A Guide on Infrastructure Design for Reduced Patient Readmissions

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Infrastructure Design for Reduced Patient Readmissions Guide

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About this Guide

With today's challenging reimbursement structures, healthcare providers can drive better bottom line performance by reducing patient readmissions. This guide provides recommendations, insight, best practices, and examples illustrating how smart infrastructure investments can help to reduce avoidable patient readmissions and ultimately improve the overall finances of a healthcare organization and the health and safety of their patients, providers and visitors. Topics including air handling and sterile fields, air infiltration and disinfection, design and management of sterile spaces, water treatment, and improved patient healing environments are addressed.

The goal of this guide is to highlight where facility management can go beyond the code and standard practices and focus on transforming the existing paradigm of health care facilities infrastructure design to improve patient treatment, care and general wellbeing.

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Thank you to the following people for their ideas and contribution to this guide.

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- **Domenic Ciavarro,** Executive Director - Catholic Medical Center
- **Jessica Stebbins**, Principal - HDR, Inc.
- **Kevin Scheriber**, President - SLD Technology, Inc.
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1 Background

Background

Reducing healthcare associated infections (HAIs) is of paramount importance in the operation of a hospital. Research has shown that the likelihood of readmission is greater for patients who experience HAIs compared to those that experience no adverse events. [1] Annually, 1 in 5 Medicare beneficiaries is readmitted within 30 days of discharge, [2] costing $26 billion per year with $17 billion of that considered avoidable. [3]

The Centers for Medicare & Medicaid Services (CMS) has instituted payment-related policies which reduces payments to hospitals with excess readmissions, where readmission is defined as admission to the same hospital within 30 days of a discharge. In August 2015, the CMS reported that 2,592 hospitals would be hit with penalties, resulting in a combined loss of $420 million. [4] Readmissions of patients ultimately cost healthcare providers out of their own pockets, decreasing capital available for vital patient services and infrastructure needs.

The Centers for Disease Control and Prevention (CDC) identified the five most prevalent sources of HAIs[5] :

- Ventilator-Associated Pneumonia
- Gastrointestinal Illness
- Catheter-Associated Urinary Tract Infections
- Central Line-Associated Bloodstream Infections
- Surgical Site Infections

The CDC identified the 5 most prevalent sources of Healthcare Associated Infections:

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According to a report published by JAMA,[6] on a per-case basis, central line-associated bloodstream infections were found to be the costliest HAIs at $45,814, followed by ventilator-associated pneumonia at $40,144, surgical site infections at $20,785, gastrointestinal illness at $11,285, and catheter-associated urinary tract infections at $896. The total annual costs for the 5 major infections were $9.8 billion, with surgical site infections contributing the most to overall costs (33.7% of the total), followed by ventilator-associated pneumonia (31.6%), central line-associated bloodstream infections (18.9%), gastrointestinal illness (15.4%), and catheter-associated urinary tract infections (<1%). Illustration 1 presents a graphical summary of the costs per HAI and total overall costs on the U.S. healthcare system.

Hospital acquired infections in general extend LOS 14 to 20 days. [7] Even short hospital stays carry risks for HAIs, which will not clinically present until more than 1 or 2 weeks after the initial hospital discharge.[1] This is especially true for surgical site infections.

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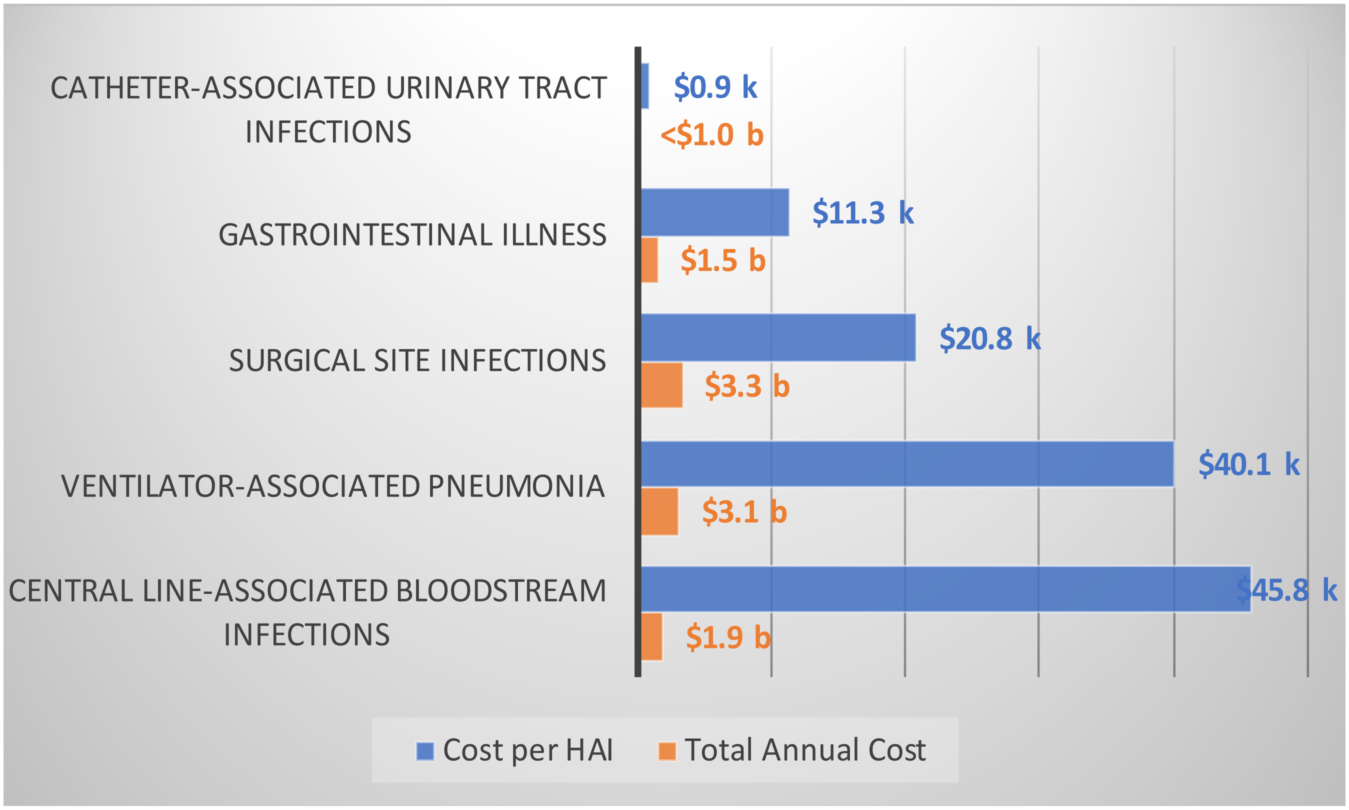

Illustration 1: Cost Impact of Hospital Acquired Infections (HAIs) in the U.S. (ref. JAMA, 2013)

Based on the data, HAIs pose a direct public health risk and will continue to strain the finances of health care institutions. However, infrastructure-based technologies and solutions are available to help lessen their prevalence and are presented in the following pages.

2 Air Handling and Sterile Fields

Air Handling and Sterile Fields

Some of the largest and most complex building infrastructure in a hospital facility is the air handling equipment. This equipment, and its associated distribution systems, can be expected to make up 4% to 8% of the total cost of original building construction. At the relatively high costs of health care construction of $500 / sq. ft. or more, the air handling systems are a significant capital expense. As such, it is important to get the design right up front with proper planning and design. For occupant comfort alone, this equipment is also among the most important.

This equipment, and its associated distribution systems, can be expected to make up 4% to 8% of the total cost of building construction.

Beyond occupant comfort, it's important to understand the effect that air handling equipment and its associated systems have on occupant well-being and controlling the spread of microbial diseases. Whether prescribed by code or guideline, or just recognized as an engineering best practice, those systems associated with the areas serving the most vulnerable patients and critical operations have unique requirements for maintaining specific air quality conditions. These include rate of air change within the space, pressurization, temperature and humidity. While much of the air design requirements and conditions are highly regulated by mechanical code and by guidelines such as ASHRAE Standard 170, there is room for solutions beyond common practice.

For managing airflow within an operating room (OR), standard practice prescribes a continuous, unidirectional laminar flow. This is intended to keep bacteria, fungi, viruses and other foreign particles mobile in the air stream and out of the space via return ducting installed just above the floor level. Systems that provide laminar flow conditions represent the best option for an operating room in terms of contamination control, as they result in the smallest percentage of particles impacting the surgical site.

In the past, an OR might have been designed with ceiling supply air diffusers located throughout the room, or with a ring of linear diffusers intended to form an air curtain around an inner sterile field at the operating table. It has become clear that to create a true sterile field over a patient, a grouping of centrally located laminar flow diffusers located directly over the patient is most effective.[8]

In study published by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) [9] maintaining a laminar flow directly above the surgical field approximately at the guideline-minimum flow rate of 20 air changes per hour was shown to reduce the quantity of particles that contact the surgical sites by approximately one-half compared to an entire ceiling system of laminar flow supplies having an air change rate as much as 150 ACH. This demonstrated that more airflow is not necessarily better. The quantity of air changes is not as significant in the surgical field as is design of the air distribution system ceiling layout.

Illustrations 2 and 3 provide a visual comparison of a sterile field, based on a minimum code-compliant system and one enhanced with a continuous diffuser air distribution system.

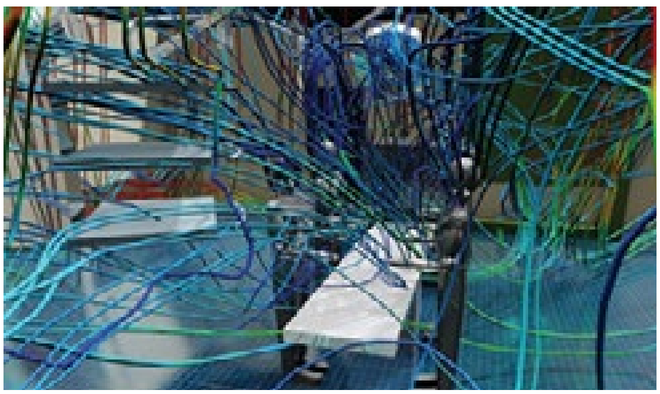

Illustration 2
Particle Trace Model for base ASHRAE 170 compliant system. Note the apparent turbulence. (Source: SLD Technology)

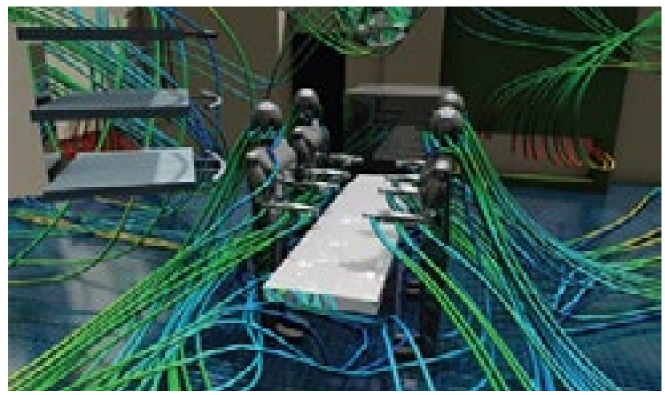

Illustration 3
Particle Trace Model for continuous ceiling diffuser model. The sterile field is maintained about the patient. (Source: SLD Technology)

The issue that arises, however, and one which cannot always be completely avoided, is the effect of the negative pressure area created by a boom arm, surgeon's instrument, lighting, or even the ceiling diffuser's frame that breaks the continuity of the field. This negative pressure results in turbulent flow which can induce those unwanted and dangerous microbials into the sterile field. Ways to reduce this impact include mounting booms outside of the diffuser group, limiting the size of the diffuser group to the space just over the operating table (which is not always feasible as the size of operating rooms has grown over time), employing a modular, single large diffuser system to mitigate the diffuser framing, and incorporating an engineered lighting system. See Illustration 4.

Illustration 4: Modular, single large diffuser system with light and boom mounts placed outside of the array. Includes integral, engineered lighting system that helps to reduce turbulence. (Source: Wilhelm Integrated Solutions)

Utilization of an integrated ceiling system, which combines several of the design aspects mentioned above, is one way to package these enhancements into a single, concentrated solution. This holistic approach to the design of an OR accounts for the interactions between many of the systems and activities functioning simultaneously in the operating theater. In addition to better performance, this modular approach can significantly reduce the time it takes to build the surgical suite and results in a consistent, as-built design over multi-room projects as compared to built-in-place systems.

The emergency department (ED) is another area of a hospital acknowledged for where ill and injured patients seeking evaluation and treatment not only have the potential to spread communicable infectious diseases to healthcare personnel and other patients, but also are vulnerable to acquiring new infections. It is also understood to be the most difficult area to regulate air quality and space pressurization. To help reduce HAIs in an emergency department, the entire ED should be kept under a general negative pressure with respect to the rest of the hospital, and the waiting room, triage, and other uncontrolled spaces exhausted at 12 air changes per hour.

There are several avenues the design team can take to minimize the impact of the ED on both the unknown infectious disease threat as well as associated construction and energy costs. First, by creative "right-sizing" of these spaces, this minimizes the overall airflow that must be managed. Second, by reducing the total area of interior connectivity between the ED and other parts of the hospital, this reduces the potential for unwanted air migration between spaces. Centralizing the exhaust in the ED waiting areas may protect those already in the uncontrolled space, by creating a general flow of air and particles away from the seating area, for instance. The registration area is one space which should not have any exhaust grilles, even as it is open to the waiting area.

Pressurization of the ED vestibule is imperative to maintain a negative airflow relationship within the space, while avoiding the occupant discomfort (and thermal load) that occurs when outside air is drawn into the space. The vestibule air supply needs only to be enough to ensure the effect of an anteroom, whereby the vestibule creates a buffer between the outside and the ED space. Full conditioning is not required.

Proper design of airborne isolation and protective isolation rooms is yet another area of concern for the design team. These rooms provide protection for the public from highly infectious airborne particles, and protection from the public for those with weakened immune systems. Design criteria and standards for these rooms are well laid-out in guidelines by the Facility Guidelines Institute (FGI) and ASHRAE 170. Of specific note, there is no longer a provision in the guidelines for an isolation room that can be switched between positive (protective environment, or PE) and negative (airborne infectious isolation, or AII). A combination AII/PE room, which is for an immune-compromised patient with a known infectious disease, is essentially a PE room, but requires an anteroom designed to AII standards.

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3 Air Filtration & Disinfection

While the considerations mentioned are usually taken up during a major renovation initiative, there are air treatment strategies that may be simply implemented during minor architectural work or even as a one-off retrofit. With this in mind, there are advantages to treating the quality of the air in a hospital to reduce airborne-mediated microbial diseases. The most common means to treat air is through filtration. Indeed, the air change rate, very commonly thought of at the heart of building health, is essentially the rate at which air from the space is passed through its filtration. The air change rate doesn't necessarily contribute to cleaner air without the right level of filtration.

The discussion of filtration level has changed. With one notable exception, no longer are filter efficiencies expressed in terms of a percentage, but per ASHRAE Standard 52.2, in terms of a Minimum Efficiency Reporting Value (MERV). It is important to understand that MERV ratings are primarily tied to the size of the particle expected to be captured. In general, the smaller the particle, the higher the MERV rating is required to meet the need.

Final filtration in a clinical healthcare setting is required. The challenges with higher levels of filtration have typically included additional fan energy consumption and added filter maintenance. Similar to addressing the unique air conditioning requirements with specifically designed air handling systems, so too can a filtration scheme be designed to ensure that the areas getting the cleanest air are only the ones that require it. As shown in Illustration 5, by utilizing small, re-circulating fan filter boxes with small horsepower, energy efficient variable-speed motors, such as those used in compounding pharmacies, the highly filtered air can be directed to specific spaces without sacrificing efficiency and increasing cost. With optimized building management controls, additional energy reduction during unoccupied times may be possible.

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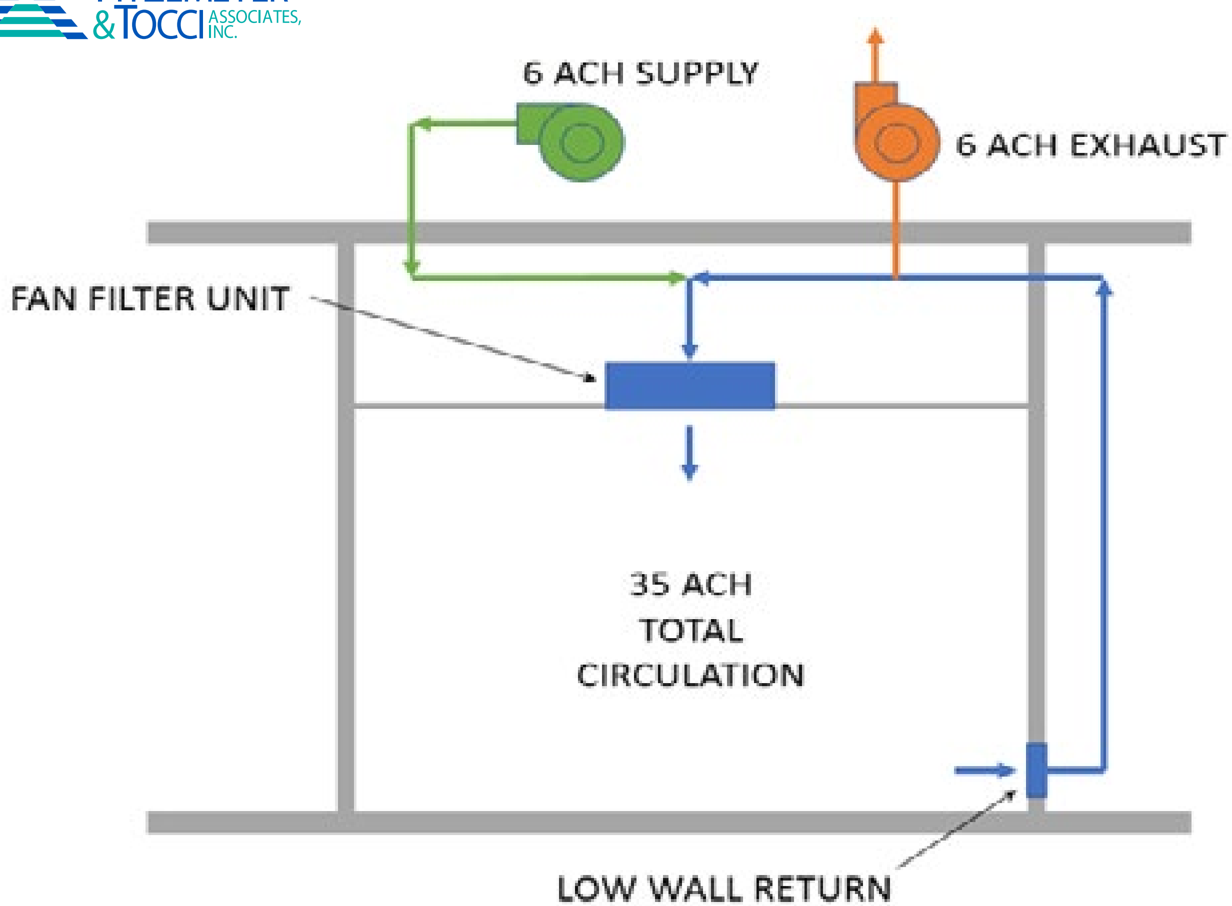

Illustration 5: Diagram of Fan Filter Application in an OR Setting

Where widespread final filtration remains a requirement, localized filtration is likely impractical. This is expected in a hospital setting for a general MERV 14 level of final filtration (required by ASHRAE 170 for general inpatient uses). One option that can be explored is electrostatic filtration, where a filter with a large free area uses a small electric current through the filter media to attract charged particles in the air to meet the same criteria for filtration as a much more restrictive (higher MERV) media. These systems tend to work well as a retrofit, and typically have a very short payback duration on the order of 2 to 4 years.

Another option for treating a hospital's airstream is using ultraviolet (UV) light. More specifically, broad-spectrum UVC light can mitigate bacteria and viruses, which may evade standard filtration methods, and is commonly used in sterile instrument processing. A UV treatment system is most effective when it's incorporated into the design from the start. UV light can be applied to the tunnel of a central air handler as a relatively low-cost, highly-effective means of secondary air cleaning. This is typically difficult as a retrofit due to space restrictions at the equipment. Applied properly, the design will consider line-of-sight to the UV bulb, the shielding of airflow from the bulb, the intensity of the light relative to the speed of the air in the tunnel, and a maintenance plan. It will likely be at its most impactful when combined with the use of final filtration of an effectiveness below that of a HEPA (High Efficiency Particulate Air) filter. Ultraviolet light can be expected to render inactive the small particles which might pass through even a MERV 14 cartridge.

An ongoing study[10] looks to show that a narrower spectrum of UVC light, which is not harmful to skin, may be used in public spaces as an effective means of infection control. Whether incorporated into nrmal lighting, or installed in dedicated fixtures, such a use would be expected to kill sources of contamination before they have a chance to spread and cause harm.

Even a HEPA filter, which is tested to remove 99.97% of 0.3 micron or larger particles from the air stream, does nothing to combat molecules that are in the gaseous state. While these contaminants may only be in the form of distracting or irritating odors, they could also be diesel emissions from outside or other potentially carcinogenic volatile organic compounds (VOCs) emitted from any number of sources inside or outside the building. If clean air cannot be realized through contamination source control or additional ventilation (to the extent practical), gas phase air filtration is another solution to be potentially incorporated into a building's air distribution system. Working similarly to UV lighting in terms of chemistry at a molecular level, typically, these systems use activated carbon to attract and hold in place these gaseous molecules. This type of filter simply consists of pleated media, so it can take the place of a traditional particulate filter. Because of its expense relative to a standard particulate filter, though, it is often its own stage of filtration. The gas-phase stage is typically located downstream from a conventional filter, to extend the carbon media's useful life.

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4 Sterile Operations

In putting a hospital in the best position to care for its occupants, the facility leadership must stay current with solutions for maintaining the sterility of its most critical spaces. Careful design of the operating rooms themselves, where patients are at their most vulnerable, and the spaces dedicated to supporting those providers and procedures, will have a positive impact on the success of patient treatment.

With sterile fields being maintained to the extent practical, the next line of defense is the ability to clean surfaces. It's important to work with the responsible staff to determine the appropriate construction materials to use. Additionally, from discussions with those operational leaders, it may be beneficial to engage in a robust initial and ongoing training plan for the staff in the cleaning and maintenance of the equipment within the care space.

Pressurization is another key component in maintaining sterility and isolating hazards. ASHRAE 170 guidelines present pressurization ranges for several types of spaces, and USP (U.S. Pharmacopeia) 795, 797, and 800 do the same for compounding pharmacies. Achieving the required pressurization doesn't typically present a problem. However, doing this while also keeping airflow rates, reheat coil operation and subsequent energy costs in balance is often a challenge, particularly in a retrofit application. The solution to maintaining pressurization is that the space envelope must be tightly constructed. Solutions include gasketed ceiling tiles, with clips in a positive pressure room, or a hard gyp-board ceiling; gasketed doors with floor sweeps; and minimal wall openings for doors, equipment pass-throughs, and even electrical terminals and lights.

Providing unoccupied airflow setback capability can reduce HVAC energy costs in operating suites by as much as 60% to 70% during off-hours.

Airflow needs to be just as tightly controlled. Where possible, employing both supply and exhaust air variable volume terminals, while optimizing the HVAC sequence of operations, will allow the space conditioning system to settle on the lowest possible airflow to meet the needs of the space. In addition, providing unoccupied airflow setback capability can reduce HVAC energy costs in operating suites by as much as 60% to 70% during off-hours.

In lab or pharmacy compounding areas where quick response to hood operation or other changes might be necessary, the addition of air valves on the exhaust is a worthwhile investment to ensure that pressurization is never lost, and contaminants are never allowed to migrate unchecked.

In addition to guidelines for pressurization discussed above, the same guidelines also require a level of control and monitoring that the users must employ. In short, in nearly every critical area, periodic monitoring and recording of air conditions, including temperature, humidity and pressurization is required to maintain certifications by CMS and other application-specific authorities. In spaces such as operating rooms and hazardous compounding buffer rooms, users should be provided the ability to control the space temperature and humidity. Controls from major manufacturers are now available that provide the ability to adjust environmental conditions in critical areas through a touchscreen controller located in the affected space in addition to providing conditions monitoring and data recording. Space pressurization monitoring is provided with a diaphragm sensor through the wall or with a hot-wire sensor, which is generally stable and maintenance free. A means of visual confirmation of the pressurization is also required. This may be through a dedicated monitoring panel at the entrance to the space, an LED display connected to the room controller, or as simple as a pneumatically actuated "ball-in-tube."

Often overlooked, plumbing fixtures should not be placed in a pressurized space, unless required by code, such as a toilet room in an isolation patient room or a hand sink in the pharmacy anteroom. Sprinkler heads may be gasketed and recessed, although it must be recognized that concealed and gasketed heads, which are the easiest to clean, are not approved by Factory Mutual (FM). If a concealed head is necessary, an enclosure can be created above the head via gypboard box or other means.

Finally, hospitals, by nature, are generally in operation continuously. As such, many critical spaces cannot cease or alter their activities. During renovations and new construction work is an opportune time for a sterile barrier to lose its integrity, whether by being directly in contact with the work area or simply because of a change in air balance relative to the pre-construction condition. A solution to this issue is to move the affected function to a temporary space, either by creation of a new building space or by re-appropriation of unused space. Such an action assures that service continuity will be maintained and that the building will experience a similar level of occupant protection.

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5 Water Treatment

Water treatment is another important topic of discussion, as a minor reduction in water quality, or minimal contamination at the source, can impact an entire facility. Some new ideas have recently emerged to keep hospital occupants safe from water contamination.

One of the technologies which can be employed for water treatment is UV light disinfection. Ultraviolet light destroys microorganisms in the water. This process requires electric power to operate, but only modest maintenance. These disinfection systems can be deployed at the point of entry (whole building) or at the point of use. Point-of-use water treatment is a relatively new concept for general service.

Copper-silver ionization is another method of central disinfection which is particularly useful for Legionella mitigation. Copper and silver ions bond to bacteria cell walls and weaken them. This system will also, over time, break down the biofilms in piping systems which harbor the waterborne bacteria and other contaminants that can cause harm to the hospital population.

Ultrafiltration is another method that can be used centrally for removing particulates from drinking water. It uses a semi-permeable membrane to very efficiently filter suspended-solids in water. This can be a particularly viable option for well water in a rural application.

Point-of-use water heaters in both patient and common areas are also being considered more often to avoid the impact of microbial growth that can occur in stagnant, heated water supplies.

A minor reduction in water quality, or minimal contamination at the source, can impact an entire facility

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Water treatment methods such as those listed above are often implemented in combination as part of an overall system of treatment to contain and control the growth of microorganisms and manage solid contaminants. This system should be developed and monitored with a focus on complying with ASHRAE Standard 188, which establishes minimum Legionella risk management requirements for building water systems.

Finally, many areas of a hospital require a minimum relative humidity level be maintained, notably surgery and procedure spaces, critical care spaces, and nurseries. Where once it had been commonplace to humidify spaces directly by utilizing steam produced in a central heating plant, it's now understood that chemical treatment typically applied to boiler feedwater can be harmful to building occupants when injected into the airstream, even at trace levels. A more effective and safe means to humidify occupant spaces includes utilizing potable water directly and generating clean steam via a dedicated gas-fired humidifier or steam-to-steam humidifier. Further purity can be attained by utilizing water run through a reverse-osmosis system or other purified water supply.

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6 Improved Patient Healing Environments

It is generally recognized that length of stay (LOS) has a direct correlation to HAIs. Many studies have shown that well-designed healing environments can reduce anxiety, lower blood pressure, and lessen pain for patients.[11] Conversely, research has linked poor design – or psychosocially unsupportive surroundings – to negative effects such as higher occurrence of delirium, elevated depression, greater need for pain drugs, and in certain situations longer hospital stays. [12,13]

Illustration 6: Example of a patient room utilizing a combination of natural and artificial light (Source: Baylor Medical Center at McKinney)

There is considerable evidence linking the type and quality of light within a healing environment and patient wellness and recovery rates. Well known is the impact of light in controlling the body's circadian rhythm. A combination of both daylighting and customizable and adjustable artificial light color systems can be used to preserve circadian system functioning. LED lighting systems are now available from many major lighting manufacturers that provide, through a combination of digital dimming and color control, the ability to replicate natural daylight throughout the day. These light systems change the the color temperature of the lighting from a very cool appearance in the morning to a much warmer color temperature in the evening. As lighting in hospitals accounts anywhere from 12% to 20% of its total energy consumption,[14] a combination of natural and engineered LED lighting has the additional benefit of providing energy savings.

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There is also considerable evidence that excessive noise can impact patient wellness, causing a decreased rate of wound healing, an increased LOS, and increased stress levels in patients.[15] Sudden changes and inconsistencies in noise level is what is most disturbing to patients. White noise machines have been used in some healthcare settings[16] to create a consistent noise that comes out evenly across all hearable frequencies.

White noise creates a masking effect, blocking out sudden changes that contribute to interrupted sleep. Data in one study showed that there was an increase in patient satisfaction after the placement of white noise machines in each patient room.[16] In addition to providing an improved healing environment, engineered white noise devices have also been used by healthcare facilities for sound masking to protect conversations between healthcare providers and patients and even as a replacement for paging systems. It is also important to note that simply limiting noise from nearby mechanical equipment through proper isolation and regular maintenance of these systems can also improve the acoustic conditions in an occupied space.

Illustration 7: Example of a recessed-mounted, sound masking transmitter (Source: Cambridge Sound Management)

7 Closing Thoughts

As demonstrated in this guide, many opportunities to improve patient healing environments and overall wellness are available to hospital facility management professionals. The opportunity to make improvements to a health care facility range from the more modest and opportunistic, such as with certain air and water treatment measures, to the planned and more capital intensive, such as with sterile fields, pressurized spaces and modernized patient rooms. In addition to hospital settings, many of the technologies described in this guide also apply to ambulatory healthcare settings as well.

Beyond this guide, facility management professionals should also be mindful of architectural nuances that can help alleviate microbial growth that lead to HAIs. Assuring positive roof slopes and maintenance to prevent standing water near air intakes to avoid the potential for Legionella is one example, while designing building envelopes in conjunction with the design of the HVAC system to reduce the potential for microbial growth within walls and other assemblies is another.

Collectively, implementing the improvements described in this guide along with other prudent measures over time will lead to a reduction in HAIs and an improved care setting for patients—the top priority of every healthcare provider.

END NOTES

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