Abstract:

There are approximately 5,700 hospitals in the United States, 3,000-4,000 which are antiquated or obsolescing. The never ending quest to meet increased service demands, remain financially viable, to upgrade aging infrastructure, and to incorporate state-of-the-art medical and technology advancements leaves healthcare facilities in a perpetual state of construction. Outbreaks of nosocomial infections have historically been documented in association with construction and renovation activities within health care facilities. For most healthy individuals, environmental exposure to etiological agents results in no adverse effects, but immunocompromised patients are left susceptible to inadvertent exposures to opportunistic bacteria, fungi and viruses during construction.

Evidence scientifically linking construction work and nosocomial infections, as well as the efficacy and clinical relevance of infection control precautions, is somewhat lacking but empirical evidence and recommendations to support protective measures is steadily growing. Opening a “Pandora’s Box” during construction can unleash unintended consequences, it is therefore imperative that a thorough, multi-disciplinary approach establishes an infection control plan that is stated clearly and put firmly in place, allowing health care construction projects to move forward with confidence that patient safety is the first specification.

Keywords:

Infection Control, ICRA, Health Care Construction, Hospital Construction, Health Care Facility Construction, Health Care Facility Renovations, Nosocomial Infection, Airborne Contamination, Fungi, Mycoses, Protective Measures, Occupational Health Hazards

Data Bases Searched:

- [http://www.hsls.pitt.edu/](http://www.hsls.pitt.edu/) (University of Pittsburgh, Health Sciences Resources)
- [http://web.ebscohost.com/ehost/search/advanced?sid=5b897b80-afe9-4ee-8df-03c19de23267%40sessionmfr115&vid=1&hid=107](http://web.ebscohost.com/ehost/search/advanced?sid=5b897b80-afe9-4ee-8df-03c19de23267%40sessionmfr115&vid=1&hid=107) (CINAHL)
List of Abbreviations:

AIA American Institute of Architects
APIC Association for Professionals in Infection Control & Epidemiology
ASHE American Society for Healthcare Engineering
ASHRAE American Society of Heating, Refrigeration & Air Conditioning Engineers
CDC Center for Disease Control
CMS Centers for Medicare and Medicaid Services
CSA Canadian Standards Association
DHHS Department of Health & Human Services
EBD Evidence Based Design
HAC Hospital Acquired Conditions
HAI Hospital Acquired Infection
HEPA High Efficiency Particulate Air
ICP Infection Control Professional
ICRA Infection Control Risk Assessment
IFI Invasive Fungal Infections
IOM Institute of Medicine
JC Joint Commission
NQF National Quality Forum
PCRA Pre Construction Risk Assessment
SOAR State of the Art Report
UPMC University of Pittsburgh Medical Center

Conflict of Interest:

This document and recommendations have been prepared in good faith using best evidence from medical literature available at the time of writing. None of the authors or any person who helped bring together this information have any conflicts of interest or financial interests to report.

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*Primum non nocere* is a Latin phrase that means “First, do no harm” and is the fundamental axiom of medical ethics around the world. Since 1860, when Florence Nightingale first proposed fixed ventilation, fresh air, proper lighting, warmth and clean water as the “very first cannon of nursing,” the phrase has been a sacred expression of hope and humility. This unfortunately carried with it the recognition that human acts with good intentions may also have unwanted consequences leading to the cliché, “Sometimes the cure is worse than the ill.”

**History**
The now infamous 1999 Institute of Medicine (IOM) Study “To Err is Human: Building a Safer Health System” estimated that over 98,000 deaths a year could be attributed to medical errors; this statistic was momentous and is still being quoted thirteen years after its publication. Bursts of public outrage and campaigns by advocacy groups followed, giving precedent to quality assurance and patient safety becoming the mantra of the modern healthcare movement. Infection Control has been listed as one of the top 10 patient safety initiatives by the National Quality Forum since 2002; leading to nosocomial infections being listed as a “Never Event” by the Center of Medicare & Medicaid Services (CMS) as part of the Deficit Reduction Act of 2005 as required by the Department of Health and Human Services (DHHS). These policies have been accepted by private insurers as well and have escalated the financial and legal impact of medical errors with questions of liability, negligence and evolving standards of care.

“Never Events” have been defined as incidents that are: (1) clearly identifiable, preventable, and serious in their consequences for patients; and (2) indicative of a real problem in the safety and credibility of a health care facility. Much discussion has been held regarding how a nosocomial infection is classified as a Never Event. Clinically significant harm has to be demarcated but this can be difficult because of its subjective nature. The term “Hospital Acquired Condition” (HAC) is also applied, which infers that it is a reasonably preventable condition, which was not present or identifiable at the time of hospital admission, but was present during discharge. Unfortunately complications can occur that will result in death or complications regardless of precautions that have been taken. Threats of decertification, pay for performance incentives, and an energized national commitment to strict, ambitious, quantitative and well tracked national goals has brought together stakeholders to advocate “clean design”, environmental risk management, standardization and innovation that creates positive, empirically measureable outcomes. Evidence based design (EBD) research has recognized the influence of design on reduction of
morbidity and incidence rates of nosocomial infections as they relate to health care construction when infection control measures are put in place in early the design phase of a project. There are approximately 5,700 hospitals in the United States, 3,000-4,000 which are antiquated or obsolescing. To meet increased service demands, remain financially viable, meet needs to upgrade aging infrastructure and incorporate medical and technology advancements, healthcare facilities are in a perpetual state of repair, remediation and construction with over $200 billion dollars of construction expected between 2007 and 2015. [1] Health care construction has become a perilous business with dangers hiding behind walls and ceilings, waiting to unleash any number of infectious sources. [2] Rapidly advancing technologies have resulted in longer hospital stays for “sicker” increasingly susceptible patients being exposed to these hazards. For most healthy individuals, breathing ambient concentrations of airborne mold, opportunistic bacteria, fungi and viruses results in no adverse effects but immunocompromised patients are left defenseless to these during construction if proper precautions are not put in place to reduce exposure from environmental reservoirs. [3 -11] This “perfect storm” has increased the role of infection control in construction projects with outbreaks being documented back to at least 1976. [12, 13]

The first general standards for healthcare construction were published in 1947 and evidence has continued to grow to support “clean” design and construction. The First Edition of the American Institute of Architects (AIA) Guidelines for Health Care Construction was distributed in 1987 and has since evolved to include infection control standards. The Association for Professionals in Infection Control and Epidemiology (APIC) released the report “The Role of Infection Control during Construction in Health Care Facilities” followed by American Society for Healthcare Engineering (ASHE) posting the first Infection Control Risk Assessment (ICRA) Matrix as a strategic tool to protect vulnerable patients and staff. These guidelines have given birth to a body of research that encompasses the impact that the hospital environment (or its disruption) has on patient and staff safety and includes the investigation of adverse events, root cause analysis and has resulted in reporting systems to track infection rates. Architects, engineers and construction contractors, environmental health scientists and industrial hygienists historically have directed the design and function of hospital’s physical plants. Increasingly however, because of the growth of the number of susceptible patients and increase in construction projects, the involvement of hospital epidemiologists and infection control professionals is required. These experts help make plains for building, maintaining, and renovating health care facilities to ensure
that the adverse impact of the environment on the incidence of health care associated infections is kept to a minimum. [14]

**Hospital Acquired Infections**

Although the science of evidence based design is relatively new, there is growing support to substantiate that specific design features can improve outcomes. [1] Over the past 3 decades hospital acquired infections (HAI) have been studied on both major and minor jobs and have established an association with environmental disturbances including but not limited to: hospital construction, maintenance, demolition, and renovation. [11, 16,24] When major construction work is planned, hospital managers need to ensure that a multidisciplinary team comprised of hospital administrators, infection control staff, technical services staff, facilities engineers, biomedical engineers, risk managers, designers, nursing staff and relevant clinicians in high risk areas is established and that policies and procedures are put in place to mitigate the risk of nosocomial infection that clearly outlines the responsibilities of all personnel involved. [2] The team’s responsibility is to comprehensively evaluate risk and to assure the contractor’s compliance is monitored, enforced and documented. Conflicts are inevitable if brought in after the construction has started. [3] The costs associated with an Infection Control and Risk Assessment (ICRA) should be included in every capital redevelopment project. The team must strike a balance among the design drivers: infection control, occupational health, staff security, work efficiency, stakeholder interests, available resources, support services, building codes, Life & Safety considerations, barrier free accessibility, construction realities, cost constraints, and environmental stability. [17]

HAIs account for approximately 1.7 million infections and 99,000 associated deaths each year in the United States; 5,000 of those deaths are infections related to construction [9, 12] HAIs include urinary tract infections (32%), surgical site infections (22%), septicemia (14%) and pneumonia (15%). It is important to note that even though pneumonia is not the most frequently occurring form of HAI, this type of HAI has the highest mortality rate. Fungal infections comprise 9% of all HAIs, Candida accounts for 85.6%, Aspergillus 1.3% respectively. Pneumonia most common clinical presentation for airborne aspergillosis and evidence reveals a very high mortality rate and is reported up to 95%. [11] CMS in 2000 estimated that $5 billion dollars were spent on nosocomial infections which include increased length of stay and dramatically increased medication costs. [18] Ultimately hospitals will not only save lives but time, money and their reputations if the hospital does not elect to do a “work around” to keep their census up and
rather take a positive, proactive approach. ICRA is much less costly then when corrections are needed. [2]

Construction projects uncover reservoirs of disease producing agents during demolition and construction; the risk for transmittal must be identified prior to starting any work. Recognizing risk is not easy but certain conditions throw up red flags for exposures and when the most susceptible hosts need to be protected in the healthcare environment from infections that may result in significant morbidity and/or mortality. [14] Legionella, for example, is a waterborne pathogen that is acute gram negative bacteria. Legionella creates biofilm within plumbing fixtures, hot water systems, HVAC cooling towers, condensers, humidifiers, fountains, shower heads, storage tanks and stagnant water. Legionella has been under reported; the fatality rate of Legionella pneumonia of hospital patients is as high as 40% [19] Testing piping following utility disruptions; before and after construction will identify risk and lines can be flushed and/or treated to prevent transmission to consumers. Care must be taken not only in areas of active construction but also in areas that have been closed during construction, and areas that share mechanical systems, domestic water systems, portable water and sanitary sewers.

Etiologic agents, including fungal contamination inside the hospital is the result of a combination of various factors that are difficult to investigate; however, researchers have established that hospital infections caused by Aspergillus occur with greater frequency when construction work in hospital is taking place or has just been completed. This has been associated with the increase of dust in the air, which facilitates the spread of fungal particles. [11]

Aspergillus is a spore-forming filamentous fungus that is ubiquitous in nature and generally airborne. It is the most common pathologic fungi, is thermotolerant to 45º C and buoyant [93]. It represents 40% of all home and hospital fungal contamination.[20] Outbreaks have occurred in association with environmental disturbances during construction with positive cultures being recovered in contaminated fireproofing materials; air filters in hospital ventilation systems, particleboard frames of air filters, ceiling tiles, rotted wood, disturbed cabling and contaminated carpeting. Environmental sources also have included unfiltered outside air entering hospital through gaps in filters, windows, backflow of contaminated air; spores released during excavation and moist environments (plumbing, leaks, rainwater, and air conditioning condensate). However, there have been no reported outbreaks of Aspergillus traced to water sources. These examples illustrate the need for efforts to be undertaken to reduce the opportunities for Aspergillus spores to
leave their reservoirs during construction and other activities which release and disperse the spores. [11, 21]

This raises issues regarding environmental culturing for Aspergillus. In general routine culturing of the environment is not recommended except in a few specific circumstances. These include when construction is within or adjacent to units housing immunocompromised and/or neutropenic patients, monitoring of dialysis water and dialysate, infant formulas, and when implicated in an epidemiologic investigation. [11, 21]

Aspergillus is the most frequently acting as the causative agents in 53 outbreaks of healthcare associated invasive aspergillosis affecting 458 patients. [102, 104] Pulmonary aspergillosis has been increasing dramatically in the last 30 years due to the increasingly frequent use of immunosuppressive therapy and is most common pulmonary mycosis in patients with hematological malignancies. [22, 23]

**Literature Search**

In completing a literature search, we found evidence scientifically linking construction work and nosocomial infections as well as the efficacy and clinical relevance of infection control precautions is somewhat lacking but the empirical evidence and recommendations to support protective measures is steadily growing. Fungal infections, Aspergillus in particular, appears primarily in the literature as the biggest and most deadly offender. It is reported that, attacking the most vulnerable, that 80% of those who contract invasive aspergillosis die. [2] Many studies were retrospective, evaluating clusters of outbreaks during construction. The following are samples of studies reviewed:

- A small retrospective case control study revealed that invasive fungal infection (IFI) cases that were confirmed on autopsy were more likely to have been hospitalized during hospital construction work. A separate clinic-epidemiological study found that rates of IFI rose 1.2% pre construction to 7.9% when construction was at its peak. [24]

- A study conducted at a university teaching hospital in Australia including patients served in an intensive care and hematology-oncology units during a construction project. Both air sampling before and after construction and a retrospective medical record review showed no difference of aspergillus infections before or after construction if adequate ICRA precautions are
enforced. [62] Air Sample studies showed aspergillus 21.1% prior to construction, 16.9% once ICRA precautions have been instituted [20]

- A prospective survey of indoor fungal contamination during phased construction in Dijon University Hospital in Burgundy, France was completed over an 18 month period from October 2005-2007. The facility has 1,250 beds, 1.7 inhalants, with construction being done in or adjacent to high risk clinical units. The study demonstrated that protective measures and cleaning limited contamination. [16]

- A twelve week comprehensive environmental surveillance was completed (2007) during heavy construction in Helsinki, Finland hospital stem cell transplantation ward looked at HEPA filtration to reduce spore load. The study did not show increased amounts of fungi or colonization in patients or patient rooms with the use of the filters. The authors subsequently recommended the use of HEPA filters in stem cell units, also citing a French study that supported regular surveillance for molds was feasible even under normal conditions as a good marker of disturbances in the cleaning activity and air filtration. [16, 25] This is however not without controversy, there is conflicting data on HEPA filter efficacy in outbreak control, finding filters complex to install and maintain and that suboptimal maintenance could actually worsen situation. A meta-analysis of 16 controlled trials in high risk hematology patients demonstrated ambiguous findings with a reduction in invasive fungal infections but no difference in mortality in studies with considerable clinical heterogeneity and evidence of publication bias. [26]

- Lucile Packard Children’s Hospital in Palo Alto, California, a study was done looking at phased demolition and construction of walls and ceilings while the remainder of the hospital functioned normally. Precautions included contained construction debris, temporary walls made of drywalls, polyethylene film barriers and HEPA filters. They found that heavy demolition & transportation of demolished debris caused the greatest aspergillus concentration in the construction zone. However, the containment systems were effective in keeping aspergillus concentration at baseline levels in nearby patient areas. The study was able to demonstrate that fungal conidia could be isolated using polyethylene barriers and negative pressure. [27]
**Preemptive Planning for Construction**

A thorough search of published guidelines and literature combined with years of practical application has resulted in the development of an Infection Control Risk Assessment (ICRA), a document which walks the Infection Control Professional (ICP) through the process of determining what type of precautions will be required during a construction or renovation process. This document is the ICRA Matrix. The more liberal meaning of ICRA is; a series of practice controls, barriers, and procedures which are to be employed during the construction or renovation process in healthcare facilities. The APIC SOAR on the role of Infection Control during construction, published in 2000, was a comprehensive set of instructions on how to establish an ICRA program at the hospital level. It clearly defined the roles and responsibilities of the ICP within the healthcare construction realm. The multidisciplinary approach to performing construction in healthcare has gone from novel expected practice over the last decade.

When preparing to begin a construction project, it is important to assemble multidisciplinary team, review the facility’s Construction and Renovation Policy and identify specific needs. [28] A Pre-Construction Risk Assessment (PCRA) should be performed this will help in filling out the ICRA Matrix. [3] The PCRA is used to determine the overall impact of the project on the patient care environment from various issues. These issues include disruption of essential services, patient placement or relocation, location of barriers, impact on egress, fire suppression and various other life safety issues. The ICRA matrix evaluates and assigns risk to construction activities based on invasiveness, scale, duration, dust generating potential [3]. There are four classes of ICRA which are determined by evaluating four levels of patient risk against four levels of construction activity. The four classes of ICRA each give direction as to the type of precautions which will be required to complete the project. An ICRA permit is then issued which outlines the precaution measures. The ICRA Permit should not be seen as a one-time evaluation but must be issued and referred to as a living document throughout the life of the construction project. [63] The importance of completing the PCRA and ICRA during the planning of a project is crucial to the overall success of a project. [10]

The multi-disciplinary team responsible for developing these documents is critical in keeping the documents active until the project’s completion and hand off to the end-user. [9] The FGIG Guidelines give a general statement as to the make-up of the ICRA Team. [29] The team should include but is not limited to: Infection Control, Environmental Health and Safety, Facility
Construction Management, Facilities Services (Maintenance and Housekeeping), Design team (Architects and Engineers), Security, Clinical Leadership and End-user Representation. Others such as Patient Transport and Dietary should be considered if elevators and main corridors will be impacted. [29] The team is to be involved in the project from design to completion. Regular project meetings should be held ICRA should be discussed and documented in the minutes for the duration of the project. This is crucial to showing evidence of compliance. [2] Any member of the ICRA team should have the authority to stop work if necessary. [7]

It is important to define the ICRA requirements in the pre-bid contract documents. The Preconstruction Design ICRA Plans give directions for compliance; barrier locations, anterooms, negative airflow requirements, adjustment of ventilation system in adjacent areas, debris transfer, emergency routes, monitoring equipment recommendations. [6] The commencement of the project into active construction should begin with a review of the ICRA requirements with the General Contractor (GC). The ICRA barriers must be established and inspected by the ICP prior to demolition commencing. [30, 29] The establishment of ICRA Containment can be as simple as closing doors or as complex as construction of temporary walls and establishing negative airflow. [5, 26] Barriers are only one part of the overall ICRA precautions. A path for debris removal and deliveries to the work site must be designated; this would include elevators, stairwells and exits. Considerations for coveralls and shoe covers, proper covering of equipment, supplies and debris, tacky mats, air flow monitors and site cleanup are all crucial. [5, 7, 13] Establishing and maintaining negative air flow is one of the most critical factors in a successful ICRA project.

Whether the project is within a facility or outside adjacent to it, air flow and air filtering must be seen as a top priority. Just because a project is outside (paving, roofing, demolition) or an external addition does not mean an ICRA plan is not needed. Factors such as air intakes, building openings and prevailing winds must be addressed prior to work commencement. [4] Consideration must be made for increased preventative maintenance and filter checks or changes when air intakes are identified as being at risk. Simply wetting down of the debris can greatly reduce dust/particulate load. Regular site rounds, air sampling for particulate load should be done routinely. [4] These, and other practices, when applied consistently, greatly reduce the risk associated with construction activities.
Literature documenting Infection Control measures during construction is abundant and paves the way for health care systems to establish internal policies and procedures based on what now have become a standard of care. An Infection control strategy includes the completion of an ICRA matrix; it is a multidisciplinary process focusing on reduction risk from infection throughout the facility planning, design and construction (including renovation) activities. A multidisciplinary team considers the environment, infectious agents, human factors and the impact of the proposed project in this process. This step by step process begins with identifying the type of construction project activity, assessing the at risk patient population and concludes with recommendations. [1]

There are elements of infection control plan for construction that are mandated and some are best practices; the team should be familiar with local, state and national compliance requirements to make recommendations. Preconstruction Design should include ICRA Plans illustrating a step by step for compliance, types and locations of barriers, anterooms, negative airflow requirements, adjustment of ventilation system in adjacent areas, debris transfer, emergency routes, monitoring equipment recommendations. [11] Patient care areas and other essential service areas such as ORs, trauma, critical care units, oncology and pharmacy require advanced confinement measures. A Life & Safety Assessment gauging vibration, air quality (dust and odors), hazardous materials (asbestos, mold and lead abatement), and utility disruptions should be completed during the design phase. [3] Protective measures to physically protect at-risk patients include relocation of high risk patients, masking, wet cleaning, and alter traffic patterns through construction site, sealing off construction site, measures to reduce dust from construction areas including anterooms, increased ventilation/air exchange rates and filtration employing negative air and HEPA Filters. [26] Collection and analysis of appropriate surface, air, and/or water samples for biological analysis should be considered once risk is determined. If routine environmental surveillance during construction identifies an outbreak, the situation must be managed with transparency, accountability, and open channels of communication between clinical units, infection control, engineering, cleaning, and ancillary staff. [24] Post construction cleaning and documentation is essential, including, where indicated, the absence of fungi/fungal spores and/or laser particulate counts. [3]
**Practical Application**

The University of Pittsburgh Medical Center (UPMC) is multi-facility health system with a wide range of facilities ranging from large urban, tertiary care teaching facilities to small community based health centers; services range from general medicine to cancer treatment and organ transplant. The ages of the facilities vary from the old (1900’s) to the new (2012). The one thing all facilities have in common is an ongoing need for renovations, additions and construction. Approximately five years ago, UPMC began to synchronize policies between facilities in various areas of practice. The System Wide Construction Management Department looked to streamline contracts, documentation and procedures; one area of interest was ICRA. The position of Infection Control Construction Manager (ICCM) was established to aide in creating a system wide consistency in ICRA requirements and procedures. Prior to the centralization of the ICRA program within the Health System, there was no consistency with any portion of ICRA. Interpretation of the guidelines varied from facility to facility, Facilities Construction Management did not fully buy into or understand the ICP’s role in construction, Design Professionals were reluctant to push the ICRA agenda, and Contractors were confused at best at what they were required to do. The positive in all of this would be that there were no known significant construction related issues during this period.

Bringing a health system of the size of UPMC to consensus is similar to turning an aircraft carrier; it requires many people to be engaged toward a common goal. This process took the better part of two years to complete and changes continue to occur. Support from administration was a critical step in making the needed changes. The multidisciplinary approach started with merging of policies into one System Construction policy. This policy gives Infection Control a formal place in the construction process and sets the system ICCM and hospital ICP as a gate keepers to the ICRA process. The policy was added to the construction contract documents which then make the design team and contractors contractually bound to ICRA requirements. The system ICCM is responsible for assuring compliance with the ICRA policy throughout the health system. Contractors now know that no matter which facility they are working in, the same standard is expected.

The knowledge gained at UPMC over the previous five years has led to a focused organized approach to all construction activities from great to small. With this in mind, a focused search of published literature, studies and current guidelines was performed. The information available
reaches a consensus on several key points. First, construction and renovation activities within an active hospital can impact the patient care environment. Second, fungus, mold, and legionella are the main culprits in causing HAI’s during construction. The third point is that an organized, pre-planned system of interventions has the greatest impact on reducing the first two points.

**Education**

Throughout the literature and published guidelines, education is mentioned as an important part of a successful program. A search for existing educational programs yielded varying results. While there are several resources available, most are aimed at management, design professionals and healthcare workers. Education for the frontline construction workers was limited at best and what there was, focused on what to do but not why to do it. When UPMC sought to improve the level of education for contractors working within their facilities, the decision was to balance the lessons with both the how and the why of ICRA. The compliance with the educational program was added to the ICRA contract documents. In the eighteen month since the education was added to the ICRA program, over 4,000 contractors and tradesmen have received the education. The key to such compliance was the decision of the Administration to make the education part of the Contract documents thus making ICRA education a condition of employment for contractors and their employees. The deadline for completing the education was set for November 1, 2012. All workers are required to carry a wallet card showing where and when they received the training, randomized checks have shown nearly 100% compliance with the requirement. Overall compliance with ICRA procedures has improved with fewer reported infractions and no reported construction related HAI’s. Feedback consistently points to greater understanding of why the ICRA precautions are important as being the key to overall behavior changes within the construction practices.

To list all of the practices and protocols that are incorporated into a successful ICRA program would take more space than any journal piece could hold. The best way to build or improve on an ICRA program is to gather proven resources, reach out to others with established, successful programs, and develop relationships with construction management, facilities and the contractors they regularly use.
Must have resources include but not limited to:

- “The Role of Infection Control During Construction in Healthcare Facilities” [10]

In summary, the multidisciplinary approach to healthcare construction has lead to important developments in multiple areas of construction. Design professionals look to incorporate more resilient finishes. Changes such as; improved wall protection materials, solid surface materials for counters and sinks, and flooring choices that look beyond carpet. [29] Manufacturers of building materials have developed drywall which resists fungal growth and ductwork is cleaned and sealed prior to delivery. Furniture manufacturers continue to improve the textiles used to upholster their chairs. Architects design spaces with an eye towards infection prevention and control assuring proper numbers and locations of sinks for hand hygiene, improving work flow to reduce risks of cross contamination. Engineers design in improved HVAC and plumbing measures. Ultra-violet lighting arrays and improved filter banks are the norm rather than the exception when new air handlers are installed. [32] The number of products, tools and materials available to create and maintain ICRA containment has improved tremendously over the previous decade. Contractors continue to look for new ways to be compliant with ICRA policy while still being productive and cost effective.

**Future Research**

So as we look to the future of healthcare and healthcare design for safety initiatives, we need to contemplate future research. Haiduven suggests topics such as- how to detect smallest number of colonies in the environment; how to make additional materials fungicidal; how to control neutropenia/immunosuppressive states; and potential use of vaccines. [11] Others include:
• Exploring ways to improve the utility of adverse event reporting, including evaluating the comparability of data reported across entities and streamlining reporting mechanisms
• Develop efficient and meaningful data collection, management and analysis methods.
• Estimate the extent and nature of nosocomial infection as it relates health care construction.
• Establish comparative data on nosocomial infections and identify changes in the incidence of infections and pathogens as they relate to health care construction and renovations.
• Conduct collaborative research studies on construction related nosocomial infection.
• Comparative studies showing cost benefit analysis of ICRA precautions looking at direct medical costs including fixed costs (buildings, utilities, labor, etc.), variable costs (medications, treatments, testing, etc.), non-medical costs (lost wages, diminished productivity, etc.) and intangible costs (psychological costs, pain/suffering, etc.). [31]
• Studies documenting risk reduction resulting from education of health system employees, contractors and patients.

**Conclusion**
What is made clear in current research, and literature supporting empirical evidence is the importance of the multidisciplinary team approach to a successful ICRA program. It is essential to have buy in from the hospital leadership down to the facilities program management; from the architects and engineers to the manufacturers and installers; to all others that hold a stake in following through the ICRA plan. Ultimately, any work being performed within the healthcare facility is done to improve patient outcomes; from a minor repair to the construction of a new facility, the ICRA process begins and ends with the patient’s welfare as the catalyst for the process. Efforts to mitigate risk, improve clinical outcomes, provide constancy of purpose and improve economic outcomes will remain dynamic and will continue to be based on the guiding precept “First, Do No Harm.” So, as we open the proverbial “Pandora’s Box” during construction, open it slowly to prevent any unintended consequences and move forward with confidence when embarking on infrastructure upgrades, keeping safety the driving force.
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