

The Human Hospital: How to Create an Autonomic Nervous System for Your Facility

by Stephanie Taylor and Estelle Schweizer

Executive summary

Proper safeguards can reduce adverse patient events such as healthcare-associated infections, medical errors, and patient falls. This paper outlines the strategies and logic for modeling a hospital's infrastructure on the human autonomic nervous system through the use and integration of intelligent automated building solutions. These building solutions can lead to improved clinical outcomes, increased patient satisfaction and safety, as well as greatly reduced costs to the hospital.

Introduction

Healthcare costs are increasing around the world without a proportional improvement in patient outcome. This is more evident in some countries, but the trend exists globally.¹ Why is the discrepancy between cost for medical care and patient outcome increasing despite the development of more precise and less invasive diagnostics and interventions? One reason is the often hidden cost of treating patients for harm sustained during their hospitalization. Statistics show that inpatient harm results from adverse patient events (APEs), which include healthcare-associated infections (HAIs), falls with resulting injury, serious medical errors, and wrong site surgeries. APE's are extremely costly for hospital budgets and human lives,² and many are preventable.

It is estimated that in the US alone, over 400,000 premature patient deaths every year could have been prevented.³ The number of patients that have incurred preventable serious harm is 10 to 20-fold times higher.⁴

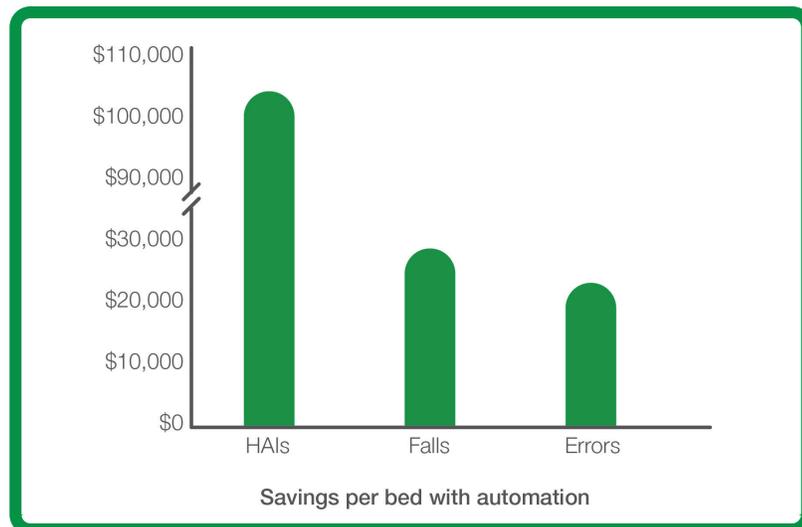
This paper examines APEs and their relationship to a hospital's physical environment. It examines how building automation and monitoring solutions can optimize a hospital's infrastructure, improve clinical care, and support better patient outcomes, thereby decreasing costs. Human anatomy and physiology is used as the model for creating an ideal structure to function relationship in a hospital.

Life-Changing solutions for patients and the CFO

Hospitals are complex environments in both their structure and function. An optimally designed hospital structure needs to accommodate the use of sophisticated equipment, allow for rapid responses to emergencies, as well as provide peaceful spaces for patients to heal and the clinical staff to work. The mechanical and physical infrastructure of the hospital should support these functions through thoughtful design that includes built-in protection against human errors and mechanical failures that can lead to APEs.

This built-in protection comes in the form of intelligent automation solutions that can help save patients' lives and hospitals millions of dollars. For example, as shown in **Figure 1**, if a

Figure 1
Savings per bed per year with automation solutions to reduce APEs



¹ Peter S. Hussey, Samuel Wertheimer, Ateev Mehrotra, "The Association Between Health Care Quality and Cost: A Systematic Review", *Annual Internal Medicine.*, 2013;158:27-34

² Denise Murphy, RN, BSN, MPH, CIC, Joseph Whiting, MBA, Christopher S. Hollenbeak, PhD, "Dispelling the Myths: The True Cost of Healthcare-Associated Infections", *An APIC Briefing*, February 2007,

³ James, John T. PhD, "A New, Evidence-based Estimate of Patient Harms Associated with Hospital Care", *Journal of Patient Safety*: September 2013, Volume 9, Issue 3: p 122– 128, Review Article

⁴ Ibid.

hospital decreased the occurrence of three prevalent APEs, they could expect to see a total savings of over \$151,000 per bed per year. A 250-bed hospital utilizing these building automation solutions could save, in just one year, a staggering \$35 million dollars. Calculations and references for these numbers are [provided later in the paper](#).

Understanding the disconnect

In a busy healthcare environment, hospital staff may make mistakes or not follow proper protocol in an urgent or rushed situation. However, in a hospital, patient lives are at stake and the consequences of these errors and omissions can be costly and deadly.

Below are examples of some human error scenarios that lead to avoidable APEs:

1. When performing daily examinations of patients, a clinician decides the hand hygiene station is too far away and forgoes hand cleaning, “just this once.” The clinician’s hands, now contaminated with virulent bacteria from patient A, passes these dangerous micro-organisms to patient B’s surgical incision, causing a serious HAI. This one “time-saving” shortcut costs the hospital thousands of dollars in prolonged care and the patient his life.
2. Frequently, medications are contained in bottles of similar shape and color. A rushed nursing staff forgets to double check the fine print on a label and the wrong medication dose is dispensed to the patient. This potentially lethal error endangers the patient’s life and consumes hospital resources.
3. The air filter to a patient’s room is in a hard-to-reach duct and has not been checked for months. The filter becomes clogged with mold which is then blown into the patient room. The patient has a compromised immune system from chemotherapy, develops *Aspergillum pneumonia* and dies – not from cancer, but from a fungal infection introduced through the ventilation system.

In the hospital the clinical staff’s primary responsibility is to focus on the patient-oriented tasks in front of them. Rarely does their awareness extend to how components of the building’s structure will impact the patient’s wellbeing. Conversely, the building facility staff members are not involved with clinical care and may not fully understand how the physical structure supports the functions of patient safety and healing. Patient care and hospital budgets have suffered tremendously as a result of this disconnect.

The cost to lives and the bottom line

The proof is in the statistics. Studies show that 7 to 10 of every 100 hospitalized patients in developed countries will acquire an HAI.⁵ This proportion increases to 15 of every 100 patients in developing countries.⁶ As shown in **Figure 2**, England, France, Australia, Greece, Norway, Thailand, and Guatemala report similar rates of preventable HAIs.⁷ Worldwide, the expenses incurred by hospitals due to APEs are unacceptably high. In fact, data published in 2013 reports that HAIs in US hospitals cost up to \$147 billion each year.⁸

⁵ World Health Organization, “Report on the Burden of Endemic Health Care-Associated Infection Worldwide”, 2011

⁶ Ibid.

⁷ Ibid.

⁸ “New Report Estimates Societal Cost of HAIs at a High of Nearly \$150 Billion Annually,” *Infection Control Today*, October 3, 2013. <http://www.infectioncontroltoday.com/news/2013/10/new-report-estimates-societal-cost-of-hais-at-a-high-of-nearly-150-billion-annually.aspx>

Figure 2
Worldwide prevalence of HAIs

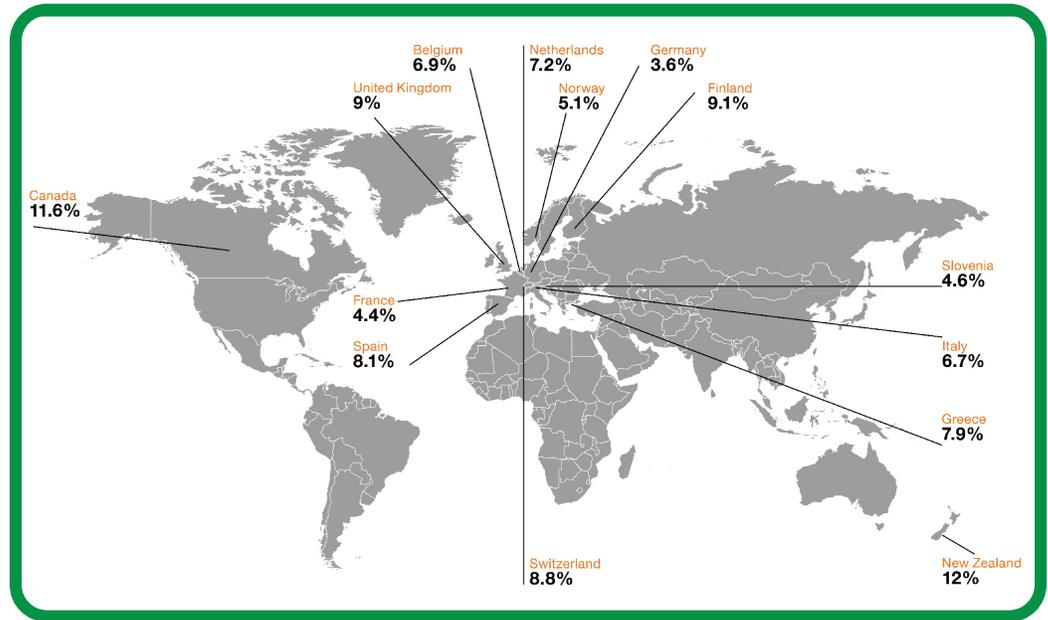


Figure courtesy of: *Report on the Burden of Endemic Health Care-Associated Infection Worldwide*, WHO 2011

Learning from biology

When researching ways to fix this disconnect, a model was found which has been tested and improved upon over hundreds of thousands of years. Perhaps surprisingly, this solution has developed within the human body – the autonomic nervous system (ANS). The ANS regulates the physiological structure unconsciously so humans can focus their conscious thinking on functional activities. The ANS only demands conscious attention when there is a problem. Without this specialised neurological network humans would never be able to sleep or work because they would be necessarily preoccupied with keeping their bodies alive.⁹

Compare a hospital to a complex, multi-system organism. How can a hospital’s infrastructure be designed and maintained to emulate the biological and involuntary 24/7 monitoring and alarming strategy of the ANS to assist with patient safety and optimal clinical outcomes?

The human hospital model

The human body’s strategy for structural support of functioning provides us with the following guidelines for a well-designed and fully integrated hospital building:

- A functional layout that reduces opportunities for infections, falls, and human errors
- Barriers against infection transmission from external sources
- Automatic alerts when a critical barrier is breached or when other problems occur
- Minimal opportunities to harbor infectious organisms in sterile spaces
- Facilities that are continuously cleaned and disinfected

Healthy people have bacterial and fungal organisms living within their bodies in properly contained non-sterile spaces.¹⁰ When the barriers maintaining these spaces are lost as a result of disease, surgery, or medical intervention, deadly infections can result if great care is not taken. A similar organization of sterile and non-sterile spaces and potentially deadly

⁹ Anthony S. Fauci, Eugene Braunwald, et al., “Harrison’s Principles of Internal Medicine “17th Edition, p. 2576 – 2582, 2008.

¹⁰ Barbara A. Methé, et al, “A Framework for Human Microbiome Work”, *Nature*, Dec. 14, 2012; 486(7402): 215–221.

consequences of barrier breakdown exists at every scale within a hospital, from within the patient room to the hospital building as a whole.

It is impossible for each individual in a hospital to know if all safety measures are functioning properly. Like the human body, a healthcare building needs a fully integrated ANS for continuous “behind-the-scenes” surveillance, alerting the proper staff only when problems arise. Existing automation technology developed to monitor building mechanical systems can be utilized with this new insight, allowing hospital staff to respond before errors and safety breaches cause patient harm. With the protective ANS in place, healthcare organizations can reduce avoidable APEs such as HAIs, falls, medication errors, and wrong site surgeries and the accompanying loss of financial and human wellbeing.

Origins of harm

In order to design and optimise a hospital’s infrastructure to mimic the human ANS and thus improve patient care, one needs to understand that APEs can arise from a variety of sources:

- The patient
- The patient’s room or environment
- Staff and visitors
- The physical structure of the building

Figure 3 illustrates those areas in a patient’s bedroom that represent potential risks.

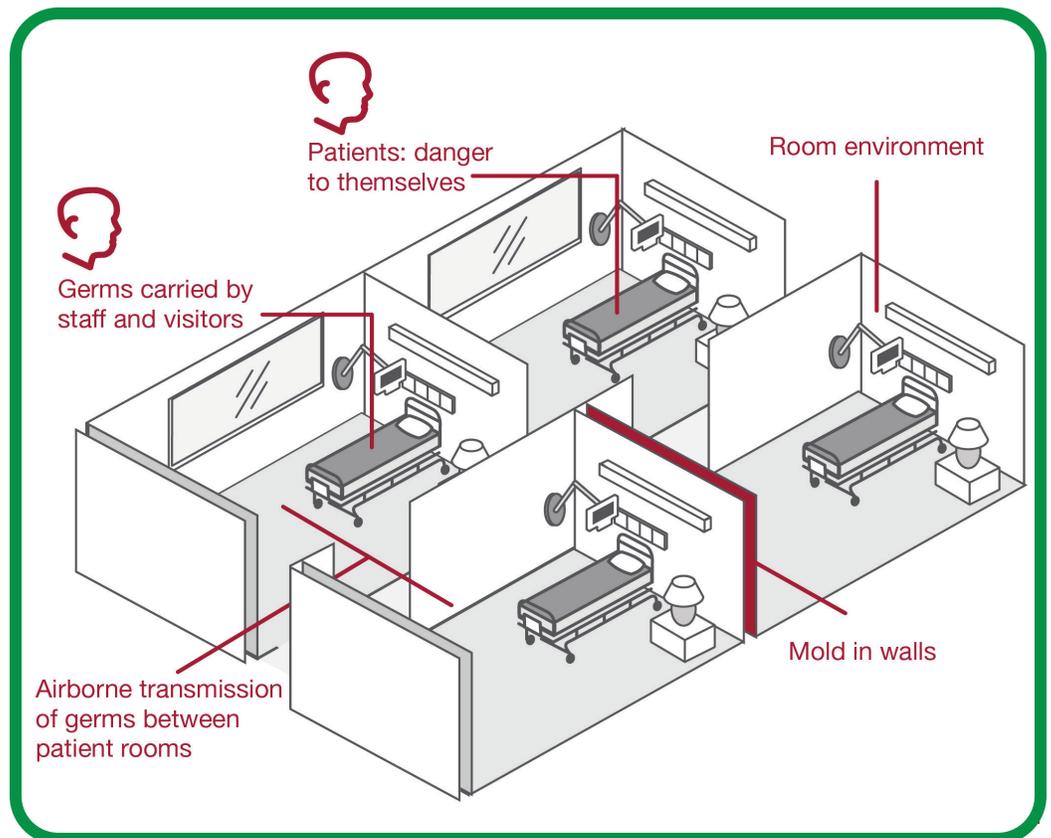


Figure 3
Example sources of APEs

The patient

A patient's own body and mind is a source of potential harm. For example, the universal law of gravity acting on a patient body can cause pressure sores if the patient is not turned frequently in bed, or falls if the patient's musculoskeletal system or coordination is faulty. Often patients with chronic conditions are on medications in doses carefully titrated by their out-patient provider. When admitted to a hospital, patients can easily forget part of their medical history or medication doses. The patient can also come with or develop a psychiatric illness which propels him or her to bring harm to themselves.

Serious infections can arise if a patient's carefully tuned and compartmentalised body loses its healthy structural or physiological barriers. Normal endogenous organisms in the mouth create a micro-flora necessary to begin the digestion of food, yet would cause a deadly infection if they reached the brain or lungs. Life-saving treatments often require penetration of the skin due to surgical incisions or intravenous catheters. Breach of this barrier, however, can allow normal skin bacteria direct access to the entire circulatory system, causing potentially fatal blood sepsis if errors occur.

The room

Other APEs can result from elements in the hospital room. For example, handrail design and placement may not provide balance at key places on the path to the bathroom, resulting in a fall with injuries. Excess noise, undesirable lighting, and uncomfortable temperature conditions can increase stress and slow the healing process.¹¹ New finishes or cleaning agents used in patient rooms can emit compounds which provoke allergic reactions.¹² Staff members and visitors can transfer pathogens left on furniture surfaces if hand hygiene practices and room cleaning are not properly performed.¹³ Bed bugs and other insects living in buildings can transport infectious particles to the patient.¹⁴ Improperly installed plumbing fixtures in the bathroom can spray droplets containing bacteria, viruses, or fungal organisms on the patient.¹⁵ HVAC systems can transmit contaminated air between hospitals rooms if proper humidity levels are not maintained.

Staff and visitors

Hazards from outside the room can be unknowingly introduced to the patient by caregivers. Infectious organisms can be transmitted to the patient through contact, airborne, or water routes. If a clinical staff member is distracted or lacks thorough knowledge of the patient's diagnosis; incorrect medications, procedures, or worse can occur. Wrong-site surgery sounds unthinkable, yet it happens more frequently than any of us like to imagine.^{16 17}

¹¹ Anjali Joseph, Ph.D , "Impact Of The Environment On Infections In Healthcare Facilities", *The Center for Health Design*, 2006, Ulrich R, Zimring C. (2004)

"The Role of the Physical Environment in the Hospital of the 21st Century: A Once-in-a-Lifetime Opportunity", *The Center for Health Design*. Concord, CA.

Leonard L Berry, PhD . et al., "The Business Case for Better Buildings. *Frontiers of Health Services Management 21:1*" *The Center for Health Design*.

¹² Ibid.

¹³ S. Harbath, H. Sax, P. Gastmeier, "The Preventable Portion of Nosocomial Infections: An Overview of Published Reports", *Infection Control Programme*, Department of Internal Medicine, University of Geneva Hospitals, 24, rue Micheli-du-Crest, CH-1211, Geneva 14, Switzerland, Division of Hospital Epidemiology and Infection Control, Institute of Medical Microbiology and Hospital Epidemiology, Hanover Medical School, Germany. *Journal of Hospital Infection* (2003) 54, 258–266.

¹⁴ Lowe CF, Romney MG, "Bedbugs as vectors for drug resistant bacteria", *CDC: Emerging Infectious Diseases*, June 2011.

¹⁵ Dror Marchaim MD, et al., "Hospital bath basins are frequently contaminated with multidrug-resistant human pathogens", *American Journal of Infection Control*, 2011

¹⁶ Robert M. Wachter, M.D., Nancy E. Foster, R. Adams Dudley, M.D., M.B.A., "Medicare's Decision to Withhold Payment for Hospital Errors: The Devil Is in the Details", *The Joint Commission Journal on Quality and Patient Safety*, February 2008 Volume 34: No 2.

Hospital infrastructure

The design of a hospital's infrastructure must support reliable monitoring, maintenance, and systems back-up in the event of loss or malfunction of external power. Without proper maintenance, heating, ventilation, air-conditioning, and decorative water elements can harbor and transmit infectious organisms, toxins, and irritants;¹⁸ the hospital room essential gases which a patient may require for breathing support could mix incorrect proportions of oxygen, nitrogen, and CO₂. A power failure without emergency backup could cause a patient to miss an opportunity for a life-saving operation or kidney dialysis, or if a failure occurred while the patient is undergoing surgery the consequences from loss of temporary respiratory or circulatory support could be deadly. Other potential accidents from equipment failure are too numerous and scary to contemplate.

A patient journey gone wrong

The following fictitious scenario follows a "Mr. Smith" through a realistic admission and hospitalisation process to help better explain how the patient can be exposed to dangers from themselves, others, and the hospital infrastructure.

Mr. Smith experiences uncomfortable chest pain following a large dinner at a family event. His wife, with flash-backs to her late father's heart attack, rushes her husband through the doors of the local hospital Emergency Department at 11:00 pm, stating that her husband is having a heart attack. The nursing staff members are changing shifts so the usual patient evaluation process is shortened. The triage assessment from an exhausted nurse's first-glance at the pale, elderly man in evident distress is a heart problem. A quick electrocardiogram is done and looks normal enough, so brief orders are written for Mr. Smith's transfer to the adult cardiac unit. The triage nurse assumes that the patient will have a complete history and physical examination done within the hour, once he is in his room.

There is an available patient room; however, nighttime housekeeping is short-staffed and the room has not been cleaned since the previous patient's discharge. After waiting for two more hours on a stretcher in the hallway while housekeeping staff find cleaning supplies to ready the room, Mr. Smith is finally wheeled to his room from the Emergency Department. Meanwhile, his wife returns home. Once in his room, Mr. Smith forgets to tell the admitting physician that he has been taking a sedative for sleep every night for the past year. Mr. Smith also does not disclose that he is a heavy drinker.

The next day, after a long, restless night without sleep medication or alcohol, Mr. Smith gets out of bed to use the bathroom. His balance is impaired from sedative and alcohol withdrawal; and he falls and fractures his hip. During a surgical procedure to pin the fractured bone, the hospital power system malfunctions from an overuse surge. The ventilation system stops, causing the operating room to lose positive air pressure. Before resumption of the ventilation, an air current from the procedure room next door flows into Mr. Smith's operating room. Microscopic skin flakes harboring MRSA bacteria are carried by this airflow.¹⁹

Unbeknownst to Mr. Smith's surgical team, the open incision and bone pin are contaminated with MRSA bacteria. The hip surgery is completed, incision closed, and the patient is returned to his room. The routine post-operative medication regimen calls for an antibiotic that does not treat the dangerous antibiotic-resistant bacteria, MRSA. Thirty-six hours later he spikes a high fever. Blood tests point to a severe bacterial infection. A second antibiotic is started at an extremely high dose and causes invisible damage to his heart muscles. Twelve hours later while visiting with his family, Mr. Smith begins struggling for breath, grasps his fist to his chest and passes out. The family runs from the room and pulls the wall-mounted emergency alert.

¹⁷ Deborah F. Mulloy; Ronda G. Hughes, "Wrong-Site Surgery: A Preventable Medical Error", *Patient Safety and Quality: Agency for Healthcare Research and Quality* (US); 2008 Apr.

¹⁸ Anjali Joseph, Ph.D, Leonard L Berry, PhD . et al., The Center of Health Design, op. cit.

¹⁹ I. Eames, J. W. Tang, Y. Li and P. Wilson, "Airborne transmission of disease in hospitals", *J. Royal Soc. Interface*, 14 October 2009

Mr. Smith is resuscitated, intubated, and placed on a mechanical respirator. Forty-eight hours later his blood pressure plummets and he is unable to be saved despite heroic efforts by the medical staff. The autopsy reveals the cause of death to be MRSA blood sepsis causing overwhelming shock and a massive myocardial infarction. There is no evidence of a prior heart attack. The ultimate cause of Mr. Smith’s death was not present at the time of his admission.

The above described disasters could have been prevented if the hospital had building automation solutions in place, alerting the staff to intervene before the errors harmed Mr. Smith. The previous scenario is just one example of how hospitals encounter APEs on a daily basis. “To err is human”²⁰; however errors are also costly, deadly, and avoidable. **Figure 4** shows the progression of Mr. Smith’s patient journey and how one APE can lead to another.

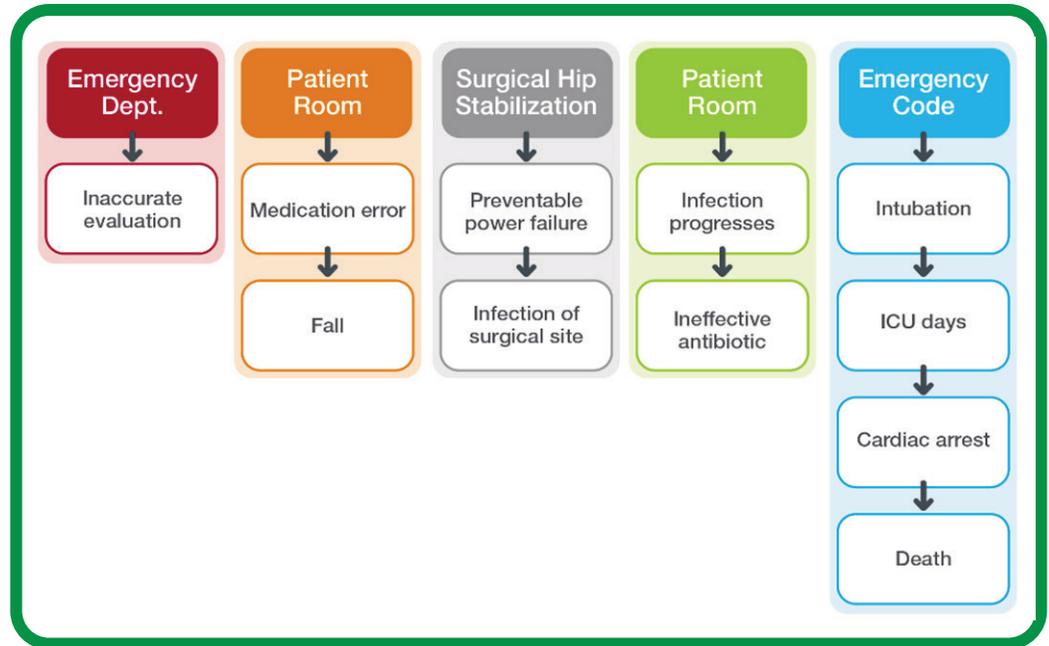


Figure 4
Progression of Mr. Smith’s patient journey gone wrong

A better story

Let’s look at the scenario again, this time with an intelligent infrastructure in place, operating as the hospital’s protective ANS.

Mr. Smith is brought to the local hospital Emergency Department for chest pain after a large holiday meal. His medical records and current medications are immediately obtained via the electronic medical records at the nurse’s station. With this information on hand, Mr. Smith is immediately and thoroughly evaluated by an alert triage nurse who is on a computer-generated staggered work schedule.

This evaluation indicates that Mr. Smith’s medical condition is stable enough for transfer to an in-patient room for best-practice 48-hour monitoring. Transfer orders are entered into the computerised admission, discharge, and transfer system and a room is located. Mr. Smith is immediately transferred to his private room because the housekeeping staff quickly located the closest cleaning supplies through the real-time location tracking system. Once settled, Mr. Smith uses his bedside tablet to set his own room conditions to enhance patient satisfaction and speed healing.

²⁰ Institute of Medicine, “To Err is Human. Building a Safer Health System.”, Washington DC: *National Academy Press*, 2000.

With the complete history available on his medical card, the admitting staff members note recent high dose steroid treatment for an arthritis flare-up, making Mr. Smith potentially vulnerable to infections. By remote access at the nursing station environmental monitoring screen, the room's humidity, air filtration status, pressure regimes, and power status were double-checked prior to arrival to his patient room.

His wife is reassured by the admission process and accurate medication management. She quietly informs the staff of her husband's heavy alcohol use. The physician places him on "fall risk" and the room motion sensors are activated. After she says goodnight to her husband, a "beep" from the infection control hand hygiene station reminds her to cleanse her hands before leaving his room.

During the night Mr. Smith gets up to use the bathroom, triggering a motion sensor and alert at the nurse station. Through the intercom, a nurse asks him if he can remain in bed for a few minutes. The nurse call prompts the lighting system to provide a lit path to the patient's room. He then gets assistance to and from the bathroom and soon settles back to sleep. The patient's cardiac status remains stable throughout the 48-hour period and there is no evidence of heart disease. Previously undiagnosed gastro-esophageal reflux is found to be the cause of the recent chest pain. A dietician recommends appropriate dietary changes and a social worker meets with the couple to address his wife's concern about alcohol use. Mr. Smith is discharged the next morning after a follow-up appointment with the primary care physician is arranged using the hospital electronic scheduling software. Three days after the family dinner, the Smiths embark upon a much healthier lifestyle.

Solutions

At the time of admission to a hospital, patients and their families are usually worried and distracted. In this vulnerable state they are particularly dependent on the care of dedicated, yet often hurried staff. The hospital and its occupants need a full-time monitoring system that protects them from human error and unforeseen events. The solutions described in the second scenario are founded on a building infrastructure equipped with "intelligent" automation. This ANS for the hospital integrates mechanical system monitoring, inter-department communication, and automatic clinical alerts to reduce the chances of APEs. This built-in protective mechanism sustains optimal conditions, commanding clinical staff attention only when intervention is required to correct a potential accident. Records of both routine monitoring and the alerts are then available to monitor trends and improve processes and efficiencies across the healthcare organization. For example, automatic hand-hygiene monitoring records can be used for staff feedback, encouragement to meet hospital improvement initiatives, and in research on the role of surface microbes in disease.

Case studies worldwide provide supporting data on the clinical efficacy of automated solutions. Four hospitals, Queen Mary Hospital, Caritas Medical Centre, Tuen Mun Hospital, and Yan Chai Hospital were enrolled in the WHO's pilot hand hygiene compliance study. Results showed hand hygiene compliance improved from 15.5% to 65% after 18 months of visual and automated monitoring.²¹

Other studies have associated significant reduction in the annual overall prevalence of HAIs and MRSA cross-transmission rates with electronic surveillance and reminding of proper hand hygiene practices.^{22 23 24}

²¹ CDC, "Recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force", CDC MMWR, Vol. 51 / RR-16

²² Gardner, M., "Aseptic Technique Is in Your Hands", *Infection Control Today*, 6 (5): 22 (2002)

²³ OECD, "Measuring healthcare worker hand hygiene activity: current practices and emerging technologies", *Infect Control Hosp Epidemiol*. 2011 Oct; 32(10):1016-28. 2011 Aug 24. OECD (2011),

²⁴ Swoboda SM, Earsing K, Strauss K, Lane S, Lipsett PA., "Electronic monitoring and voice prompts improve hand hygiene and decrease nosocomial infections in an intermediate care unit", *Critical Care Med* 2004; 32: 358-63

Table 1 illustrates the solutions available to help create an ANS in the hospital to reduce APEs and their impact on patient care and hospital financial health. The solutions are organized by APEs to clarify the various solutions available for each type of problem.

Table 1
Solutions available to reduce APEs

Adverse patient events	Solutions	Automation assistance				
		Video monitoring	RTLS patient and supply tracking	HVAC maintenance & monitoring	Critical power for data backup	Best practice building design
Healthcare-associated infections	Adherence to hand-hygiene regulations	X				
	Easy access to sterile supplies for patient care		X			X
	Appropriate antibiotic use to avoid c diff		X		X	
	Proper placement of hand hygiene stations					X
	Elimination of airborne transmission of pathogens			X		
	Thorough and rapid patient room cleaning		X			X
	Use of easily cleaned or antimicrobial surfaces					X
	Proper room air conditions to ensure patient protection			X		X
Patient falls	Proper placement of bathroom and handrails to avoid falls					X
	Prevention of patient falls due to water leakage or condensation			X		
	Knowledge of patient location at all times	X	X		X	
Medical errors	Ensure frequent turning of patient in bed to prevent skin pressure sores	X	X			
	Prevention of patient venous clotting from inactivity	X				
	Ensure up-to-date and correct patient medical records				X	
	Ensure patient receives correct medication and/or procedure		X		X	

Beyond the patient – operational benefits

The solutions in the chart are just some of the intelligent automation solutions that can help save patients' lives and hospitals millions of dollars. All of the solutions discussed in this paper provide the opportunity to help solve multiple problems at once. This leads to significantly reduced chances for APEs, as well as a greater return on investment because one technology can be used in almost a dozen different applications to improve patient safety. Due to the high number of APEs and the costs that hospitals incur because of them, the operational and cost benefits of solutions are significant. The following example savings are based on calculations using data from the US and WHO database. No data from long-term care or rehabilitation centers or litigation costs are included.

The average occupancy rate for hospitals globally is 80% with the average length of stay of 4.838 days.²⁵ This allows 60.36 annual admissions per bed, or 292 annual patient-days per bed. Calculation: [365 days/year / 4.838 days/admission] = 60.36 admissions/year

HAIs

- HAI in-patient prevalence = 8.5% of all admissions²⁶
- HAI rate per bed per year = 4.53
- Cost per HAI = \$91,733²⁷
- HAI cost per bed per year = \$415,700
- **Savings per bed per year with hand-hygiene solution if 25% reduction in HAI's = \$103,800²⁸**

Patient falls with injury

- Fall rate 5.87 per 1000 patient days²⁹
- Falls per bed per year = 1.7126
- Cost per fall \$20,000^{30 31}
- Cost per bed per year = \$34,352
- **Savings per bed per year with 75% reduction in falls with monitoring: \$25,689^{32 33}**

Medical errors and wrong site surgery

- Error rate per annual admissions: 4.16%³⁴
- Annual errors per bed = 2.51
- Cost per error \$13,000³⁵
- Cost per bed per year: \$32,676
- **Savings per bed per year with 67% reduction from monitoring \$21,893³⁶**

²⁵ OECD Publishing, "Average length of stay in hospitals, Health at a Glance" *OECD Indicators*, 2011

²⁶ World Health Organization, "The Burden of Health Care-Associated Infection Worldwide, a Summary. Patient Safety", 2010.

²⁷ Albert Marchetti, Richard Rossiter, op. cit.

²⁸ Swoboda SM, Earsing K, Strauss K, Lane S, Lipsett PA., op. cit.

²⁹ Dykes, P. C. et al., "Fall Prevention in Acute Care Hospitals: A Randomized Trial", *JAMA*, 304(17):1912-1918, (2010).

³⁰ Stevens JA, Corso PS, Finkelstein EA, Miller TR, "The costs of fatal and nonfatal falls among older adults", *Injury Prevention*;12:290-5, 2006.

³¹ Shumway-Cook A, Ciol MA, Hoffman J, Dudgeon BJ, Yorston K, Chan L., "Falls in the Medicare population: incidence, associated factors, and impact on health care", *Physical Therapy* 89(4):1-9, 2009.

³² Hendrich A.L., Bender, P.S., Nyhuis, A., "Validation of the Hendrich II Fall Risk Model: A Large Concurrent Study", *Applied Nursing Research*, 2003.

³³ Hendrich, A., Nyhuis, A., Kippenbrock, T., & Soja, M. E., "Hospital falls: Development of a predictive model for clinical practice", *Applied Nursing Research*, 8(3), 129-139. (1995).

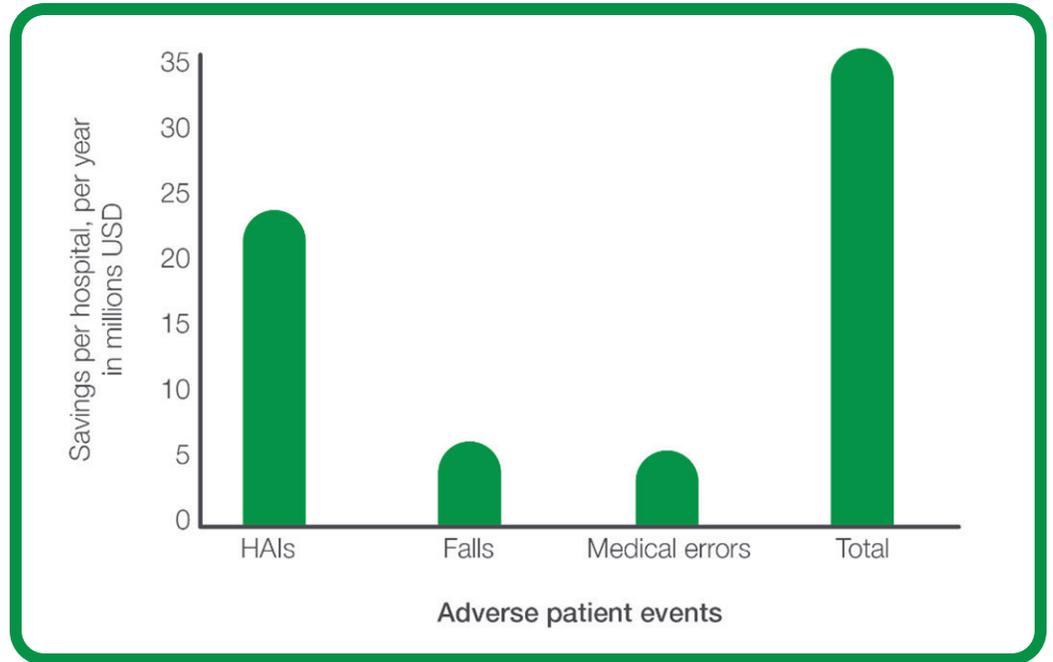
³⁴ Shreve, J., et al., "The Economic Measure of Medical Errors", *Society of Actuaries*, Milliman. 2010

³⁵ Ibid.

³⁶ Ibid.

As mentioned earlier, if the per bed per year savings of each APE are applied to a typical 250-bed hospital, the savings that one hospital can realise in one year from automated solutions that reduce APEs is staggering—\$35 million see **(Figure 5)**. A large portion of savings is achieved by reducing HAIs, which accounts for nearly \$23 million in potential savings.

Figure 5
Annual savings possible for 250-bed hospital



A checklist is provided in the [Appendix](#) to help you take successful steps toward reducing APEs and achieving similar savings in your hospital.

Conclusion

The hospital's physical environment clearly has a huge impact on the health of patients. Unfortunately, hospitals are causing harm to patients and wasting money on avoidable events. Preventable APEs account for 440,000 deaths—roughly one-sixth of all deaths that occur in the United States each year.³⁷ These figures are conservative! Other research shows that hospital reporting and peer-review systems document only a fraction of patient harm or negligent care.^{38 39}

Many of the individual behaviors preceding these dangerous events or errors are undetected by the human eye and therefore are unforeseeable. This can be changed! Patient hazards within hospitals can be made visible with intelligent and automated building solutions that bridge the disconnect between the structure and function of a hospital. This visibility provides previously hidden opportunities to greatly reduce transmission of HAIs, patient falls, medical errors, and wrong site surgeries. By modeling a hospital's infrastructure to emulate the human ANS to prompt safe behavior, hospitals can greatly improve clinical outcomes, shorten in-patient stays, decrease readmissions, and reduce hospital expenditures.

When searching for and working with a patient safety solution provider, hospital executives should consider the following:

- Seek out organizations with both physical infrastructure and healthcare knowledge and expertise to address the unique challenges of hospitals.
- Assess current facility policies and procedures for patient safety and identify areas where additional safety measures are needed.
- Prioritize the potential hazards and note any regulatory compliance issues, associated loss of revenue, and potential ROI on possible solutions.
- Choose a solution provider that can offer the greatest level of integration and scalability for future technology, change, and expansion.



About the authors

Dr. Stephanie Taylor is the CEO of Taylor Healthcare Commissioning, Inc. After working as a physician for many decades, Dr. Taylor obtained a Masters in Architecture as well as Infection Control certification. Her lifelong commitment to patient care includes focusing on improving the healthcare physical environment and clinical work processes to help patients heal quickly and save hospitals valuable dollars. Dr. Taylor is a graduate of Harvard Medical School (MD), and Norwich University (Masters Architecture). She has numerous research publications in *Nature*, *Science*, and other peer-reviewed journals.

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³⁷ John T. James, PhD, "A New, Evidence-based Estimate of Patient Harms Associated with Hospital Care", *Journal of Patient Safety*, Vol. 9:3, 2013

³⁸ Zane Robinson Wolf, Ronda G. Hughes, "Error Reporting and Disclosure", *Chapter 35, Agency for Healthcare Research and Quality*

³⁹ Makary, M, "Unaccountable: What Hospitals Won't Tell You and How Transparency Can Revolutionize Health Care," Bloomsbury Press, 2012.

Appendix

Steps to creating your hospital's autonomic nervous system

Consider available automation solutions and their benefits

- Implement Electronic Medical Records data at all nurse stations and mobile devices
- Streamline admission processes by facilitating patient room cleaning with RTLS tracking of cleaning supplies
- Decrease patient room transfers by computerised room occupancy charts
- Monitor falls with RTLS and video surveillance solutions
- Monitor patient and visitor location and prevent destructive behaviors with RTLS, video surveillance, and access control solutions
- Create reminder alerts at nurse stations and mobile devices to change patient position to prevent pressure ulcers
- Track pharmaceutical products with RTLS to identify antibiotic usage consistent with bacterial resistance or overgrowth
- Track opiate pharmaceuticals and monitor distribution with RTLS solutions
- Track medical equipment with RTLS to optimise availability for quick diagnosis and treatment of the patient
- Optimise room sanitation by tracking cleaning time and products used
- Monitor hand hygiene compliance with video surveillance and electronic reminders. and RTLS supply tracking
- Improve patient satisfaction and healing with patient-controlled lighting, temperature, curtains, and entertainment
- Install integrated nurse station consoles which display clinical and patient needs alerts
- Implement operating room environmental monitoring to maintain optimal comfort and safety conditions
- Use building management functionality to monitor and maintain proper HVAC function and cleanliness, room temperature, humidity, air pressures, air exchange rates, lighting, and safe water temperature and flow
- Integrate security, building management, and fire safety solutions to provide superior hospital security
- Implement emergency power supply testing and safety solutions to ensure 24/7 reliable power

Perform ongoing assessment and improvement initiatives

- With alarm and monitoring records available, improve clinical workflows and safeguards to prevent adverse events
- Ensure proper fire safety protocols are followed and equipment is installed and properly working at all times
- Investigate cost, quality, and outcomes feedback for ongoing improvement and decision support for providers
- Aggregate and study logs to identify correlations between hospital structural events with patient outcomes
- Maintain and audit records to identify the most common injuries and errors to develop specific protocols to reduce APEs

Encourage a culture of high-value care

- Create transparency in hospital metrics, such as reduction in HAIs, improvement in hand hygiene compliance, etc.
- Distribute resources for optimal availability of imaging and treatment equipment, reduce stockpiling, eliminate waste
- Celebrate improved performance outcomes