Energy Conservation & Infection Control in Surgical Suite Design

An artist's impression of Alexis Hospital, Nagpur

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Introduction

There are healthcare facilities where, as a part of the standard regimen, patients are put on antibiotics both before and after a surgery. This stems largely from the well-meaning consideration that the patient should not develop an infection through and post-surgery. But an over-exposure to antibiotics is avoidable.

There are *universal precautions* that can be adopted for checking contact infection. And for airborne infection, the HVAC design has a very significant role to play. Designed correctly, HVAC can help check infection. And designed or managed inappropriately, the HVAC system can become the very source of infection. What makes for a safe operating room?

Operating Rooms (ORs) see a higher tonnage per square foot than one would see in a regular comfort conditioned space. This is owing to lower temperature requirements, greater humidity control and fairly high air changes per hour (ACPH). When HVAC is known to be an energy guzzler and among the more important contributors to energy consumption in a hospital setting, can we look at safe measures of energy conservation in ORs?

Asepsis

We start with recent history. Over the past 300 years, the design of ORs and ancillary spaces has responded to changes in surgical needs and practices. The discovery of anesthesia in 1846, the use of carbolic spray in 1866 during surgery to avoid infection, Von Bergmann's introduction to aseptic technique and the sterilization of instrumentation in the late 1800s through to the introduction of intra-operative imaging and keyhole surgery in the 20th century have made it necessary to provide designated facilities to encompass these technological changes in a safe environment.

Architect Louis Sullivan stated, '… form ever follows function'. This may have been a matter of intense debate among architects. But insofar as engineering is concerned, it must follow architecture. All the architects and the engineers reading

About the Author

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Figure 1: An operating room of the yore!

Figure 2: A post-modern operating room

this will know too well the tussle for that little space for the electrical room, for that shaft, for that AHU room. No offence to the good architect, but inevitably the refrain is, "…but you can have a ceiling suspended AHU". And the design engineer has that harried look on the face knowing only too well the challenges that the maintenance will pose later. If one did not have to manage these tussles, architects and engineers would be less stressed!

When one speaks of the surgical suite, the focus, quite naturally, is the operating room. But one must necessarily include the spaces that the patient traverses right from the elevator lobby from where the patient is brought in, the receiving bay, the pre-op, the anesthesia room and the sterile corridor culminating in the operating room. And then there are the staff interfaces – the counseling room, the change rooms, the scheduling stations, the scrub bays* and the equipment room – whose paths too converge in the operating room. Any exercise in planning must necessarily address all these spaces and adjacencies.

** (A scrub bay is a space that accommodates a scrub sink – where the surgical staff performs ablutions before and after surgery. See Figure 3. A break of scrub event is one where the staff working on the patient in the OR comes into 'touch' contact with an unsterile object or person.)*

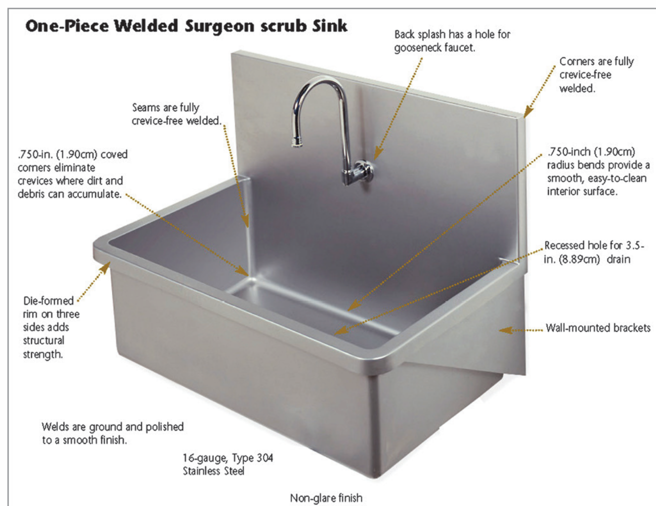

Figure 3: A one piece welded surgeon scrub sink

The First Principle

A surgical suite is a complex of operating rooms with all the attendant clinical and general support spaces such as the pre-operative room, the post-operative room, the change rooms, the utility rooms, the equipment bay *et al*.

The zoning in a surgical suite is categorized into unrestricted, semi-restricted and restricted. One gets into progressively cleaner spaces as one transits from unrestricted to restricted. The zoning is also governed by a dress code where one cannot access the semi-restricted spaces in street wear and where one must be gowned and capped before one enters the restricted zone. This is important as it dictates both the extent of physical movement of man and material and the pressure gradient. For instance, one does move beyond the change rooms that fall in the semi-restricted zone in street wear. And the pressure gradient is designed to ensure that the cleanest area is at the highest pressure!

This principle is further reinforced by that of Unidirectional Flow – essentially avoidance of criss-crossing of clean and dirty traffic to reduce human error by way of contact. Thus, patients and doctors move in and out through the same corridor, but clean material has a dedicated passage where it will not come into contact with the used material being carried out.

There are a few simple design measures that can be adopted for asepsis, safety and generally, a better clinical outcome.

Prevention is Better than Cure

- Ensure there are no wet lines (pipes that are likely to condense moisture on the outer surface) running along the ceiling above the OR. It works well if there is an interstitial floor above that accomodates all the services;
- Any opening in the slab for running of services should be neatly and effectively sealed;
- Adopt finishes that afford a seamless finish, avoiding 90 degree joints;
- Use material that inhibits growth of pathogens.

Enable Focus

- Define a perimeter/ radius around the operating table such that all operating staff, instrument trolleys and surgical equipment are within the boundary so defined: the table is in the centre, i.e. the hub. By design, the operating surgical team remains within this circle during the operation, and no one from outside the circle is permitted within the circle. This minimizes "break of scrub" events, and limits the chances for loss of sterility. But defining this perimeter is important for another reason. It defines the size of the plenum. It is a common practice to play with the size of the plenum for convenience. But there has to be a certain logic to it. *HTM 2025** does mention a plenum size of 3.0m x 3.0m and now, in India, the National Accredita-

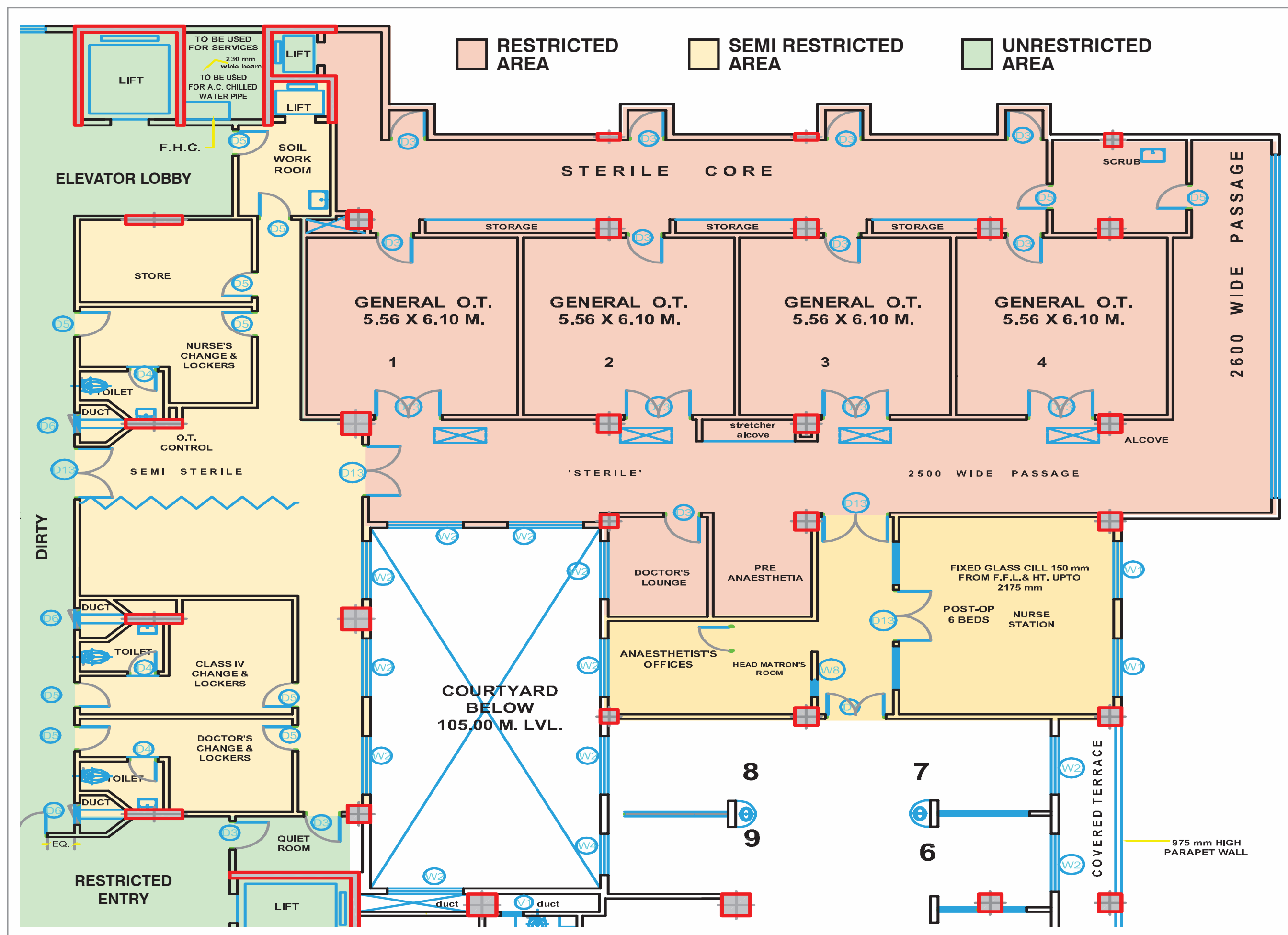

Figure 4: Zoning on a typical hospital floor

tion Board for Hospitals & Healthcare Providers (NABH) specifies certain dimensions. What matters is that not merely the patient and the surgical staff, but also the equipment trolley needs to be covered under the flow; else, the purpose stands defeated.

*(*Health Technical Memorandum 2025 (HTM 2025) is a UK standard that provides comprehensive advice and guidance on the operation of ventilation in all types of healthcare premises. It is applicable to new and existing sites, and is for use at various stages during the inception, design, upgrading, refurbishment, extension and maintenance of a building. HTM 2025 focuses on the legal and mandatory requirements, design of systems, maintenance of systems and operation of systems.)*

- Controls should be designed such that support staff need not enter the boundary so defined – this helps minimize break of scrub events.
- Orient the table such that the surgeon does not face the door – this reduces avoidable distraction.
- If one must have windows, provide blinds in sandwiched panes to reduce distraction.
- Integration, beyond the surgeons' panel:
  - Wired interface to access information on monitors conveniently suspended and viewed; real-time access to lab data and easy archiving of patient history and pictures/ images.
  - Wireless interface to operate the surgical equipment, operating table, operating lights, timers, telephone.

Safety

- If there are no wires on the floor, no one will trip over them, or inadvertently disconnect equipment to disrupt the surgeon's activities. Therefore, encourage use of pendants, media bridge etc.
- If there is no X-ray box in the room, then an X-ray cannot be put up backwards, and wrong site surgery events can be avoided by the surgical staff. Therefore, provide for screens and monitors on which the imagery can be archived from Radiology Information System (RIS) or Hospital Management Information System HMIS, as the case may be.
- If the circulating nurse never has to leave the room to search for equipment, then the surgeon will always have help when a complication occurs or worsens. Therefore, provide for adequate and carefully configured storage within.
- If the room can be sterilized, concerns for infestation of surfaces by superbugs can be eliminated. So choose seamless,

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microbicidal finishes that afford coved joints and can be cleaned easily. (In coved joints, the angles are treated so that they are not 90°. Instead, they are rounded so that dirt and dust do not accumulate and they become more amenable to cleaning.)

It is true that operating rooms require the most aseptic environment. A common belief is that the HVAC design must provide for 100% fresh air. Now, this is not quite true. One may design the system to operate in 100% exhaust mode under exceptional circumstances. Fresh air is important in HVAC design, as it helps maintain positive pressure; also, it dilutes the exhalations inside the procedure room, important perhaps when no active gas scavenging system is in use. Else, *ASHRAE Standard 170-2008* clearly specifies a requirement of 20% fresh air. This implies that it is okay to recirculate up to 80% of air. But this minimum specified dilution is important to maintain IAQ.

Ultra violet irradiation has its advantages, but its efficacy is lost in merely switching on the lamp in the OR as one exits after the last surgery clean-up. There is a common practice of providing a UV lamp in the operating room that is switched on after the room is shut down for the day. It is believed that the germicidal properties of UV light would help render the operating room aseptic. The effectiveness is actually dependent on line-of-sight exposure to micro-organisms and is, at best, seen to have some impact on upper air irradiation, closer to where the lamp is mounted. Exposure in a contained space such as the return air duct or the supply plenum would be more effective than in a large volume of say, 108 cu m in a typical operating room. It makes sense to provide the lamps in the return air risers, where the exposure could be more effective – though the velocity compromises the potential.

Energy Conservation

Many among us, who keep a tab on the revenues, would be aware of the electricity costs. What many may not be aware of, is the collective impact that we as an industry have on electricity consumption. Square foot for square foot, healthcare facilities constitute the highest energy consuming industry.

Reality Check

Energy has been conventionally conserved by harnessing natural light and ventilation. However, this is not entirely feasible in a modern operating room. Artificial lighting is quite necessary. And therefore, most conservation measures would hinge on the HVAC loads. It may interest some to know that the HVAC load for an operating room of 600 sq ft can go up to 20 TR. Relate this with the conventional 1.5 TR AC unit for an office cabin – one can make do with 5 to 6 TR – and the difference becomes glaring. Conservation here can be achieved by way of both architectural and engineering designs.

Architectural Design

In the event the ORs are located on the top floor with the slab exposed to sunlight, provision of both over-deck and under-deck insulation helps. Windows are usually and preferably avoided, but if required, these should be sandwich panes with blinds inside to cut the glare and heat transfer.

Temperature and RH

Surgeons work in layers of surgical garb. And despite the newer OR lights emitting next to no heat, the surgeons need to be comfortable. Therefore, the temperature is typically set at 20±1°C. There are some surgeons who prefer the temperatures even cooler at 18°C. This, by itself, is not difficult; the drop of every degree below 20°C, though, costs disproportionately higher. The challenge lies in yet maintaining the humidity below 55%. Unless RH is contained within 55%, with the temperature set lower, one could witness condensation with water dripping from grilles, louvres, on the walls and some very uncomfortable and vexed surgeons, not to speak of proliferation of mold and organisms. This containment has conventionally been achieved with hot water or strip heaters. Dry/ solid desiccants help reduce the latent/ humidity loads, but we need a system that removes both sensible and latent loads. Else, with the heating required for dehumidification followed by extra energy to cool, the system is both expensive and energy-inefficient. One can only imagine the energy expended in cooling, heating and then cooling again. An alternative is available in liquid desiccant systems. This system deploys lithium bromide solution, dispenses with the heating requirement and, therefore, is energy efficient. Cooling coils are required to condense airborne water vapour. And over time, these wet coils spew organisms and throw them in the airflow. UV lights have been mooted, but the limited exposure poses questions about the efficacy of this option. Liquid lithium bromide kills pathogens that come into contact with it and, therefore, offers an additional bargain.

Building Automation

We are aware that HVAC for operating rooms is expected to function 24X7, being shut down only for planned maintenance. And equally true is the fact that some actually shutdown at night – why fritter away expensive power? We have a solution in Building Automation Management Systems – where the temperature could be reset from 20 to 24°C, translating into lower pumping requirement of chilled water; where the fan speed of the AHU can be varied to a lower rpm, commensurately lowering the fan speed of the AHUs catering to the adjacent areas so that the pressure differential is not compromised. Pressure differentials and gradients have to be maintained and monitored across the three zones in the surgical suite. And yet, many baulk at the idea of having to spend on building automation. It can be as simple as reverting from normal to setback operation or vice versa by linking it with time, correlated with operating lights. And, there is always the choice of a manual override.

The Fad of 100% Fresh Air

Does the provision of the much preferred 100% fresh air unit really help improve the clinical outcomes? More often than not, the high operating cost of a 100% fresh air unit is mitigated by way of a 'green' heat recovery wheel (HRW). How many of us know that the conventional heat recovery wheel does result in some mixing of air? HEPA filters effectively help us arrest particulate matter and no filters are yet available with a porosity of 200 milli-microns, the size of a virus. And thus, it is fine to not insist on 100% fresh air, but to go with 20% fresh air as is also recommended by ASHRAE, and

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dispense with the HRW. Compare the cost of energy expended on cooling 100% fresh air with that of cooling just 20% fresh air!

Table 1: Cost comparison between 100% and 20% fresh air

TR	Capital Cost/ AHU (Rs.)	Energy Cost/ Year (Rs.)	Notes
16	780,000	946,080	100% FA with HRW
13	495,000	768,690	20% FA
Difference	285,000	177,390	

Table 1 compares the costs of two HVAC systems for a 500 sq ft OR – one with 100% FA (with HRW) and the other with 20% fresh air as permitted by standards. The resultant savings clearly indicate the best option.

Table 2: Cost savings over time

Saving	Rs.462,390	Year 1
	Rs.1,650,277	By year 5
	Rs.3,849,070	By year 10

- Figures pertain to one OR of 500 sq ft.
- Assumed 18 hour working, accounting for setback mode.
- Energy cost pegged effectively at Rs. 6/unit
- Savings compounded at 10% p.a.

HEPA Filters – a Must?

Speaking of filters, another very common misconception is that an OR is not good if not equipped with HEPA filters. HEPA filters are a welcome proposition and provide an environment as clean as technology feasibly permits. But here too, *ASHRAE 170-2008* endorses MERV 7 and MERV 14 in sequence for Class B and Class C operating rooms. MERV 17 or HEPA is thus optional, not mandatory. For Class A surgery, depending on the type of surgeries intended, provision of HEPA filters could be considered.

Unidirectional Airflow and Size of Plenums

HEPA filters are typically located terminally for laminar or unidirectional air flow. As mentioned earlier, *HTM 2025* and *NABH* specify certain dimensions. What matters is that not merely the patient and the surgical staff, but also the equipment trolley needs to be covered under the flow, or the purpose is defeated. Here too, variable frequency drives (VFDs) aid conservation. Maintaining the pressure differential is important and VFDs help do just that. With time, as the pressure drops against the filters increase, the VFDs modulate to compensate.

Conclusion

In conclusion, there are evidence-based standards established by collaboration between reputed bodies in the fields of healthcare and HVAC, and it will be important to design conforming to these standards. Importantly, the requirements should be studied well in advance so that space and funds can be budgeted adequately. Having installed a good system, it becomes important to test and monitor the operations at defined intervals. Means are available; it is a matter of will !