70 years of innovation in operating theatre design

Since the birth of the National Health Service in 1948, the healthcare landscape in the UK has undergone incredible transformation. Hospital design has changed along with it, and the design of operating theatres in particular continues to evolve at a rapid pace to this day. This frequency of change means that the lifespan of the operating theatre is relatively short compared to the lifespan of the hospital building as a whole. On average, operating theatres can be expected to undergo significant refurbishment every ten to twelve years.

Although it is difficult to pin down specific changes in design theory and architectural practice to particular decades – the complexity of healthcare buildings means that the design process often spans years, as does the construction phase – it is clear the operating theatres have undergone a dramatic transformation over the past seventy years.

1950s

The NHS was in its infancy during the post-war period, when many aspects of UK industry were still recovering. As a result, much of the NHS estate remained as it had been prior to the implementation of state-funded healthcare. Operating theatres were often part of a ‘twin suite’ design – two operating rooms designed as part of a self-contained department, sharing ancillary facilities and often staff between the two theatres. While this adhered to the functionalist principles of ease of access to necessary facilities, with instrument sterilisation for example often taking place either within the theatre or in an immediately adjacent room, it meant that patients had to be transported long distances in order to reach wards. Often mechanised transport was required to move patients the necessary distance to recovery, so corridors were designed with adequate width to allow this kind of movement. Towards the end of the decade, however, as the country began to regain momentum following the war, theatre technology began to change. The first studies in operating theatre ventilation were published in the USA, noting that when the flow of contaminated air into the theatre from outside was reversed by positive pressure, there was “an immediate reduction in the bacteria in the air and... a striking fall in the incidence of wound infections from 37 out of 427 clean operations to 5 out of 532.”¹ This new knowledge led to further investigations and evidence-based development of positive-pressure air flow, the precursor to the ultra-clean ventilation systems in use today. The goal of asepsis, rather than antisepsis, led to developments in operating theatre practice and attire. Crucially, in 1955 the Nuffield Trust published its research report Studies in the Function and Design of Hospitals, which was to change and inform hospital and operating theatre design for the next thirty years.

1960s

In the 1960s, healthcare architects widely adopted a new style of hospital building which changed the way operating theatres interacted with the rest of the hospital. In the fifties, what became known as the ‘matchbox on a muffin’ hospital; the first of these was the Hospital Memorial France-Etats-Unis Saint-Lo in 1956. These hospitals featured a podium of several storeys’ height which housed the critical hospitals services: operating theatres, diagnostics, sterilisation departments and domestic services. Stacked on top of these in a tall ‘matchbox’ tower were the wards, which were all

served from a central, high-tech core. This vertical hospital design meant that theatres stepped away from the older twin suite design, and operating rooms became a much more focussed surgical environment. Centralised sterilisation was adopted, birthing the CSSD model that is still widely followed today; an article in the *British Medical Journal* published in 1962 stated, “A strong case could be made in favour of removing sterilising-rooms and sink rooms from the vicinity of the theatres”\(^2\), citing rising concerns about cross-infection within the older ‘twin suite’ theatre design as evidence of the need for change. This design increased the adaptability of service configuration; changes could be made to the lower structure, including to operating theatres, without impacting the wards above.

This focus on flexibility led to widespread discussion of operating theatre layout and materials. The Nuffield Trust report states, “If a 20-foot square is drawn round the core of activity surrounding the table, it is apparent that sufficient peripheral space will be enclosed to allow free movement and the placing of equipment.”\(^3\) It is interesting to note that this report also included a section on the use of colour in the operating theatre, an area of healthcare practice that is coming increasingly into wider focus today. This exploration of the theatre environment also led to a move away from the traditional method of natural illumination, with operating theatres now becoming a much more mechanised environment. Surgeons’ preference for control over their operating environment grew apace with developments in lighting, ventilation and temperature; environmental variables gradually came under machine control as the technology boom spawned improvements such as commercially viable air conditioning systems. The work of Gordon Friesen, a hospital administrator in Canada whose life’s work became based around healthcare planning, introduced the concept of strict separation of clean and dirty workflows during this time, based on theories of microbiological cross-contamination and staff practice.

**1970s**

Late in the preceding decade, design began on the Greenwich Hospital, which broke away from the widely popularised ‘matchbox on a muffin’ typology. The Greenwich design followed the ‘horizontal hospital’ concept, with low rise buildings spread out across a broader length rather than the widely-accepted towers of the previous generation of hospitals. This idea aimed to make hospitals more flexible by enabling additional service areas to be added to the outer extremities of the building without disrupting activity in adjacent areas. The previous high-tech circulation methods that had seen mobilised transport taking patients to and from theatre was replaced with low tech methodologies, with theatres and functionally related departments now being sited close to one another; in this capital- and energy-starved decade, innovations in theatre design slowed considerably and the healthcare market stagnated.

**1980s and 1990s**

Throughout these decades, the basic precepts of healthcare in the UK began to shift towards ‘patient centric’ care. The nucleus hospital concept was developed in the early ’80s in an attempt to build replicable, low-energy hospitals, with operating theatres located at the central hub of the building and wards spread across the projecting wings. The focus on operating theatre environment, previously maintained from the surgeon’s perspective, expanded to include patient experience as a

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\(^2\) Essex-Lopresti, M. and Hubert, D. *Planning operating theatre suites*, British Medical Journal, 1962, p. 1471

\(^3\) Nuffield Provincial Hospitals Trust, *Studies in the functions and design of hospitals*, 1957, p. 60
deciding factor in hospital design. Natural light, often previously discarded in favour of controlled, artificial lighting, made a return to the operating theatre, with daylight-excluding blinds fitted between two panes of glass to prevent dust build-up and retain the flexibility to suit different surgical requirements and preferences. As minimally-invasive and day surgical techniques developed through the late ‘80s and into the ‘90s alongside new technology, operating theatres for day cases began to be widely housed in separate day surgery units, with independent workflows and pathways for both staff and patients. Inpatient theatre suites began to follow a new design, with the traditional separation of clean and dirty flows discarded in favour of a single corridor system as “the simplest and often the most economic”\(^4\). The recommended size of operating theatres in the UK increased\(^5\) to 40m\(^2\) in an effort to accommodate the growing amount of equipment present in theatre, such as surgical stack systems or medical lasers. The height of new operating theatres designed during this period increased as part of a future-proofing activity, driven in part by the difficulties experienced in the late ‘80s and early ‘90s when refurbishing theatres to include laminar flow canopies. By the end of the ‘90s, these specialist ventilation systems were fitted to theatres across the UK where high-risk operations were conducted, in an effort to minimise surgical site infections. The reconfiguration of lighting and electricals was required in order for retrofitted canopies not to infringe on surgeon’s headroom\(^6\), delaying some of these projects and increasing the associated costs.

\(^5\) *Health Building Note 26: Operating department*, 1991
\(^6\) *Health Building Note 26: Operating department*, 1991

2000s

This decade saw another shift in focus within operating theatre design, with learnings from previous decades bringing discussion on future-proofing theatres to the fore. The arrival of the hybrid theatre
concept, incorporating diagnostic technology within surgical theatre space to provide an integrated care platform, spurred these discussions. Hybrid theatres require considerably more space than traditional theatres, both horizontally and vertically; the extensive equipment that is often ceiling-mounted in these designs means that additional headroom must be catered for to minimise the risk of injury to personnel, making it challenging to retrofit hybrid theatres rather than building from new. Some types of hybrid theatre, such as angiography operating theatres, also require lead shielding of the walls, floors and ceilings, making refurbishment of existing space into a hybrid theatre a costly and disruptive process. Conventional theatres in this era also expanded, with guidance citing an optimum size of 55m². This updated guidance also included newer ‘touch free’ technology in an ongoing effort to minimise contagion carried on the hands, including automated self-closing doors between the theatre and ancillary rooms and foot-operated waste receptacles.

Today
In recent years, the increasing size of conventional operating theatres has come under scrutiny. With emphasis being placed on theatre efficiency and patient turnover, designers and manufacturers are querying whether these large theatres are the most effective. While larger theatre areas reduce disruption within the surgical environment, they also increase the travel distance for staff and can lengthen procedure times. A four-year study being conducted at the Medical University of South Carolina by researchers from Clemson University is aiming to design the footprint to a safer, more efficient operating theatre, utilising evidence-based simulations to determine the best size, shape and layout of the room to facilitate the safest and most efficient patient care. Designers are also considering the further application of methods like interstitial floor spaces between storeys to allow additional room for ventilation systems, equipment and maintenance access. Further development of ceiling-mounting or underfloor equipment frames to allow for theatre layout adaptability continues, with architects juggling possible future requirements with the practical necessities of disruption, timescales and cost in a resource-light healthcare system. With physical space becoming increasingly sparse in the UK, with many hospitals unable to further expand, research is also ongoing into utilising underutilised space within operating theatres, with concepts like the ‘self-contained’ operating table arising, which makes use of the space beneath the table itself to store electronics, monitoring equipment and more.

7 Department of Health, Health Building Note 26: Facilities for surgical procedures, volume 1, 2004
8 Neyens D.M. et al, Using a systems approach to evaluate a circulating nurse’s work patterns and workflow disruptions, Applied Ergonomics, Mar. 2018
9 Bitterman, N. OR design: characteristics and future directions, European Healthcare Design 2018
Refurbishing operating theatres

Whichever direction the future of operating theatres takes, it is clear from the frequency and nature of these changes that the life cycle of an operating theatre is finite. On average, operating theatres need to be significantly refurbished every 10 – 12 years. As technological developments accelerate, this requirement seems set to continue for the foreseeable future. In a highly pressurised climate, however, finding the time and resources to close operating theatres in order to make these essential upgrades is challenging. The 2017 Naylor review\textsuperscript{10} estimated that backlog maintenance costs alone were in the vicinity of £5bn, and Trust financial teams are in the difficult position of having to stretch available funding to cover urgent repairs, leaving little capital for planned refurbishments. Closing theatres for renovation also impacts on the Trust’s revenue; the loss of elective patient flow also means the loss of the tariff income associated with performing these surgeries, so that many Trusts cannot afford to close theatres for refurbishment if they are to meet their financial targets. Traditionally, Trusts wishing to maintain patient flow during these periods of downtime have outsourced patients to the private sector, which not only equates to a loss of tariff income but can also mean they are operating at a loss for each procedure they are paying for outside of the core NHS pathway.

The advent of mobile operating theatres in the 2000s offers an alternative to hospitals looking to refurbish their theatres. Designed to promote ergonomic staff workflow and enable smooth, continuous patient flow, these self-contained facilities can be brought onto site to serve as decant capacity for theatres closed for refurbishment. Each mobile operating theatre has the necessary ancillary spaces included within the footprint, including an anaesthesia room and a first-stage recovery bay. The electrical and water systems are integral, requiring only a connection to mains supplies ahead of the commissioning process to ensure that clinical activity can safely begin. Through the deployment of this flexible infrastructure model, Trusts are able to meet targets

\textsuperscript{10} Naylor, Sir R. NHS Property and Estates: why the estate matters for patients,
through maintaining access to services during what would otherwise be periods of downtime, or
times when care is diverted to the private sector. It also enables Trusts to meet key performance
indicators in activity volumes and revenue flow that could only otherwise be maintained at the
expense of delaying or cancelling refurbishment programmes.

In summary
Technology and patient demographics have changed significantly in the seventy years of the NHS’
existence, necessitating extensive changes to operating theatre design. This trend of rapid change
looks set to continue, with technological advances in fields like communications, robotics and even
artificial intelligence making their way into the operating theatre and changing the fundamental
structure required to support innovative surgical practice. Already there is growing debate as to the
efficacy of laminar air flow systems, and what the next generation of theatre ventilation technology
will look like and what infrastructure changes would be required to support it. With the maintenance
backlog growing and current funding settlements widely reported as being unable to bridge the gap
between the state of existing NHS infrastructure and the required standards for optimal patient
care, NHS hospitals are running the risk of falling behind developments in operating theatre design
and technology unless they can find a way to balance the need for upgrades to their theatres with
the necessities for continuous patient flow.