kitting out a new 400 bed general hospital, normally takes six months of planning and purchasing: "During normal operating conditions, there are often delays, as the lead in times for manufacturers differ. However, the speed in which the healthcare sector has had to respond to the coronavirus has been unprecedented."

This speed of response poses some key challenges and requires conventional strategies to be adapted: "During the pandemic, buyers have to purchase whatever equipment they can lay their hands on; ▶

The MTS and Avensys team at NHS Nightingale London.

clinical engineers often do not know exactly what is going to arrive. It is delivered on a pallet and they have to commission it quickly.

"The time this process takes depends largely on the equipment – a highly complex intensive care ventilator, for example, may take an hour to commission, while a simple oxygen flow meter will take five minutes. For a bed space with 15 pieces of equipment, the average commissioning time at these emergency field hospitals has been reduced 20-30 minutes per device. When you have a complex, such as the Excel or NEC Nightingale Hospital, where there are thousands of beds, this is a huge undertaking – but, to achieve this in a matter of weeks, rather than many months, is even more of an undertaking," he commented.

Strategy to reduce commissioning time for field hospitals

Commissioning equipment in an emergency (COVID-19) ITU field hospital requires medical equipment engineers and technicians on site, plus support staff to:

1) Unpack the equipment and give a quick physical inspection for transit damage;
2) Add it to the computerised asset management database;
3) Take it to the designated bed space;
4) Install it onto the bed, wall, drip stand, etc;
5) Connect the devices to electrical and/or compressed air and/or O_2 supplies;
6) Electrical safety testing (Class 1 patent connected equipment only);
7) Functional testing (basic checks);
8) Signing off on a database for use.

The first four of these tasks can be performed by the armed forces or semi-skilled volunteers, while tasks 5-8 require specialist EBME expertise.

Dr. Sandham explained: "The armed forces have supported the logistics, helping with unpackaging, putting together of the trollies and stands, and generally getting everything ready for the clinical engineers to commission the equipment. However, often there is an element of assembly and attaching the accessories that requires a full understanding of the way that equipment will work operationally. It should be acknowledged that being a clinical engineer requires a good understanding of physiology and the clinical application techniques used within the clinical environment."

The Bart's team at the NHS Nightingale London.

Before the Nightingale Hospital, at London Excel, became operational

The quick turnaround of these engineering installations has been a major achievement, so how have engineers adapted to the emergency situation?

Dr. Sandham explains that it is vital to use a 'stripped down' procedure, to minimise administration and pre-use testing when setting up these types of field hospitals. On projects, such the Nightingale sites, key questions for the commissioning manager include:

Do we need to keep a computerised asset management system?

A computerised asset management system is essential – in the event of a safety alert being issued, it is important to know where devices are located, for example. Any devices that are rented or on loan will also need to be identified, located and returned. Furthermore, if a fault is reported, the device will need to be found, repaired or replaced and a record made of the work completed. A computerised maintenance management system (CMMS) will help keep track of the work and to automate some processes.

Which devices should be electrically safety tested?

Class 1 (earthed) equipment should also receive an automated safety test. (IEC 62353 – see https://www.ebme.co.uk/articles/electrical-safety/electrical-safety-testing-in-accordance-with-iec-62353). Where equipment is double insulated (class 2) equipment, the risk is very low, and there is no need to electrically safety test.

Is a physical inspection necessary before use?

A physical inspection to check for any obvious signs of damage must be done by the person unpacking the device. This doesn't need to be an engineer.

Is a functional test required?

All equipment requires a functional test, but in many instances, this can be done without test equipment by the user, especially for small battery powered items such as thermometers, oxygen flowmeters, air flowmeters, suction regulators, etc. The equipment must be risk-assessed and separated into 'device groups', then commissioned in line with the rapid commissioning process. Patient warming devices, in particular, present challenges in non-standard field hospital environments, as they draw a lot of current, Dr. Sandham explained.

"In large spaces, such as the exhibition halls, where the ambient temperature can drop significantly, patient warmers are required to keep patients comfortable and normothermic.

However, large field hospitals are not designed for the high current loads required by large volumes of intensive

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>
> Dr. John Sandham

care equipment, so there needs to be contingencies in place – especially during winter months.

"In the Gulf War, for example, electrical generators and consumer units were added to the electrical systems for field hospitals, to enable a greater draw of power. Ensuring there is enough current per bed space is vital," he commented.

Clinical engineers rise to the challenge

While getting the commissioning strategy right is vital, scaling up the huge number of skilled clinical engineers on site has also been a major undertaking – the response to the emergency has been overwhelming.

"The Health Care Science (HCS) community has been essential in providing a willing and skilled workforce to step up to the challenge of providing 24/7 support to the clinical teams on the COVID ward," commented Malcolm Birch, director of clinical physics at Bart's Health – the host NHS Trust for the Nightingale London hospital. "Scientists from numerous HCS professions responded to the call from the London network, who then managed their focussed training prior to joining Nightingale teams where they were led by experienced Bart's clinical engineers," he explained.

Many of the institutes and the www.EBME.co.uk website have also got involved in gathering volunteers from the clinical engineering community.

"As an educational resource, we have shared information on the EBME forums. There has been an openness and an exchange of knowledge across the sector. During these unprecedented times, the clinical engineering community has come together to understand what the commissioning issues are – the response has been phenomenal. Sharing information across these platforms has helped to accelerate the process of getting the field hospitals up and running," commented Dr. Sandham.

He added that clinical engineers inside UK hospitals have been working extremely long hours to transform normal medical space spaces into intensive care bed spaces: "Engineers have been working 14-16 hours per day to get all of the equipment commissioned. This has included the postponement of normal elective surgery, so the operating theatres can be converted into intensive care bed spaces. In my 35 years of working in this sector, I have never seen the clinical engineering community come together in the way it has. It has been amazing to see how quickly they have turned around the equipment to make sure it is available for patients.

Intensive care bed at NHS Nightingale London.

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> Malcolm Birch

"Many of the engineers have volunteered; they have put themselves at risk, not in the same way as nurses and doctors, but they have gone into environments where there have been lots of people – especially on the Nightingale projects in London, Manchester and Birmingham. While they are doing their best to ensure social distancing, the equipment they are working on will have been handled by many other people. There are also shortages of PPE. Yet they still carry on working. In extraordinary times like these, engineers are pulling out all the stops to ensure lives can be saved."

Operational delivery

A large team of engineers – including teams from MTS Health, Avensys and Althea – have worked tirelessly and collaboratively together on the London Nightingale site.

Having initially set up the governance processes for commissioning equipment, MTS, led by Andrew Frost, director of technical services, has managed an on-site team, working closely initially with the Capital Projects team from NHSE London and latterly with Bart's Health (the host NHS Trust for London).

Once the hospital became operational in early April, the MTS Health team was retained to work in partnership with the Bart's Health Clinical Physics team – comprising the core Bart's clinical engineering team, led by Malcolm Birch, and volunteer clinical scientists who have undertaken specialist training. Working collaboratively, these teams are providing full clinical engineering and management support for all medical devices, as clinicians care for patients during the global pandemic.

"It has been an incredible achievement to turn around the Nightingale Hospital in London in under two weeks. Industry and the public sector have collaborated effectively, crossing traditional divides. In normal circumstances, there is an element of reluctance in the NHS to engage with the private sector. During this pandemic, all of this has been swept away, and everyone has pulled together. It has been 'all hands to the pump'," commented Caroline Finlay, managing director of MTS Health.

She reported that the clinical engineering teams have had to work closely with users to assist them in adapting to unfamiliar equipment: "There is a lot of equipment that has not been seen before, in this country – including a variety of Chinese technologies and ventilators from Sweden," she explained. "As there is a lot of unfamiliar equipment, the clinical engineers on site have had to be on top of their game – not just in terms of setting up the equipment, but also in ensuring users have the right training. The clinical engineering teams have provided a vital role in helping users navigate their way through these changes."

The London Nightingale hospital has segregated clinical areas and non-clinical areas, separated by what has been dubbed the 'Berlin Wall', to enable work to carry on safely, to equip the additional beds on site.

"As patients are now occupying the Nightingale-style wards, a system has been set up where the Bart's healthcare scientists and clinical engineers are working within the clinical environment in full PPE, while the MTS and Avensys clinical engineers are working on the other side, with a buffer zone in between.

"The buffer zone is where we interact on a day-to-day basis and conduct handover meetings. We have two handover meetings with the clinical teams per day and there are clinical engineers working 24 hours around the clock," Finlay commented.

Challenges

Althea's specialist biomedical engineers have also played an important role in helping to ▶

set up the Nightingale hospital in London, during the first phase of the project.

"The biomedical engineering team has been really responsive to a fast-moving situation and worked well beyond their contracted hours, spending time away from their families to help make sure the hospital is ready and functional," commented David Rolfe, UK&I chief executive officer at Althea.

"One of the key challenges was coordinating the arrival of the equipment with the commissioning and installation. It was a very dynamic time with frequently changing information about what equipment was coming, in what quantity and at what time. The engineers on site had to be flexible enough to deal with whatever came through the door.

"We also had to make sure that our own workforce engineers were able to work in as safe an environment as possible, so they were not exposed to the virus themselves – this included social distancing, obtaining PPE, and changing servicing practices to lower the risk of transmission of the disease from wards with COVID 19 patients."

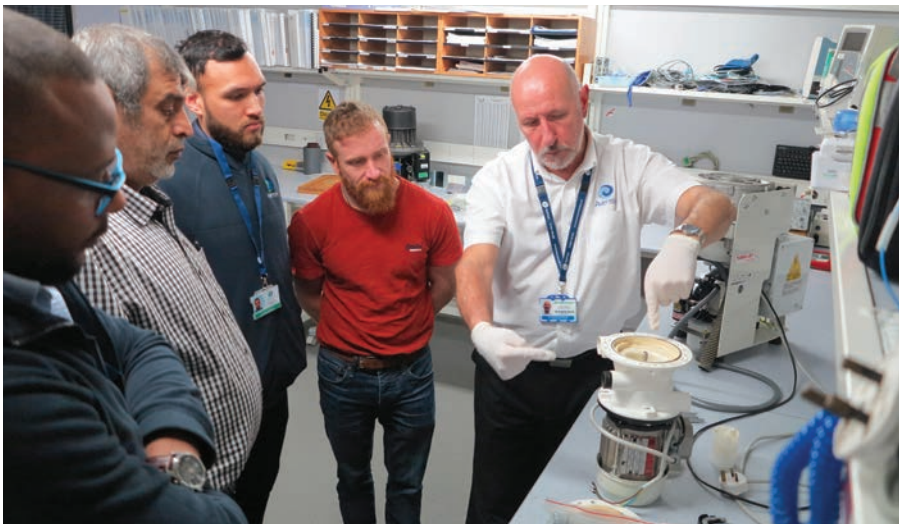
While setting up the Nightingale hospitals, the clinical engineering teams have had to contend with national and international shortages of equipment. While 4,000 beds have been planned for the site, obtaining 4,000 ventilators in two weeks has been an impossible task.

"It isn't just the UK looking for additional capacity, it is virtually every country in the world. As a result, we have had to accept many items that we haven't seen before – these are models that are perfectly good, but not well known in the UK. The clinical engineering teams have had to be extremely vigilant around electrical and safety testing. Most of the equipment has come with European electrical connections, but in some instances, we have had to change the power supplies," Finlay reported.

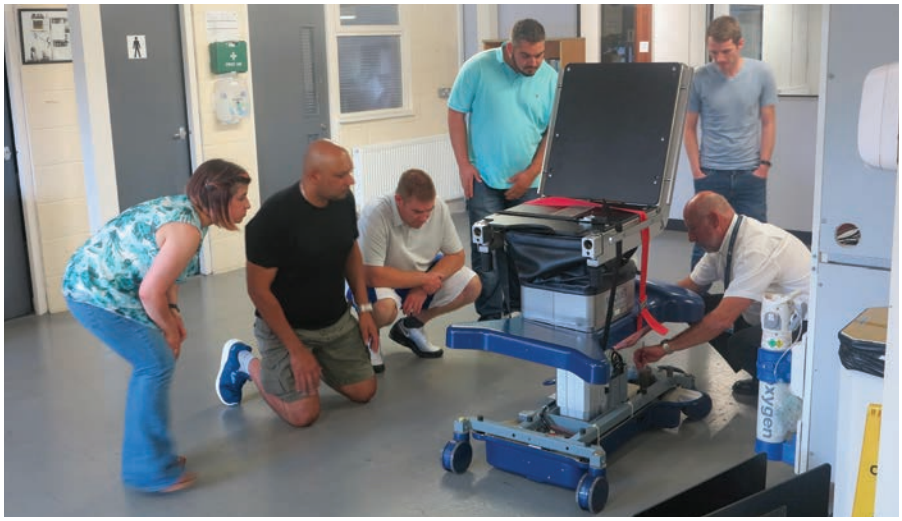
The volume of consumables required has also presented some challenges and was initially underestimated – these consumables need to be matched to a wide variety of models and devices: "The lack of standardisation in terms of the design of these accessories is an industry-wide issue – they are all bespoke to the equipment. Ventilators require tubing and filters, for example, and there needs to be an understanding of the typical usage, as well as the different models and manufacturers.

"In addition, the cables are not always supplied with the equipment. If the person procuring the devices hasn't had the right technical engineering input, they may not purchase everything required to make the equipment functional. This is where the clinical engineering teams have had to really step up to the plate," continued Finlay.

"Now we are further into the project, these issues are now resolving. Clinical engineers do not normally get involved with these types of procurement issues. It has pushed them outside of their comfort zone – they have had to understand what the clinical pathway is, what the patients require, and work closely with the clinicians to ensure they have everything they need at the bedside. It has been a massive learning curve."



Additional training for the Nightingale Hospitals has been a key requirement.



MTS and Avensys have also been working on the Manchester Nightingale Hospital. Over 3,000 devices have been commissioned and there is still equipment arriving. The Manchester University NHS Foundation Trust has now been appointed as the 'host' for the site.

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>
> Caroline Finlay

Finlay explains that the Manchester Nightingale hospital has required a different approach to the London Excel: "While London has a designated EBME facility on site, Manchester has an equipment library. This means there are duplicates of everything required. If there are any issues with a piece of equipment, they can simply replace it with an item from the library, although there is also a core project team on site to deal with any problems.

"Ultimately, I see our role as transferring skills to the NHS staff who need to manage these facilities going forward. This is where good relationships and collaboration between the private and public sector are important. Going forward we will be working under their governance," she commented.

A military mindset

Avensys has worked in collaboration with MTS at Excel and has had a large number of engineers on site. The company's clinical

engineers are also involved with Harrogate, Bristol and Manchester and the soon to open site at Exeter.

"Working with 'competitor companies' and OEMs has been fruitful for all concerned and bodes well for the future," commented Robert Strange, CEO at Avensys. "At the end of the day, all the engineers – irrespective of employer – simply wanted the same result and set about the task as a team. I think good friendships have been made.

"At Harrogate and Bristol, we have been involved in the procurement of some of the equipment, as well as engineering support on site," Strange continued. "Recycling older infusion devices, ventilators and suction pumps has been equally important and beneficial. We have been able to draw on our contacts within this industry and across the globe. We are now part of the Vamed International group and this wider community has been helpful from a procurement perspective," he explained.

The fact that a number of the engineers are ex-forces, with a history of emergency situations, has also helped, according to Strange: "The company has been founded by ex-military personnel with experience from a number of conflicts around the globe, and our senior engineers at the Nightingale sites are all ex-military. They are used to working all hours in an emergency situation to get the job done – establishing a robust structure; quickly establishing a workshop area; and then facilitating a 'production line' of engineers."

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>
> David Rolfe

Commissioning equipment, servicing and repairing equipment, and purchase of devices have been key at all these sites. However, it has also been necessary to share equipment between Nightingale hospitals to cover the shortfalls in certain devices.

"In these instances, we have relayed some equipment between sites using company vehicles and admin staff, speeding up the process that would normally take weeks. If one site needs an infusion pump, for example, and another site has excess, we would simply load it into the back of a van and have the device commissioned and available that same day. I cannot express how important it is to have a military mindset in this sort of arena," commented Strange.

Training

Training and lines of communication are also important in these emergency situations, and additional training at the Excel site has been a key requirement. Avensys training academy has established a temporary training facility, at the Crown Plaza next to the Excel arena, where it has provided training for other engineers and clinical scientists on the basics of ventilators, gasses, anaesthetic machines, monitors and infusion pumps.

"By the time we have completed the ▶

training, we will have trained an additional 80 engineers and clinical scientists on the fundamentals of the equipment. We have also been asked to do this at Manchester with further possible extensions in the pipeline."

This has helped clinical scientists develop their knowledge of areas such as fault finding with anaesthetic machines, for example. The company has also developed an 18-hour, online training platform to support hospitals across the country.

Strange hopes a new appreciation for the clinical engineering role will lead to increased investment in EBME departments across UK hospitals in the future. He believes the NHS needs to develop its in-house teams.

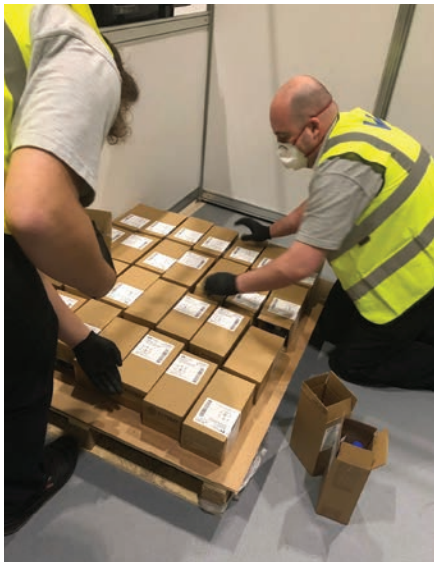
"During this pandemic, biomedical engineers have been recognised as key workers for the first time in their lives," he commented. "At the Nightingale Excel site, engineering colleagues from the NHS have shown they have the knowledge and ability. However, across the country, the contribution that these departments have to offer, in ensuring safe patient care, has not been given the recognition that it deserves; they have been given poor facilities in the basement and allowed limited influence over procurement.

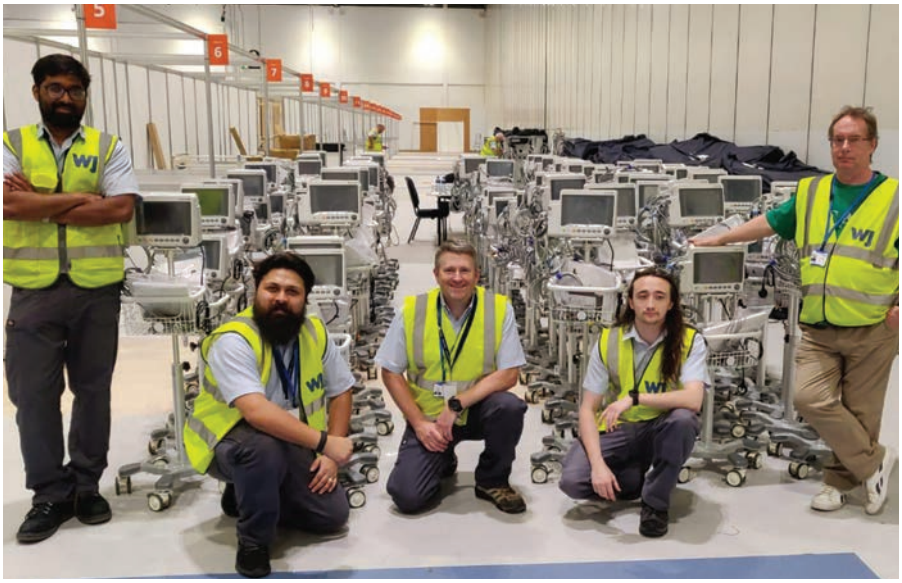
"There has been an over reliance on OEMs and expensive service contracts in the NHS. Every EBME department should have the ability and capacity to maintain and manage all of a Trust's equipment. The need for expert engineers in house has been proven.

"As a result of this emergency, EBME engineers are now being put back in the spotlight. Their knowledge across a wide range of equipment has been really key on site."

Decommissioning the Nightingale hospitals: what next?

Once the pandemic subsides and the field hospitals are no longer required, the question arises of what should happen to all the extra medical equipment procured. How should it be decommissioned? There is also the question of what should happen to ensure the UK is equipped and better prepared to deal with future outbreaks of this kind.





A production line was created to build the trollies, mount the patient monitors, perform tests, then configure these to the desired settings requested by the doctors.

"It would be a mistake to deploy all of the medical equipment into the NHS as 'free issue'," said David Rolfe. "I believe a pandemic preparedness equipment stock should be built which could be deployed quickly in the case of another pandemic. It is far from clear when this virus will be expunged or when a vaccine will be deployed on a wide basis.

"The cost of providing this contingency would be very small compared to the cost incurred, so far, in reacting to the pandemic without preparation. Companies like Althea have the means to store the equipment and ensure it remains in serviced order and then rapidly deploy and commission it in the event of another major emergency.

"The major lesson to be learnt for the future is that proper pandemic planning and putting real contingencies in place, in terms of medical equipment, would be at a fraction of the cost – perhaps hundreds of millions of pounds *versus* the hundreds of billions of pounds that this has cost the whole economy."

Dr. Sandham believes we can learn from history: "In the 1970s-1990s, the Government had 'mothballed' hospitals that were controlled by the military in the case of a war and the equipment was maintained. As the Cold War dissipated, these mothballed hospitals were closed down and they got rid of all the equipment. The military also had their own operational hospitals and medical staff, which offered additional capacity. The last military hospitals closed, or were turned over to the NHS Trust, in 1995.

"Today, there are no more military hospitals and all of the UK's mothballed facilities have been closed. If the pandemic had happened in 1990, we would have been able to open all of these facilities; there would have been beds and all of the equipment would have been maintained. This would have made things much easier for the Government. Once we are through this pandemic, I believe the Government should find somewhere to mothball all of the equipment that has been purchased."

He believes that using large exhibition spaces is a good model for getting field hospitals up and running, but the challenge has been "having the equipment ready to go". Going forward, a strategy must be developed to ensure contingency in the future.

"If the equipment was mothballed it could still be used in 10 years-time. There needs to be a replacement programme, with a budget for replacing equipment after a set period. There also needs to be a strategy for storing this contingency equipment in the event of another pandemic, or even a war, rather than disposing of the equipment. Either the Government or the military should be responsible for finding this storage capacity".

"In terms of the clinical engineering community, it would also be useful to have a database for emergency equipment that is used by all NHS hospitals, in the event of a pandemic or disaster," he continued.

He added that hospital directors who are already responsible for overseeing emergency responses, such as terrorist attacks, should also be given responsibility for ensuring there is sufficient contingency stock of equipment during a pandemic.

Caroline Finlay agrees with John Sandham that there is an opportunity for a pooled resource in the future. "We could learn a lot from the military and the way they respond to incidents, particularly in terms of their use of centralised libraries. It isn't feasible for every hospital to store emergency

equipment, but centralised equipment libraries could be established, and the medical devices kept in a state of readiness.

"Rather than being stored solely for pandemic situations, this equipment should be kept for hospitals that need to deal with additional activity, as well as being utilised for training young engineers. This needs to be driven at a national level by a Government taskforce," she asserted.

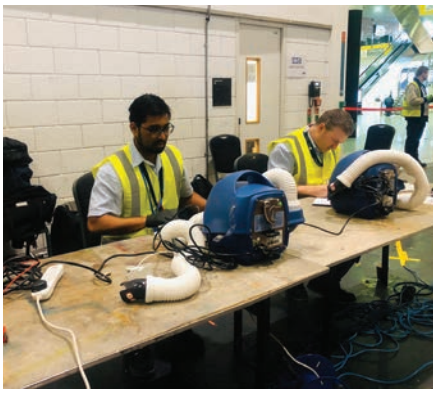
Rob Strange favours a Ministry of Defence model in the future: "The MoD have field hospitals in storage awaiting rapid deployment during any crisis should the need arise. All associated medical equipment is maintained by their own in-house 'medical and dental' technicians."

He points out that Avensys already operates a similar model and the approach is tried and tested. "We have a 16,000 sq ft warehouse already set up for this type of work and currently provide this service for several companies, including Vanguard Healthcare. Equipment like ventilators and infusion pumps cannot simply be left in storage to gather dust – they must be charged and continually maintained. We are ready to support this effort."

Planning for the future

Strange also believes the pandemic has highlighted the need for the NHS to invest in developing in-house skills and knowledge. Training for apprentices and upskilling staff will be crucial to ensure the NHS can mount a robust response in the future:

"The Avensys training academy is delivering degree training for biomedical engineers, as well as apprenticeships. But we are also working with Dudley College and the new Institute of Technology in the development of a 'mock hospital' for biomedical engineering training. This will train medical engineers – from Level 2, all the way through to honours degree level. The mock hospital is due to open in the Summer of 2021.



A production line was created to commission the Bair Hugger patient warmers. This included control checks, electrical safety testing and temperature checks.

Penlon anaesthesia units were commissioned for use as ventilators.

"This is the future – to raise the profile of medical engineers. We need to shout from the treetops, while it is still in everyone's minds."

Caroline Finlay agrees that the sector should think strategically about how it develops the skills required to respond to emergencies of this kind. "In the future, we are going to have to make contingency plans and this needs to include encouraging more people into biomedical engineering. Scientists have their role, but there is far too much emphasis on the science element of training schemes run by the NHS, as opposed to the engineering. We need to have a fresh look at how we encourage young engineers into the sector, including developing opportunities around apprenticeships," she commented.

She believes there has been a lack of development and investment in clinical engineering departments, particularly within non-teaching, district general hospitals. There needs to be a shift away from the traditional 'workshop', to the bedside.

"This pandemic has highlighted the need to put the 'clinical' back into engineering. This is a message that will stay with us for quite some time. Clinical engineers do more than just fix equipment in a workshop. The NHS needs to build a whole workforce and develop the skills required within the clinical engineering sector. This means learning about physiology, being able help clinicians to set up equipment, and to be very much part of the patient experience," she concluded.

Conclusion

At the time of writing, the Nightingale hospitals were moving to a passive role, effectively on stand by, in case of a second or third surge in COVID positive patients. However, at the beginning of the pandemic, planning for the worst case models was accepted by all as being sensible. Thankfully the spread of the disease has been significantly curtailed by the co-operation of the majority of Londoners who, like the rest of the UK, have stayed home and enabled the rapid expansion of ICU beds across the London Trusts to stay ahead of the peak demand. The role of clinical engineers from Bart's and commercial partners has been central to the equipment management at the Nightingale and exemplifies the absolute need for this level of expertise to be properly utilised by Trust management.

"The engagement between clinical engineering and medical consultants has brought a much needed focus to the management of risk during the astonishing pace at which this hospital has evolved. Arguably the elements of incoherence in the central supply chain would not have occurred if the expert advice of experienced clinical engineers had been utilised," concluded Malcolm Birch.

"The crisis has demonstrated the paramount importance of clinical engineering to both the technical and clinical governance of medical equipment, particularly, in this case, within the ICU – but also across the delivery of safe and effective healthcare in our Trusts."

Ultimately, we should take the time to celebrate the huge efforts of the clinical engineering community and the personal commitment shown to ensuring the safety of patients during this national emergency. What happens to the equipment installed at the field hospitals, the lessons learned, and the strategy for future responses will all be up for debate. Clinical engineers will need to have a central role in this discussion, going forward. CSJ