Chapter 6

Intensive Care Unit Operational Modeling and Analysis

Yue Dong
Mayo Clinic, USA

Huitian Lu
South Dakota State University, USA

Ognjen Gajic
Mayo Clinic, USA

Brian Pickering
Mayo Clinic, USA

ABSTRACT

The outcome of critical illness depends not only on life threatening pathophysiologic disturbances, but also on several complex "system" dimensions: health care providers' performance, organizational factors, environmental factors, family preferences and the interactions between each component. Systems engineering tools offer a novel approach which can facilitate a "systems understanding" of patient-environment interactions enabling advances in the science of healthcare delivery. Due to the complexity of operations in critical care medicine, certain assumptions are needed in order to understand system behavior. Patient variation and uncertainties underlying these assumptions present a challenge to investigators wishing to model and improve health care delivery processes. In this chapter we present a systems engineering approach to modeling critical care delivery using sepsis resuscitation as an example condition.

DOI: 10.4018/978-1-60960-872-9.ch006

MEDICAL ERROR IS A GROWING PUBLIC HEALTH PROBLEM IN ACUTE CARE ENVIRONMENT

In 2005, intensive care unit (ICU) costs represented 13.4% of hospital costs, 4.1% of national healthcare expenditures and 0.66% of the gross domestic product in the US (Halpern & Pastores, 2010). With ever-increasing demands and decreasing available resources, the provision of cost-effective healthcare and the elimination of waste is a major focus of policy makers, healthcare providers, and the general public. Indeed, we know today that between $.30 and $.40 of every healthcare dollar spent in the US does not contribute to high quality care. Resources are wasted through over-use, misuse, duplication, system failures, poor communication and inefficiency (Lawrence, 2005) and are estimated to cost between $600 billion and $850 billion annually (Kelley, 2009). On the other hand, less than one cent ($.01) of every healthcare dollar is spent on health services research which might eliminate these wasteful activities (Coalition for Health Services Research, 2009). Such spending discrepancies highlight the importance of implementation research proposed as "Blue Highways" on the NIH roadmap (Westfall et al., 2007). There is a dichotomy between science discovery and failure of everyday patient care delivery (Blendon et al., 2002; Grol & Grimshaw, 2003).

Sir Cyril Chantler stated, "Medicine used to be simple, ineffective and relatively safe. Now it is complex, effective and potentially dangerous."(Chantler, 1999). The ICU is a complex environment with multiple team members, interacting with several critically ill patients, many of whom are receiving life supports such as mechanical ventilation and dialysis. With increasing complexity of patient disease, treatment options and technology, the healthcare delivery comes at increased risk of error and poor patient outcome. One of the few studies to systematically examine processes of care delivery and errors in the ICU was carried out in a relatively small (6 bedded) ICU by Israeli investigators. They reported an average of 178 processes of care per day per patient and the absolute number of error was determined to be 1.7 errors/patient per day (Donchin et al., 2003). Given the system complexity, 1.7 errors may not seem to be a large number, however, the consequences of error in this patient population is profound. In addition, more common and complex diagnostic errors have not been considered in this study. Several studies have described increased patient morbidity, increased resource utilization and reduced survival in association with error in the ICU (Bracco et al., 2001; Garrouste-Orgeas et al., 2010).

RATIONALE FOR A SYSTEMS APPROACH TO REDUCING ERROR IN THE ICU

ICU systems are complex. The components of the system include patients, family members, physicians, nurses, allied health staff, support staff, physical and electronic infrastructure, equipment, supplies, processes and culture (Schmidt & Taylor, 1970). Ideally these components work together to optimize patient-centered outcomes. In order to ensure that ICU systems deliver high quality care to patients we need to understand how each system component (patient, provider, equipment, etc.) interacts and works together. This understanding is not easily derived from conventional analytic approaches and optimization of the system can not rely solely on single interventions such as those aimed at improving an individual provider's skills. , Systems-based approaches to error prevention have proven markedly effective in reducing medical errors and iatrogenic complications. For example, Dr. Pronovost's use and distribution of a simple checklist during central