Systems-based Practice in Burn Care

Prevention, Management, and Economic Impact of Health Care–associated Infections

Charles Scott Hultman, MD, MBA[a,*],
David van Duin, MD, PhD[b],
Emily Sickbert-Bennett, PhD, MPH[c], Lauren M. DiBiase, MS[c],
Samuel W. Jones, MD[d], Bruce A. Cairns, MD[d],
David J. Weber, MD, MPH[b,c]

KEYWORDS

• Systems-based practice • Burn injury • Patient safety • Quality improvement
• Health care–associated infections

KEY POINTS

- Age, size of burn, and presence of inhalation injury remain the key predictors of outcome after thermal injury, but the development of health care–associated infections (HAIs) compromises outcomes and increases morbidity and mortality.
- Many HAIs can be prevented, through rigorous application of patient safety protocols, standardization of care, vigilant monitoring, and quality improvement initiatives.
- Systems-based practice serves as both an analytical tool and an interventional opportunity, in which an individual provider, functioning across interconnected microsystems, can leverage those relationships to improve the function of the larger health care system.

INTRODUCTION

The classic determinants of survival after thermal injury are age, burn size, and presence of inhalation injury, but infection remains the leading cause of mortality, ahead of burn shock and organ failure.[1] The American Burn Association estimates that 486,000 patients with burn injury require medical treatment in the United States annually, involving 40,000 hospital admissions and resulting in 3275 deaths.[2] Paramount to achieving improved outcomes and reducing morbidity and mortality are the prevention and effective management of health care–associated infections (HAIs). Due to disruption of the integument, which provides a mechanical and immunologic barrier to pathogens, patients with severe burns are at high risk for both local and systemic infections.

The Centers for Disease Control and Prevention (CDC) identified HAIs as a preventable cause of morbidity and concluded appropriately that these infections represent a major threat to patient

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[a] Division of Plastic Surgery, NC Jaycee Burn Center, University of North Carolina at Chapel Hill, Suite 7038, Burnett-Womack, Chapel Hill, NC 27599, USA; [b] Division of Infectious Diseases, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599, USA; [c] Hospital Epidemiology, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599, USA; [d] NC Jaycee Burn Center, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599, USA
* Corresponding author.
E-mail address: cshult@med.unc.edu

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safety.[3] The HAI Prevalence Survey, published in 2014, exposes the full burden of this problem: approximately 722,000 patients develop HAIs per annum, accounting for approximately 75,000 in-hospital deaths.[4] Although the incidence of HAIs has dropped considerably over the past decade, due to improved surveillance, education, training, feedback, bundles, and checklists, 1 in 25 hospitalized patients still has at least 1 HAI on any given day. Prevention of HAIs, their early diagnosis, and the rational use of antibiotics are largely responsible for these improved outcomes, all tangible benefits of systems-based practice (SBP), in which individual health care providers, teams, clinical microsystems, and the macro-organization work together to improve patient safety.

First introduced in 1999 by the Accreditation Council for Graduate Medical Education, and later adopted by the American Board of Medical Specialties as part of Maintenance of Certification, SBP is a clinical competency in which physicians strive to understand how patient care relates to the health care system, as a whole, and how to utilize and even leverage that system to improve the quality and safety of patient care.[5,6] SBP serves as both an educational tool to measure and enhance performance of clinicians and an analytical model to improve the overall health care system. In contrast to the competency of practice-based learning, which asks, "How can I improve the care of my own patients," SBP poses the question, "How can I improve the system of care?" Because health care is a complex, adaptive system, which contains microsystems that are sometimes aligned but often have competing behaviors, objectives, and opportunities, the importance of systems thinking cannot be overstated. Understanding large organizations, with their interacting, interrelated, and interdependent elements, improves health care not only at the patient level but also for populations of patients.

The purpose of this investigation is to analyze the impact of SBP on the outcomes of burn patients who developed HAIs. Specifically, what measures have been implemented to prevent and treat HAIs at the authors' institution? What is the economic impact of the development of HAIs in these burn patients? In what areas has progress been made, and where does work remain? Finally, what lessons have been learned that can be extrapolated to other health care systems, such that all burn patients can benefit from the authors' experience?

METHODS

Patient Population

The authors performed an institutional review board–approved, retrospective cohort study of all patients admitted to the University of North Carolina (UNC) Jaycee Burn Center, from 1999 to 2012. The initial data set was obtained from a prospectively maintained institutional registry, which was part of the National Burn Repository of the American Burn Association. This database was then cross-referenced and merged with a comprehensive, hospital-wide surveillance registry for all HAIs, as defined by the CDC, for catheter-associated urinary tract infections (CAUTIs) from 2006 to 2012, central line–associated bloodstream infections (CLABSIs) from 1999 to 2012, ventilator-associated pneumonias (VAPs) from 2004 to 2012, and surgical site infections (SSIs) and skin and soft tissue infections (SSTIs) from 2002 to 2012.

The study was conducted at the UNC Hospitals, an 806-bed tertiary/quaternary care facility, which includes a 21-bed burn ICU plus another 20-bed step-down unit for burns and wound care. Active members of the UNC Jaycee Burn Center team include burn and plastic surgeons (all of whom are board certified in surgical critical care), dedicated anesthesiologists, infectious disease specialists, hospital epidemiologists, nurses proficient in advanced burn care, occupational and physical therapists, nutritionists, pharmacists, recreational therapists, social workers, and chaplains. Almost all patients were housed in single, isolated ICU beds as well as semiprivate step-down beds when stable for transfer. Burn wound precautions for all patients included monitored hand hygiene, gloves, and gowns, for all providers entering ICU rooms.

Data Collection and Study Design

The following data points were extracted from the burn center registry and the surveillance database from hospital epidemiology: age, size of burn, presence of inhalation injury, incidence of HAI, identification of pathogens, length of stay (LOS), mortality, and total hospital charges. These data to were used to

1. Observe the incidence of HAI, CAUTI, CLABSI, and VAP as a function of time
2. Compare those patients who developed index SSIs/SSTIs with those who did not, from 2008 to 2012
3. Understand the changing distribution of pathogens, from 2007 to 2012
4. Create a financial model that would predict the direct medical costs of developing HAIs, specifically at the authors' burn center

Previously published CDC estimates for low, high, and adjusted costs (pegged to the consumer price index) were used for comparison.[7] Impact of

HAI on LOS was based on clinical practice guidelines for treatment of SSI/SSTI, CAUTI, CLABSI, VAP, and *Clostridium difficile* infection (CDI).

Interventions

Standard burn wound precautions (monitored hand hygiene, gloves, and gown) for all ICU patients and all step-down patients with open wounds, were begun before the start of the study period and were continued throughout the duration of the study. Quality improvement initiatives, implemented at different time points from 1999 to 2012, included education and training of all clinical personnel, feedback loops with closure of communication, clinical reminders (posters, flowcharts, and fact sheets), introduction of clinical care bundles developed by the Institute for Healthcare Improvement (IHI), procedural and patient safety checklists, empowerment to stop procedure or ask questions, Team Strategies and Tools to Enhance Performance and Patient Safety training (designed by the Agency for Healthcare Research and Quality), active surveillance and distribution of HAI data to the health care team, utilization of the Plan-Do-Study-Act model to improve throughput, selective use of lean Six Sigma for specific projects (such as management of multidrug-resistant [MDR] HAI outbreaks), and active participation in the monthly hospital infection control committee.

Statistical Analysis

HAI rates for CAUTI, CLABSI, and VAP were calculated as infections per 1000 patient-days, whereas incidence of SSIs/SSTIs is reported as percent of patients who developed a culture-documented clinical infection. Surveillance data for the various HAIs began at different starting points, depending on when the CDC may have revised their diagnostic criteria and reporting definitions. For the SSI versus non-SSI analysis, the Student *t* test was used for continuous data, and 2-tailed χ^2 test analysis was used for categorical variables. Statistical significance was assigned to $P<.05$.

RESULTS

Overall Health Care–associated Infections

From 2007 to 2012, total number of admissions to the burn ICU increased from 737 to 1242 (**Table 1**), whereas the number of HAIs dropped from 88 to 48 per year. Furthermore, the infection rate per 1000 patient-days decreased from 11.73 to 6.48 for all HAIs. **Fig. 1** demonstrates that in 2008, the authors introduced and maintained (1) strict, monitored, 2-pump hand-hygiene before room entry; (2) a switch from paper to plastic gowns plus gloves, hat, and mask when inspecting wounds; and (3) isolation and semiquarantine of MDR patients (specifically *Acinetobacter*). Incidence of HAIs, in the non–burn ICUs, dropped from 6 to 4.5 infections per 1000 patient-days over this period.

Catheter-associated Urinary Tract Infections

Incidence of CAUTI peaked in 2007 to almost 6 infections per 1000 patient-days but rapidly declined to less than 3 infections per 1000 patient-days (**Fig. 2**). To comply with guidelines drafted by the Surgical Care Improvement Project (sponsored by the Centers for Medicare & Medicaid Services), in 2007 the authors started removing indwelling urinary catheters within 24 hours after initial resuscitation or surgery. This intervention had a direct, immediate, and lasting effect on reduction of CAUTIs in the burn ICU.

Central Line–associated Bloodstream Infections

From 2000 to 2012, the incidence of CLABSIs decreased from more than 20 to 2.5 infections per 1000 patient-days. Most likely, no specific

Table 1
Incidence of health care–associated infections in the burn ICU at University of North Carolina Hospitals, 2007–2012, with infection rate adjusted to 1000 patient-days

Year	No. of Admissions to Burn ICU	No. of HAIs	No. of Patient-days	Infection Rate per 1000 Patient-days
2007	737	88	7500	11.73
2008	771	63	6003	10.49
2009	872	52	7415	7.01
2010	966	62	7393	8.39
2011	1312	56	7485	7.48
2012	1242	48	7402	6.48

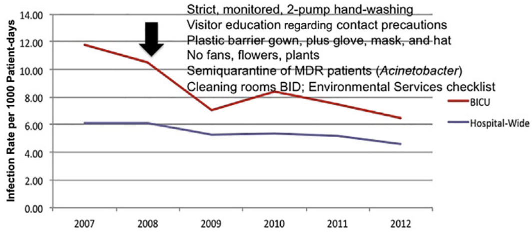

Fig. 1. Overall incidence of HAIs in the ICUs at UNC Hospitals. BICU, burn ICU; BID, twice per day.

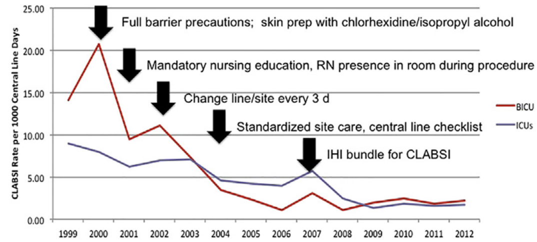

Fig. 3. Incidence of CLABSI in the ICUs at UNC, 1999 to 2012. BICU, burn ICU; prep, peparation; RN, registered nurse.

intervention accounted for this approximately 90% reduction; rather, this was the result of multiple initiatives related to SBP (**Fig. 3**). In addition to full barrier precautions for central line placement, the authors switched from betadine to chlorhexidine-isopropyl alcohol for skin preparation, in 2000. The other important intervention, which occurred in 2004, seems to be the rotation of central lines to a new site, with a fresh stick, every 3 days. Standardization of site wound care, combined with use of IHI-defined CLABSI bundles, allowed reaching a very low infection rate, comparable to the other ICUs at the authors' hospital.

Ventilator-associated Pneumonia

Unfortunately, from 2004 to 2012, incidence of VAP was variable from year to year, despite the steady decline observed in the rest of the authors' surgical and medical ICUs (**Fig. 4**). In 2008, the authors introduced several measures to address climbing VAP rates, such as serial bronchoscopy for inhalation injury, bronchoalveolar lavage to obtain pulmonary cultures, stress ulcer prophylaxis, and head of bed elevation. Preventing VAP continues to be a work in progress.

Surgical Site Infections/Skin and Soft Tissue Infections

Although not the focus of the authors' interventions, the incidence of SSIs and SSTIs dropped from almost 11% in 2004 to less than 1% in 2012 (**Fig. 5**). Such reduction may be a collateral benefit of focusing on those HAIs that represented a challenge and opportunity. Approximately 15 years ago, the authors made deliberate attempts to standardize wound care protocols and decrease variability between faculty members, so that rotating medical students, new nursing staff, and changing residents could quickly integrate into team dynamics, without having to learn myriad options for wound care. As a result, wound care algorithms have remained consistent, the details of which include

- The use of topical silver sulfadiazine for all open and unexcised burn wounds below the neck
- The application of bacitracin to the face and neck
- The intraoperative placement of xenograft on most partial-thickness scald burns, within 36 hours of injury
- Daily chlorhexidine baths with reapplication of topical antimicrobials
- The early excision of deep partial-thickness and full-thickness burn wounds, 3 days to 7 days after injury, after resuscitation is complete
- The irrigation of skin grafts with sulfamylon and nystatin postoperatively, for 4 days to 5 days
- The initiation of silver nitrate at 4 days to 5 days postoperatively, if skin graft take is compromised

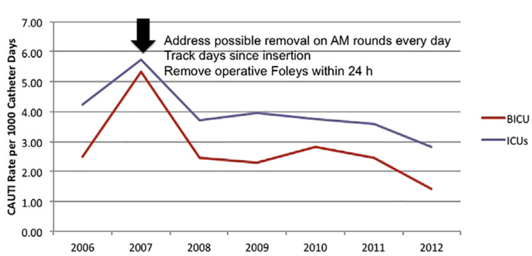

Fig. 2. Incidence of CAUTIs in the ICUs at UNC, 2006 to 2012. BICU, burn ICU; OR, operating room.

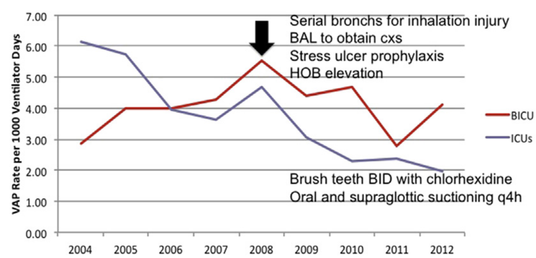

Fig. 4. Incidence of VAP in the ICUs at UNC, 2004 to 2012. BAL, bronchoscopic alveolar lavage; BICU, burn ICU; bronch, bronchoscopy; cxs, cultures; HOB, head of bed.

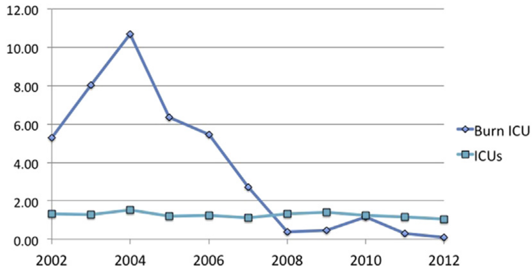

Fig. 5. Incidence of SSIs/SSTIs in the ICUs at UNC, 2002 to 2012. BICU, burn ICU.

Index Cases

Although SSIs and SSTIs have become considerably less prevalent in the authors' burn center population, the development of these infections is associated with significantly worse outcomes. From 2008 to 2012, 20 index cases, involving MDR organisms, were reported to hospital epidemiology. Compared with the 5143 nonindex patients, the 20 index cases with SSI or SSTI had a larger burn size (35.8% vs 7.2% total burn surface area), higher incidence of inhalation injury (40% vs 4.4%), greater mortality (30% vs 3%), and higher direct medical costs ($325,000 vs $57,000). Refer to **Table 2** for *P* values and SDs.

Microbiology

From 2007 through 2012, the microbiologic flora found in burn patients with HAIs varied considerably. **Fig. 6** demonstrates that MDR *Acinetobacter* was particularly prevalent from 2008 to 2010. Across this 3-year period, the authors experienced several outbreaks, which were due to 3 distinct strains, with different genomes for drug resistance.[8] Likewise, beginning in 2010, the burn center experienced a prolonged outbreak of carbapenem-resistant *Enterobacter* and *Klebsiella*, with whole-genome sequencing revealing that the organisms were genetically linked, despite seeming to be epidemiologically unlinked.[9] At the end of the study period, in 2012, the most common organisms were *Pseudomonas*, *Stenotrophomonas*, *Enterococcus*, and *Staphylococcus aureus*, in decreasing order respectively.

Economic Impact

CDC data from 2002, compared with 2011, indicated that total HAIs in the United States, per year, dropped from 1.737 million to 722,000, with the greatest decreases observed in CLABSIs and CAUTIs (**Table 3**). The incidence of VAP, however, has not decreased and remains close to 50,000 cases per year.[3,4] Estimates for cost of care, published by the CDC in 2009, include low and high valuation as well as an estimate adjusted in conjunction with the consumer price index.[7] For the authors' model, an increased LOS, based on current clinical guidelines for therapy for SSI/SSTI, CAUTI, CLABSI, VAP, and CDI, was assumed. Direct medical costs, which include use of fixed assets, variable overhead, labor, and supplies, were calculated for each HAI using a conversion factor of $5199 per day of ICU care. If the development of an HAI adds 10 days of hospital care, for example, then this would increase the direct medical cost (excluding physician professional fees) by $51,999, which is twice the CDC adjusted estimate of $25,903. All the predicted direct medical costs are greater than those estimated by the CDC, perhaps because thermally injured patients have both the burn and the HAI from which to recover.

DISCUSSION

In summary, this article reports that HAIs in burn patients, ranging from VAP to SSTIs, can

Table 2
Comparison of burn patients with index surgical site infections/skin and soft tissue infections versus all other patients admitted, 2008–2012. Index case is defined as a burn wound infection reported to hospital epidemiology, often involving MDR organisms

Surgical Site Infections/Skin and Soft Tissue Infections	N	Age (y)	Total Burn Surface Area (%)	Length of Stay (d)	Inhalation Injury (No., %)	Death (No., %)	Charges
Index cases	20	42.2 ± SD 22.0	35.8 ± SD 22.1	94.2 ± SD 92.0	8, 40%	6, 30%	$325,000 ± SD $313,000
Nonindex patients	5143	32.7 ± SD 22.5	7.2 ± SD 11.6	12.0 ± SD 21.0	225, 4.4%	155, 3.0%	$57,000 ± SD $113,000
P value		.059	<.001	<.001	<.001	<.001	.012

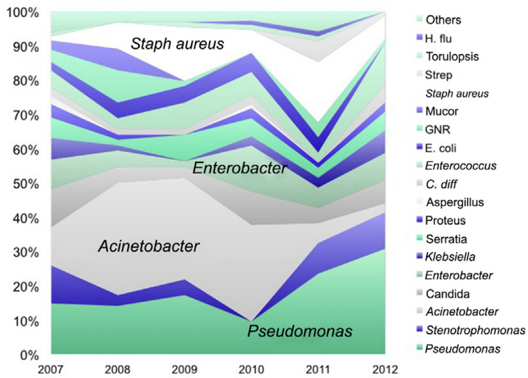

Fig. 6. Relative percentage of pathogens isolated from the burn ICU at UNC, 2007 to 2012. C. diff, Clostridium difficile; E. coli, Escherichia coli; GNR, Gram negative rod; H. flu, Hemophilus influenza; Mucor, Mucormycosis; Staph aureus, Staphylococcus aureus; Strep, Streptococcus.

substantially compromise outcomes, because these complications are associated with longer LOSs, increased mortality, and greater direct medical costs. HAIs are largely preventable, through surveillance, education, hand hygiene, and culture change, especially device-related infections, such as CLABSIs and CAUTIs. SBP, which allows individuals and clinical microsystems to navigate and improve the macro health care system, may be one of the most powerful skill sets to effect change, because this permits a shift in culture toward patient safety and quality improvement.

Although considered a competency by accrediting councils, certifying boards, and hospital credentialing committees, SBP really serves as an analytical tool to study the inefficiencies, constraints, and defects of a system. Furthermore, SBP empowers health care providers, at the individual level, to work within a complex system of inter-related and interdependent microsystems, to align their competing goals and objectives with those of the entire organization. In cases of burn care, HAIs represent a clinical challenge that is partially due to miscommunication, suboptimal teamwork, and failure of smaller units to appreciate the nuances of how to provide the safest, most cost-effective, highest value care.

SBP produces real results. In a sense, SBP is a bundle of interventions that focus on improving the culture of an institution, by focusing on human capital as a critical resource. Clinicians not only implement evidence-based guidelines for clinical care but also develop them within the context of an institution. The ultimate goal of SBP is the dissemination of new knowledge to improve the outcomes of patients at the bedside, groups of patients treated in a specific clinical setting, cohorts of patients that the health care system services, and populations of patients beyond the reach of a single health care system.

Domains of competence within SBP include[6]

1. Working effectively in various health care delivery settings and systems relevant to their clinical specialty
2. Coordinating patient care within the health care system relevant to the clinical specialty
3. Incorporating considerations of cost awareness and risk/benefit analysis in patient care
4. Advocating for quality patient care and optimal patient care systems
5. Working in interprofessional teams to enhance patient safety and improve patient care quality
6. Participating in identifying systems errors and in implementing potential systems solutions
7. Knowing how to advocate for the promotion of health and the prevention of disease and injury in populations

Over the past 15 years, at the authors' institution, slowly but unequivocally the incidence of HAIs in the burn center has decreased, resulting in improved survival and shorter LOSs, for the overall population of patients treated.[1,10,11] Although the rate of CLABSI has been reduced dramatically,[12] VAP continues to be a major clinical challenge,[13] consistent with national data from the HAI Prevalence Survey[4] and CDC trends over time.[3] One meta-analysis and systematic review confirmed that quality improvement interventions were effective in decreasing the incidence of CLABSI, in 41 of 43 before–after cohort studies, all of which met methodologic criteria established by the Cochrane Group.[14,15] Initiatives that involved implementation of care bundles and checklists seemed to yield the stronger risk reductions compared with education and training, feedback and empowerment, and clinical reminders. Other groups have studied the potential impact of chlorhexidine baths,[16] standardization of antibiotic regimens,[17] methicillin-resistant *Staphylococcus aureus* screening and eradication,[18] high-frequency percussive ventilation,[19] adherence to core ICU measures,[20] and treatment in a dedicated burn ICU[21] as interventions to prevent HAIs in burn patients, with good to equivocal results.

One of the unexpected but positive findings in the authors' study is the dramatic reduction in the incidence of SSIs and SSTIs in burn patients from 2004 to 2012, despite no specific, directed intervention designed to prevent these HAIs, which dropped from almost 11% to less than 1%. Although wound infections have become far less common, the clinical and economic toll

Table 3
Economic impact of health care–associated infections in burn care

Infection Type	Estimated Infections in United States, 2002 (No.)	Estimated Infections in United States, 2011 (No.)	Centers for Disease Control and Prevention Estimate, Low ($)	Centers for Disease Control and Prevention Estimate, High ($)	Centers for Disease Control and Prevention Estimate, Adjusted Using Consumer Price Index ($)	Increased Length of Stay (d)	University of North Carolina Estimate ($)
All HAIs	1,737,125	721,800	16,359	19,430	25,903	10	51,990
SSI	290,485	157,500	10,443	25,646	34,670	7	36,393
CAUTI	449,334	93,300	589	758	1007	1	5199
CLABSI	92,011	15,600	5734	22,939	29,156	7	36,393
VAP	52,543	49,900	11,897	25,072	28,508	14	72,786
CDI	178,000	123,100	5042	7179	6408	3	15,597

Each additional day at UNC Hospitals accrues an additional $5199 of direct medical costs (fixed + variable), excluding indirect and intangible costs. CDC estimates from 2009. LOS estimated by authors.

remains staggering. Patients who develop an index SSI/SSTI had a mortality of 30%, compared with 3% for nonindex cases. Furthermore, LOS was 94 days for the index group, compared with 12 days for the nonindex group, resulting in a charge differential of $325,000 versus $57,000. The authors speculate that the efforts to decrease the incidence of other HAIs, such as CLABSI and CAUTI, produced a scenario in which "a rising tide floats all boats." It can reasonably be concluded that the intentional efforts to improve communication and teamwork, in the UNC Jaycee Burn Center, improved SBP, through a culture shift toward patient safety, quality, and value. Although individual providers must accrue medical knowledge and sharpen their patient care skills, SBP may prove the most important competency a health care system can purse, to meet its goal and public expectation to improve the health of populations.

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