A Bundled Care Process for the Prevention of Delirium in Patients in the Intensive Care Unit: Implementation Strategies and Uptake, Impact on Patient Outcomes, and Cost-effectiveness

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By

Ashley W. Collinsworth

Ashley W. Collinsworth

Approved:

Claudia Campbell, Ph.D.

Eva Silvestre, Ph.D.

Joni Steinberg, Ph.D.

Andrew Masica, M.D.

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ABSTRACT

Delirium is a common and severe problem for older, hospitalized adults occurring in up to 80% of mechanically ventilated patients in the intensive care unit (ICU) and costing $4 to $16 billion annually in the United States. The ABCDE (Awakening and Breathing Coordination, Delirium monitoring/management, and Early exercise/mobility) bundle has been proposed as an interdisciplinary, multi-component intervention in ICUs to reduce incidence of delirium. However, few ICUs have adopted the ABCDE bundle, and its effectiveness has not been established. Knowledge regarding how to facilitate implementation and promote widespread adoption of the bundle in different ICU settings is lacking. In addition, no published studies have examined the cost-effectiveness of the bundle.

This dissertation addressed gaps in knowledge pertaining to the implementation and adoption, effectiveness, and cost-effectiveness of the ABCDE bundle. The bundle was implemented in 12 adult ICUs in 6 hospitals belonging to a large, integrated healthcare delivery system using two implementation strategies. The basic strategy consisted of modification of the electronic health record (EHR) to support bundle uptake and the enhanced strategy involved EHR modification plus structured trainings and clinical champions. The first study examined the effect of the two bundle implementation strategies on bundle adherence and the impact of bundle adherence on patient outcomes. ICUs in both intervention groups had statistically significant improvements in bundle adherence between pre- and post- periods with basic group ICUs achieving a 22% greater

increase in adherence relative to enhanced group ICUs. High bundle adherence (≥60%) was associated with significant decreases in inpatient mortality, incidence of coma, ventilator days, and increased odds of mobilizing out of bed. Although high bundle adherence was not associated with reductions in incidence of delirium, patients with high adherence had a significant increase in the percentage of delirium and coma free days.

The second study was a mixed methods evaluation of the implementation and routinization of the ABCDE bundle in study ICUs. Interviews and surveys were conducted with 82 frontline ICU staff and managers including nurses, physicians, and respiratory, physical, and occupational therapists. Across ICUs, respondents agreed that use of the ABCDE bundle resulted in "best care" through the standardization and coordination of care processes and improved patient outcomes. ICUs in both intervention groups had significant improvements in bundle adherence following implementation efforts, but ICUs in the basic intervention group had environments that were more conducive to bundle implementation and outperformed the other sites after hearing about the enhanced intervention and initiating their own implementation strategies. Successful bundle implementation tactics included incorporating the bundle into multidisciplinary rounds and providing ongoing support, training, and routine auditing and feedback.

The third study examined the impact of ABCDE bundle adherence on inpatient and 1-year mortality, quality-adjusted life years (QALYs), and costs of care. Patients with high adherence had significantly decreased odds of inpatient mortality, increased QALYs, and a non-significant increase in the cost of care. Overall, our findings indicate that implementation of the ABCDE bundle into everyday practice is feasible and an effective and cost-effective strategy for improving patient care and outcomes in the ICU.

CHAPTER 1. BACKGROUND AND SIGNIFICANCE

Delirium or acute brain dysfunction is a common and severe problem for older, hospitalized adults (Leslie & Inouye, 2011). Described in the Diagnostic and Statistical Manual of Mental Disorders as a disturbance in attention or awareness that is accompanied by a change in baseline cognition that cannot be better explained by a preexisting or evolving neurocognitive disorder, delirium occurs in an estimated 14% to 56% of hospitalized patients and is associated with an in-hospital mortality rate of 25% to 33% (American Psychiatric Association, 2013; Leslie & Inouye, 2011). Delirium is more prevalent in intensive care units (ICUs) affecting 35% to 80% of all critically ill patients (Flinn, Diehl, Seyfried, & Malani, 2009; Skrobik, 2011). Patients undergoing mechanical ventilation are particularly susceptible to the condition, as the analgesics, sedatives, and hypnotics that are frequently used in ICUs to achieve patient comfort are often deliriogenic (Banerjee, Girard, & Pandharipande, 2011; Hipp & Ely, 2012). ICU-acquired delirium is independently associated with increased cognitive and physical impairment, mortality, hospital length of stay (LOS), and health care costs (Ely, Gautam, et al., 2001; Inouye, 2006; Inouye, Schlesinger, & Lydon, 1999; Lundstrom et al., 2005; Mercer, DeVinney, Fine, Green, & Dougherty, 2007; Milbrandt et al., 2004; P. P. Pandharipande et al., 2013; Pisani, Murphy, Van Ness, Araujo, & Inouye, 2007; Reston & Schoelles, 2013; Vidan et al., 2009). It is estimated that treatment of delirium costs $4 to $16 billion dollars annually in the United States alone.

Delirium can be triggered by a number of factors including comorbidities, specific patient characteristics, and ICU treatment modalities. Thus, a single intervention is unlikely to effectively address the underlying causes of delirium in most patients (Brummel & Girard, 2013; Reston & Schoelles, 2013). However, improved alignment of people, processes, and technology that currently exist in ICUs may lead to reductions in the incidence and severity of delirium (Hipp & Ely, 2012; Vasilevskis, Ely, et al., 2010). Care "bundles" which generally consist of three to five evidence-based processes of care for specific conditions to be applied as an all-or-none measure have been proposed as tools to promote adoption of proven therapies and improve patient care. "Bundled" therapies have been applied to the management and prevention of complex conditions such as central line infections, ventilator-associated pneumonia, and sepsis as a means to help clinicians reliably deliver evidence-based processes of care (Barochia et al., 2010; Furuya et al., 2011; Hawe, Ellis, Cairns, & Longmate, 2009; Morandi, Brummel, & Ely, 2011). Studies examining use of care bundles for these conditions have shown improvements in the delivery of care processes and reductions in incidence of central line infections and pneumonia as well as sepsis mortality (Barochia et al., 2010; Bird et al., 2010; Furuya et al., 2011; Hawe et al., 2009; Pronovost et al., 2006; Wip & Napolitano, 2009).

The ABCDE bundle has been proposed as an interdisciplinary, multi-component patient safety intervention to reduce incidence of delirium in ICUs by improving collaboration among clinical team members, standardizing care processes, and breaking the cycle of oversedation and prolonged ventilation (Balas et al., 2013; Balas et al., 2012; Girard, Pandharipande, & Ely, 2008; Hipp, Ely, & Dittus, 2013; Vasilevskis, Ely, et al.,

2010; Vasilevskis, Pandharipande, Girard, & Ely, 2010). The bundle consists of spontaneous awakening trials (SATs) to decrease the use of sedation, spontaneous breathing trials (SBTs) to wean patients off mechanical ventilation faster, coordination of awakening and breathing trials to maximize benefits of SATs and SBTs, delirium screening and treatment, and early progressive mobility to decrease ICU-acquired muscle weakness. Individually, these interventions have been associated with reductions in incidence and duration of delirium and improved patient outcomes such as shorter duration of mechanical ventilation, shorter ICU and hospital LOS, improved functional outcomes, and improved survival (Brummel & Girard, 2013; Girard, Kress, et al., 2008; Schweickert et al., 2009; Vasilevskis, Ely, et al., 2010).

Despite the potential improvements in patient care and outcomes that could result from combining these evidence-based processes of care for delirium into a care bundle, few ICUs have implemented the ABCDE bundle and only one small study has examined its effectiveness. Limited information exists regarding how to facilitate implementation, promote widespread adoption, and ensure sustainability of the ABCDE bundle in different ICU settings. In addition, no published studies have examined the effect of the bundle on the costs of patient care. This study aims to fill these critical gaps in knowledge pertaining to the prevention and mitigation of delirium in ICU patients. First, we examined the impact of two implementation strategies (basic versus enhanced) on ABCDE bundle adherence and the impact of bundle adherence on incidence and duration of delirium, and related patient outcomes such as days spent on a ventilator, coma days, ICU and hospital LOS, nursing home utilization, and mortality. Next, we conducted a mixed methods evaluation to determine how to facilitate adoption, implementation, and

routinization of the ABCDE bundle. Finally, we examined the cost-effectiveness of the ABCDE bundle in terms of cost per life and life year saved and quality-adjusted life years gained in the year following ICU admission.

CHAPTER 2. LITERATURE REVIEW

Diagnosis of Delirium

Delirium is characterized by a disturbance in attention or awareness that is accompanied by a change in baseline cognition that cannot be better explained by a preexisting or evolving neurocognitive disorder (American Psychiatric Association, 2013). The disturbance in attention is manifested by reduced ability to direct, focus, sustain, and shift attention and the disturbance in awareness is manifested by a reduced orientation to the environment or oneself. Delirium tends to fluctuate throughout the day, often worsening in the evening and night when external orienting stimuli decrease (American Psychiatric Association, 2013). The condition can be subcategorized as hypoactive, hyperactive, or mixed delirium (Hipp & Ely, 2012). Hypoactive delirium is characterized by psychomotor slowing, apathy, and decreased responsiveness. Hyperactive is characterized by psychomotor agitation, hallucinations, and emotional lability (Vasilevskis, Han, Hughes, & Ely, 2012). Patients with mixed delirium display symptoms of both types. Patients with some but not all symptoms of delirium are often diagnosed with subsyndromal delirium (Hipp & Ely, 2012).

Pathophysiology of Delirium

The pathophysiology of delirium is not well understood (Banerjee et al., 2011; Girard, Pandharipande, et al., 2008; Hipp & Ely, 2012). Delirium has been termed “organ failure” of the brain similar to other end-organ damage resulting from severe systemic disease and has multiple different and potentially interacting etiologies (Ouimet, Kavanagh, Gottfried, & Skrobik, 2007; Vasilevskis et al., 2012). The condition may be a

neurobehavioral manifestation of imbalances in the synthesis, release, and inactivation of neurotransmitters, particularly dopamine and acetylcholine, that normally control cognitive function, behavior, and mood (Hipp & Ely, 2012). Inflammation often contributes to multiple organ dysfunction in patients with critical illness, and inflammatory abnormalities induced by endotoxin and cytokines are likely to contribute to the development of delirium in the intensive care unit (ICU). Delirium may also be the result of a global failure of cerebral oxidative metabolism (Fink & Evans, 2002). The altered availability of large neutral amino acids may also be a contributing factor (van der Mast, 1998).

Delirium in Intensive Care Unit Patients

Delirium is common in ICU patients occurring in 40% to 60% of non-ventilated patients and 60% to 80% of ventilated patients (Hipp & Ely, 2012). Patients undergoing mechanical ventilation are particularly susceptible to the condition, as the analgesics, sedatives, and hypnotics that are frequently used in ICUs to achieve patient comfort are often deliriogenic (Banerjee et al., 2011; Hipp & Ely, 2012). The variation in delirium incidence rates can be attributed to differences in the severity of illness in ICU populations and poor diagnosis rates in some ICUs. Despite the high prevalence of delirium and the increasing publications on this topic, delirium remains unrecognized by the majority of clinicians (Morandi, Jackson, & Ely, 2009). Delirium symptoms can also overlap with symptoms of other neuropsychiatric disorders which makes diagnosis challenging. The prevalence of coma may also impact the prevalence of delirium, since delirium cannot be assessed among comatose patients (Vasilevskis et al., 2012). Delirium may be present on admission or develop during a patient's ICU stay, due to critical illness

or as a complication of medical treatment (Vasilevskis, Pandharipande, et al., 2010). Most ICU patients have hypoactive delirium (60%) or mixed delirium (Hipp & Ely, 2012). Hyperactive delirium is rare in the ICU and when it does occur it tends to fluctuate with hypoactive delirium (Vasilevskis et al., 2012).

Effect of ICU Delirium on Patient Outcomes

ICU-acquired delirium has been independently associated with increased cognitive and physical impairment, mortality, hospital length of stay (LOS), and health care costs (Ely, Gautam, et al., 2001; Inouye, 2006; Inouye et al., 1999; Lundstrom et al., 2005; Mercer et al., 2007; Milbrandt et al., 2004; P. P. Pandharipande et al., 2013; Pisani et al., 2007; Reston & Schoelles, 2013; Vidan et al., 2009). In a recent study, Panharipande et al. found that longer duration of delirium in ICU patients was independently associated with worse global cognition at 3 and 12 months as measured by scores on the Repeatable Battery for the Assessment of Neuropsychological Status (P = 0.001 and P = 0.04, respectively) and worse executive function as measured by scores on the Trail Making Test at 3 and 12 months (p = 0.004 and p = 0.007, respectively) (P. P. Pandharipande et al., 2013).

In a prospective study of 820 consecutive patients admitted to a 16-bed medical-surgical ICU, Ouimet et al. found that patients who developed delirium had significantly longer ICU stays (11.5 ± 11.5 vs. 4.4 ± 3.9 days, $p \leq 0.005$), longer hospital stays (18.2 ± 15.7 vs. 13.2 ± 19.4 days, $p \leq 0.005$), higher ICU mortality (20% vs. 10%, $p \leq 0.005$), and higher in-hospital mortality (31% vs. 24%, $p \leq 0.005$) (Ouimet et al., 2007). Similarly, in a prospective study of 144 postoperative patients admitted to the ICU, Robinson et al. found that patients who developed delirium had significantly longer ICU

stays (9.7 ± 8.0 vs. 4.6 ± 2.1 days, $p < 0.001$), longer hospital stays (16.3 ± 10.9 vs. 7.9 ± 3.9 days, $p < 0.001$), higher hospital costs ($50,100 ± $33,600 vs. $31,600 ± $14,100, $p < 0.001$), increased post-discharge utilization (33% vs. 1%, $p < 0.001$), increased 30 day mortality (9% vs. 1%, $p < 0.045$), and increased 60 day mortality (20% vs. 3%, $p = 0.001$) (Robinson et al., 2009). Given that ICU delirium is often a "missed" diagnosis (non-detection rates of 33%-66% have been reported), (Meagher, 2001) ICU delirium could have an even greater negative impact on patient outcomes and costs than reported by these and other studies.

Risk Factors for the Development of Delirium in the Intensive Care Unit

Multiple studies have examined risk factors for the development of delirium in ICUs (Aldemir, Ozen, Kara, Sir, & Bac, 2001; Dubois, Bergeron, Dumont, Dial, & Skrobik, 2001; Girard, Pandharipande, et al., 2008; McNicoll et al., 2003; Ouimet et al., 2007; P. Pandharipande et al., 2008; Pisani et al., 2007; Van Rompaey et al., 2009; Van Rompaey, Schuurmans, Shortridge-Baggett, Truijen, & Bossaert, 2008). These studies differ greatly in study design, site location, and study population and have investigated over 100 different variables for potential association with incidence and duration of delirium in the ICU (Vasilevskis et al., 2012). Although findings from these studies vary considerably, reported risk factors can be divided into 3 categories: 1) patient factors, 2) characteristics of acute illness, and 3) environmental or iatrogenic factors (Girard, Pandharipande, et al., 2008). Patients who are critically ill are often exposed to numerous factors that may precipitate delirium (Girard, Pandharipande, et al., 2008).

1) Patient Characteristics and Comorbidities

Increased age has been identified as one of the most significant risk factors for

development of delirium outside the ICU and the current evidence suggests that increased age may also be a risk factor for development of ICU delirium. (Barr & Pandharipande, 2013; Girard, Pandharipande, et al., 2008). Studies have reported rates of delirium among elderly ICU patients of between 70% and 87% (Flinn et al., 2009; Millar, 1981; Pisani, McNicoll, & Inouye, 2003; Seymour & Pringle, 1983). Pandharipande et al. found that the probability of developing delirium increased by 2% for every 1 year increase in patient age (P. Pandharipande et al., 2006). It is thought that delirium occurs more commonly in older adults as a result of several physiologic changes that influence how the body reacts to stress (Amador & Goodwin, 2005). With age, the central nervous system undergoes decreases in cerebral blood flow, loss of nerve cells, and neurotransmitter systems alterations, including reductions in carbonic anhydrase and acetylcholinesterase activity, serotonin receptors, and muscarinic receptors. Changes in drug metabolism as a result of aging may also play a role (Masica et al., 2007).

Several studies have demonstrated that pre-existing dementia is a risk factor for the development of ICU delirium (Barr et al., 2013; Pisani et al., 2007). In a prospective cohort study of 304 patients 60 years or older admitted to the ICU in an urban university teaching hospital, Pisani et al. found that a history of dementia was the strongest risk factor for developing delirium (odds ratio [OR] = 6.3; 95% confidence interval [CI] = 2.9-13.8; $P < .001$) (Pisani et al., 2007) Similarly, in a study of 144 patients over 50 years of age requiring postoperative ICU admission, Robinson et al. found that pre-existing dementia was the strongest risk factor for the development of postoperative delirium (Robinson et al., 2009). McNicoll et al. also found that patients with dementia were significantly more likely to develop delirium (risk ratio [RR] = 1.4, 95% CI: 1.1-

1.7) in a prospective study of 118 consecutive patients aged 65 and older admitted to the ICU of an 800-bed university teaching hospital.

Increased comorbidities, smoking, and alcoholism, may also place patients at greater risk of developing delirium (Girard, Pandharipande, et al., 2008). Robinson et al. found that increased comorbidities (as measured by the Charlson Index) and poorer functional status (as measured by the Barthel Index) were associated with increased risk of delirium (Robinson et al., 2009). Ouimet et al. found that risk of delirium was independently associated with a history of hypertension (OR = 1.88; 95% CI: 1.3-2.6; p = 0.005) and alcoholism (OR = 2.03; 95% CI: 1.2-3.2; p = 0.002) (Ouimet et al., 2007). Van Rompaey et al. found that intensive smoking (OR = 2.04; 95% CI: 1.05-3.95; p = 0.03) and daily use of more than three units of alcohol (OR = 2.48; 95% CI: 1.29-4.80; p = 0.01) contributed to the development of delirium (Van Rompaey et al., 2009).

Some patients may have a genetic predisposition to delirium. Ely et al. found that patients with the apolipoprotein E4 (APOE4) were more likely to have longer duration of delirium after adjusting for age, severity of illness, duration of coma, and admission diagnosis of sepsis, acute respiratory distress syndrome, or pneumonia (OR = 7.32; 95% CI: 1.82-29.51; p = 0.05) (Ely et al., 2007). Other patient characteristics including hearing or vision impairment and depression have been associated with delirium in hospitalized patients without critical illness and may pose similar risks in patients in the ICU (Girard, Pandharipande, et al., 2008)

2) Characteristics of Acute Illness

Ouimet et al. found that risk of delirium was independently associated with severity of illness as measured by APACHE II score at admission. Each increased

increment in APACHE II score increased the risk of delirium by 4.9% (95% CI: 1.03-1.07; $p < 0.0001$) (Ouimet et al., 2007). Similarly, Pandharipande et al. found that the probability of developing delirium increased by 6% for every one point increase in APACHE II score (95% CI: 1.02–1.11; $p = 0.004$) (P. Pandharipande et al., 2006). Aldemir et al. found that respiratory diseases (OR = 30.6; 95% CI: 9.5–98.4), infections (OR = 18.0; 95% CI: 3.5–90.8), fever (OR = 14.3; 95% CI: 4.1–49.3), anemia (OR = 5.4, 95% CI: 1.6–17.8), hypotension (OR = 19.8, 95% CI: 5.3–74.3) were predictors of delirium as well as metabolic disturbances such as hypocalcemia, hyponatremia, azotemia, hyperamylasmia, hyperbilirubinemia, and metabolic acidosis (Aldemir et al., 2001). Robinson et al. found that lower albuminium and anemia were also risk factors for the development of delirium (Robinson et al., 2009).

3) Environmental or Iatrogenic Factors

Psychoactive medications are a major iatrogenic factor associated with the development of delirium in the ICU (Ely, Siegel, & Inouye, 2001; Hipp & Ely, 2012). Mechanically ventilated patients requiring sedation have traditionally been treated with benzodiazepines, opiates, and propofol (Morandi et al., 2011). These drugs are used to reduce the work of breathing and alleviate agitation but are associated with increased risk of delirium, with benzodiazepines appearing to pose the highest risk (Vasilevskis, Ely, et al., 2010; Vasilevskis et al., 2012). The benzodiazepines lorazepam and midazolam are commonly used for sedation in ICU patients and have been found to be independent risk factors for transitioning into delirium (P. Pandharipande et al., 2008; P. Pandharipande et al., 2006). In a study of 100 surgical and trauma ICU patients, Pandharipande et al. identified exposure to the sedative midazolam (OR = 2.75; 95% CI: 1.43-5.26; $p = 0.002$)

as the strongest independent risk factor for transitioning to delirium (P. Pandharipande et al., 2008). In another study, Pandharipande et al. found that exposure to lorazepam (OR = 1.2; 95% CI: 1.1-1.4; $p = 0.003$) significantly increased a patient's risk of developing delirium. Only one high quality study has explicitly addressed the association between propofol and delirium risk, and the researchers found no significant relationship (Barr et al., 2013) (P. Pandharipande et al., 2006). Several studies have examined the relationship between use of opiods and development of delirium, but medication type, study design, and study outcomes vary considerably among these studies (Barr et al., 2013). The majority of studies reported either an increased risk of delirium (Dubois et al., 2001; Pisani et al., 2009) or no association (P. Pandharipande et al., 2006; Van Rompaey et al., 2009).

Sedatives and analgesics have been found to increase the risk of delirium when used to induce coma (Ouimet et al., 2007). Patients are often placed in a medically-induced coma to reduce distress and oxygen consumption, but this approach often results in long periods of unconsciousness and immobility (Schweickert et al., 2009). Ouimet et al. found that iatrogenic coma was associated with increased risk of delirium (OR = 3.22; 95% CI: 1.52–6.81) (Ouimet et al., 2007). Ely et al. found that the number of days patients spent in a coma was associated with increased duration of delirium (OR = 1.32; 95% CI: 1.08-1.60; $p = 0.006$).

Lack of mobilization during hospitalization has been recognized as a risk for hospital-related functional decline (Brown, Friedkin, & Inouye, 2004). ICU-acquired weakness affects 25-60% of critically ill patients and has been associated with prolonged mechanical ventilation, increased hospital LOS, and increased likelihood of death

(Morandi et al., 2011). Immobilization resulting from the placement of catheters or restraints has been associated with the development of delirium in hospitalized patients without critical illness (McCusker et al., 2001).

Prevention and Treatment of Delirium

Strategies for the prevention of treatment of delirium include pharmacologic and non-pharmacologic approaches.

1) Pharmacologic Approaches

The Food and Drug Administration has not approved any medications specifically for the prevention and treatment of delirium (Brummel & Girard, 2013; Hipp & Ely, 2012). Haloperidol and atypical anti-psychotics have emerged as the standard pharmacological treatments for delirium in ICU patients (Hipp & Ely, 2012). However, no prospective clinical trials have verified their safety and efficacy (Barr et al., 2013). Use of non-benzodiazepine sedatives may help prevent development of delirium in ICU patients (Barr et al., 2013; Hipp & Ely, 2012). Recent guidelines issued by the American College of Critical Care Medicine for the management of pain, agitation, and delirium suggest that sedation with propofol or the alpha-2 agonist dexmedetomidine may be preferred over sedation with the benzodiazepines midazolam or lorazepam. In a randomized controlled trial, Pandharipande et al. compared dexmedetomidine with lorazepam for sedation in 375 mechanically ventilated patients at 68 centers and found sedation with dexmedetomidine resulted in more days alive without delirium or coma ($p < 0.001$) than sedation with lorazepam and reduced the daily risk of delirium ($p = 0.02$) (P. P. Pandharipande et al., 2007) (P. P. Pandharipande et al., 2010). However, the clinical significance of the comparative deliriogenic effects is unclear, as only one high

quality clinical trial has indicated that benzodiazepines pose higher risks than dexmedetomidine and benzodiazepines remain important for managing agitation in ICU patients (Barr et al., 2013).

2) Non-Pharmacologic Approaches

Non-pharmacological approaches for the prevention and mitigation of delirium in ICU patients include “liberation” and “animation” strategies and the application of delirium mediating measures including environmental adjustments (Morandi et al., 2011; P. Pandharipande, Banerjee, McGrane, & Ely, 2010). Liberation refers to reducing the harmful effects of sedative exposure through the use of target-based sedation protocols, spontaneous awakening trials (SATs), and the proper choice of sedative, as well as liberation from mechanical ventilation and the ICU (Hipp & Ely, 2012). Patients who are continuously sedated are at risk for longer duration of mechanical ventilation, longer ICU and hospital LOS, and limited physical and neurological examination (Kress, Pohlman, O'Connor, & Hall, 2000). Kress et al. found that use of a daily SAT featuring an interruption of sedatives to allow the patient to “wake up” decreased duration of mechanical ventilation by 2 days ($p = 0.004$) and length of stay in the ICU by 3.5 days (Kress et al., 2000).

Liberating patients from mechanical ventilation as soon as they are ready to breathe on their own may reduce incidence of delirium and reduce length of stay (Kress et al., 2000; Morandi et al., 2011). Terminating mechanical ventilation requires objective assessment of patient readiness; however, many decisions to discontinue mechanical ventilation are based on an individual clinician’s judgment and experience (Ely et al., 1996). Ely et al. found that the use of daily spontaneous breathing trials (SBTs) to assess

patient readiness for ventilator weaning lead to a 1.5 day decrease ($p = 0.003$) in weaning time and 50% fewer ventilator-related complications compared to the use of physician judgment alone (Ely et al., 1996).

"Animation" refers to early mobilization of patients to help rehabilitate the muscles and nerves (P. Pandharipande et al., 2010). Two studies indicated that use of early mobilization in combination with other delirium prevention and mitigation strategies was associated with reduced incidence of delirium and improved patient outcomes (Needham et al., 2010; Schweickert et al., 2009).

Despite its high prevalence in ICU patients, delirium often goes undetected and unmanaged (Soja et al., 2008). Thus, the most important step in delirium management is early recognition through validated assessments (Morandi et al., 2011) The Confusion Assessment Method for the ICU (CAM-ICU) is a validated tool for the assessment of delirium, demonstrating a sensitivity of 93% to 100%, a specificity of 98% to 100% , and high inter-rater reliability ($\kappa = 0.96$) (Ely, Inouye, et al., 2001).

In addition, providing patients with cognitive stimulation and assistive devices such as glasses and hearing aids and ensuring sleep preservation and pain control have been associated with reductions in the incidence of delirium as have interventions that have addressed environmental factors such as lack of natural light and clocks in patient rooms (Chen et al., 2011; Inouye, Bogardus, Williams, Leo-Summers, & Agostini, 2003; Rubin, Neal, Fenlon, Hassan, & Inouye, 2011; Vasilevskis, Ely, et al., 2010). The American College of Critical Care Medicine's recently issued "Clinical Practice Guidelines for the Management of Pain, Agitation, and Adult Patients in the Intensive Care Unit" recommend many of these strategies for prevention and management of

delirium including routine monitoring of delirium in patients using valid tools such as the CAM-ICU or the Intensive Care Delirium Screening Checklist; early mobilization; daily sedation interruption or a light level of target sedation; and the promotion of sleep in ICU patients by optimizing patients' environments, using strategies to control light and noise, clustering patient care activities, and decreasing stimuli at night (Barr et al., 2013).

Evidence-based Practices for Delirium Prevention have not been Widely Adopted

Despite more than a decade of evidence indicating the hazards of delirium and the benefits of these interventions in preventing and mediating this condition, a substantial implementation gap continues to exist between the current state and ideal ICU practice in this area (Vasilevskis, Ely, et al., 2010). Less than 60% of ICUs in the United States have implemented protocols for the management of delirium, and when instituted, protocol adherence is low (Barr et al., 2013). Rates of daily sedation interruptions and breathing trials for mechanically ventilated patients have been reported to be under 40% in cross-sectional surveys (Kahn, Brake, & Steinberg, 2007; Mehta et al., 2006). Use of validated tools for delirium monitoring and sedation scales reportedly is below 40% (Mehta et al., 2006; Patel et al., 2009). Likewise, less than 50% of patients receive any physical therapy during their ICU stay (Morris et al., 2008; Thomsen, Snow, Rodriguez, & Hopkins, 2008).

The failure of ICU clinicians to implement and adhere to evidence-based care practices targeting delirium prevention is due to a number of factors including a lack of awareness surrounding the high prevalence of delirium and its adverse effects and a paucity of details on how to incorporate these care practices into daily workflow. Clinicians often fail to identify delirium, and when recognized, it may not be addressed to

the same degree as other acute organ system dysfunctions (Inouye et al., 1999). Delirium is often mistaken for depression, senescence, or dementia, and it is commonly believed that delirium has no impact on a patient's overall outcome (Ely et al., 2004). Furthermore, although practice guidelines exist for ICU delirium, delivering these measures to patients is hampered by issues of staff availability, competing clinical priorities, and suboptimal coordination of care team activities (Inouye et al., 2003; Jacobi et al., 2002).

Changing Behaviors and Routines in Health Service Delivery Organizations to Improve Health Outcomes

Given the prevalence of delirium, its negative effects on patient outcomes, and its associated costs, innovations in ICUs are needed to promote the uptake of evidence-based guidelines that have been associated with reductions in delirium and improved patient outcomes. In their theoretical framework of complex innovation in health services organizations, Greenhalgh et al. define innovation in service delivery as a novel set of behaviors, routines, and ways of working that are directed at improving health outcomes, administrative efficiency, cost effectiveness, or users' experience and that are implemented by planned and coordinated actions (Greenhalgh, Robert, Macfarlane, Bate, & Kyriakidou, 2004). Greenhalgh et al.'s framework builds on Everett Rogers' diffusion of innovation studies in rural sociology (Rogers, 2003), as well as studies in fields such as medical sociology, communication studies, health promotion, evidence-based medicine, and organizational culture.

Rogers and Greenhalgh et al. have emphasized that diffusion of innovation in organizations is highly dependent on how potential adopters view the attributes of the

innovation as well as organizational factors. In a systematic review, Rogers found that five key attributes of innovations (relative advantage, compatibility, complexity, trialability, and observability) explained approximately 49% to 87% of the variance in the rate of adoption of innovations. Relative advantage is the degree to which an innovation is perceived as better than the idea it supersedes and is one of the strongest predictors of an innovation's rate of adoption (Rogers, 2003). Relative advantage is not so much dependent on "objective" advantage but is more a function of the individual's perception of the innovation as advantageous. Compatibility is defined as the degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs of potential adopters. An innovation can be compatible or incompatible with sociocultural values and beliefs, previously introduced ideas, and/or client needs for innovation.

Complexity is the degree to which an innovation is perceived as difficult to understand and use. Innovations that are perceived by key players as simple to use are adopted more rapidly than innovations that require the adopter to develop new skills and understandings. Trialability is the degree to which an innovation may be experimented with on a limited basis. New ideas that can be tried on the installment plan are generally adopted more rapidly as they reduce levels of uncertainty of the adopter and allow the adopter to learn by doing. Designing an innovation so that it may be tried out more easily will improve the likelihood of adoption. Observability is the degree to which the results of an innovation are visible to others. Studies have shown that the easier it is for individuals to observe the results of the innovation, the more likely they will be to adopt the innovation (Rogers, 2003).

The United Kingdom Department of Health commissioned Greenhalgh et al.'s work to determine how innovations in health service delivery could be spread and sustained (Greenhalgh et al., 2004). Greenhalgh et al.'s conceptual model describing the determinants of diffusion, dissemination, and implementation of innovations in health service delivery and organization depicts how the diffusion or dissemination process leads to adoption and assimilation of an innovation followed by implementation. The researchers distinguish between diffusion (passive spread of an innovation), dissemination (active and planned efforts to persuade target groups to adopt an innovation), and implementation (active and planned efforts to mainstream an innovation within an organization). The model also describes the links between the user system and the resource system and change agency, the role of knowledge purveyors, the influence of system antecedents, system readiness consequences of implementation, and the external environment.

In a multi-site case study of the implementation of shared electronic health records, Greenhalgh et al. narrowed the multiple components of the diffusion of innovation model for complex innovations to nine key components (Greenhalgh et al., 2008). These key components included the attributes of the innovation including the five innovation attributes identified by Rogers plus the attribute of reinvention and organizational-level factors including communication channels, organizational antecedents for innovation, organizational readiness for change, the implementation and routinization process, and the wider environment. Reinvention is the degree to which users can adapt, refine, or otherwise modify the intervention to suit their own needs. Communication channels include the mass media and interpersonal influence that can

change individuals' attitudes toward adoption. Organizational antecedents for innovation include factors such as absorptive capacity for new knowledge, leadership and management, risk-taking climate, effective data capture systems, and slack resources. Organizational readiness for change describes innovation-system fit, tension for change, balance between supporters and opponents, and specific preparedness. Key components of the implementation and routinization process include an appropriate change model, good project management, autonomy of frontline teams, human resource factors, and alignment between new and old routines. The wider environment is defined as the socio-political climate and the presence of mandates at the national level.

Use of Care Bundles as an Innovation to Improve Delivery of Evidence-based Medicine

Although evidence-based guidelines have been developed for several conditions, many clinicians are unaware of them or have difficulty translating them into practice (Go et al., 2013; Hawe et al., 2009; Levy et al., 2004). Care bundles have been proposed as tools to promote rapid adoption of proven therapies, benchmark performance, and improve patient outcomes (Barochia et al., 2010). A bundle is a vetted collection of interventions or processes of care that are derived from evidence-based practice guidelines that, when utilized together, can enhance the quality of care (*Crossing the Quality Chasm: A New Health System for the 21st Century*, 2001; Levy et al., 2004). Care bundles have been applied to the management and prevention of complex conditions such as central line infections, ventilator-associated pneumonia, and sepsis as a means to help clinicians reliably deliver evidence-based processes of care (Barochia et al., 2010; Furuya et al., 2011; Hawe et al., 2009; Morandi et al., 2011). Use of care bundles for

these conditions has been associated with improved delivery of evidence-based practices and patient outcomes in ICUs (Barochia et al., 2010; Bird et al., 2010; Croce et al.; Furuya et al., 2011; Koll et al., 2008; Miller et al., 2013; O'Keefe-McCarthy, Santiago, & Lau, 2008; Pronovost et al., 2006; Resar et al., 2005; Wip & Napolitano, 2009). Use of ventilator care bundles, for example, has been found to reduce ventilator-associated pneumonia rates by 44.5 % (Resar et al., 2005). In a systematic review of clinical trials examining the use of bundled care for septic shock, Barochia et al. found that sepsis bundles were associated with a consistent and significant increase in survival (OR 1.91) (Barochia et al., 2010). For all studies included in the review reporting such data, there were consistent decreases in time to antibiotics and increases in the appropriateness of antibiotics.

Use of Care Bundles for Prevention and Mitigation of Delirium

Delirium is a complex condition that may be prevented or mitigated through the alignment of people, processes, and technology that currently exist in ICUs (Hipp & Ely, 2012; Vasilevskis, Ely, et al., 2010). Two bundled care processes have been proposed for the management of delirium, the ABCDE bundle and the PAD bundle.

ABCDE Bundle

The ABCDE bundle has been proposed as an interdisciplinary, multi-component patient safety intervention in ICUs to reduce incidence of delirium by improving collaboration among clinical team members, standardizing care processes, and breaking the cycle of oversedation and prolonged ventilation (Balas et al., 2013; Balas et al., 2012; Girard, Pandharipande, et al., 2008; Hipp et al., 2013; Vasilevskis, Ely, et al., 2010; Vasilevskis, Pandharipande, et al., 2010). The ABCDE bundle incorporates several

individual evidence-based critical care processes into a single, integrated package. The following clinical practices are included in the bundle:

- **Awakening Trials (SATs)**

  Daily awakening of patients with cessation of sedating medications

- **Breathing Trials (SBTs)**

  Daily assessment of patients' readiness to discontinue mechanical ventilation

- **Coordination of daily awakening and breathing trials**

  Administration of SAT followed by SBT within the same nursing shift

- **Delirium Monitoring and Management**

  Daily assessment for delirium using the Confusion Assessment Method for the ICU (CAM-ICU)

- **Exercise/Early Mobility**

  Daily physical therapy evaluation and mobilization out of bed during previous 24 hours

PAD Bundle

Recently, the Society of Critical Care Medicine issued guidelines for the management of pain, agitation, and delirium (PAD) in the ICU and created a PAD bundle and corresponding metrics to facilitate implementation of multiple care processes (Barr et al., 2013). The PAD bundle is broader than the ABCDE bundle and includes regular assessment of PAD with validated screening tools, guidelines for pharmacologic and non-pharmacologic treatment of PAD, use of daily breathing trials, early mobility and exercise, and strategies to preserve patients' sleep-wake cycles (Balas et al., 2013).

Multifaceted Care Approaches for the Prevention and Mitigation of Delirium in ICU Patients

We conducted a systematic literature review to examine the impact of the ABCDE and PAD bundles and other multifaceted care approaches for the prevention and mitigation of delirium in ICU patients on: 1) improving patient-centered clinical outcomes; 2) care process adoption success; and 3) cost savings (Collinsworth, Priest, Campbell, Vasilevskis, & Masica, 2014). The review was based on the PRISMA statement guideline and was conducted utilizing PubMed, EMBASE, and CINAHL. We included randomized controlled trials, clinical trials, or comparative studies of multifaceted or bundled care processes that examined the incidence of delirium in ICU patients as a primary or secondary outcome and evaluations of the implementation or cost-effectiveness of these types of interventions. For inclusion, studies had to demonstrate usage of at least two of the following therapies:

1. daily sedation interruption (spontaneous awakening trial (SAT))
2. daily assessment of patient readiness for extubation (spontaneous breathing trial (SBT))
3. daily sedation monitoring with a validated screening tool
4. daily delirium monitoring with a validated screening tool
5. targeted pharmacological strategies (i.e. protocols for prescription of analgesics and sedatives)
6. non-pharmacological delirium management/mediating strategies (i.e. cognitive stimulation, use of glasses/hearing aids, sleep preservation)
7. early exercise or mobility protocol

Fourteen studies met our inclusion criteria for the systematic review: six studies examined outcome measures related to multicomponent interventions, five studies

examined implementation strategies (Balas et al., 2013; Balas et al., 2014; Colombo et al., 2012; Girard, Kress, et al., 2008; Mehta et al., 2012; Schweickert et al., 2009; Skrobik et al., 2010), two studies examined both outcomes measures and implementation strategies (Hager et al., 2013; Needham et al., 2010), and one study examined the cost-effectiveness of a multifaceted care processes for the management of analgesia, sedation, and delirium (Awissi, Begin, Moisan, Lachaine, & Skrobik, 2012).

Effectiveness of Bundled and Multifaceted Care Practices on Patient Outcomes

Eight studies examined outcome measures pertaining to delirium. Three of the studies were randomized controlled trials (RCTs) and five were controlled clinical trials (CCTs) that examined differences in patient outcomes before and after the implementation of multifaceted care processes. There was great heterogeneity among the studies in terms of intervention components and outcome measures. The majority of studies featured interventions for sedation interruption and management; however, these interventions differed across studies and were combined with various therapies including daily breathing trials, reorientation strategies, early rehabilitation, environmental stimulation, pain assessment, and delirium screening. One study examined the effectiveness of the ABCDE bundle (Balas et al., 2014). Adherence to intervention components ranged from 52% to 100%, but overall compliance was difficult to assess as five of the studies did not report adherence for at least one component of the intervention. Improvements in outcomes for ICU patients receiving care bundles were noted in all studies with the exception of the RCT conducted by Mehta et al., which found that the addition of daily sedation interruption for mechanically ventilated adults under

protocolized sedation did not reduce duration of mechanical ventilation or length of ICU stay (Mehta et al., 2012).

Delirium Outcomes

Delirium was not assessed consistently across the seven studies, but five of the studies found that use of multifaceted care processes was associated with significant reductions in incidence of delirium, duration of delirium, or days patients spent awake and not delirious. Colombo et al. found that adding a re-orientation strategy and environmental, acoustic, and visual stimulation to an ICU process of care that included daily sedation interruption and breathing trials as well as a twice daily delirium assessment reduced the incidence of delirium from 35% to 22% ($p = 0.020$) (Colombo et al., 2012). After implementation of a new sedation protocol designed to decrease use of continuous sedative infusions and twice-daily delirium screening, Hager et al. observed a significant increase in the median proportion of ICU days awake and not delirious per patient (0% vs. 19%, $p < 0.001$) (Hager et al., 2013). Needham et al. found that use of a multi-disciplinary team focused on reducing heavy sedation and adding physical and occupational therapists to ICU staffing increased the percentage of days that ICU patients were alert (29% vs. 66%, $p < 0.001$) and not delirious (21% vs. 53%, $p = 0.003$) (Needham et al., 2010). Similarly, Schweickert et al. found that combining daily interruption of sedation with physical and occupational therapy reduced the duration of delirium in mechanically ventilated ICU patients compared to sedation interruption alone (median 2.0 days vs. 4.0 days, $p = 0.02$) (Schweickert et al., 2009). Balas et al. found that implementation of the ABCDE bundle significantly decreased the risk-adjusted odds of developing delirium (OR = 0.55; 95% CI: 0.33-0.93; $p = 0.03$) (Balas et al., 2014). Also,

the percent of ICU days spent delirious decreased by 17% (50% vs. 33%, $p = 0.03$) following bundle implementation.

Although Skrobik et al. did not observe a difference in incidence of delirium in patients after the introduction of a management protocol for analgesia, sedation, and delirium and reorientation strategies, a significant reduction in the incidence of subsyndromal delirium occurred post-implementation (Skrobik et al., 2010). Mehta et al. found no significant differences between treatment and control groups in incidence (53% vs. 54%, $p = 0.83$) of delirium, and Girard et al. found no significant differences between groups in incidence (74% vs. 71%, $p = 0.66$) or duration (2.0 days vs. 2.0 days, $p = 0.50$) of delirium (Girard, Kress, et al., 2008; Mehta et al., 2006).

Coma/Ventilator Days

Four out of five studies that examined ventilator use found that multicomponent interventions were associated with significant reductions in ventilator days. In addition, three of the five studies found that multicomponent care processes were associated with a significant reduction in coma days or incidence of iatrogenic coma (Girard, Kress, et al., 2008; Schweickert et al., 2009; Skrobik et al., 2010).

Length of Stay

In 3 studies, use of multicomponent strategies for delirium prevention was associated with significant decreases in both ICU and/or hospital length of stay (LOS). Girard et al. observed a 3.8 day reduction in median ICU LOS ($p < 0.001$) and a 4.3 day reduction in median hospital LOS ($p <.001$) in the treatment group (Girard, Kress, et al., 2008). Needham et al. and Skrobik et al. found a 2.1 and 0.97 day reduction in mean ICU LOS ($p = 0.020$, $p = 0.009$) and similar significant reductions in mean hospital LOS

for patients in the treatment groups, respectively (Needham et al., 2010; Skrobik et al., 2010). Two studies did not report outcomes related to LOS (Colombo et al., 2012; Hager et al., 2013), and three studies found no significant differences in LOS between treatment and control groups (Balas et al., 2014; Mehta et al., 2012; Schweickert et al., 2009).

Use of Sedatives and Analgesics

Seven studies examined the effect of multifaceted interventions on benzodiazepine and narcotic use, and four of these studies also examined propofol use. The remaining study examined risk factors for delirium and found that sedation with midazolam plus opiates was a significant predictor of delirium (HR = 2.145; 95% CI: 2.247-4.032; $p = 0.018$) (Colombo et al., 2012). Three studies reported that multifaceted interventions were associated with significant decreases in the number of patients who received benzodiazepines and narcotics (Hager et al., 2013; Needham et al., 2010; Skrobik et al., 2010). Mehta et al. found that adding daily sedation interruption to a sedation protocol resulted in significant increases in benzodiazepine and narcotic use while Schweickert et al. and Girard et al. found that use of these drugs did not differ significantly between treatment and control groups (Girard, Kress, et al., 2008; Mehta et al., 2012; Schweickert et al., 2009). One of the 3 studies that examined propofol use found a significant decrease in propofol administration (Skrobik et al., 2010) after the introduction of a management protocol for analgesia, sedation, and delirium and reorientation strategies. Balas et al. found no significant differences in the number of patients treated with or dosing of benzodiazepines, opiates, or propofol after ABCDE bundle implementation (Balas et al., 2014).

Mortality

Seven studies examined in-hospital or short-term mortality as an outcome measure. Skrobik et al. found that use of a multifaceted management process for delirium was associated with a significant decrease in 30-day mortality risk, while the other studies found no significant differences in in-hospital or short-term mortality between treatment and control groups (Skrobik et al., 2010). Girard et al. observed a significant reduction in 1-year mortality (HR = 0.68, $p = 0.01$) in patients who received a daily SBT and a SAT compared to patients who only received an SBT.

Functional Status

Three studies examined the effect of multifaceted care approaches on functional status. Schweickert et al. found that patients who were treated with a multifaceted care process including early physical therapy were significantly more likely to regain functional status at discharge (OR = 2.7, $p = 0.02$), and Skrobik et al. found that patients who received a multifaceted intervention were more likely to be able to return home (74.8% vs. 68.2%, $p = 0.049$) following hospitalization (Schweickert et al., 2009; Skrobik et al., 2010). Balas et al. found no significant differences in the number of patients who were able to return home following discharge following ABCDE bundle implementation (Balas et al., 2014).

Safety Outcomes

Four studies reported the effect of implementation of multifaceted care processes on self-extubations. Girard et al. found that a paired sedation and ventilator weaning protocol led to a significant increase in self-extubation (10% vs. 4%, $p = 0.03$); however, the rate of reintubation was similar to the control group indicating that some patients who

self-extubated were ready to come off the ventilator (Girard, Kress, et al., 2008). Mehta et al. and Schweickert et al. did not observe significant differences in self-extubation rates between treatment and control groups (Mehta et al., 2012; Schweickert et al., 2009). In addition, Girard et al. and Mehta et al. found no significant differences between groups in the number of patients requiring reintubation within 48 hours or eventual tracheostomy (Girard, Kress, et al., 2008; Mehta et al., 2012). Balas et al. found no significant differences in unplanned extubation, self-extubations, or tracheostomy following ABCDE bundle implementation.

Implementation

Seven studies examined the implementation of multifaceted care processes for delirium. The majority of studies used structured educational processes. Two studies used the 4Es (engage, educate, execute, evaluate) framework as a structured approach to quality improvement with ongoing “evaluation” through audit and feedback (Hager et al., 2013; Needham et al., 2010). This approach combined with the use of multidisciplinary teams of ICU physicians, nursing and pharmacy representatives, delirium experts, and rehabilitation therapists was associated in both studies with substantial changes in routine practice and observed decreases in the use of continuous sedative infusions. One study found a significant increase in early physical and occupational therapy. Radtke et al. found that the use of a modified extended training strategy for ICU monitoring tools led to higher intermediate and long-term implementation rates compared to standard training (Radtke et al., 2012). Both training strategies featured lectures, videos, handouts, and one-on-one bedside instruction. The modified training included a support team of 2

nurses and physician experts and 3 rounds of standard training with an enhanced curriculum.

Pun et al. used a systematic implementation strategy consisting of staged education interventions at regular intervals, daily collection of compliance data, and spot checks on a random 40% of nurses (Pun et al., 2005). The researchers reported that with minimal training, bedside nurses applied the sedation instrument 94.4% of the time in one ICU and 99.7% in another ICU, and applied the delirium instruments 90% and 80% of the time respectively. Nurses reported the most common barriers to implementation were time (31%), physicians (27%), and confidence in performing delirium assessments (20%). Beck et al. deployed a nurse-driven sedation protocol for management of delirium including a standardized drug ordering policy, use of infusion pumps with standardized drug concentrations, education for ICU nurses over a 3-month span, and clinical experts to provide staff support (Beck & Johnson, 2008). A survey of ICU nurses found no significant changes in quality of care, perception of autonomy, the protocol's ease of use, and perceived confidence at 3, 6, and 12 months. However, several staff provided feedback that the protocol was easier to use over time and that they became increasingly comfortable using the infusion pumps. The researchers reported many implementation challenges including a lengthy protocol development and approval process, difficulties in educating nurses and physicians, lack of physician and nurse compliance, perceptions that administration of the protocol was difficult, fear of patient harm, and equipment/resource problems.

Similarly, Balas et al. examined a multifaceted strategy for the implementation of the ABCDE bundle consisting of the use of clinical champions, an online education

module, posters, pocket cards, on-going in-services, electronic documentation, ongoing reporting of outcomes data, focus groups, and surveys (Balas et al., 2013). Participants reported that they learned the most about the ABCDE bundle by completing the online education program (38%) and attending unit-based in-services (17%). After completing the online training, participants felt that the bundle positively influenced patient outcomes (77%), was applicable to their current practice (68%), and was evidence-based (67%). Following ABCDE bundle implementation, the majority of surveyed ICU team members indicated that they were confident in their ability to use the bundle (75%), the bundle was being used in their unit (57%), and they had the necessary support to implement the bundle (53%). However, half of the respondents indicated that they did not think the ABCDE bundle improved outcomes and 28% indicated that the ABCDE documentation was too time consuming. Identified barriers to implementation included intervention-related issues (e.g., timing of trials, fear of adverse events), communication and care coordination challenges, knowledge deficits, workload concerns, and documentation burden.

Kastrup et al. found that use of an electronic feedback system to monitor and report compliance with key performance indicators (KPIs) was associated with a significant increase in completion of delirium screening, analgesia evaluation, and a weaning protocol. Implementation strategies included using the electronic health record to capture data from the ventilation and monitoring systems, producing 24-hour color-coded summary reports of KPI data, monthly reporting of the KPI summary to physician and nurses, and training of the ICU team.

Cost

Awissi et al. examined the cost-effectiveness of the I-SAVE study conducted by Skrobik et al. in 2010 (Awissi et al., 2012). Although the incidence of delirium remained the same between groups, the mean total costs of an ICU hospitalization (in 2004 Canadian dollars) decreased from $6,213 in the control group to $5,280 in the group of ICU patients treated with a sedation, analgesia, and delirium management protocol (p = .02). The duration of mechanical ventilation was shorter for patients in the treatment group, and the approximately $1,000 reduction in costs in this group was primarily due to an average one day reduction in LOS. Analgesic, sedative, and antipsychotic drug use was also lower in the treatment group, which slightly contributed to observed reductions in cost. Cost-effectiveness was calculated by associating the variation of costs and effectiveness measures (proportion of patients within targeted pain, sedation, and delirium goals). Costs were calculated as the sum of acquisition costs of drugs used for sedation, analgesia, or delirium in the ICU and the cost of ICU stay (number of ICU days multiplied by the average 1-day cost of ICU hospitalization for the facility). Nursing time, professional fees, and workload costs were not taken into account.

Summary of Findings

Despite the great variation in interventions and measured and observed outcomes in the studies included in this review, the evidence indicates that utilizing a multifaceted care process for the prevention and treatment of delirium in ICUs may improve patient outcomes including incidence and duration of delirium, coma days, days spent on a ventilator, hospital LOS, functional status, and mortality rates. Significant decreases in the use of sedative and analgesics, which are associated with an increased risk of

delirium, were observed in several of the included studies (Vasilevskis, Ely, et al., 2010). Multi-faceted interventions did not appear to pose a threat to patient safety, although only four studies reported safety outcomes. Many different implementation strategies were used including structured quality improvement approaches with ongoing audit and feedback, multi-disciplinary care teams, order sets, intensive training, electronic reporting systems, and local support teams. Time, confidence in deploying the care processes, resistance to change by physicians and nurses, and concerns about patient safety were reported barriers to implementation. The one evaluation of costs associated with implementation of a multifaceted care process found that hospital costs for patients in the intervention group were $1,000 less on average.

The majority of the studies included in this review indicated that multifaceted care processes in the ICU can reduce incidence and duration of delirium. However, three of the studies reported no significant differences in incidence or duration of delirium between the treatment and the control groups. Reduction in coma rates, heterogeneity among interventions, differences in the existing standard of care in study ICUs, choice of sedation, and poor adherence to intervention protocols likely contributed to the observed variation in outcomes.

While noting improvements in other outcomes such as coma and ventilator days and LOS, Girard et al. and Skrobik et al. did not observe significant reductions in delirium in the intervention groups, although Skrobik et al. did observe a significant decrease in subsyndromal delirium. Skrobik et al. suggested that the lack of observed differences in incidence of delirium could be attributed to the reduction in iatrogenic coma in the intervention group which “unmasked” patients with delirium (Skrobik et al.,

2010). This observation has significant implications for research on prevalence of delirium in ICUs as ICU patients are more susceptible to sedation-induced coma than non-ICU patients, and patients who are sensitive to the effects of sedation may also be more likely to develop delirium. Reducing the number of patients who receive coma-inducing sedation may increase the number of patients with observed delirium and vice versa. Thus, the number of delirium and coma free days may be a more appropriate primary outcome measure in studies examining prevalence of delirium in ICUs.

The lack of observed reductions in incidence or prevalence of delirium in some of the studies included in this review may be attributable to the types of interventions selected as components of the multifaceted interventions and/or the treatment received by the control group. For instance, Girard et al. compared a daily SAT plus a daily SBT to the use of a SBT alone (Girard, Kress, et al., 2008; Skrobik et al., 2010). Although the bundle deployed by Skrobik et al. was broader and featured a management protocol for analgesia, sedation, and delirium as well as reorientation treatments, the control group received a pain, sedation, and delirium evaluation every 8 hours, and clinicians may have employed care strategies designed to reduce delirium based on the results of the evaluations. Contrary to findings of the other studies included in this review, Mehta et al. did not observe any significant improvements in delirium or other clinical outcomes in patients who received a multifaceted care process, but they did observe significant increases in the administration of sedative and analgesics. However, the intervention was limited to protocolized sedation combined with daily sedation interruption, and patients in the control group received protocolized sedation as standard of care. The largest effect of a multifaceted strategy on incidence of delirium (OR = 0.55) was observed in the study

conducting by Balas et al., which included all five elements of the ABCDE Bundle (Balas et al., 2014).

Choice and dosing of sedation may also mask potential beneficial effects of multi-faceted interventions for delirium. The 2013 Society of Critical Care Medicine's Guidelines for the Management of Pain, Agitation, and Delirium in ICU Patients suggest that sedation strategies using non-benzodiazepine sedatives (either propofol or dexmedetomidine) may be preferred over sedation with benzodiazepines such as midazolam (Barr et al., 2013). Several studies have demonstrated reduced incidence of delirium and duration of mechanical ventilation in patients treated with non-benzodiazepines compared to patients treated with benzodiazepines (P. P. Pandharipande et al., 2007; Riker et al., 2009). In the study conducted by Mehta et al., patients in both the treatment and control groups received high average daily doses of midazolam (102 mg and 82 mg, respectively $p = 0.04$) compared to other published studies. In comparison, in studies of daily sedation conducted by Kress et al. and Colombo et al., average daily doses of midazolam were between 27.5 mg and 58.0 mg (Colombo et al., 2012; Kress et al., 2000). The high doses of midazolam in general combined with the fact that the intervention group received significantly higher doses of the drug may have offset the effects of sedation interruption in the study conducted by Mehta et al. (Kress & Hall, 2012).

Adherence to intervention protocols was low in some of the studies reviewed and may have contributed to the lack of observed differences in treatment and control groups in reductions in incidence or prevalence of delirium. In the study conducted by Mehta et al., patients did not receive daily sedation interruption and SBT for 28% and 18%

respectively of all eligible study days (Mehta et al., 2012). In addition 53% of patients missed at least one daily sedation interruption. In the study conducted by Skrobik et al., only 52% of the patients in the intervention group received pharmacological management of analgesia and sedation prescribed by protocol. Although patients in the Mehta at al. study were supposed to be treated according to a protocol designed to reduce incidence of oversedation, patients in the treatment group received higher and more frequent doses of sedatives, and clinical personnel expressed reluctance to interrupt sedation infusions due to concerns regarding the safety and comfort of the patients. These findings emphasize the need for cultural change in ICUs to facilitate the adoption of new care processes and improve protocol adherence.

Variable effectiveness of interventions can also be related to differing adoption of the interventions or contextual factors (Auerbach et al., 2013). While some studies examined implementation processes, only the study by Balas et al. used an implementation framework to examine contextual factors in ICUs that may have influenced adoption. Understanding the organizational factors that facilitate or hinder implementation of new processes of care and how to tailor implementation to overcome barriers is crucial to the widespread adoption of practices to reduce delirium. Despite the abundance of evidence that has been produced over the last 10 years indicating the hazards of delirium and benefits of certain interventions to prevent and mediate this condition, a substantial implementation gap exists between the current state and ideal delirium management practices in ICUs (Barr et al., 2013; Vasilevskis, Ely, et al., 2010). Several of the studies included in this review noted difficulties in implementation due to clinical staff resistance to change and not understanding the benefit of bundle

implementation. This finding is consistent with studies examining implementation of bundles for other conditions and emphasizes the need for ongoing education, continuous measurement and reporting of process and outcome performance, and accountability related to bundle implementation.

The one cost-effectiveness study included in this review indicated that multifaceted care processes for management of sedation, analgesia, and delirium may produce cost savings through reductions in length of ICU stay (Awissi et al., 2012). Although the multifaceted intervention did not result in a reduction in incidence of delirium, reductions in the number of patients requiring more than 24 hours of ventilation support and duration of delirium were observed in the treatment group. The major limitations of this study were that ICU hospitalization and drug costs were not measured directly for each patient, and nursing time, professional fees, and workload costs were not taken into account. However, the staffing and workload costs were unlikely to vary significantly between groups based on the nature of the staffing models (Awissi et al., 2012). Although hospital and drug costs were not measured directly for each patient, the fact that patients in the treatment group had shorter ICU LOS and staffing costs were unlikely to vary between groups indicates that the actual hospital costs of patients who received the multifaceted intervention were less than the actual hospital costs of patients in the control group. The lack of studies pertaining to the costs and cost-effectiveness of multifaceted interventions for prevention of delirium indicates a need for further research pertaining to this topic.

Given the deleterious effects of delirium, and the variation in ICU practices, interventions, and outcomes that we observed among studies, it is clear that there is a

need for the development and widespread testing of standardized, comprehensive processes of care for prevention and mitigation of this complex condition. The use of care bundles consisting of several evidence-based medical practices has been advocated by organizations such as the Joint Commission and the Institute for Healthcare Improvement as a means to promote rapid adoption of therapies and to produce synergistic improvements in outcomes (Barochia et al., 2010). The PAD and ABCDE bundles have been proposed as standard bundles of ICU care processes to reduce the burden of ICU-acquired delirium, but the effectiveness of these bundles remains unknown (Barr et al., 2013; Barr & Pandharipande, 2013; Brummel & Girard, 2013; Girard, Kress, et al., 2008; Hipp & Ely, 2012; Morandi et al., 2011; P. Pandharipande et al., 2010; Schweickert et al., 2009; Skrobik et al., 2010; Vasilevskis, Ely, et al., 2010). Only one study has evaluated the effectiveness of the ABCDE bundle. Balas et al. found that the implementation of the ABCDE bundle resulted in a significant decrease in incidence of delirium and ventilator days and increased likelihood of mobilizing out of bed (Balas et al., 2014). However, this was a small study that was implemented in one medical center and utilized a pre-post design without a concurrent control. Thus, temporal factors and unbalanced confounders may have biased the results. No studies have examined the effectiveness of the PAD bundle. The remainder of the studies included in this review incorporated different elements of the PAD and ABCDE bundles. Implementation of care processes specified by either ABCDE or PAD in a coordinated fashion may be more effective in improving care and outcomes for ICU patients at risk for delirium as they address the major modifiable factors that are associated with development of this condition. Future research should examine the effectiveness of these bundles and address other gaps in the literature

pertaining to the effect of these interventions on patient safety, costs, cost-effectiveness, and quality of life.

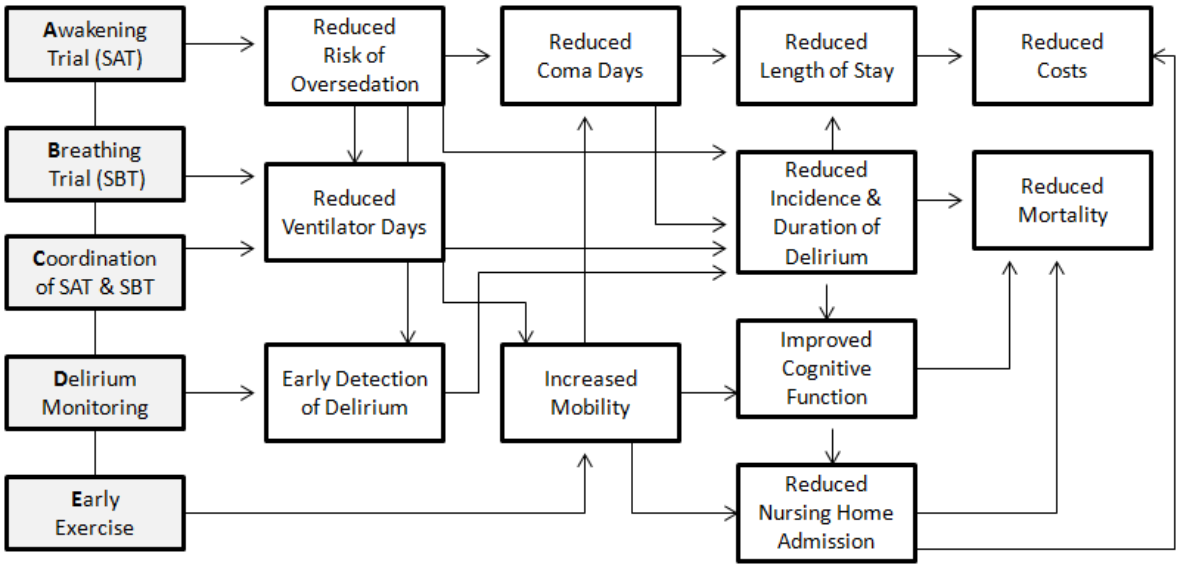
Summary of Research Questions

ICU delirium is a common complication of critical care that is associated with increased morbidity, mortality, and health care costs but is often undiagnosed and untreated. New approaches to the delivery of care in the ICU are needed to counter this threat to patient safety. The literature indicates that implementation of multi-component interventions can help reduce incidence of delirium and improve patient outcomes. The ABCDE bundle combines evidence-based care processes for the prevention and treatment of delirium including awakening and breathing trials, delirium monitoring and treatment, and early exercise. As depicted in Figure 1, the ABCDE bundle can reduce the risk of over-sedation and ventilator days and improve detection of delirium leading to reduction in coma days, improved mobility, and decreased incidence and duration of delirium. Reducing incidence and duration of delirium can improve cognitive function and reduce mortality, LOS, nursing home admissions, and costs.

This dissertation addressed several gaps in the literature pertaining to use of the ABCDE bundle for prevention and mitigation of delirium in ICU patients. To date, only one published study has examined the effect of the ABCDE bundle on patient outcomes (Balas et al., 2014). We examined the effect of two bundle implementation strategies (basic versus enhanced) in 12 adult ICUs in 6 hospitals belonging to a large, integrated healthcare delivery system on ABCDE bundle adherence and the impact of bundle adherence on incidence and duration of delirium, and related patient outcomes such as

days spent on a ventilator, coma days, ICU and hospital LOS, nursing home utilization, and mortality.

Figure 1. Conceptual Framework



Secondly, limited information is available pertaining to how to facilitate implementation, promote widespread adoption, and ensure sustainability of the ABCDE bundle in different ICU settings. We conducted a mixed methods evaluation to determine how to facilitate adoption, implementation, and routinization of the ABCDE bundle. Guided by Rogers' and Greenhalgh et al.'s theoretical frameworks for diffusion of innovations in health service delivery, we interviewed individuals involved in the implementation and delivery of the ABCDE bundle to identify the individual and organizational-level factors that served as facilitators or barriers to bundle adoption.

Finally, interventions to reduce delirium in ICU patients may lead to the reductions in the costs of patient care by improving patient functionality, reducing

ventilator days, and reducing ICU and hospital LOS. However, only one published study has examined the cost-effectiveness of a multifaceted intervention for the management of delirium in the ICU. To date, no published studies have examined the cost-effectiveness of the ABCDE bundle. We examined the cost-effectiveness of the ABCDE bundle compared to usual care in terms of cost per and life years saved and cost per quality-adjusted life year gained. The three studies included in this dissertation make important contributions to the critical care literature and will inform efforts to improve the quality of care for ICU patients.

CHAPTER 3. RESEARCH METHODS

This dissertation includes three studies pertaining to the implementation of the ABCDE bundle in the ICUs of several Baylor Scott & White Health (BSWH) hospitals. This chapter provides an overview of the ABCDE bundle and implementation strategies and details the research questions and methodologies for each of the three studies: A) Effect of ABCDE Bundle Implementation Strategies on Bundle Adherence and Patient Outcomes, B) Implementation and Routinization of the ABCDE Bundle: A Mixed Methods Evaluation, and C) Evaluating the Cost-Effectiveness of the ABCDE Bundle: Impact of Bundle Adherence on Inpatient and 1-Year Mortality, Quality of Life, and Costs of Care. All three studies were approved by the Baylor Research Institute and Tulane University Biomedical IRBs.

Overview of ABCDE Bundle Intervention and Implementation Strategies

ABCDE Bundle

The ABCDE bundle incorporates several individual evidence-based critical care processes (spontaneous awakening trials (SATs), spontaneous breathing trial (SBTs), delirium screening, and early mobility) into a single, integrated package. As critically ill patients may be clinically unstable (labile blood pressures or oxygenation status), safety screens are performed to determine appropriateness of specific care processes for each patient. Bundle elements are delivered by nurses, physicians, respiratory therapists, and physical/occupational therapists. The care processes, respective safety screen criteria, and

responsible provider(s) are described in Table 1. The number of care processes a patient is eligible for on a given day depends on whether or not the patient is ventilated and passes the appropriate screening criteria.

Table 1. ABCDE Bundle Elements and Main Safety Criteria

Element		Description	Frequency	Safety Criteria	Performed by
A	Spontaneous Awakening Trial (SAT)	Awaken patients with cessation of sedating medications	1 x daily	No active seizures No alcohol withdrawal No agitation No paralytics No myocardial ischemia Normal intracranial pressure	Nurses Physicians
B	Spontaneous Breathing Trial (SBT)	Daily assessment of patients' readiness to discontinue mechanical ventilation	1 x daily	No agitation Oxygen saturation ≥ 88% FiO2 ≤ 50% PEEP ≤ 7.5 cm H_20 No myocardial ischemia No vasopressor use Inspiratory efforts	Respiratory therapists
C	Coordination	SAT conducted prior to SBT; Coordination between physicians, nursing, and therapy service lines	1 x daily	Meets SAT and SBT Criteria	Nurses Physicians Respiratory therapists
D	Delirium Assessment (CAM-ICU) and Management	Objective delirium screening with the Confusion Assessment Method for the ICU.(Ely, Inouye, et al., 2001) Systematic evaluation for causation of delirium with appropriate interventions.	2 x daily	None	Nurses
E	Early Mobility (EM)	Patients meeting criteria receive mobility evaluation and therapy as indicated	1 x daily	No myocardial ischemia Stable heart rate & cardiac rhythm $FiO_2 \leq 0.6$ PEEP ≤ 10 cm H_2O Minimal vasopressor Response to verbal stimulation	Nurses Physical/ Occupational therapists

PEEP = positive end-expiratory pressure

Study Setting

Baylor Scott & White Health (BSWH), is one of the largest non-profit health care systems in the United States including 46 hospitals, >800 patient care sites, >6,000 affiliated physicians, 35,000 employees and an accountable care organization. This study included patients treated in the 12 ICUs of 6 BSWH North (previously Baylor Health Care System) hospitals (Table 2). The hospitals included a large, urban tertiary referral center, 4 community hospitals, and a rural hospital. ICUs included medical/surgical, trauma, neurological, and cardiac care units. We intentionally selected hospitals with heterogeneity in size, practice culture, and patient populations in order examine the effectiveness of bundle implementation across settings. We selected 3 hospitals to receive the basic intervention and 3 hospitals to receive the enhanced intervention.

Table 2. Participating Hospitals and ICUs

ICU	Intervention	ICU(s) Description	# of Beds	Daily Census	# of Nurse FTEs
A	Basic	Medical/Surgical	16	11.0	40.2
B	Basic	Medical/Surgical	14	10.8	32.4
C	Basic	Medical/Surgical	16	12.0	43.0
D	Basic	Cardiac	15	11.0	37.1
E	Basic	Cardiac	16	10.8	32.3
F	Enhanced	Medical/Surgical	24	22.0	59.3
G	Enhanced	Medical/Surgical	19	12.5	45.0
H	Enhanced	Medical/Surgical	6	5.0	16.0
I	Enhanced	Cardiac	24	13.0	38.9
J	Enhanced	Cardiac	18	12.0	32.7
K	Enhanced	Neurological	15	13.0	32.0
L	Enhanced	Trauma	37	35.0	83.8

Standard of Care

Care for ICU patients in all BSWH North hospitals was guided by a standardized critical care flowsheet in the EHR. Hospitals had standard order sets for the management of sedation and analgesia, ventilated patients, and delirium. The sedation/analgesia order set included prescriptions for dexmedetomidine, propofol, and fetanyl and for a SAT to be administered twice daily. The ventilator order set included orders for SATs, SBTs, and daily exercise for ventilated patients as well as prescriptions for fetanyl and morphine as analgesics and midazolam, propofol, and dexmedetomidine for sedation. The delirium order set prescribed the assessment of patient sedation level, screening for delirium every shift using the CAM-ICU (Ely, Inouye, et al., 2001) and use of haloperidol or dexmedetomidine for agitation. The order set also prescribed non-pharmacologic delirium mitigation strategies such as day/night orientation, access to hearing aids and glasses, informing patient of day/time/location, noise reduction, and uninterrupted sleep at night. Although the sedation, ventilator, and delirium protocols existed prior to ABCDE bundle implementation efforts, they were not applied consistently or as a coordinated bundle.

Basic Intervention (EHR Modification)

As part of ABCDE bundle implementation efforts, the EHR (Allscripts™) for all BSWH North hospitals was modified to facilitate uptake and documentation of ABCDE bundle elements (A.W. Collinsworth et al., 2014). Changes included the addition of structured data fields for the documentation of ABCDE bundle eligibility and delivery of bundle processes. These data fields were added to the existing nursing critical care flowsheet or the respiratory therapist structured note, depending on who was responsible

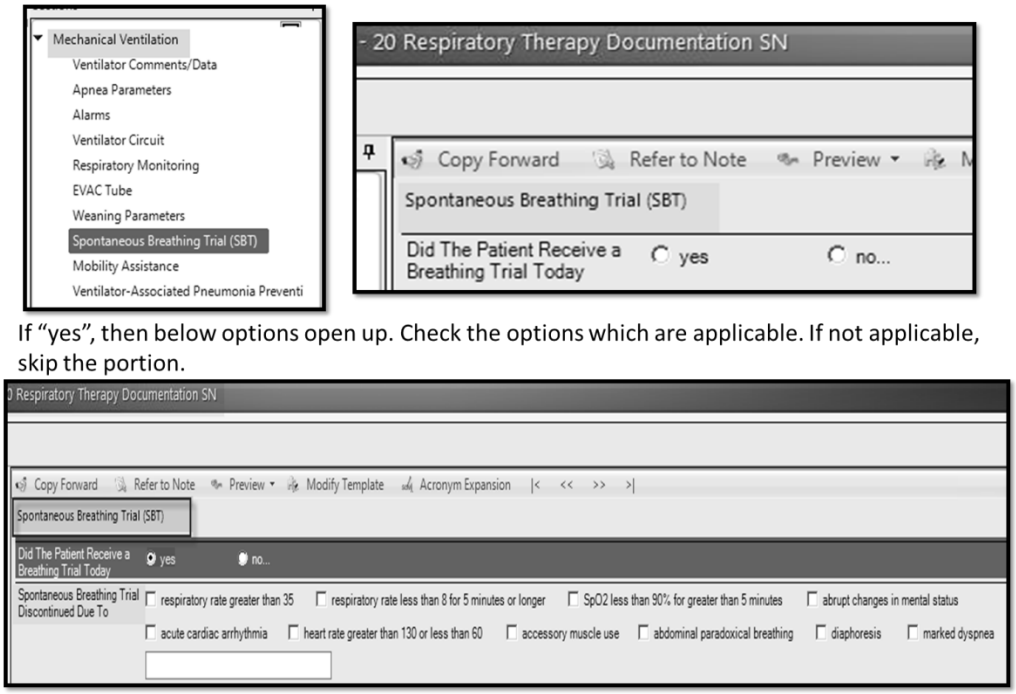
for providing the process of care. “Sedation Vacation/Daily Awakening Trial" and “Exercise/ Mobility” sections were added to the nursing critical care flowsheet under the ventilator bundle section (Figure 2). The fields in the “Sedation Vacation/Daily Awakening Trial" section prompted nurses to document if the patient had received a SAT that day or why the patient had failed to receive a SAT, if the sedative infusion was resumed, and why sedation was resumed. The “Exercise/Mobility” section prompted nurses to document if the patient received an early mobility assessment that day and the level of mobility the patient achieved.

Figure 2. Adding Spontaneous Awakening Trial (SAT) to the Nursing Critical Care Flowsheet

	◀	05/08/2014 14:00	05/08/2014 15:00
Sedation Vacation/Daily Awakening Trial Did the Patient Receive a Sedation Vacation Today If Not, Why Not Was the Sedative Infusion Resumed If So, Why			
Exercise/Mobility Did the Patient Receive Exercise/Mobility Therapy Today If Not, Why Not What Level Was Achieved			
+ CRRT			
- Sedation Scale			
Richmond Agitation Sedation Scale (RASS)			
-			
Confusion Assessment Method RASS/Ramsay: Step 1, if RASS -4 0r -5 or Ramsay 5 or 6, STOP Reassess later Feature 1: Acute Onset or Fluctuating Course Feature 2: Inattention Feature 3: Altered Level of Consciousness Feature 4: Disorganized Thinking CAM Overall Score			

A line was added to the respiratory therapist structured note for “Spontaneous Breathing Trial" with a pull down box indicating whether or not a SBT was performed, and if not, why not (Figure 3). The physical/occupational (PT/OT) structured note already included structured fields for documentation of early mobility.

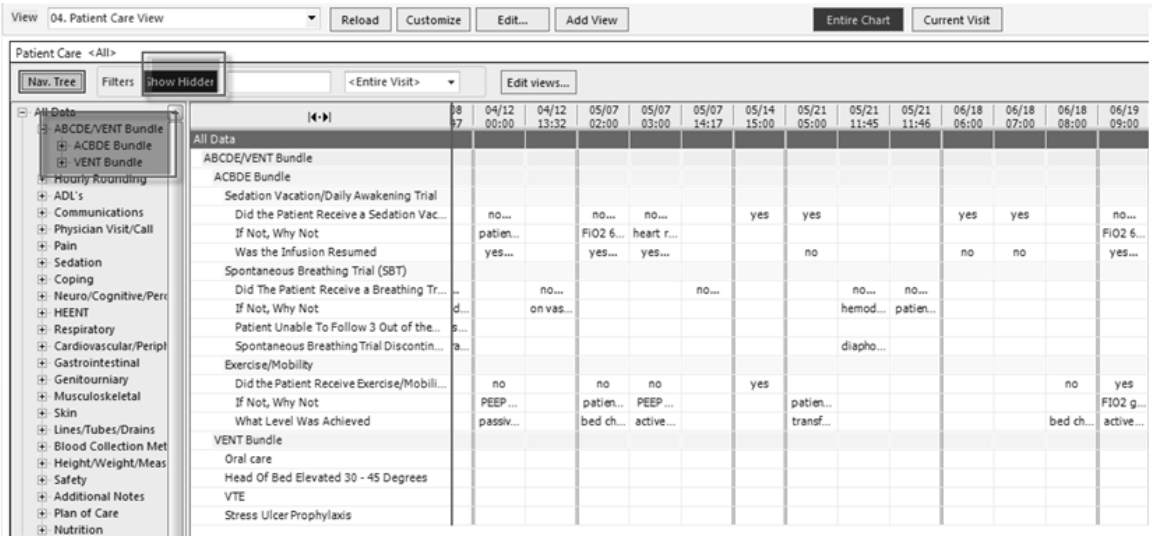
Figure 3. Documenting Spontaneous Breathing Trial (SBT) in Respiratory Therapy Structured Notes



In addition, the design team created an “ABCDE” tab in the existing Patient Care Viewer that provided a summary of SAT, SBT, delirium (CAM-ICU), and early mobility assessments to promote quick viewing of the bundle elements received by individual patients and enhance interdisciplinary communication (Figure 4). The informatics team sent out an electronic notification to all BSWH North hospitals highlighting all EHR modifications immediately prior to implementation per standardized protocol. ICUs in

the basic intervention group did not receive any additional ABCDE bundle training or communication from the study team.

Figure 4. Creation of the Patient Viewer for the ABCDE Bundle



Enhanced Intervention

In addition to the EHR modifications, ICUs in the 3 hospitals selected to receive the enhanced intervention participated in a multifaceted implementation strategy targeting physician, nursing, and allied health staff. These ICUs received additional ABCDE bundle training and implementation tools, had designated bundle champions, and participated in the development of the structured EHR documentation and ABCDE performance reports. Enhanced intervention sites received these interventions before and after the EHR was modified to facilitate ABCDE bundle use and documentation (Table 3). Nurses, respiratory therapists, and physical and occupational therapists from these hospitals attended an initial 4-hour ABCDE bundle workshop lead by nurse bundle experts from Vanderbilt University Medical Center at the end of November 2012. Site-specific trainings were conducted by a BSWH North clinical nurse champion at all

enhanced intervention hospitals from January to March of 2013, and one site participated in an additional 4 hour workshop lead by Vanderbilt nurses in May 2013.

Table 3. Implementation Timeline

Component	**Date**
Study period begins	July 2012
ABCDE bundle workshop for enhanced intervention ICUs (F-L) led by nurse bundle experts from Vanderbilt University	November 2012
ICU H site training	January 2013
ICU G site training	March 2013
ICU F site training	March 2013
ICUs I & J site training	July 2013
EHR modifications implemented – Beginning of post period	**July 2013**
ICUs L & K site training	September 2013
Refresher training for ICUs F, I, J, K, L	November 2013
Refresher training for ICUs G & H	April 2014
Study period ends	June 2014

Following the implementation of the EHR modifications, the BSWH North clinical nurse champion conducted refresher trainings for the ICUs in July 2013 (2 ICUs), September 2013 (2 ICUs), and April 2014 (3 ICUs). In addition the ICUs in one hospital appointed ABCDE super trainers to assist with ongoing ABCDE bundle implementation and training within their respective ICUs, and these super users participated in trainings on delirium screening, delirium management, and early mobility from November 2013 to January 2014. Enhanced intervention sites also received supplemental in-person training on proper documentation of ABCDE processes within the EHR once the EHR modifications were implemented and implementation tools including pocket cards describing sedation and delirium assessment processes and posters promoting ABCDE

bundle use. Nurse and physician ABCDE bundle champions were also designated at all enhanced intervention sites prior to the EHR modification.

A. Effect of ABCDE Bundle Implementation Strategies on Bundle Adherence and Patient Outcomes

Research Question: How does implementation of the ABCDE bundle affect adherence to delirium care processes and what is the impact of bundle adherence on incidence and duration of delirium, and related patient outcomes?

Delirium is a common complication of critical care that is associated with negative health outcomes including increased ventilator days, coma days, intensive care unit (ICU) and hospital length of stay (LOS), mortality, and likelihood of discharge to a nursing facility. Several individual care practices have been associated with reduced incidence and prevalence of delirium in ICU patients. However, these practices have not been widely adopted. The ABCDE (Awakening and Breathing Coordination, Delirium Monitoring and Management, and Early Exercise and Mobility) bundle is designed to facilitate adoption of these evidence-based practices. Implementation of the ABCDE bundle can potentially reduce incidence and duration of delirium and lead to improvements in the health outcomes of ICU patients.

We examined the effect of two implementation strategies (basic vs. enhanced) on ABCDE bundle adherence and the impact of bundle adherence on patient outcomes in 12 adult ICUs in 6 different Baylor Scott & White (BSWH) hospitals. The basic strategy involved the modification of the electronic health record (EHR) to facilitate bundle implementation and documentation while the enhanced strategy included EHR modification plus additional ABCDE bundle training and implementation tools, designated bundle champions, and participation by ICU staff in the development of the EHR modifications and ABCDE performance reports.

We used a prospective, quasi-experimental, pretest-posttest design to compare changes in adherence to delirium care processes between ICUs that received the basic intervention versus those that received the enhanced intervention and to examine the effect of high versus low bundle adherence on risk-adjusted patient outcomes. We examined adherence to four individual components of the ABCDE bundle (SATs, SBTs, delirium screening (CAM-ICU), and early mobility) as well as to the entire bundle. ABCDE bundle adherence for each patient was calculated as the total number of care processes the patient received divided by the total number of care processes the patient was eligible for during the course of the patient's ICU stay.

Hypothesis 1

H_1: ICUs receiving the enhanced intervention will have a greater increase in ABCDE bundle adherence than ICUs receiving the basic intervention in the year following the modification of the EHR to support bundle implementation.

$$y_{it} = \beta_0 + \beta_1 ICU_{1\text{-}12} + \delta_0 Post_{it} + \beta_2 Enhanced_u + \delta_1 Post_{it} * Enhanced_u + \beta_3 Month_{it} + \beta_4 Age_{it} + \beta_5 Male_{it} + \beta_6 Race_{it} + \beta_7 Hispanic_{it} + \beta_8 Insurance_{it} + \beta_9 Comorbidities_{it} + \beta_{10} IllnessSeverity_{it} + \beta_{11} MortalityRisk_i + \beta_{12} Apache_{it} + \beta_{13} VentLOS_{it} + \beta_{14} ICU_LOS_{it} + \beta_{15} Alcohol_{it} + \beta_{16} Dementia_{it} + \beta_{17} Surgical_{it} + \beta_{18} Quality_u + \varepsilon_{it}$$

for patient *i* in month *t* in ICU *u*

Model variables for Hypothesis 1 are described in Table 4.

Table 4. Description of Study Variables for Hypothesis 1

Variables	Variable Type	Description
Y_{it}	Continuous	the % of appropriate bundle elements a patient receives over the course of ICU stay
ICU	Categorical	the ICU the patient was treated in
Post	Dichotomous	1 for post-implementation period, 0 for pre-implementation period
Enhanced	Dichotomous	1 if patient was treated in an enhanced intervention ICU, 0 if patient was treated in a basic intervention ICU
Month	Discrete	month in which care episode occurred (1-24)
Age	Continuous	patient age (years)
Male	Dichotomous	1 if the patient was male, 0 if the patient was female
Race	Categorical	variable indicating patient race (White, Black, Asian, Other)
Hispanic	Dichotomous	1 if the patient was Hispanic, 0 if the patient was not Hispanic
Insurance	Categorical	variable indicating insurance status (privately insured, Medicare, Medicaid, other federal, self-pay, other)
Comorbidities	Discrete	Charlson Comorbidity Index score for the patient
IllnessSeverity	Dichotomous	1 if patient had high severity of illness represented by a score of 4 on the APR-DRG Severity of Illness score, 0 if patient had a score <4
MortalityRisk	Dichotomous	1 if patient had high mortality risk represented by a score of 4 on the APR-DRG Mortality index, 0 if patient had a score <4
Apache	Discrete	Patient's severity of illness as measured by APACHE II score (0-71)
VentLOS	Count	Number of days the patient spent on the ventilator
ICU_LOS	Count	Number of days the patient spent in the ICU
Alcohol	Dichotomous	1 if patient was an alcoholic, 0 if the patient was not an alcoholic
Dementia	Dichotomous	1 if patient had a diagnosis of dementia at admission, 0 if otherwise
Surgical	Dichotomous	1 if a patient was a surgical patient, 0 if otherwise
Quality	Continuous	a quality score for each ICU calculated as the average number of central line associated blood stream (CLABSI) infections and catheter associated urinary tract (CAUTI) infections divided by the number of line/catheter days per 1,000 patient days.
ε_{it}		Non-independent error term to account for clustering within ICUs

We examined the impact of bundle adherence on patient outcomes for patients treated in both enhanced intervention and basic intervention ICUs. Measured outcomes included incidence of delirium, duration of delirium (days), incidence of coma, duration of coma (days), number of days the patient spent in the ICU and was not in a coma and

was not delirious (coma and delirium free days), ventilator days, ICU and hospital LOS, highest level of mobility achieved in the ICU, discharge disposition, inpatient mortality, and safety outcomes including unplanned extubation and tracheostomy.

Hypothesis 2

H_2: There is a negative association between bundle adherence and the incidence of delirium and duration of delirium in ICU patients.

Hypothesis 3

H_3: There is a negative association between bundle adherence and incidence of coma, duration of coma (days), days spent on a ventilator, ICU and hospital LOS, and inpatient mortality.

Hypothesis 4

H_4: There is a positive association between bundle adherence and the percentage of coma and delirium free days, likelihood of being mobilized out of bed, and probability of discharge home.

Hypothesis 5

H_5: There is no association between bundle adherence and safety outcomes of unplanned or self-extubation and tracheostomy.

Model for Hypotheses 2-5

$$y_{it} = \beta_0 + \beta_1 \text{BundleAdherence} + \beta_2 \text{ICU}_{1\text{-}12} + \beta_3 \text{Month}_{it} + \beta_4 \text{Age}_{it} + \beta_5 \text{Male}_{it} + \beta_6 \text{Race}_{it} + \beta_7 \text{Hispanic}_{it} + \beta_8 \text{Insurance}_{it} + \beta_9 \text{Comorbidities}_{it} + \beta_{10} \text{IllnessSeverity}_{it} + \beta_{11} \text{MortalityRisk}_{i} + \beta_{12} \text{Apache}_{it} + \beta_{13} \text{VentLOS}_{it} + \beta_{14} \text{ICU_LOS}_{it} + \beta_{15} \text{Smoker}_{i\,t} + \beta_{16} \text{Alcohol}_{it} + \beta_{17} \text{Dementia}_{it} + \beta_{18} \text{Surgical}_{it} + \beta_{19} \text{Quality}_{u} + \varepsilon_{it}$$

for patient *i* in month *t* in unit *u*

Outcome variables and covariates for Hypotheses 2-5 are described in Tables 5-6.

Table 5. Description of Outcome Variables for Hypotheses 2-5

	Variables	H_o	Variable Type	Description
y_{2a}	DeliriumIncidence	-	Dichotomous	1 if the patient developed delirium; 0 if the patient did not develop delirium
y_{2b}	DeliriumDuration	-	Continuous	Number of days the patient experienced delirium
y_{3a}	ComaIncidence	-	Dichotomous	1 if the patient was in a coma; 0 if the patient was not in a coma
y_{3b}	ComaDuration	-	Count	Number of days the patient was in a coma
y_{3c}	VentilatorDays	-	Count	Number of days the patient spent on the ventilator
y_{3d}	ICU_LOS	-	Count	Number of days the patient spent in the ICU
y_{3e}	HospitalLOS	-	Count	Number of days the patient spent in the hospital
y_{3f}	Inpatient Mortality	-	Dichotomous	1 if the patient died in the hospital, 0 if the patient did not die in the hospital
y_{3e}	DischargedHome	-	Dichotomous	1 if the patient was discharged to a nursing facility, 0 if the patient was not discharged to a nursing facility
y_{4a}	ComaFreeDays	+	Continuous	the percentage of ICU days the patient was coma free
y_{4b}	ComaDeliriumFree Days	+	Continuous	the percentage of ICU days the patient was delirium and coma free
y_{4c}	Mobilized	+	Dichotomous	1 if the patient was mobilized out of bed during ICU stay, 0 if the patient was not mobilized out of bed.
y_{4d}	DischargedHome	+	Dichotomous	1 if the patient was discharged home, 0 if the patient was not discharged home.
y_{5a}	SelfExtubation	null	Dichotomous	1 if the patient had an unplanned extubation or self-extubated, 0 if otherwise
y_{5b}	Tracheostomy	null	Dichotomous	1 if the patient had a tracheostomy, 0 if the patient did not have a tracheostomy

H_0 = Hypothesized relationship between bundle adherence and outcome

Table 6. Description of Covariates for Hypotheses 2-5

Variables	Variable Type	Description
ICU	Categorical	the ICU the patient was treated in
Month	Discrete	month in which care episode occurred (1-24)
Age	Continuous	patient age (years)
Male	Dichotomous	1 if the patient was male, 0 if the patient was female
Race	Categorical	variable indicating patient race (White, Black, Asian, Other)
Hispanic	Dichotomous	1 if the patient was Hispanic, 0 if the patient was not Hispanic
Insurance	Categorical	variable indicating insurance status (privately insured, Medicare, Medicaid, other federal, self-pay, other)
Comorbidities	Discrete	Charlson Comorbidity Index score for the patient
IllnessSeverity	Dichotomous	1 if patient had high severity of illness represented by a score of 4 on the APR-DRG Severity of Illness score, 0 if patient had a score <4
MortalityRisk	Dichotomous	1 if patient had high mortality risk represented by a score of 4 on the APR-DRG Mortality index, 0 if patient had a score <4
Apache	Discrete	Patient's severity of illness as measured by APACHE II score (0-71)
VentLOS	Count	Number of days the patient spent on the ventilator
ICU_LOS	Count	Number of days the patient spent in the ICU
Smoker	Dichotomous	1 if the patient was a current smoker, 0 if otherwise
Alcohol	Dichotomous	1 if patient was an alcoholic, 0 if otherwise
Dementia	Dichotomous	1 if patient had a diagnosis of dementia at admission, 0 if otherwise
Surgical	Dichotomous	1 if a patient was a surgical patient, 0 if otherwise
Quality	Continuous	a quality score for each ICU calculated as the average number of central line associated blood stream (CLABSI) infections and catheter associated urinary tract (CAUTI) infections divided by the number of line/catheter days per 1,000 patient days.
ε_{it}		Non-independent error term to account for clustering within ICUs

Measures and Data

ABCDE Bundle Adherence

The ABCDE bundle incorporates several individual evidence-based critical care processes into a single, integrated package. The following clinical practices are included in the bundle:

- **Awakening Trials (SATs)**

  Daily awakening of patients with cessation of sedating medications

- **Breathing Trials (SBTs)**

  Daily assessment of patients' readiness to discontinue mechanical ventilation

- **Coordination of daily awakening and breathing trials**

  Administration of SAT followed by SBT within the same nursing shift

- **Delirium Monitoring and Management**

  Daily assessment for delirium using the Confusion Assessment Method for the ICU (CAM-ICU)

- **Exercise/Early Mobility**

  Daily physical therapy evaluation and mobilization out of bed during previous 24 hours

We measured ABCDE bundle compliance for each patient as the total number of care processes the patient received divided by the total number of care processes the patient was eligible for during the course of the patient's ICU stay. The number of care processes a patient was eligible for depended on whether or not the patient was ventilated and the patient's ICU LOS. Patients who were on a ventilator were eligible to receive all 5 bundle elements every day they remained in the ICU and were on the ventilator. Patients who were not on a ventilator were eligible to receive 3 bundle elements (spontaneous awakening trial (SAT), delirium monitoring and early exercise) every day they remained in the ICU and were not on a ventilator.

Covariates for the models included ICU, month of admission, patient age, gender, race, ethnicity, insurance status, comorbidities, illness severity, risk of mortality, alcoholism, smoking status, pre-existing dementia, the number of days the patient spent on the ventilator, if the patient was a surgical or non-surgical patient, and an ICU quality indicator.

Comorbidities

Comorbidities were assessed with the Charlson Comorbidity Index (Charlson, Pompei, Ales, & MacKenzie, 1987). This measure is a weighted index that takes into account the number and the seriousness of comorbid disease. We also included smoking status, pre-existing diagnosis of dementia, and alcoholism as covariates in the model, as these factors have been associated with increased incidence of delirium in the literature. Smoking status was a binary variable indicating if the patient smoked. Dementia was a binary variable indicating if the patient had been diagnosed with dementia. Alcoholism was a binary variable indicating if the patient had reported consuming two or more servings of alcohol per day.

Severity of Illness

Severity of illness was measured by the Acute Physiology and Chronic Health Evaluation (APACHE II) score on the day of patient admission (Knaus, Draper, Wagner, & Zimmerman, 1985). APACHE II is a severity of disease classification system that uses a point score based upon initial values of 12 routine physiologic measurements, age, and previous health status to provide a general measure of severity of disease. An increasing score (range 0 to 71) indicates a higher risk of hospital death.

Surgical or Medical Patient

We included a variable in the model to designate if the patient was a surgical or medical patient, as bundle adherence and patient outcomes may differ between these groups of patients.

ICU Quality Indicator

We calculated a quality score for each ICU as a proxy measure to control for differences in the quality of care provided in ICUs, as we did not have an existing measure of ICU quality. The score was calculated as the average number of central line associated blood stream (CLABSI) infections and catheter associated urinary tract (CAUTI) infections divided by the number of line/catheter days per 1,000 patient days. CLABSI and CAUTI are common infections in critical care units that can be prevented through proper management of central lines and catheters, and the Centers for Medicare and Medicaid Services has selected these infection rates as critical care quality measures for 2015 (Centers for Disease Control and Prevention, 2014a, 2014b).

Differences in the quality of ICU leadership between basic and enhanced intervention ICUs may have influenced bundle adoption. The only leadership measure we had ICU-level data for was the leadership domain score of a patient safety culture survey administered to all hospital staff in August 2013. There was not a significant difference between mean scores for basic and enhanced intervention ICUs on this measure. There was some variation in scores among ICUs, but leadership scores were not correlated with bundle adherence and were not included in the models.

Patient Outcomes

Delirium was assessed using the Confusion Assessment Method for ICU (CAM-ICU). The CAM-ICU is a reliable and validated instrument for assessing delirium in ventilated and non-ventilated patients recommended by the Society of Critical Care Medicine (Barr et al., 2013; Ely, Inouye, et al., 2001). Coma incidence was assessed with the Richmond Agitation-Sedation Scale (RASS) with coma indicated by a score of -4 or -5 (Ely et al., 2003). Patients were first screened with the RASS to determine if they were conscious and delirium screening was appropriate. RASS scoring ranges from -3 to +4. Patients with a RASS score equal to -3 or higher were eligible for delirium assessment. Patients with a score of -4 or -5 indicating that they were comatose were not eligible for delirium screening. Incidence of delirium was a binary variable indicating if a patient was CAM-ICU positive one or more times during ICU stay. Duration of delirium was a continuous variable defined as the number of ICU days in which the patient was CAM-ICU positive. Duration of coma was a continuous variable defined as the number of ICU days in which the patient had a RASS score of -4 or -5. Coma and delirium free days were the percentage of ICU days the patient had a RASS score of -3 or higher and was not CAM-ICU positive.

Ventilator days were defined as the number of days the patient spent on the ventilator during an ICU stay. ICU LOS was calculated as the number of days from ICU admission to ICU discharge. Hospital LOS was calculated as the number of days from hospital admission to hospital discharge. Mobilized was a binary variable indicating if the patient was mobilized out of bed during the ICU stay. Discharged home was a binary variable indicating if the patient was discharged home as opposed to a nursing, long-term

care, or rehabilitation facility or hospice. Mortality was a binary variable indicating if the patient died in the hospital. Unplanned extubation was a binary variable indicating if the patient had an unplanned or self-extubation. Tracheostomy was a binary variable indicating if the patient had a tracheostomy.

Measure Validity and Reliability

The majority of measures are based on previously published instruments. To ensure reliability of incidence and duration of delirium we performed inter-rater reliability checks for delirium (CAM-ICU) and sedation (RASS) screening.

Study Population and Data Sources

Study Setting

This study included patients treated in the 12 ICUs of 6 BSWH North (previously Baylor Health Care System) hospitals. The hospitals included a large, urban tertiary referral center, 4 community hospitals, and a rural hospital. ICUs included medical/surgical, trauma, neurological, and cardiac care units. We intentionally selected hospitals with heterogeneity in size and patient populations in order examine the effectiveness of bundle implementation across settings. We selected 3 hospitals to receive the basic intervention and 3 hospitals to receive the enhanced intervention.

Patients

All patients who were admitted to study ICUs during the 12 months (July 2012 – June 2013) prior to the implementation of the basic intervention (EHR modification) and during the 12 months (July 2013 – June 2014) following who met the ABCDE bundle inclusion criteria were included in the analysis. Patients were eligible to receive the bundle if they were 18 years of age or older, had an ICU admission lasting more than 24

hours, and were on the ventilator for more than 24 hours and less than 14 days. Patients were excluded if they were on comfort care; were pending a transfer order to a non-ICU bed; were never on the ventilator; had a primary diagnosis of brain tumor, mental disorder, stroke, intracranial injury, or poisoning by drugs, medicinal and biologic substances based on ICD-9 classification; or had an hospital stay greater than 30 days.

Data Sources

Process measures related to ABCDE bundle adherence were collected from the BSWH inpatient EHR (Allscripts™). There were unstructured data fields within the EHR for nurses to record all ABCDE bundle elements with the exception of early mobility prior to the EHR modification. We reviewed a stratified random sample of 300 charts for patients admitted to study ICUs from January-December of 2012 to estimate average early mobility rates for each ICU in the pre-period and to assess the reliability of the EHR documentation for the other bundle process measures. Patient demographic and outcomes data were collected from the EHR and BSWH administrative data.

Research Design

We used a prospective, quasi-experimental pretest-posttest design to compare changes in adherence to delirium care processes between ICUs that received the basic intervention versus those that received the enhanced intervention and the effect of high versus low bundle adherence on risk-adjusted patient outcomes.

Statistical Analysis

We conducted a univariate analysis to examine un-adjusted differences in patient characteristics and outcome measures between patients in the basic and enhanced groups in the pre- and post-intervention time periods. We compared differences in categorical

variables and outcomes using Chi-square and Fisher's exact tests. Differences in continuous variables and outcomes that did not violate normality assumptions were analyzed with independent t-tests.

We used a risk-adjusted difference-in-differences model to compare changes in adherence to delirium care processes between pre- and post- implementation periods in patients treated in ICUs that received the basic intervention and patients treated in ICUs that received the enhanced intervention. Covariates included patient age, gender, comorbidities (Charlson Comorbidity Index), illness severity (APR-DRG Severity Score), mortality risk (APR-DRG Risk of Mortality), alcoholism, dementia as well as the number of days the patient spent on the ventilator and if the patient was a surgical or non-surgical patient. These variables were included based on findings in the literature that some nurses are reluctant to apply the bundle out of fear of harming patients, particularly those who are frail or may be agitated and/or aggressive when they wake up. We calculated a quality score for each ICU as a proxy measure to control for differences in the quality of care provided in ICUs. The score was calculated as the average number of central line associated blood stream (CLABSI) infections and catheter associated urinary tract (CAUTI) infections divided by the number of line/catheter days per 1,000 patient days. CLABSI and CAUTI are common infections in critical care units that can be prevented through proper management of central lines and catheters, and the Centers for Medicare and Medicaid Services has selected these infection rates as critical care quality measures for 2015 (Centers for Disease Control and Prevention, 2014a, 2014b).

As the primary objective of this study was to assess the impact of improved bundle adherence on patient outcomes, we used linear and logistic regression to examine

the impact of high versus low bundle adherence on risk-adjusted outcomes over the entire two year study period in the basic and intervention groups and in both groups combined. Only a few patients achieved 100% bundle adherence, so we could not examine the effect of an all-or-none adherence measure as is common in studies of care bundles for other conditions. High bundle adherence was defined as receiving ≥60% of bundle elements, based on the mean level of adherence obtained in sites following ABCDE bundle implementation efforts. We varied this threshold from 20% to 80% in a sensitivity analysis. Due to the fact that patients with greater severity of illness and risk of mortality were more likely to have low levels of bundle adherence, a propensity score adjustment approach was used to reduce the impact of selection bias on the association between bundle adherence and the outcomes of interest. The propensity score, the conditional probability of a patient having high bundle adherence, was determined from a multivariable logistic regression model. Covariates included ICU, age, sex, race, ethnicity, insurance status, APR-DRG Severity and Risk of Mortality scores, Charlson Comorbidity Index, Acute Physiology and Chronic Health Evaluation II (APACHE II) score, ventilator days, ICU length of stay, alcohol use, smoking status, pre-existing dementia, month of ICU admission, and ICU quality.

We used generalized estimating equations (GEE) methods using the GENMOD procedures in SAS version 9.3 (SAS Institute, Inc. Cary, NC) to build regression models that accounted for clustering of patients within ICUs by controlling for the ICU as a random effect. A Poisson distribution was used to model delirium and coma duration, delirium and coma free days, ventilator days, and length of stay. We used a negative

binomial distribution to model ICU and hospital LOS. All statistical analyses were conducted using SAS®. Statistical significance was indicated at the $\alpha < 0.05$ level.

Statistical Power

This study was sufficiently powered. We determined our target sample size based on our ability to detect changes in bundle adherence and incidence of delirium, our primary outcomes of interest, within and between the basic and enhanced intervention groups. Given a sample size of approximately 300 patients in the pre- and post- periods in the basic intervention group and of 900 patients in the enhanced intervention group and a standard deviation of 0.20, we were able to detect a 5% mean change in bundle adherence between pre- and post- periods in the basic intervention ICUs, a 3% mean change in the enhanced intervention ICUs, and a 4% mean change between basic and enhanced intervention ICUs with 90% power and 2-tailed alpha = .05. With this same sample size and a standard deviation of 0.40 we were able to detect a 11% mean change in delirium incidence between pre- and post- periods in the basic intervention ICUs, a 6% mean change in the enhanced intervention ICUs, and a 9% mean change between basic and enhanced intervention ICUs with 90% power and 2-tailed alpha = .05.

B. Implementation and Routinization of the ABCDE Bundle: A Mixed Methods Evaluation

Research Question: What are the individual and organizational-level factors that facilitate or impede ABCDE bundle adoption?

Achieving widespread improvements in health care quality is dependent on both the identification of effective interventions and the diffusion of these innovations across health care settings. Over the course of the last decade, researchers have produced strong evidence demonstrating the hazards of delirium and the benefits of certain interventions, such as the individual components of the ABCDE (Awakening and Breathing Coordination, Delirium Monitoring and Management, and Early Exercise and Mobility) bundle, in preventing and mediating this condition. However, these evidence-based treatments have not been integrated as standard of care in most ICUs, and as a result most patients receive less than optimal care. For example, rates of daily sedation interruptions and breathing trials for mechanically ventilated patients have been reported as being less than 40% in cross-sectional surveys (Kahn et al., 2007; Mehta et al., 2006). Use of validated tools for delirium monitoring and sedation scales has also been found to be below 40% (Mehta et al., 2006; Patel et al., 2009). Likewise, studies have found that less than 50% of patients receive any physical therapy during their ICU stay (Morris et al., 2008; Thomsen et al., 2008).

Rogers and Greenhalgh et al. have emphasized that diffusion of innovation in organizations is highly dependent on how potential adopters view the attributes of the innovation as well as organizational factors. In a systematic review, Rogers found that 5 key attributes of innovations (relative advantage, compatibility, complexity, trialability,

and observability) explained approximately 49% to 87% of the variance in the rate of adoption of innovations. Greenhalgh et al. identified key components for the diffusion of innovation in health service delivery which included the five innovation attributes identified by Rogers as well as organizational-level factors including communication channels, organizational antecedents for innovation, organizational readiness for change, the implementation and routinization process, and the wider environment. Guided by key components of Rogers' and Greenhalgh et al.'s theoretical frameworks, we identified the individual and organizational-level factors that served as facilitators or barriers to bundle adoption in 8 adult ICUs.

Proposition 1

P_1: ICUs with staff who rate the ABCDE bundle more favorably in terms of its relative advantage, compatibility, simplicity, trialability, and observability will achieve higher levels of bundle adherence.

Proposition 2

P_2: ICUs with strong organizational antecedents for innovation such as strong leadership, available resources, and an innovative climate will achieve higher levels of bundle adherence.

Proposition 3

P_3: ICUs in the enhanced intervention group will achieve higher levels of bundle adherence as a result of a structured, multifaceted implementation and routinization process including staff trainings, bundle implementation tools, bundle champions, and performance reports in addition to EHR modifications.

Proposition 4

P_4: Barriers to ABCDE bundle implementation will include time and resource constraints, challenges related to care coordination among providers, fear of patient harm, and competing quality improvement initiatives.

Study Population and Data Sources

Sampling

The ABCDE bundle was implemented in the 12 ICUs of 6 BSWH North (previously Baylor Health Care System) hospitals. We included 8 of the 12 study ICUs in the mixed methods evaluation. We selected at least 1 ICU from each of the 6 hospital sites in the basic and enhanced intervention groups. For the 2 hospitals with both medical/surgical and coronary care ICUs, we only included the medical/surgical ICUs. For the tertiary hospital with 5 ICUs we included 1 medical/surgical, 1 trauma, and 1 coronary care unit, in order to compare bundle implementation across different types of units.

The sampling frame included nurses, nurse managers, physician bundle champions and leaders, and respiratory, physical, and occupational therapists from these ICUs. The number of full-time equivalent (FTE) nurses per ICU ranged from 16 to 84. The number of FTE respiratory therapists and physical/occupational therapists ranged from 1 to 4. Enhanced intervention sites had 1 appointed physician bundle champion, and we interviewed ICU physician leaders in the basic intervention ICUs. As the ABCDE bundle was primarily a nurse-driven intervention and there were significantly greater

numbers of nurses per ICU unit, we planned for our stratified sample to include more nurses than other care providers.

Before we recruited participants to participate in the interviews and surveys, the project manager for the study conducted an environmental scan by meeting with the nurse managers of all the study ICUs to gather information about ICU characteristics and staffing and to formulate a strategy for the identification of interview participants and the conduct of interviews. Through our conversations with the nurse managers, we determined that the limited availability and/or willingness of nurses, respiratory and physical/occupational therapists to participate in interviews before and after shifts and the unpredictable schedules of ICU care providers would serve as substantial barriers to the recruitment of participants and the conduct of the study. In order to overcome these barriers we decided to obtain a convenience sample of nurses and respiratory, physical, and occupational therapists by going to ICU units during the day shift and asking care providers who were not engaged in patient care activities to participate. We scheduled these visits with the nurse managers of each unit and the respiratory and physical therapy managers at each facility and visited ICUs on different days and at different times to ensure representation from different shifts. We contacted physician champions/leaders by email and phone and scheduled interviews with those who indicated they would be willing to participate.

All of the nurses and respiratory, physical, and occupational therapists that we approached agreed to participate. Two of the 8 physician champions/leaders that we contacted did not participate in the interviews; 1 physician did not have time to participate, and the other did not respond to our messages. Interviews were conducted in

each ICU until saturation was achieved, as determined through daily discussions with the interview teams to identify potential gaps in data and topics for clarification and the simultaneous coding of interview responses.

Recruitment and Consent

The interview teams met with potential respondents in private conference rooms on the ICU floors to explain the study and obtain consent for participation in an interview and a brief survey. We obtained a waiver of informed consent from the IRB, as we felt a signed consent form posed a threat to participant anonymity. Respondents were given a cover letter describing the study and asked to consent verbally to participate in interviews with audio recording and a brief survey.

Instruments

Study instruments included the environmental scan, interview guides, and a survey. We created the environmental scan questionnaire (Appendix B1) by modifying an existing site visit form from a national diabetes evaluation (Robert Wood Johnson Foundation, 2010). The questionnaire included questions pertaining to the characteristics, staffing, and working environment of the ICU and key staff involved in ABCDE bundle implementation. Interviews were conducted with an interview guide (Appendix B2). We developed separate interview guides for ICUs in the basic and enhanced intervention groups. The 6-part guide for the 5 ICUs that received the enhanced intervention contained 24 questions pertaining to: 1) the role of the respondent in the ICU and regarding ICU processes of care, 2) ABCDE bundle adoption, 3) characteristics of the bundle, 4) organizational-level factors influencing ABCDE bundle implementation, 5) implementation and routinization of the bundle, and 6) other factors

that may have facilitated or hindered bundle implementation efforts. The guide for the 3 ICUs that received the basic intervention contained the same questions as the enhanced intervention interview guide plus an alternative set of questions for respondents who indicated that they were not familiar with the ABCDE bundle, as ICUs in the basic intervention group were only given EHR tools and were not provided with ABCDE bundle education or training by the study team. The alternative questions pertained to current ICU processes for delirium prevention, detection, and management; experience with and current quality improvement projects; and attitudes of ICU staff and leadership regarding innovation. Questions were open-ended to allow respondents to fully explain their perceptions of the ABCDE bundle and implementation process. We pre-tested the interview guides with members of the research staff and two nurses, one who was familiar with ABCDE bundle implementation and one who was not and revised the guides based on their feedback.

Following the interview, interviewees were asked to complete a brief paper-based survey designed to further assess perceptions of the bundle and bundle implementation (Appendix B3). This instrument was based on a survey developed by Helfrich et al. and contained questions about the organizational factors within the ICU and attributes of the ABCDE bundle (Helfrich, Savitz, Swiger, & Weiner, 2007). We examined bundle attributes based on the 5 qualities identified by Rogers as key drivers of innovation: relative advantage, compatibility, complexity, trialability, and observability (Rogers, 2003). For example, respondents were asked about the advantages of bundle use and the visibility of bundle benefits. Items were assessed on a 5-point Likert scale. The survey

was used to augment data collected from the interviews and its psychometric properties were not formally assessed.

Data Collection

The environmental scan, semi-structured interviews, and surveys were conducted between July and October of 2014. The project manager for the study conducted the environmental scan through in-person meetings with the nurse managers of the study ICUs. ICU staff interviews were conducted by 4 interview teams consisting of 2 researchers each in private conference rooms on ICU floors. One researcher conducted the interview, while the other researcher took notes in a Microsoft Access database designed specifically for the study. Interviews were audio recorded with the consent of the respondents.

After each interview session, the research team reviewed the notes and clarified responses by listening to the audio recordings. Survey responses were entered into an Access database and verified by a member of the study team. All researchers attended 2 webinars on qualitative interviewing and data collection conducted by experts from the High Value Healthcare Collaborative and completed two practice interviews. Interview notes from the practice interviews were compared with the interview script and across interview teams to ensure that data was collected accurately and reliably.

Research Design

This mixed methods study examined the individual and organizational-level factors that facilitated or impeded ABCDE bundle adoption. We viewed each of the 8 ICUs that were selected to participate in this evaluation as a case study and used replication logic permitting analyses of responses among individual ICUs and between

the basic and enhance intervention groups (Stake, 1995; Yin, 1994). We also compared responses between the basic and enhanced intervention groups to identify barriers and enabling factors for successful implementation of the ABCDE bundle practices.

Data Analysis

Two researchers analyzed interview responses using a shared codebook (Appendix B4). The researchers created the codebook by developing pre-set codes based on the research questions and themes from the literature and creating emerging codes based on interview responses. The researchers coded the interviews in Microsoft Access by creating a coding form featuring drop-down menus with the pre-set and emerging codes. Both researchers coded three of the same interviews and compared coding schemes to ensure they were interpreting and applying the codes in a consistent manner. The minor differences in coding styles that were detected were resolved via discussion between the two researchers. The researchers were in constant communication during the coding process and discussed the creation of emerging codes and any other questions regarding interpretation to ensure agreement between researchers.

We used thematic content analysis to identify thematic patterns from narrative responses (Miles & Huberman, 1994). Following identification and description of the themes and their underlying relationships from the interview data as a whole, we conducted a comparison analyses among ICUs and between the basic and enhanced intervention groups to identify barriers and enabling factors for successful implementation of the ABCDE bundle practices based on key components of Rogers' and Greenhalgh et al.'s theoretical framework for diffusion of innovation: perceptions of the ABCDE bundle, organizational factors influencing bundle implementation, the

implementation and routinization process, and barriers to implementation. Survey data were analyzed using independent t-tests in SAS version 9.3 (SAS Institute, Inc. Cary, NC).

C. Evaluating the Cost-Effectiveness of the ABCDE Bundle: Impact of Bundle Adherence on Inpatient and 1-Year Mortality, Quality of Life, and Costs of Care

Research Question: What is the impact of the ABCDE bundle adherence on inpatient and 1-year mortality, quality of life, and costs of care?

The scarcity of health resources necessitates the assessment of costs and effectiveness of clinical interventions to determine the most efficient use of these resources. Interventions to reduce delirium in intensive care unit (ICU) patients may lead to the reductions in the costs of patient care by improving patient functionality, reducing length of mechanical ventilation, and reducing ICU and hospital length of stay (LOS). However, only one published study has examined the cost-effectiveness of a multifaceted intervention for the management of delirium in the ICU. Awissi et al. found that multifaceted care processes for management of sedation, analgesia, and delirium led to improved health outcomes including reduction of delirium cases and generated a cost savings of approximately $1,000 per hospitalization (Awissi et al., 2012). No published studies have examined the cost-effectiveness of the ABCDE (Awakening and Breathing Coordination, Delirium Monitoring and Management, and Early Exercise and Mobility) bundle.

The third paper examined the impact of ABCDE bundle adherence on inpatient and 1-year mortality, quality-adjusted life years (QALYs), and costs of care. We evaluated differences in outcomes and costs of care for patients with high (≥60%) versus low bundle adherence. We calculated the cost-effectiveness of the ABCDE bundle for study patients in terms of lives and life years saved. We used a Markov model with

estimates obtained from the literature to estimate the potential effect of improved ABCDE bundle adherence on health care costs and QALYs in the year following ICU admission.

Hypothesis 1

$H_{1:}$ There is a negative association between high ABCDE bundle adherence and incidence of delirium, length of stay, inpatient mortality, and direct costs of patient care.

Model:

$$y_{it} = \beta_0 + \beta_1 \text{ABCDE_Adherence}_{it} + \beta_2 \text{ICU}_{1\text{-}12} + \beta_3 \text{Month}_{it} + \beta_4 \text{Age}_{it} + \beta_5 \text{Male}_{it} + \beta_6 \text{Race}_{it} + \beta_7 \text{Hispanic}_{it} + \beta_8 \text{Insurance}_{it} + \beta_9 \text{Comorbidities}_{it} + \beta_{10} \text{IllnessSeverity}_{it} + \beta_{11} \text{MortalityRisk}_{i} + \beta_{12} \text{Apache}_{it} + \beta_{13} \text{VentLOS}_{it} + \beta_{14} \text{ICU_LOS}_{it} + \beta_{15} \text{Smoker}_{i\,t} + \beta_{16} \text{Alcohol}_{it} + \beta_{17} \text{Dementia}_{it} + \beta_{18} \text{Surgical}_{it} + \beta_{19} \text{Quality}_{u} + \varepsilon_{it}$$

for patient *i* in month *t* in unit *u*.

Outcome variables and covariates for Hypothesis 1 are described in Tables 7-8.

Table 7. Description of Outcome Variables for Hypothesis 1

	Variables	H_o	Variable Type	Description
y_1	DeliriumIncidence	-	Dichotomous	1 if the patient developed delirium, 0 if the patient did not develop delirium
y_2	HospitalLOS	-	Count	hospital length of stay (days)
y_3	DischargeStatus	+	Categorical	where the patient was discharged (home, home health, hospice, long term care facility, inpatient rehabilitation facility, skilled nursing facility)
y_4	InpatientMortality	-	Dichotomous	1 if the patient died in-hospital, 0 if the patient did not die in-hospital
y_5	Costs	-	Continuous	direct costs of inpatient care

H_0 = Hypothesized relationship between bundle adherence and outcome

Table 8. Description of Covariates for Hypothesis 1

Variables	Variable Type	Description
ABCDE_Adherence	Dichotomous	if patient had high levels of bundle adherence, 0 if the patient had low levels of bundle adherence based on the defined threshold
ICU	Categorical	the ICU the patient was treated in
Month	Discrete	month in which care episode occurred (1-24)
Age	Continuous	patient age (years)
Male	Dichotomous	1 if the patient was male, 0 if the patient was female
Race	Categorical	variable indicating patient race (White, Black, Asian, Other)
Hispanic	Dichotomous	1 if the patient was Hispanic, 0 if the patient was not Hispanic
Insurance	Categorical	variable indicating insurance status (privately insured, Medicare, Medicaid, other federal, self-pay, other)
Comorbidities	Discrete	Charlson Comorbidity Index score for the patient
IllnessSeverity	Dichotomous	1 if patient had high severity of illness represented by a score of 4 on the APR-DRG Severity of Illness score, 0 if patient had a score <4
MortalityRisk	Dichotomous	1 if patient had high mortality risk represented by a score of 4 on the APR-DRG Mortality index, 0 if patient had a score <4
Apache	Discrete	Patient's severity of illness as measured by APACHE II score (0-71)
VentLOS	Count	Number of days the patient spent on the ventilator
ICU_LOS	Count	Number of days the patient spent in the ICU
Smoker	Dichotomous	1 if the patient was a smoker, 0 if otherwise
Alcohol	Dichotomous	1 if patient was an alcoholic, 0 if the patient was not an alcoholic
Dementia	Dichotomous	1 if patient had a diagnosis of dementia at admission, 0 if otherwise
Surgical	Dichotomous	1 if a patient was a surgical patient, 0 if otherwise
Quality	Continuous	a quality score for each ICU calculated as the average number of central line associated blood stream (CLABSI) infections and catheter associated urinary tract (CAUTI) infections divided by the number of line/catheter days per 1,000 patient days.
ε_{it}		Non-independent error term to account for clustering within ICUs

Hypothesis 2

H_2: The ABCDE bundle will be a dominant strategy as patients with high bundle adherence will have lower costs of care and will achieve gains in life years and QALYs compared to patients with low bundle adherence.

Study Population and Data Sources

This study included patients treated in the 12 ICUs of 6 BSWH North (previously Baylor Health Care System) hospitals. The hospitals included a large, urban tertiary referral center, 4 community hospitals, and a rural hospital. ICUs included medical/surgical, trauma, neurological, and cardiac care units.

All patients who were admitted to study ICUs from July 2012 – June 2014 who met the ABCDE bundle inclusion criteria were included in the analysis. Patients were eligible to receive the bundle if they were 18 years of age or older, had an ICU admission lasting more than 24 hours, and were on a ventilator for more than 24 hours and less than 14 days. Patients were excluded if they were on comfort care; were awaiting a transfer order to a non-ICU bed; were never on the ventilator; had a primary diagnosis of brain tumor, mental disorder, stroke, intracranial injury, or poisoning by drugs, medicinal and biologic substances based on ICD-9 classification; or had an hospital stay greater than 30 days.

Process measures related to ABCDE bundle adherence were collected from the EHR. Patient demographic and outcomes data were collected from the EHR and BSWH administrative databases. The cost of inpatient care was calculated as the direct care cost for each patient and was obtained from the BSWH TRENDSTAR database. These costs included the costs of any additional patient services associated with application of the

ABCDE bundle. The cost of ABCDE bundle implementation trainings and one-time costs associated with the development of EHR forms to support bundle use were considered sunk costs and were excluded from the cost calculation. Costs were adjusted to 2012 dollars using the medical component of the consumer price index (United States Department of Labor, 2014).

Post-acute care costs were estimated from 2012 Medicare average payments for patients receiving care from home health services, skilled nursing facilities, inpatient rehabilitation facilities, and long-term care hospitals (Medicare Payment Advisory Committee, 2014). One-year mortality rates and quality adjusted life years (QALYs) based on discharge status were obtained from a one-year prospective cohort study of 817 critically ill patients aged 18 years of age or older who received mechanical ventilation for ≥ 48 hours in the medical, general surgical, trauma, and neurological ICUs of an academic tertiary care medical center (Cox, Carson, Govert, Chelluri, & Sanders, 2007; Cox, Carson, Lindquist, et al., 2007).

Research Design

We used a prospective, quasi-experimental design to examine differences in bundle adherence on incidence of delirium, hospital LOS, inpatient mortality, inpatient costs, and discharge status. We then conducted a cost-effectiveness analysis using a Markov model to estimate differences in 1-year costs and QALYs for patients with low and high levels of bundle adherence.

Statistical Analysis

We conducted a univariate analysis to examine unadjusted differences in patient characteristics and delirium incidence, inpatient mortality, inpatient costs, and discharge

status between patients with high and low bundle adherence. We compared differences in continuous variables and outcomes that did not violate normality assumptions with independent t-tests. We compared differences in categorical variables and outcomes using Chi-square and Fisher's exact tests.

Due to the fact that patients with greater severity of illness and risk of mortality were more likely to have low levels of bundle adherence, a propensity score adjustment approach was used to reduce the impact of selection bias on the association between bundle adherence and the outcomes of interest. The propensity score, the conditional probability of a patient having high bundle adherence, was determined from a multivariable logistic regression model. Covariates included ICU unit, age, sex, race, ethnicity, insurance status, APR-DRG Severity and Risk of Mortality scores, Charlson Comorbidity Index, Acute Physiology and Chronic Health Evaluation II (APACHE II) score, ventilator days, ICU length of stay, alcohol use, smoking status, pre-existing dementia, month of ICU admission, and ICU quality. These variables were included based on findings in the literature and evidence that some nurses are reluctant to apply the bundle out of fear of harming patients, particularly those who are frail or may be agitated and/or aggressive when they wake up. We calculated a quality score for each ICU as a proxy measure to control for differences in the quality of care provided in ICUs. The score was calculated as the average number of central line associated blood stream (CLABSI) infections and catheter associated urinary tract (CAUTI) infections divided by the number of line/catheter days per 1,000 patient days. CLABSI and CAUTI are common infections in critical care units that can be prevented through proper management of central lines and catheters, and the Centers for Medicare and Medicaid

have selected these infection rates as critical care quality measures for 2015(Centers for Disease Control and Prevention, 2014a, 2014b).

Propensity score adjusted effects of bundle adherence on delirium incidence, inpatient mortality, and discharge status were modeled using logistic regression. A generalized linear model with a log link function and a gamma distribution was used to model direct costs due the highly skewed nature of hospital cost data. All statistical analyses were conducted using SAS®. Statistical significance was indicated at the $\alpha < 0.05$ level.

Cost-effectiveness Analysis

Potential patient life years saved were calculated by estimating the number of life years lost for each person who died in the study. Life expectancy was projected based on the age and sex of the patient using the Social Security Administration's actuarial life tables for 2010 (U.S. Social Security Administration), discounted based on the five year survival for patients discharged from ICUs compared to the general population (Wright, Plenderleith, & Ridley, 2003). The number of life years saved was calculated as the difference in projected life expectancy and the age of the patient at the time of death.

We used recycled predictions to estimate the effect of high versus low adherence on incidence of delirium, hospital LOS, inpatient mortality, discharge status and inpatient costs, using the different models considered (Glick, Doshi, Sonnad, & Polsky, 2007). High bundle adherence was defined as receiving ≥60% of bundle elements, based on the average level of adherence obtained in sites following ABCDE bundle implementation efforts. We varied this threshold from 50% to 70% as a sensitivity analysis. Outcomes were predicted from the modeled equations based on two scenarios: 1) every patient had

high adherence to the ABCDE bundle; and 2) every patient had low adherence to the ABCDE bundle. The difference between these two predictions constituted the predicted mean differences in delirium incidence, hospital LOS, inpatient mortality, discharge status, and direct inpatient costs between patients who had high and low levels of ABCDE bundle adherence. We generated 1,000 bootstraps of this process to estimate: 1) the mean differences in these outcomes and 2) the standard errors of these statistics.

The estimates obtained from the bootstraps for inpatient mortality, direct costs, and discharge status for both high and low adherence groups were used as inputs in the Markov model for the cost-effectiveness analysis along with the 1-year mortality risks, QALYs, and costs of care obtained from the literature. Life expectancy estimates for the Markov model for the patients who died in the year following discharge were based on LOS averages for Medicare patients discharged to nursing facilities, inpatient rehabilitation centers, and long term acute care facilities. We assumed a life expectancy of 30 days for patients who died after being discharged home or to home health. We calculated the one-year incremental cost effectiveness of high ABCDE bundle adherence as the ratio of incremental health care costs in the year following ICU admission to the incremental effects (QALYs).

CHAPTER 4. SUMMARY OF RESULTS

The findings from the three studies are highlighted in the three manuscripts in Appendices A-C. The first manuscript "Effectiveness of ABCDE Bundle Implementation Strategies on Bundle Adherence and Patient Outcomes" examines the effect of the two implementation strategies (basic versus enhanced) on ABCDE bundle adherence and the impact of bundle adherence on patient outcomes. We found that ICUs in both intervention groups had statistically significant improvements ($p < .001$) in ABCDE bundle adherence between pre- and post- periods. Contrary to our hypothesis that ICUs in the enhanced intervention group would outperform ICUs in the basic intervention group, basic group ICUs achieved a 22% greater increase in adherence relative to enhanced group ICUs. High bundle adherence (≥60%) was associated with significant decreases in inpatient mortality (OR = 0.40; 95% CI: 0.29-0.56), incidence of coma (OR = 0.70; 95% CI: 0.57-0.86), ventilator days (OR = -0.20; 95% CI: -0.27 to -0.14), and increased odds of mobilizing out of bed (OR = 2.06; 95% CI: 1.65-2.57). Although high bundle adherence was not associated with reductions in incidence of delirium, patients with high adherence had a significant increase in the percentage of delirium and coma free days.

The second manuscript "Implementation and Routinization of the ABCDE Bundle: A Mixed Methods Evaluation" describes the implementation and routinization of the ABCDE bundle in study ICUs based on findings from interviews with frontline ICU staff and managers including nurses, physicians, and respiratory, physical, and

occupational therapists. Across ICUs, respondents agreed that use of the ABCDE bundle resulted in “best care” through the standardization and coordination of care processes and improved patient outcomes. ICUs in the basic intervention group had environments that were more conducive to bundle implementation. These ICUs tended to be smaller and respondents cited strong leadership, good communication, availability of staffing and other resources to support bundle implementation, and good working relationships among nurses, physicians, and respiratory, physical, and occupational therapists as organizational factors that facilitated bundle implementation. Respondents in these ICUs indicated that they felt “left out” of the intervention and initiated their own implementation strategies after learning about the enhanced intervention at systemwide council meetings. Successful ABCDE bundle implementation tactics deployed by basic intervention ICUs included incorporating the bundle into multidisciplinary rounds and providing ongoing support, training, and routine auditing and feedback.

The third manuscript “Evaluating the Cost-Effectiveness of the ABCDE Bundle: Impact of Bundle Adherence on Inpatient and 1-Year Mortality and Costs of Care” examines the impact of ABCDE bundle adherence on incidence of delirium, length of stay, inpatient and 1-year mortality, quality-adjusted life years (QALYs) and costs of care. We found that patients with high ABCDE bundle adherence (≥60%) had significantly decreased odds of inpatient mortality (OR 0.40) and slightly, but not significantly, higher costs ($1,877) of inpatient care. The incremental cost effectiveness ratio (ICER) of high bundle adherence was $18,770 (95% CI: $13,750-$21,705) per life saved and $1,341 per life year saved. A Markov model was used to estimate the potential effect of improved bundle adherence on health care costs and QALYs in the year

following ICU admission. High bundle adherence was associated with a 0.05 increase in QALYs, a $939 increase in cost, and an ICER of $17,792 per QALY.

These three manuscripts will be submitted to *Critical Care Medicine*.

CHAPTER 5. DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS FOR PRACTICE AND FUTURE RESEARCH

This study addressed a gap in the literature pertaining to the implementation and adoption of the ABCDE bundle and the effectiveness and cost-effectiveness of this strategy for the care of critically ill patients. To date, only one published study has examined the effectiveness of the ABCDE bundle. We examined the adoption of the ABCDE bundle in 12 adult ICUs in 6 hospitals belonging to a large, integrated health care delivery system. Consistent use of the bundle did not increase the risk of patient harm and was associated with improved patient care and outcomes including significant reductions in incidence of coma, duration of coma, ventilator days, and inpatient mortality and significant increases in the percentage of patients who were mobilized out of bed.

Although the ABCDE bundle has been promoted as an intervention to reduce delirium in ICU patients, we did not observed a significant decrease in incidence of delirium in patients with higher levels of bundle adherence. However, we believe that this finding was due to a contamination or detection bias. While adherence rates for the other bundle components did not increase until the EHR was modified at the beginning of the post-period, adherence rates for the delirium screening component of the bundle (CAM-ICU) increased in the pre-period, likely due to a systemwide emphasis on improving delirium detection in BSWH hospitals. Like other studies examining the effectiveness of bundle elements that observed improvements in patient outcomes but not in incidence of delirium, we observed reductions in incidence of coma which may have

‘‘unmasked’’ patients with delirium (Girard, Kress, et al., 2008; Skrobik et al., 2010). This “unmasking” may have offset any reductions in incidence of delirium that may have been achieved through improved bundle adherence. Although improved bundle adherence was not associated with a significant decrease in delirium incidence, it was associated with an increase in the percentage of ICU days that patients spent awake and not delirious.

No published studies have examined the cost-effectiveness of the ABCDE bundle. We found that bundle use resulted in gains in life years and QALYs and was not associated with significant increases in the cost of patient care. Overall, our findings indicate that the ABCDE bundle is an effective and cost-effective strategy for improving patient care and outcomes in the ICU.

Patients who are admitted to ICUs are unlikely to return to pre-ICU levels of health following ICU discharge, and ICU-acquired delirium has been recognized as a major public health problem that is independently associated with increased cognitive and physical impairment, mortality, hospital LOS and health care costs (Barr et al., 2013). Controlled trials have provided evidence that use of individual bundle components including spontaneous awakening trials, spontaneous breathing trials and early mobility are not associated with increased risk of patient harm and reduce duration of mechanical ventilation, lower the prevalence of coma and delirium, and result in improved health outcomes following ICU discharge (Girard, Kress, et al., 2008; Kress et al., 2000; Schweickert et al., 2009). In its 2013 Clinical Practice Guidelines for the Management of Pain, Agitation and Delirium in Adult ICU patients, the Society for Critical Care Medicine recommended the use of SATs, SBTs, and early mobility;

however, these interventions are not routinely performed in ICUs (Barr et al., 2013; Devlin & Pohlman, 2014; Tanios, de Wit, Epstein, & Devlin, 2009).

Similar to the findings of Balas et al, we found that implementation of the ABCDE bundle improved use of SATs, SBTs, delirium screening, and early mobility. We observed increased adherence to bundle elements across 12 ICUs in 6 different hospitals following bundle implementation. We hypothesized that ICUs receiving an enhanced intervention consisting of bundle training, clinical champions, and staff participation in bundle implementation efforts as well as EHR modifications would achieve greater gains in bundle adherence than ICUs receiving a basic intervention consisting of the EHR modifications alone. However, ICUs assigned to the basic intervention group achieved greater gains in and higher overall bundle adherence rates. Through the mixed methods component of this study, which included interviews with ICU staff, we discovered that basic intervention ICUs learned about ABCDE bundle implementation efforts at other sites through the system wide Critical Care Council and other channels and had launched their own bundle implementation strategies after feeling they had been excluded from the intervention.

Guided by Roger's and Greenhalgh et al.'s theoretical frameworks for diffusion of innovation, we examined differences between basic and enhanced intervention groups in perceptions of the ABCDE bundle, organizational factors influencing bundle implementation, the implementation and routinization process, and barriers to implementation to identify key drivers of bundle uptake. The majority of respondents in both intervention groups agreed that the bundle helped them improve the delivery of care to ICU patients by standardizing care processes and improving coordination of care

among multidisciplinary care teams. Given the favorable impression of the bundle across sites, much of the observed variation in adherence is likely attributable to differences in organizational factors and routinization efforts. In the interviews, members of basic intervention ICUs cited strong leadership; good working relationships among nurses, physicians, respiratory therapists, and physical therapists prior to bundle implementation; good communication; and sufficient resources as organizational factors that facilitated bundle implementation. By chance, the ICUs that were selected as the basic intervention group appeared to be more conducive to innovation. These ICUs were smaller than ICUs in the enhanced intervention group, with the exception of the rural ICU, and one ICU had a closed staffing model which may have made created more familiarity among staff and better working relationships. When surveyed, respondents from ICUs in the basic intervention group were more likely to agree that their ICU encouraged innovation and new ways of providing care and rewarded creativity. The success of basic intervention ICUs largely may be due to the fact that the managers of these ICUs chose to pursue ABCDE bundle implementation and were personally vested in the bundle's success rather than having the bundle forced on them as part of a study.

Enhanced intervention ICUs participated in trainings, had clinical champions, and received implementation tools such as posters and pocket cards describing the bundle as part of the study. Following the EHR modifications, ICUs in the basic intervention group initiated their own bundle implementation strategies including formal trainings, use of clinical champions and super-trainers, piecemeal implementation of bundle elements, verbal and email reminders, and visual aids. Respondents in basic intervention ICUs felt that the bundle had become routinized through incorporation into daily huddles and daily

assessment schedules. Basic intervention ICUs were successful in establishing performance measurement and feedback and held staff accountable for bundle use and documentation while ICUs in the enhanced intervention group were still waiting for accurate performance reports from the study team at the time of the interviews.

Despite the fact that the ICUs had some site-specific challenges, we observed that facilitators and barriers to ABCDE bundle implementation across sites were similar across ICUs and consistent with those from other studies examining ABCDE bundle implementation (Balas et al., 2013; Carrothers et al., 2013). The most common barrier to ABCDE bundle implementation reported by respondents in the interviews was EHR documentation. Although some respondents felt that the EHR streamlined ABCDE bundle adherence by providing a structured checklist of bundle elements, many respondents indicated that they were unsure of how to document certain bundle elements or that there were too many different places where they needed to document the bundle. Other frequently cited barriers were staff shortages, time constraints, and lack of coordination among care providers. Many respondents indicated that it was difficult to administer the bundle when the nurse to patient ratio exceeded 1:2 and that often there were very few physical therapists assigned to ICUs to assist with early mobility. These findings reiterate the need for engaged leadership, supporting resources and ongoing training, EHR tools, and multidisciplinary communication and rounding to drive the adoption and routinization of the ABCDE bundle.

The findings from our study indicate that the implementation of the ABCDE bundle into everyday practice is feasible and cost-effective. Bundle processes of care could be carried out by existing ICU staff, although some staff indicated more staffing

resources would facilitate bundle adherence. Implementation costs were approximately $165,000 and included salary support (1.65 FTEs) for the project lead, project manager, clinical champions, IT personnel for EHR modifications, and data analysts. The direct costs of patient care for patients with high bundle adherence were slightly higher than the costs of care for patients with bundle adherence. However, the cost per life ($18,770) and life year saved ($1,341) fell well below the threshold of $50,000 per life-year or QALY frequently used as to assess the cost-effectiveness of health interventions in the United States (Grosse, 2008). When we modeled the potential effect of improved bundle adherence on health care costs and QALYs in the year following ICU admission we found that bundle adherence was associated with a 0.05 increase in QALYs, a $939 increase in the direct cost of care, and an ICER of $17,792 per QALY. We did not have data available to examine the actual costs and impact of the ABCDE bundle on life years and QALYs following ICU discharge for our study population and likely underestimated the effect of the ABCDE bundle on improving patient outcomes.

Study Implications

Achieving the triple aim of health care, defined as improving the health of the population, enhancing the experience and outcomes of the patient, and reducing per capita cost of care for the benefit of communities, requires the identification and successful implementation of best care practices. The Institute for Healthcare Improvement (IHI) developed the concept of ‘bundles’ to help healthcare providers improve the reliability of delivery of essential healthcare processes. The delivery of care for critically ill patients could be greatly improved through the standardized use of evidence-based practices such as those contained in the ABCDE bundle, and we found

that deploying these practices as a bundle was associated with increased adherence to these practices and patient outcomes. Based on our findings, and those from the previous study examining ABCDE bundle effectiveness, we have implemented the ABCDE bundle as the standard of care in all 18 BSWH acute care facilities and recommend widespread adoption of the ABCDE bundle for the provision of care in ICUs.

The decision to adopt the ABCDE bundle must be accompanied by support from a multidisciplinary team of hospital and ICU leadership, a structured implementation process, and a commitment to provide resources such as clinical champions, staff trainings, IT resources to develop EHR tools for capture of bundle adherence, and data analysts to assist with the development of bundle adherence reports. Bundle uptake will likely represent a shift in ICU culture and require more coordination among an interdisciplinary team of care providers, and implementation strategies will need to be tailored for individual ICUs to address site-specific barriers to implementation. Implementation teams should be prepared to address common barriers such as lack of knowledge about the deleterious effects of ICU-acquired delirium, fear of patient harm, the need for ongoing trainings, staff time constraints, lack of coordination among care providers, and proper documentation of bundle adherence. BSWH has facilitated bundle uptake by tying bundle process measures to system-level performance goals.

Despite the evidence of the ABCDE bundle's effectiveness, widespread implementation will not be achieved in ICUs without external pressure from national quality improvement organizations and health care payers. We recommend that organizations such as the Society for Critical Care Medicine and the Institute for Healthcare Improvement promote the ABCDE bundle as a means to improving the

quality of care for critically ill patients. Although some health care delivery organizations will be motivated to adopt the ABCDE bundle out of the desire to provide best care to patients, other organizations will not be motivated to do so without financial incentives for bundle adherence or penalties for lack thereof. Ultimately, ABCDE bundle adherence rates could be included as quality measures for pay-for-performance programs such as the Centers for Medicare & Medicaid Services Hospital Value-Base Purchasing Program, which rewards hospitals with better performance on quality metrics with higher incentive payments.

Limitations

This dissertation had several limitations. The ABCDE bundle was implemented as a quality improvement project using a quasi-experimental design and not as part of a randomized controlled trial. The implementation of the bundle in a real world hospital setting as opposed to a highly controlled environment posed many threats to internal validity. A major limitation was that leadership in ICUs in the basic intervention group learned about the enhanced intervention through the systemwide critical care council and launched their own bundle implementation initiatives. This unintended exposure resulted in contamination which made it difficult to determine the impact of the EHR modification alone on bundle implementation for ICUs in the basic intervention group. There was a lack of intervention fidelity as enhanced intervention groups did not receive consistent or real time feedback about bundle adherence and patient outcomes as planned due to resource constraints associated with the development of EHR data abstraction tools. In addition, several systemwide QI projects were launched during the bundle implementation period including initiatives to reduce ventilator mortality through

improved adherence to ventilator order sets. These order sets initially included the awakening and breathing trial elements of the bundle and were later updated to include the early mobility component.

Measurement and selection biases may have also influenced our findings. We relied heavily on data collected from routine care delivery that were documented in the EHR rather than more structured forms of data collection. Observed increases in ABCDE bundle adherence in both intervention groups could have been due in part to improved bundle documentation as a result of the EHR modifications rather than improved performance. However, the improvements in patient outcomes were observed in conjunction with improvements in bundle adherence indicating improved performance and not just improved documentation.

As this was not a randomized controlled trial, unmeasured and uncontrolled factors may have influenced bundle adherence and resulted in an overestimation of the impact of improved bundle adherence on patient outcomes, particularly the observed reduction in mortality. We used a risk-adjusted difference-in-differences model and regression models to account for variation in baseline bundle adherence among sites and patient and ICU characteristics that may have influenced bundle adoption and patient outcomes to improve internal validity of findings. Additionally, we attempted to control for selection bias in terms of which patients had high versus low bundle adherence and reduce potential endogeneity by using a propensity score risk-adjustment approach to estimate the conditional probability of a patient having high bundle adherence. However, risk-adjustment can only account for observed confounders and does not ensure a balanced distribution of covariates between patients with low and high bundle adherence.

All patients in this study were critically ill, and it was difficult to differentiate levels of illness severity and mortality within this population with existing measures. Differences between intervention groups in the use and dosing of sedatives and analgesics may have also influenced our results, but we did not assess medication use.

Another limitation of this study is the fact that bundle adherence remained relatively low for the majority of patients, as only 29% of patients received >60% of bundle elements. Greater adherence may lead to better outcomes; however, our findings do suggest that even low levels of bundle adherence result in improved outcomes.

Limitations of the mixed methods study included a small number of respondents per ICU, recall bias, and hesitance of respondents to reveal their true feelings about bundle implementation. Although, we tried to mitigate sampling bias by recruiting interview and survey respondents on different days and on different times, the use of convenience sampling may have prevented us from obtaining a representative sample of ICU staff. Because the study was based on Rogers' and Greenhalgh et al.'s frameworks for diffusion of innovation and for diffusion of innovations in health service delivery, we may have only elicited important factors pertaining to the implementation and adoption of the ABCDE bundle that were congruent with Rogers' or Greenhalgh et al.'s model.

A major limitation of the cost-effectiveness study was our lack of post-discharge data for our patient population. Because we did not have data for patients beyond their inpatient stay, we chose to model the impact of ABCDE bundle adherence on 1-year outcomes using estimates from another study and likely overestimated the 1-year mortality risk and underestimated QALYs due to differences in the study population. In addition our basic Markov model did not account for readmissions and transitions other

than from hospital to home/discharge facility and from discharge facility to home or death. Due to the fact that patients with low bundle adherence may not have been routinely screened for delirium, and the incidence of delirium was likely underestimated for this group, we could not conduct a valid assessment of the impact of the ABCDE bundle on incidence of delirium and the impact of delirium on patient costs and outcomes. Prevention of delirium could result in potential gains in QALYs as the development of ICU-acquired delirium has been associated with increased cognitive and physical impairment in both the short and long term (Pandharipande, Girard et al. 2013). We also did not examine what led to differences in costs between patients with low and high levels of bundle adherence. These costs are likely due to increases in LOS and additional physical therapy consults that may have been received with higher bundle adherence.

Despite these limitations, our results indicate patient care and outcomes in the ICU can be improved through implementation and consistent use of the ABCDE bundle. The fact that we observe improvements across a number of ICUs in a variety of hospital settings strengthens the external validity of these findings. Although randomized controlled trials are considered the gold standard of research designs, our use of a quasi-experimental design provides a realistic estimate of the effect of ABCDE bundle implementation on patient outcomes that may be observed in similar real world settings.

Recommendations for Future Research

Admission to the ICU negatively impacts patients in the short and long term, with many patients failing to return to the level of functionality they had prior to ICU admission. Widespread implementation of the ABCDE bundle is feasible and has the

potential to improve the quality of patient care and both short and long term health outcomes for critically ill patients. Further research is needed to better quantify the impact of bundle use on patient outcomes and costs of care, particularly the effect of bundle adherence on long-term health outcomes and costs in the years following ICU discharge. Future studies should examine differences in quality of life after discharge between patients with low and high bundle adherence and if these differences are attributable to prevention or mitigation of delirium. These studies should utilize structured data collection efforts to reliably assess incidence and duration of delirium at baseline and following bundle implementation to ensure valid assessment of the impact of the bundle on delirium. The generation and dissemination of additional evidence linking bundle use to improved patient outcomes will encourage bundle adoption. However, widespread bundle implementation will not occur unless hospitals and ICUs have multidisciplinary leadership that supports bundle use, access to toolkits and trainings on bundle implementation, can easily record and monitor bundle adherence in the EHR and provide real time feedback on bundle adherence rates to frontline staff, and receive incentives for bundle adherence or are penalized for failure to adhere to these key process measures.

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APPENDIX A. THE EFFECT OF ABCDE BUNDLE IMPLEMENTATION STRATEGIES ON BUNDLE ADHERENCE AND PATIENT OUTCOMES

Abstract

Objective: The objective of this study was to examine the effect of two implementation strategies (basic vs. enhanced) on ABCDE (Awakening and Breathing Coordination, Delirium monitoring/management, and Early exercise/mobility) bundle adherence and the impact of bundle adherence on patient outcomes.

Design: Two-year, prospective, quasi-experimental, pretest-posttest study conducted between July 2012 and June 2014.

Setting: 12 adult ICUs in 6 hospitals belonging to a large, integrated healthcare delivery system. Hospitals included a large, urban tertiary referral center, 4 community hospitals, and a rural hospital. ICUs included medical/surgical, trauma, neurological and cardiac care units.

Patients: 2501 patients, 18 years of age or older, with an ICU stay >24 hours, who were on a ventilator for more than 24 hours and less than 14 days.

Interventions: The basic strategy involved the modification of the electronic health record (EHR) to facilitate bundle implementation and documentation while the enhanced strategy included EHR modification plus additional bundle training, clinical champions, and staff participation in bundle implementation efforts.

Measurements and Main Results: ICUs in both intervention groups had statistically significant improvements (P <.001) in ABCDE bundle adherence between pre- and post-

periods with basic group ICUs achieving a 22% greater increase in adherence relative to enhanced group ICUs. High bundle adherence (≥60%) was associated with significant decreases in inpatient mortality (OR = 0.40; 95% CI: 0.29-0.56), incidence of coma (OR = 0.70; 95% CI: 0.57-0.86), ventilator days (-0.20; 95% CI: -0.27 to -0.14), and increased odds of mobilizing out of bed (OR = 2.06; 95% CI: 1.65 to 2.57). Although high bundle adherence was not associated with reductions in incidence of delirium, patients with high adherence had a significant increase in the percentage of delirium and coma free days. **Conclusions:** Consistent use of the ABCDE bundle can greatly improve patient safety, care, and outcomes. Modification of the EHR to facilitate integration of the bundle into clinical workflow and documentation of bundle processes may facilitate uptake and adherence.

Background

Delirium is a common and serious complication for patients who are critically ill. Between 35% to 80% of Intensive Care Unit (ICU) patients develop delirium and as a result, are more likely to experience negative health outcomes including increased ventilator days, coma days, ICU and hospital length of stay (LOS), mortality, and likelihood of discharge to a nursing facility. Several individual care practices such as awakening and breathing trials, delirium screening, and early mobility protocols have been associated with reduced incidence and prevalence of delirium in ICU patients. However, despite more than a decade of evidence indicating the hazards of delirium and the benefits of these interventions in preventing and mediating this condition, a substantial implementation gap continues to exist between the current state and ideal ICU practice in this area (Vasilevskis, Ely, et al., 2010). Less than 60% of ICUs in the United States have implemented protocols for the management of delirium, and when instituted, protocol adherence is low (Barr et al., 2013). Rates of daily sedation interruptions and breathing trials for mechanically ventilated patients have been reported to be under 40% in cross-sectional surveys (Kahn, Brake, & Steinberg, 2007; Mehta et al., 2006). Use of validated tools for delirium monitoring and sedation scales is reportedly below 40% (Mehta et al., 2006; Patel et al., 2009). Likewise, less than 50% of patients reportedly receive any physical therapy during their ICU stay (Morris et al., 2008; Thomsen, Snow, Rodriguez, & Hopkins, 2008).

Adoption of other patient safety practices (e.g., prevention of central line–associated blood stream infections, venous thromboembolism prophylaxis) has been facilitated by multifaceted implementation approaches such as: 1) combining discrete

practices into a single bundle of integrated care processes (Berenholtz et al., 2004; Pronovost et al., 2006), 2) engagement of physician and nursing "champions" (Bayley, Sorensen, Brown, & al, 2009; McGrath, 2006; Middleton et al., 2005; Nebeker, Masica, Sorensen, & al, 2009) 3) clinical decision support and workflow enhancement tools (in electronic and paper formats) (Ely, Inouye, et al., 2001; Ely, Margolin, et al., 2001; Ely et al., 2003; Quinn & Mannion, 2005; Sessler et al., 2002; Tham et al., 2011), and 4) timely feedback on process performance to frontline clinical care providers (Phillips, Hughes, & Savitz, 2008; Wall et al., 2005). The ABCDE (Awakening and Breathing Coordination, Delirium Monitoring and Management, and Early Exercise and Mobility) bundle has been proposed as an interdisciplinary, multi-component patient safety intervention to reduce incidence of delirium in ICUs by improving collaboration among clinical team members, standardizing care processes, and breaking the cycle of oversedation and prolonged ventilation (Balas et al., 2013; Balas et al., 2012; Girard, Pandharipande, & Ely, 2008; Hipp, Ely, & Dittus, 2013; Vasilevskis, Ely, et al., 2010; Vasilevskis, Pandharipande, Girard, & Ely, 2010). The bundle consists of spontaneous awakening trials (SATs) to decrease the use of sedation, spontaneous breathing trials (SBTs) to wean patients off mechanical ventilation faster, coordination of awakening and breathing trials to maximize benefits of SATs and SBTs, delirium screening and treatment, and early progressive mobility to decrease ICU-acquired muscle weakness. Individually, these interventions have been associated with reductions in incidence and duration of delirium and improved patient outcomes such as shorter duration of mechanical ventilation, shorter ICU and hospital LOS, improved functional outcomes, and improved survival

(Brummel & Girard, 2013; Girard, Kress, et al., 2008; Schweickert et al., 2009; Vasilevskis, Ely, et al., 2010).

Despite the potential improvements in patient care and outcomes that could result from consistent bundle use, few ICUs have implemented the ABCDE bundle and only one small study has examined its effectiveness (Balas et al., 2014). More evidence is needed to determine which implementation strategies improve uptake of the ABCDE bundle in various, real world ICU settings and whether use of the bundle improves patient outcomes in a manner consistent with previous findings. The objective of this study was to address this gap in knowledge by examining the effect of two ABCDE bundle implementation strategies (basic vs. enhanced) on bundle adherence in the ICUs of a large, integrated health care delivery system and the impact of bundle adherence on patient outcomes. The basic strategy involved the modification of the electronic health record (EHR) to facilitate bundle implementation and documentation while the enhanced strategy included EHR modification plus additional ABCDE bundle training and implementation tools, designated bundle champions, and participation by ICU staff in the development of the EHR modifications and ABCDE performance reports.

Methods

Study Setting

Baylor Scott & White Health (BSWH), is one of the largest non-profit health care systems in the United States including 43 hospitals, >500 patient care sites, >6,000 affiliated physicians, 34,000 employees and an accountable care organization. This study included patients treated in the 12 ICUs of 6 BSWH North (previously Baylor Health Care System) hospitals. The hospitals included a large, urban tertiary referral center, 4

community hospitals, and a rural hospital. ICUs included medical/surgical, trauma, neurological, and cardiac care units. We intentionally selected hospitals with heterogeneity in size, practice culture, and patient populations in order examine the effectiveness of bundle implementation across settings.

Patients

All patients who were admitted to study ICUs during the 12 months (July 2012 – June 2013) prior to the implementation of the basic intervention (EHR modification) and during the 12 months (July 2013 – June 2014) following who met the ABCDE bundle inclusion criteria were included in the analysis. Patients were eligible to receive the bundle if they were 18 years of age or older, had an ICU admission lasting more than 24 hours, and were on the ventilator for more than 24 hours and less than 14 days. Patients were excluded if they were on comfort care; were pending a transfer order to a non-ICU bed; were never on the ventilator; had a primary diagnosis of brain tumor, mental disorder, stroke, intracranial injury, or poisoning by drugs, medicinal and biologic substances based on ICD-9 classification; or had an hospital stay greater than 30 days.

Standard of Care

Care for ICU patients in all BSWH North hospitals was guided by a standardized critical care flowsheet in the EHR. Hospitals had standard order sets for the management of sedation and analgesia, ventilated patients, and delirium. The sedation/analgesia order set included prescriptions for dexmedetomidine, propofol, and fetanyl and for a SAT to be administered twice daily. The ventilator order set included orders for SATs, SBTs, and daily exercise for ventilated patients as well as prescriptions for fetanyl and morphine as analgesics and midazolam, propofol, and dexmedetomidine for sedation. The delirium

order set prescribed the assessment of patient sedation level, screening for delirium every shift using the Confusion Assessment Method for the ICU (CAM-ICU) (Ely, Inouye, et al., 2001), and use of haloperidol or dexmedetomidine for agitation. The order set also prescribed non-pharmacologic delirium mitigation strategies such as day/night orientation, access to hearing aids and glasses, informing patient of day/time/location, noise reduction, and uninterrupted sleep at night. Although the sedation, ventilator, and delirium protocols existed prior to ABCDE bundle implementation efforts, they were not applied consistently or as a coordinated bundle.

ABCDE Bundle

The ABCDE bundle incorporates several individual evidence-based critical care processes (SATs, SBTs, delirium screening, and early mobility) into a single, integrated package. As critically ill patients may be clinically unstable (labile blood pressures or oxygenation status), safety screens are performed to determine appropriateness of specific care processes for each patient. Bundle elements are delivered by nurses, physicians, respiratory therapists, and physical/occupational therapists. The care processes, respective safety screen criteria, and responsible provider(s) are described in Table 1. The number of care processes a patient is eligible for on a given day depends on whether or not the patient is ventilated and passes the appropriate screening criteria.

Basic Intervention (EHR Modification)

As part of ABCDE bundle implementation efforts, the EHR (Allscripts™) for all BSWH North hospitals was modified to facilitate uptake and documentation of ABCDE bundle elements (Collinsworth, Masica et al. 2014). Changes included the addition of structured data fields for the documentation of ABCDE bundle eligibility and delivery of

bundle processes. These data fields were added to the existing nursing critical care flowsheet or the respiratory therapist structured note, depending on who was responsible for providing the process of care. “Sedation Vacation/Daily Awakening Trial" and “Exercise/ Mobility” sections were added to the nursing critical care flowsheet under the ventilator bundle section. The fields in the “Sedation Vacation/Daily Awakening Trial" section prompted nurses to document if the patient had received a SAT that day or why the patient had failed to receive a SAT, if the sedative infusion was resumed, and why sedation was resumed. The “Exercise/Mobility” section prompted nurses to document if the patient received an early mobility assessment that day and what level of mobility the patient achieved. A line was added to the respiratory therapist structured note for “Spontaneous Breathing Trial" with a pull down box indicating whether or not a SBT was performed, and if not, why not. The physical/occupational (PT/OT) structured note already included structured fields for documentation of early mobility.

In addition, the design team created an “ABCDE” tab in the existing Patient Care Viewer that provided a summary of SAT, SBT, delirium (CAM-ICU), and early mobility assessments to promote quick viewing of the bundle elements received by individual patients and enhance interdisciplinary communication. The informatics team sent out an electronic notification to all BSWH North hospitals highlighting all EHR modifications immediately prior to implementation per standardized protocol. ICUs in the basic intervention group did not receive any additional ABCDE bundle training or communication from the study team.

Enhanced Intervention

In addition to the EHR modifications, ICUs in the 3 hospitals selected to receive

the enhanced intervention participated in a multifaceted implementation strategy targeting physician, nursing, and allied health staff. These ICUs received additional ABCDE bundle training and implementation tools, had designated bundle champions, and participated in the development of the structured EHR documentation and ABCDE performance reports. Enhanced intervention sites received these interventions before and after the EHR was modified to facilitate ABCDE bundle use and documentation. Nurses, respiratory therapists, and physical and occupational therapists from these hospitals attended an initial 4-hour ABCDE bundle workshop lead by nurse bundle experts from Vanderbilt University Medical Center at the end of November 2012. Site-specific trainings were conducted by a BSWH North clinical nurse champion at all enhanced intervention hospitals from January to March of 2013, and one site participated in an additional 4 hour workshop lead by Vanderbilt nurses in May 2013.

Following the implementation of the EHR modifications, the BSWH North clinical nurse champion conducted refresher trainings for the ICUs in July 2013 (2 ICUs), September 2013 (2 ICUs), and April 2014 (3 ICUs). In addition the ICUs in one hospital appointed ABCDE super trainers to assist with ongoing ABCDE bundle implementation and training within their respective ICUs, and these super users participated in trainings on delirium screening, delirium management, and early mobility from November 2013 to January 2014. Enhanced intervention sites also received supplemental in-person training on proper documentation of ABCDE processes within the EHR once the EHR modifications were implemented and implementation tools including pocket cards describing sedation and delirium assessment processes and posters promoting ABCDE

bundle use. Nurse and physician ABCDE bundle champions were also designated at all enhanced intervention sites prior to the EHR modification.

Study Design

We used a prospective, quasi-experimental pretest-posttest design to compare changes in adherence to delirium care processes between ICUs that received the basic intervention versus those that received the enhanced intervention and the effect of high versus low bundle adherence on risk-adjusted patient outcomes.

Process Measures

We examined adherence to four individual components of the ABCDE bundle (SATs, SBTs, delirium screening (CAM-ICU), and early mobility) as well as the entire bundle. ABCDE bundle adherence for each patient was calculated as the total number of care processes the patient received divided by the total number of care processes the patient was eligible for during the course of the patient's ICU stay. Patients who were on a ventilator were eligible to receive all 5 bundle elements (provided they met the safety screening criteria) every day they remained in the ICU and were on the ventilator. Patients who were not on a ventilator were eligible to receive 3 bundle elements (SAT, CAM-ICU, and early exercise) every day they remained in the ICU and were not on a ventilator.

Outcome Measures

Patient outcomes included incidence of delirium, duration of delirium (days) incidence of coma, duration of coma (days), number of days the patient spent in the ICU and was not in a coma and was not delirious (coma and delirium free days), ventilator

days, intensive care unit (ICU) and hospital length of stay (LOS), highest level of mobility achieved in the ICU, discharge disposition, inpatient mortality, and safety outcomes including unplanned extubation and tracheostomy. Delirium was diagnosed with the CAM-ICU, a reliable and validated instrument recommended by the Society of Critical Care guidelines (Barr et al., 2013; Ely, Inouye, et al., 2001). Coma was diagnosed using the Richmond Agitation-Sedation Scale (RASS) (Ely et al., 2003). Incidence of delirium and coma were binary variable indicating if a patient was CAM-ICU positive or had a RASS of -4 or -5 one or more times during ICU stay.

Data Sources

Process measures related to ABCDE bundle adherence were collected from the EHR. There were unstructured data fields within the EHR for nurses to record all ABCDE bundle elements with the exception of early mobility prior to the EHR modification. We reviewed a stratified random sample of 300 charts for patients admitted to study ICUs from January-December of 2012 to estimate average early mobility rates for each ICU in the pre-period and to assess the reliability of the EHR documentation for the other bundle process measures. Patient demographic and outcomes data were collected from the EHR and BSWH administrative data.

Statistical Analysis

We conducted a univariate analysis to examine un-adjusted differences in patient characteristics and outcome measures between patients in the basic and enhanced groups in the pre- and post-intervention time periods. We compared differences in categorical variables and outcomes using Chi-square and Fisher’s exact tests. Differences in

continuous variables and outcomes that did not violate normality assumptions were analyzed with independent t-tests.

We used a risk-adjusted difference-in-differences model to compare changes in adherence to delirium care processes between pre- and post- implementation periods in patients treated in ICUs that received the basic intervention and patients treated in ICUs that received the enhanced intervention. Patient covariates included patient age, gender, comorbidities (Charlson Comorbidity Index), illness severity (APR-DRG Severity Score), mortality risk (APR-DRG Risk of Mortality) alcoholism, dementia as well as the number of days the patient spent on the ventilator and if the patient was a surgical or non-surgical patient. These variables were included based on findings in the literature that some nurses are reluctant to apply the bundle out of fear of harming patients, particularly those who are frail or may be agitated and/or aggressive when they wake up. We calculated a quality score for each ICU as a proxy measure to control for differences in the quality of care provided in ICUs. The score was calculated as the average number of central line associated blood stream (CLABSI) infections and catheter associated urinary tract (CAUTI) infections divided by the number of line/catheter days per 1,000 patient days. CLABSI and CAUTI are common infections in critical care units that can be prevented through proper management of central lines and catheters, and the Centers for Medicare and Medicaid Services has selected these infection rates as critical care quality measures for 2015 (Centers for Disease Control and Prevention, 2014a, 2014b).

As the primary objective of this study was to assess the impact of improved bundle adherence on patient outcomes, we used linear and logistic regression to examine the impact of high versus low bundle adherence on risk-adjusted outcomes over the entire

two-year study period in the basic and intervention groups and in both groups combined. Only a few patients achieved 100% bundle adherence, so we could not examine the effect of an all-or-none adherence measure as in common in studies of care bundles for other conditions. High bundle adherence was defined as receiving ≥60% of bundle elements, based on the mean level of adherence obtained in sites following ABCDE bundle implementation efforts. We varied this threshold from 20% to 80% in a sensitivity analysis. Due to the fact that patients with greater severity of illness and risk of mortality were more likely to have low levels of bundle adherence, a propensity score adjustment approach was used to reduce the impact of selection bias on the association between bundle adherence and the outcomes of interest. The propensity score, the conditional probability of a patient having high bundle adherence, was determined from a multivariable logistic regression model. Covariates included ICU unit, age, sex, race, ethnicity, insurance status, APR-DRG Severity and Risk of Mortality scores, Charlson Comorbidity Index, Acute Physiology and Chronic Health Evaluation II (APACHE II) score, ventilator days, ICU length of stay, alcohol use, smoking status, pre-existing dementia, month of ICU admission, and ICU quality.

We used generalized estimating equations (GEE) methods using the GENMOD procedures in SAS version 9.3 (SAS Institute, Inc. Cary, NC) to build regression models that accounted for clustering of patients within ICUs by controlling for the ICU as a random effect. A Poisson distribution was used to model delirium and coma duration, delirium and coma free days, and ventilator days. We used a negative binomial distribution to model ICU and hospital LOS. All statistical analyses were conducted using SAS®. Statistical significance was indicated at the $\alpha < 0.05$ level.

Results

Patient Characteristics

A total of 2501 eligible patients received care in the 12 study ICUs from July 2012-June 2014; 616 received care in ICUs assigned to the basic intervention group, and 1885 received care in ICUs assigned to the enhanced intervention group (Table 3). The number of patients was equally distributed across pre- and post- periods for both intervention groups. Mean patient age ranged 59.3 to 61.8 years. The percentage of male and female patients was almost equal for both groups, except in the post-period enhanced intervention group, which had a greater percentage of males (61%). The majority of patients in both intervention groups was white. ICUs in the enhanced group treated a greater percentage of nonwhite patients, and ICUs in the basic intervention group treated a higher percentage of Hispanic patients. At least half of the patients in both groups were on Medicare, but both groups had significant changes in payer mix between the pre- and post- periods, mainly due to increases in self-pay and privately insured patients and an increase in Medicaid patients in the basic intervention group. There were only slight differences in mean Charlson Comorbidity Index scores between groups and between pre- and post- periods, and both groups experienced a similar reduction (4-5%) in the number of patients with highest severity of illness and risk of mortality based on APR-DRG scores. The number of surgical patients was much higher in the enhanced group in the pre-period (18% vs. 6%), and this difference increased in the post-period (25% vs. 18%). The number of patients with pre-existing dementia, alcoholism, and who were current smokers was slightly higher in the enhanced intervention group.

Effect of Basic and Enhanced Interventions on Bundle Adherence

We observed statistically significant improvements ($P<.0001$) in adherence to the ABCDE bundle as well as to all of the individual elements of the bundle between the pre- and post- periods for both basic and enhanced intervention sites (Table 4). ABCDE bundle adherence improved from 25% to 63% in ICUs that received the basic intervention and from 38% to 55% in ICUs that received the enhanced intervention. The results of the risk-adjusted difference-in-differences model indicated that ICUs in the basic intervention group had a 22% greater increase in bundle adherence in the year following bundle implementation than ICUs in the enhanced intervention group (Table 5). Adherence rates for the ABCDE bundle and its individual components for both intervention groups during the 12 months before and after EHR modification are displayed in Figures 1-2. There were no significant changes in monthly adherence rates for any of the individual bundle elements for either of the intervention groups in the 12 month pre- period, with the exception of delirium screening (CAM-ICU), which significantly increased for both groups 6 months prior to EHR modification. Significant improvements in adherence to SATs, SBTs, and early mobility were observed in the months immediately following EHR modification. Bundle adherence varied greatly among units, and some units had significantly better adherence than others in both intervention groups. Better (lower) quality scores were associated with higher bundle performance.

Effect of Bundle Adherence on Patient Outcomes

The unadjusted patient outcome measures for the pre- and post- periods are listed in Table 6. Incidence of delirium increased significantly in the basic group (18% to 27%)

and slightly in the enhanced group (31% to 32%). Patients treated in ICUs in the enhanced group experienced a significant increase in incidence of coma (0.10) and ventilator days (0.31) and a slight decrease (1%) in the percentage of ICU days that patients were free of delirium and coma. Patients treated in ICUs in the basic group experienced significant reductions in ventilator days (-0.80), ICU LOS (-1.14 days), hospital LOS (-1.10 days), and inpatient mortality (-0.07). Patients in basic intervention ICUs also were significantly more likely to be discharged home in the post- period (30% vs. 45%) while the percentage of patients who were discharged from enhanced intervention ICUs remained relatively unchanged (45% vs. 44%). Patients in both groups had significant improvements in the highest level of mobility achieved, with the percentage of patients who achieved ambulation increasing from 12% to 42% in basic intervention ICUs and from 10% to 16% in enhanced intervention ICUs. No significant changes in self-extubations or tracheostomies were observed in either group in the post-period.

The results of the risk-adjusted models examining the impact of improved bundle adherence on patient outcomes over the entire two year study period in the basic and enhanced intervention groups and in both groups combined are displayed in Table 7. Overall, high bundle adherence was associated with a non-significant increase in the incidence of delirium. (OR = 1.19; 95% CI: 0.97-1.47). Patients in the basic intervention group with high bundle adherence had a significant decrease in the duration of delirium (-0.34 days) while patients in the enhanced intervention group had a non-significant increase (0.24 days). High bundle adherence was associated with significant decreases in incidence of coma (OR = 0.70; 95% CI: 0.57-0.86) and duration of coma (-0.35 days;

95% CI: -0.50 to -0.20) and a significant increase in the percentage of days that ICU patients were free of coma and delirium (3%, $p < .001$) across both groups. Overall, we observed a significant decrease in ventilator days (-0.20 days, $p < .001$) and an increase in ICU (0.13 days, $p < .001$) and hospital LOS (0.39 days, $p < .001$) with higher bundle adherence. High bundle adherence was associated with a significant increase in the odds of being mobilized out of bed (OR = 2.06; 95% CI: 1.65-2.57) and a non-significant increase in the odds of being discharged home (OR = 1.19; 95% CI: 0.97-1.46) instead of to a nursing or other care facility. Overall, high bundle adherence was associated with a significant decrease in risk-adjusted mortality (OR = 0.40; 95% CI: 0.29-0.56). We observed similar effects when we varied the bundle adherence threshold from 20-80% in the sensitivity analysis (Table 8). However, when bundle threshold was set at 20% and 40%, we observed that patients with high adherence had greater odds of developing delirium and of being discharged home.

Discussion

Limited data exist regarding successful ABCDE bundle implementation tactics and the effect of bundle adherence on patient outcomes. In this quasi-experimental, pre-post study, we found that ICUs that were provided with modified EHR workflow and documentation tools to promote ABCDE uptake achieved greater gains in bundle adherence than sites that were provided with the EHR modifications plus bundle training, implementation tools, and clinical champions. High bundle adherence (≥60%) was associated with significant decreases in inpatient mortality, incidence of coma, duration of coma, ventilator days, and increased odds of mobilizing out of bed. Although high bundle adherence was not associated with reductions in incidence of delirium, patients

with high adherence had a significant increase in the percentage of delirium and coma free days.

Only one previous study has examined the effectiveness of the ABCDE bundle. Balas et al. found that implementation of the ABCDE bundle reduced the risk-adjusted odds of developing delirium by 45% (Balas et al., 2014). Contrary to these findings, we did not observe a significant decrease in risk-adjusted incidence of delirium in either of the intervention groups in the post period. We feel this is a result of contamination and/or detection bias. While adherence rates for the other bundle components did not increase until the EHR was modified at the beginning of the post-period, adherence rates for the delirium screening component of the bundle (CAM-ICU) increased in the pre-period, likely due to a systemwide emphasis on improving delirium detection in BSWH hospitals. Like other studies examining the effectiveness of bundle elements that observed improvements in patient outcomes but not in incidence of delirium, we observed reductions in incidence of coma which may have ‘‘unmasked’’ patients with delirium (Girard, Kress, et al., 2008; Skrobik et al., 2010). This “unmasking” may have offset any reductions in incidence of delirium that may have been achieved through improved bundle adherence. Although improved bundle adherence was not associated with a significant decrease in delirium incidence, it was associated with an increase in the percentage of ICU days that patients spent awake and not delirious. Similar to our findings, Balas et al. found that increased ABCDE bundle adherence was associated with reductions in ventilator LOS and increased odds of mobilizing out of bed. However, no significant changes in ICU or hospital LOS, mortality, or discharge status were observed.

The results of this study and the study conducted by Balas et al. build on evidence generated by previous studies, including randomized controlled trials, linking various care processes within the ABCDE bundle to improved patient outcomes (Collinsworth, Priest, Campbell, Vasilevskis, & Masica, 2014) and make the case for widespread bundle adoption. Although bundle use may not be associated with reductions in delirium incidence, possibly due to contamination or detection biases, there is consistent evidence of improved patient care and outcomes associated with bundle use such as reduced ventilator LOS and increased odds of mobilizing out of bed. These outcomes were observed despite the fact that average bundle adherence in this study was only 55% in the enhanced group and 63% in the basic group and was "lower than anticipated" in the study conducted by Balas et al.(Balas et al., 2014). The results of the sensitivity analysis indicate that patients may achieve improved outcomes even with very low levels of bundle adherence. Neither study observed significant increases in unplanned extubations or tracheostomies as a result of bundle implementation, indicating that use of the bundle was not harmful to patients.

Given the gap between current evidence and implementation of best practices in ICUs, we wanted to examine the effect of different implementation strategies on bundle adoption. We thought that the use of traditional quality improvement methods plus EHR modifications to facilitate bundle uptake would result in higher adherence rates. However, ICUs that only received the EHR modification had a 22% greater increase in bundle adherence compared to ICUs in the basic intervention group. Also, the greatest increase in bundle adherence for both groups occurred immediately following implementation of EHR changes, particularly when controlling for the uptake in CAM-

ICU that occurred in both groups in the months preceding EHR implementation. Training received by ICUs in the enhanced group prior to the EHR modification was either not effective or ineffective without supporting EHR tools. Focusing resources on EHR modification to support integration of bundle elements into the workflow (and placing this phase as early as possible in the implementation program sequence) appears to be an effective means to improve ABCDE bundle uptake.

This study had several limitations. As it was a quasi-experimental study and not a randomized controlled trial, unmeasured and uncontrolled factors may have influenced bundle adherence and observed differences in patient outcomes. The fact that ABCDE bundle implementation utilized frontline clinical staff precluded patient level randomization, as it would not be realistic for clinicians educated on use of the ABCDE bundle to apply the practices selectively on individual patients. Likewise, unit level randomization was not practical as some hospitals had only 1 ICU, and sites with multiple ICUs had clinical staff that provided care in multiple units. We could have randomized sites at the hospital level, but we chose to select intervention ICUs BSWH's large tertiary hospital, rural hospital, and several community hospitals and to enhance generalizability of study findings. While randomization may have been ideal, the use of a quasi-experimental design likely provided a more realistic estimate of the effect of ABCDE bundle implementation on patient outcomes that may be observed in similar real world settings. We used a risk-adjusted difference-in-differences and regression models to account for variation in baseline bundle adherence among sites and patient and ICU characteristics that may have influenced bundle adoption and patient outcomes to

improve internal validity of findings. However, we recognize that risk-adjustment can only account for measured confounders and cannot eliminate selection bias.

Given that this study was a quality improvement (QI) initiative that was implemented in a real world setting and not in a highly controlled environment there were many threats to internal validity. The enhanced intervention groups did not receive consistent or real time feedback about bundle adherence and patient outcomes as planned due to resource constraints. Basic intervention sites may have found out about ABCDE bundle implementation efforts at other facilities through channels such as the systemwide Critical Care Council and launched their own bundle implementation initiatives. Several systemwide QI projects were launched during the bundle implementation period including initiatives to reduce ventilator mortality through improved adherence to ventilator order sets. These order sets initially included the awakening and breathing trial elements of the bundle and were later updated to include the early mobility component.

We relied heavily on data collected from routine care delivery that were documented in the EHR rather than more structured forms of data collection. Thus, observed increases in ABCDE bundle adherence in both groups could be due in part to improved bundle documentation as a result of the EHR modifications rather than improved performance. An audit of a random sample of 300 charts for patients admitted to study ICUs in 2012 indicated that performance of bundle care processes may have been underreported in the EHR. Total baseline bundle adherence based on the chart audits was 32% for the basic group and 42% for enhanced group compared to 25% and 38% based on EHR documentation. However, the improvements in patient outcomes that

were observed in conjunction with improvements in bundle adherence indicate improved performance and not just improved documentation.

Conclusion

Many opportunities exist to improve the quality and safety of care and patient outcomes in ICUs. This large, multi-site study corroborates existing evidence from the only published study examining the effectiveness of the ABCDE bundle by demonstrating an association between improved bundle adherence and reduced incidence of coma and ventilator LOS and increased likelihood that a patient is mobilized out of bed during an ICU stay. We also observed a significant reduction in inpatient mortality. Modification of the EHR to facilitate integration of the bundle into clinical workflow and improve documentation appeared to be a successful implementation tactic. While recognizing the limitations of our quasi-experimental study design, we believe that widespread implementation and consistent use of the ABCDE bundle can greatly improve patient safety, care, and outcomes. Further research is needed to confirm these findings and to better understand and improve the process of ABCDE bundle implementation and adoption.

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Figure 1. ABCDE Bundle Adherence Before and After EHR Modifications

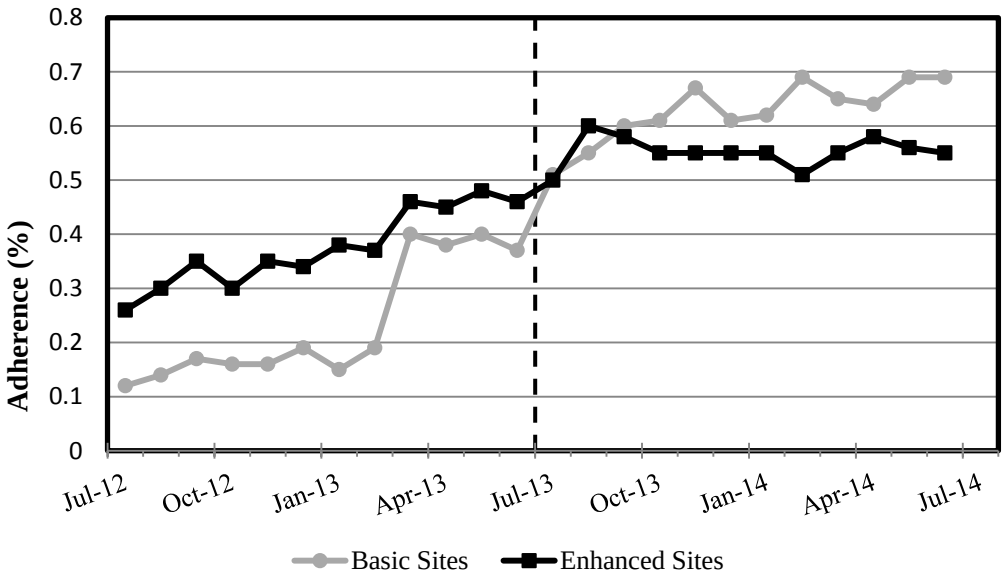

Figure 2. Adherence to Individual Bundle Elements Before and After EHR Modification

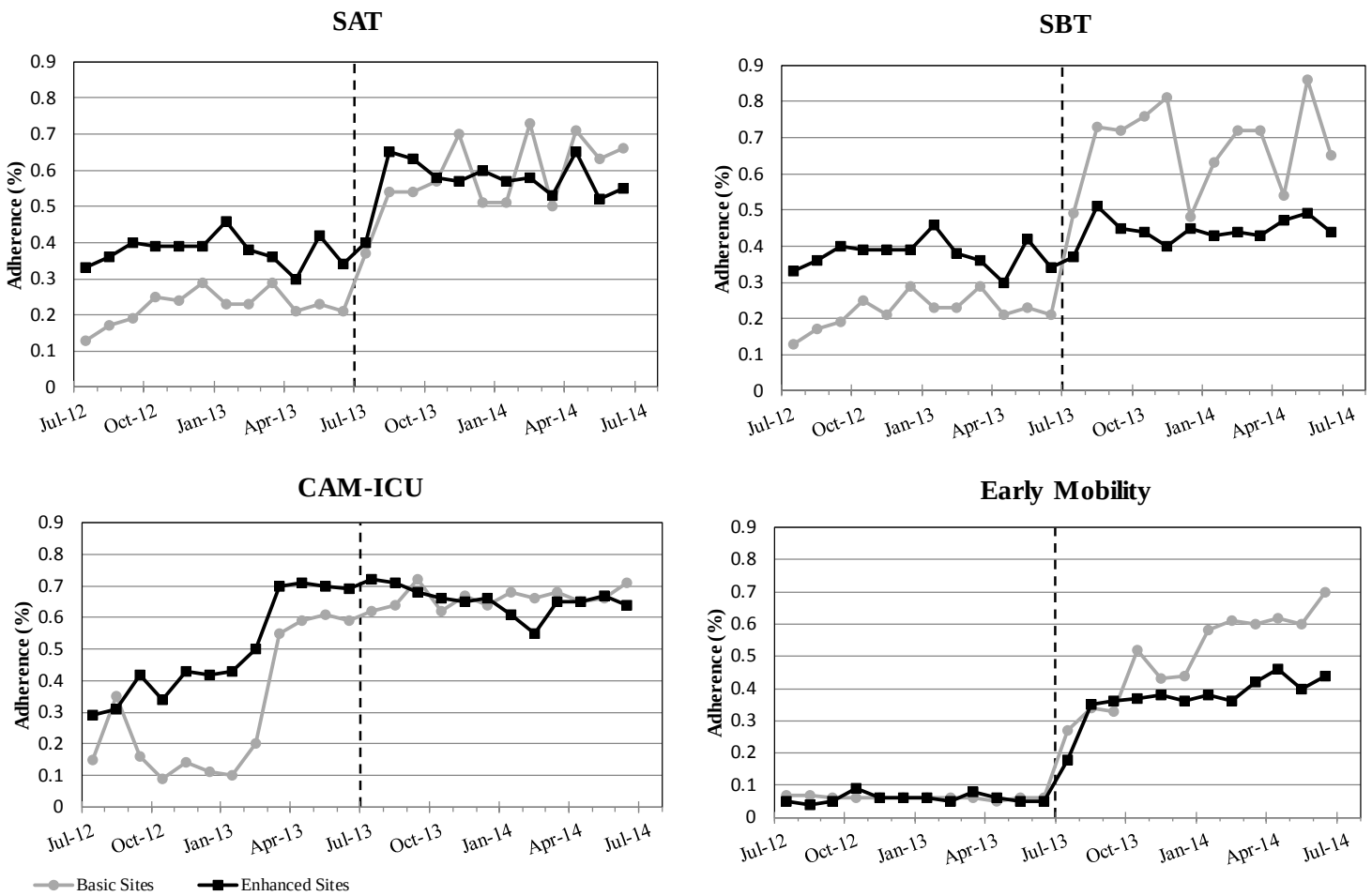

Table 1. ABCDE Bundle Elements and Main Safety Criteria

Element		Description	Frequency	Safety Criteria	Performed by
A	Spontaneous Awakening Trial (SAT)	Awaken patients with cessation of sedating medications	1 x daily	No active seizures No alcohol withdrawal No agitation No paralytics No myocardial ischemia Normal intracranial pressure	Nurses Physicians
B	Spontaneous Breathing Trial (SBT)	Daily assessment of patients' readiness to discontinue mechanical ventilation	1 x daily	No agitation Oxygen saturation ≥ 88% FiO2 ≤ 50% PEEP ≤ 7.5 cm H_20 No myocardial ischemia No vasopressor use Inspiratory efforts	Respiratory therapists
C	Coordination	SAT conducted prior to SBT; Coordination between physicians, nursing, and therapy service lines	1 x daily	Meets SAT and SBT Criteria	Nurses Physicians Respiratory therapists
D	Delirium Assessment (CAM-ICU) and Management	Objective delirium screening with the Confusion Assessment Method for the ICU.(Ely, Inouye, et al., 2001) Systematic evaluation for causation of delirium with appropriate interventions.	2 x daily	None	Nurses
E	Early Mobility (EM)	Patients meeting criteria receive mobility evaluation and therapy as indicated	1 x daily	No myocardial ischemia Stable heart rate & cardiac rhythm $FiO_2 \leq 0.6$ PEEP ≤ 10 cm H_2O Minimal vasopressor Response to verbal stimulation	Nurses Physical/ Occupational therapists

PEEP = positive end-expiratory pressure

Table 2. Participating Hospitals and ICUs

ICU	Intervention	ICU(s) Description	# of Beds	Daily Census	# of Nurse FTEs	# of Patients in Study	Overall Quality Score*
A	Basic	Medical/Surgical	16	11.0	40.2	126	1.02
B	Basic	Medical/Surgical	14	10.8	32.4	148	1.42
C	Basic	Medical/Surgical	16	12.0	43.0	89	1.24
D	Basic	Cardiac	15	11.0	37.1	119	0.78
E	Basic	Cardiac	16	10.8	32.3	134	1.19
F	Enhanced	Medical/Surgical	24	22.0	59.3	455	1.65
G	Enhanced	Medical/Surgical	19	12.5	45.0	328	0.83
H	Enhanced	Medical/Surgical	6	5.0	16.0	41	0.77
I	Enhanced	Cardiac	24	13.0	38.9	219	0.97
J	Enhanced	Cardiac	18	12.0	32.7	245	1.54
K	Enhanced	Neurological	15	13.0	32.0	92	3.64
L	Enhanced	Trauma	37	35.0	83.8	505	2.92

* Quality score was calculated as the yearly average of the central line associated blood stream (CLABSI) infection and catheter associated urinary tract (CAUTI) rates at each sits. CLABSI and CAUTI rates are calculated as the number of infections divided by the number of line/catheter days per 1,000 patient days.

Table 3. Characteristics of Patients Admitted to Study ICUs

	Basic			Enhanced		
	Pre *n =300*	Post *n=316*	*p*-value	Pre *n =950*	Post *n=935*	*p*-value
Age, mean (SD)	61.82 (14.74)	60.40 (15.95)	0.2519	59.81 (15.54)	59.26 (15.55)	0.4395
Male, n (%)	147 (49)	164 (52)	0.4728	508 (53)	569 (61)	0.0012*
Race, n (%)						
White	226 (75)	234 (74)	0.0745	564 (59)	595 (64)	0.0032*
Black	42 (14)	53 (17)	-	323 (34)	299 (32)	-
Asian	9 (3)	17 (5)	-	18 (2)	23 (2)	-
Other	23 (8)	12 (4)	-	45 (5)	18 (2)	-
Ethnicity, n (%)						
Hispanic	107 (15)	115 (17)	0.4884	107 (11)	115 (12)	0.4855
Insurance, n (%)						
Private	32 (11)	48 (15)	0.0043*	122 (13)	138 (14)	0.0038*
Medicare	184 (61)	158 (50)	-	493 (52)	475 (51)	-
Medicaid	16 (5)	23 (7)	-	58 (6)	25 (3)	-
Other federal	10 (3)	22 (7)	-	89 (9)	78 (8)	-
Self-pay	20 (7)	37 (12)	-	118 (12)	138 (15)	-
Other	38 (13)	28 (8)	-	70 (7)	81 (9)	-
Charlson Comorbidity Index, mean (SD)	4.71 (2.68)	4.90 (2.86)	0.3834	4.56 (2.87)	4.41 (2.75)	0.2557
APR DRG Severity, n (%)						
1	1 (0)	0 (0)	0.3359	0 (0)	1 (0)	0.0154*
2	3 (1)	4 (1)	-	3 (0)	10 (1)	-
3	30 (10)	44 (14)	-	96 (10)	126 (13)	-
4	266 (89)	268 (85)	-	850 (90)	797 (85)	-
APR-DRG Mortality Risk, n (%)						
1	3 (1)	5 (1)	0.4011	2 (0)	1 (0)	0.0861
2	10 (3)	10 (30)	-	24 (3)	21 (2)	-
3	55 (18)	74 (23)	-	206 (22)	249 (27)	-
4	232 (77)	227 (72)	-	717 (76)	663 (71)	-
Surgical, n (%)	18 (6)	9 (3)	0.0563	171 (18)	234 (25)	0.0003*
Dementia, n (%)	14 (5)	16 (5)	0.8195	82 (9)	72 (7)	0.4609
Alcohol, n (%)	4 (1)	6 (2)	0.5796	30 (3)	42 (4)	0.1309
Current Smoker, n (%)	53 (18)	63 (20)	0.4721	205 (22)	207 (22)	0.7688

* $p < 0.05$

Table 4. Unadjusted Average Bundle Adherence Pre- and Post- EHR Modification (Basic Intervention)

	Basic				Enhanced			
%	Pre n=300	Post n=316	Difference	*p*-value	Pre n=950	Post n=935	Difference	*p*-value
SAT	0.23	0.59	0.36	<.0001	0.38	0.57	0.19	<.0001
SBT	0.23	0.67	0.44	<.0001	0.38	0.44	0.06	<.0001
CAM-ICU	0.31	0.66	0.35	<.0001	0.51	0.66	0.15	<.0001
Early Mobility	0.06	0.52	0.46	<.0001	0.06	0.37	0.31	<.0001
ABCDE Bundle	0.25	0.63	0.38	<.0001	0.38	0.55	0.17	<.0001

Table 5. Effect of Basic vs. Enhanced Intervention on Bundle Adherence (Difference-in-Differences Model)

Variable	Estimate	95% CI		*p*-value
Intercept	0.0754	0.0113	0.1394	0.0212
Post	0.2406	0.1798	0.3015	<.0001*
Enhanced	0.2667	0.2167	0.3168	<.0001*
Post*Enhanced	-0.2241	-0.2812	-0.1670	<.0001*
Unit[a]				
A	0.0478	0.0292	0.0664	<.0001*
B	0.0873	0.0753	0.0993	<.0001*
D	0.0249	-0.0008	0.0505	0.0572
E	0.0541	0.0389	0.0694	<.0001*
F	0.0152	-0.0291	0.0596	0.5011
G	-0.0201	-0.0885	0.0483	0.5650
H	-0.1319	-0.2026	-0.0612	0.0003*
I	-0.0882	-0.1514	-0.0250	0.0063*
J	-0.1209	-0.1657	-0.0762	<.0001*
K	0.0250	0.0046	0.0455	0.0162*
Month	0.0131	0.0081	0.0180	<.0001*
Age	0.0004	-0.0002	0.0009	0.2048
Male	0.0055	-0.0154	0.0265	0.6048
Race				
Asian	0.0029	-0.0232	0.0289	0.8279
Black	-0.0025	-0.0167	0.0117	0.7266
Other	0.0029	-0.0195	0.0254	0.7977
Hispanic	-0.0060	-0.0263	0.0143	0.5615
Insurance				
Private	0.0006	-0.0279	0.0292	0.9646
Medicaid	-0.0161	-0.0459	0.0136	0.2870
Other federal	-0.0031	-0.0352	0.0290	0.8500
Self-pay	-0.0100	-0.0446	0.0245	0.5694
Other	0.0115	-0.0082	0.0312	0.2525
Charlson Comorbidity Index	0.0010	-0.0020	0.0040	0.5105
APR DRG Severity				
1	0.2376	-0.027	0.5021	0.0784
2	0.0378	-0.0432	0.1188	0.3605
3	0.0204	-0.0003	0.0411	0.0529
APR DRG Risk of Mortality				
1	-0.0042	-0.1435	0.135	0.9527
2	0.0360	-0.0188	0.0908	0.1983
3	0.0505	0.0264	0.0746	<.0001*
Ventilator days	-0.0196	-0.0243	-0.0150	<.0001*
ICU LOS	0.0145	0.0104	0.0186	<.0001*
Alcoholic	-0.0068	-0.0548	0.0413	0.7827
Pre-existing dementia	-0.0040	-0.0202	0.0122	0.6297
Surgical	-0.0056	-0.0172	0.0060	0.3453
ICU quality score	-0.0376	-0.0685	-0.0067	0.0171*

[a]Unit C and Unit L were reference groups for the basic and intervention ICUs, respectively.
* $p < 0.05$

Table 6. Differences in Unadjusted Outcome Measures Pre- and Post- EHR Modification

	Basic				Enhanced			
	Pre n=300	Post n=316	Difference	*p*-value	Pre n=950	Post n=935	Difference	*p*-value
Incidence of delirium	0.18	0.27	0.09	0.0046*	0.31	0.32	0.01	0.4356
Duration of delirium (days)[a]	1.42	1.02	-0.40	0.1522	0.16	0.21	0.05	0.0559
% Delirium free days	0.98	0.97	-0.01	0.0996	0.99	0.99	0.00	0.1514
Incidence of coma	0.60	0.64	0.04	0.4035	0.66	0.76	0.10	<.0001*
Duration of coma (days)[b]	1.45	1.20	-0.25	0.0917	0.39	0.38	-0.01	0.7422
% Coma free days	0.89	0.90	0.01	0.4164	0.96	0.95	0.01	0.0158*
% Coma and delirium free days	0.87	0.87	0.00	0.9966	0.95	0.94	-0.01	0.0054*
Ventilator days	4.98	4.18	-0.80	0.0020*	4.27	4.58	0.31	0.0346*
ICU LOS	8.62	7.48	-1.14	0.0034*	6.22	6.43	0.22	0.2426
Hospital LOS	13.66	12.56	-1.10	0.0466*	12.27	12.76	0.50	0.1120
Inpatient mortality	0.24	0.17	-0.07	0.0432*	0.16	0.16	0.00	0.8311
Discharge disposition								
Home	0.30	0.45	0.15	0.0301*	0.45	0.44	-0.01	0.0920
Rehab	0.14	0.10	-0.04	-	0.10	0.10	0.00	-
Hospice	0.08	0.09	0.01	-	0.05	0.07	0.02	-
Skilled nursing facility	0.12	0.09	-0.03	-	0.14	0.15	0.01	-
Long term hospital	0.10	0.07	-0.03	-	0.07	0.05	-0.02	-
Other facility	0.03	0.02	-0.01	-	0.04	0.03	-0.01	-
Highest level of mobility achieved								
Ambulate	0.12	0.42	0.30	<.0001*	0.10	0.16	0.06	<.0001*
Transfer to chair (active)	0.03	0.07	0.04	-	0.06	0.06	0.00	-
Dangle	0.07	0.03	-0.04	-	0.06	0.10	0.04	-
Active range of motion	0.02	0.05	0.03	-	0.07	0.05	-0.02	-
Passive range of motion	0.00	0.23	0.23	-	0.00	0.27	0.27	-
Self-extubation	0.00	0.00	0.00	0.1576	0.00	0.00	0.00	0.0833
Tracheostomy	0.01	0.01	0.00	0.6952	0.01	0.02	0.01	0.0925

[a]For patients diagnosed with delirium
[b]For patients diagnosed with coma
*$p < 0.05$

Table 7. Effect of High (>60%) Versus Low Bundle Adherence on Risk-adjusted Outcomes

Risk-adjusted Outcomes	Basic (n =616)		Enhanced (n=1885)		Overall (n=2501)	
	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
Incidence of delirium (OR)	0.94	(0.57, 1.55)	1.24	(0.98, 1.57)	1.19	(0.97, 1.47)
Duration of delirium (days)[a]	-0.34*	(-0.51, -0.17)	0.24	(-0.06, 0.54)	-0.09	(-0.36, 0.17)
% Delirium free days	0.01*	(0.00, 0.02)	0.00*	(-0.01, 0.00)	0.00	(-0.01, 0.00)
Incidence of coma (OR)	0.93	(0.6, 1.45)	0.65*	(0.51, 0.83)	0.70*	(0.57, 0.86)
Duration of coma (days)[b]	-0.41*	(-0.70, -0.12)	-0.29*	(-0.38, -0.20)	-0.35*	(-0.50, -0.20)
% Coma free days	0.04	(0.00, 0.09)	0.02*	(0.01, 0.02)	0.03*	(0.01, 0.04)
% Coma and delirium free days	0.06*	(0.00, 0.11)	0.02*	(0.01, 0.02)	0.03*	(0.01, 0.04)
Ventilator days	-0.14*	(-0.25, -0.02)	-0.21*	(-0.30, -0.13)	-0.20*	(-0.27, -0.14)
ICU LOS (days)	0.20*	(0.03, 0.36)	0.12*	(0.11, 0.13)	0.13*	(0.10 ,0.17)
Hospital LOS (days)	0.04	(-0.07, 0.15)	0.07*	(0.03, 0.11)	0.06*	(0.02, 0.11)
Mobilized out of bed (OR)	2.49*	(1.59, 3.91)	1.82*	(1.39, 2.38)	2.06*	(1.65, 2.57)
Discharged home (OR)	1.02	(0.64, 1.6)	1.19	(0.95, 1.50)	1.19	(0.97, 1.46)
Inpatient mortality (OR)	0.57	(0.31, 1.04)	0.35*	(0.23, 0.52)	0.40*	(0.29, 0.56)

[a]For patients diagnosed with delirium
[b]For patients diagnosed with coma
*$p < 0.05$

Table 8. Sensitivity Analysis: Effect of High Versus Low Bundle Adherence on Risk-adjusted Outcomes by Adherence Threshold

	Adherence Threshold							
	20%		40%		60%		80%	
Risk-adjusted Outcomes	**Estimate**	**95% CI**	**Estimate**	**95% CI**	**Estimate**	**95% CI**	**Estimate**	**95% CI**
Incidence of delirium (OR)	3.31*	(2.23, 4.93)	1.73*	(1.38, 2.17)	1.19	(0.97, 1.47)	1.00	(0.70, 1.42)
Duration of delirium (days)[a]	0.24	(-0.42, 0.90)	0.62*	(0.25, 0.99)	-0.09	(-0.36, 0.17)	-0.45	(-1.11, 0.21)
% Delirium free days	-0.01*	(-0.02, 0.00)	-0.01*	(-0.02, 0.00)	0.00	(-0.01, 0.00)	0.00	(0.00, 0.01)
Incidence of coma (OR)	0.52*	(0.39, 0.69)	0.70*	(0.57, 0.87)	0.70*	(0.57, 0.86)	0.69*	(0.49, 0.95)
Duration of coma (days)[b]	-0.53*	(-0.68, -0.39)	-0.4*	(-0.49, -0.31)	-0.35*	(-0.50, -0.20)	-0.71*	(-1.05, -0.37)
% Coma free days	0.07*	(0.05, 0.09)	0.04*	(0.02, 0.05)	0.03*	(0.01, 0.04)	0.03*	(0.01, 0.04)
% Coma and delirium free days	0.06*	(0.04, 0.08)	0.03*	(0.01, 0.04)	0.03*	(0.01, 0.04)	0.03*	(0.01, 0.05)
Ventilator days	0.00	(-0.15, o0.15)	-0.14*	(-0.20, -0.09)	-0.20*	(-0.27, -0.14)	-0.38*	(-0.49, -0.27)
ICU LOS (days)	0.14	(-0.03, 0.32)	0.18*	(0.14, 0.23)	0.13*	(0.10 ,0.17)	0.09	(-0.01, 0.19)
Hospital LOS (days)	0.18*	(0.02, 0.34)	0.10*	(0.05, 0.15)	0.06*	(0.02, 0.11)	0.04	(-0.05, 0.13)
Mobilized out of bed (OR)	2.71*	(1.77, 4.15)	2.22*	(1.71, 2.87)	2.06*	(1.65, 2.57)	2.05*	(1.47, 2.87)
Discharged home (OR)	2.41*	(1.78, 3.25)	1.43*	(1.16, 1.77)	1.19	(0.97, 1.46)	1.34	(0.97, 1.86)
Inpatient mortality (OR)	0.23*	(0.17, 0.30)	0.30*	(0.23, 0.40)	0.40*	(0.29, 0.56)	0.34*	(0.17, 0.70)

[a]For patients diagnosed with delirium
[b]For patients diagnosed with coma
*$p < 0.05$

APPENDIX B. IMPLEMENTATION AND ROUTINIZATION OF THE ABCDE BUNDLE: A MIXED METHODS EVALUATION

Abstract

Objective: The objective of this study was to determine how to facilitate adoption, implementation, and routinization of the ABCDE (Awakening and Breathing Coordination, Delirium monitoring/management, and Early exercise/mobility) bundle.

Design: Two-year, prospective, pretest-posttest study conducted between July 2012 and June 2014.

Setting: Eight adult ICUs in 6 hospitals belonging to a large, integrated healthcare delivery system. Hospitals included a large, urban tertiary referral center, 4 community hospitals, and a rural hospital. ICUs included medical/surgical, trauma, and cardiac care units.

Subjects: A total of 84 nurses, nurse managers, physicians, and respiratory, physical, and occupational therapists.

Interventions: Two implementation strategies were used to rollout the ABCDE bundle to study ICUs. The basic strategy involved the modification of the electronic health record (EHR) to facilitate bundle implementation and documentation while the enhanced strategy included EHR modification plus additional bundle training, clinical champions, and staff participation in bundle implementation efforts.

Measurements and Main Results: Data were obtained from an environmental scan, semi-structured interviews, and a short survey. Across ICUs, respondents agreed that use

of the ABCDE bundle resulted in “best care” through the standardization and coordination of care processes and improved patient outcomes. ICUs in both intervention groups had significant improvements in bundle adherence following implementation efforts, but ICUs in the basic intervention group had environments that were more conducive to bundle implementation and outperformed the other sites after initiating their own implementation strategies. Successful implementation tactics included incorporating the bundle into multidisciplinary rounds and providing ongoing support, training, and routine auditing and feedback.

Conclusions: The ABCDE bundle is a viable strategy for improving quality of care and outcomes for ICU patients. Implementation can be accelerated if managers and front line staff have a vested interest in the process and through the use of EHR tools, ongoing trainings, multidisciplinary collaboration, and performance feedback.

Background

Achieving widespread improvements in health care quality is dependent on both the identification of effective interventions and the diffusion of these innovations across health care settings. Over the course of the last decade, researchers have produced strong evidence demonstrating the hazards of delirium and the benefits of certain interventions, such as the individual components of the ABCDE (Awakening and Breathing Coordination, Delirium Monitoring and Management, and Early Exercise and Mobility) bundle, in preventing and mediating this condition. The bundle consists of spontaneous awakening trials (SATs) to decrease the use of sedation, spontaneous breathing trials (SBTs) to wean patients off mechanical ventilation faster, coordination of awakening and breathing trials to maximize benefits of SATs and SBTs, delirium screening and treatment, and early progressive mobility to decrease ICU-acquired muscle weakness. Individually, these interventions have been associated with reductions in incidence and duration of delirium and improved patient outcomes such as shorter duration of mechanical ventilation, shorter ICU and hospital LOS, improved functional outcomes, and improved survival (Girard, Kress et al. 2008; Schweickert, Pohlman et al. 2009; Vasilevskis, Ely et al. 2010; Brummel and Girard 2013).

Despite evidence of their effectiveness, the individual bundle elements have not been integrated as standard of care in most ICUs, and as a result most patients receive less than optimal care. For example, rates of daily sedation interruptions and breathing trials for mechanically ventilated patients have been reported as being less than 40% in cross-sectional surveys (Mehta, Burry et al. 2006; Kahn, Brake et al. 2007). Use of validated tools for delirium monitoring and sedation scales has also been found to be

below 40% (Mehta, Burry et al. 2006; Patel, Gambrell et al. 2009). Likewise, studies have found that less than 50% of patients receive any physical therapy during their ICU stay (Morris, Goad et al. 2008; Thomsen, Snow et al. 2008).

Adoption of other patient safety practices such as prevention of central line–associated blood stream infections and venous thromboembolism prophylaxis has been facilitated by multifaceted implementation approaches such as combining discrete practices into a single bundle of integrated care processes (Berenholtz, Milanovich et al. 2004; Pronovost, Needham et al. 2006), engagement of physician and nursing "champions"(Middleton, Fox et al. 2005; McGrath 2006; Bayley, Sorensen et al. 2009; Nebeker, Masica et al. 2009), clinical decision support and workflow enhancement tools (in electronic and paper formats) (Ely, Inouye et al. 2001; Ely, Margolin et al. 2001; Sessler, Gosnell et al. 2002; Ely, Truman et al. 2003; Quinn and Mannion 2005; Tham, Calmes et al. 2011), and timely feedback on process performance to frontline clinical care providers (Wall, Ely et al. 2005; Phillips, Hughes et al. 2008). The ABCDE bundle has been proposed as an interdisciplinary, multi-component patient safety intervention to improve the uptake of evidence-based care processes for prevention of ICU-acquired delirium by improving collaboration among clinical team members, standardizing care processes, and breaking the cycle of oversedation and prolonged ventilation (Girard, Pandharipande et al. 2008; Vasilevskis, Ely et al. 2010; Vasilevskis, Pandharipande et al. 2010; Balas, Vasilevskis et al. 2012; Balas, Burke et al. 2013; Hipp, Ely et al. 2013).

Use of a bundled approach and an implementation strategy that aligns bundle use with organizational priorities and infrastructure may facilitate adoption of ABCDE bundle elements. Rogers and Greenhalgh et al. have emphasized that diffusion of

innovation in organizations is highly dependent on how potential adopters view the attributes of the innovation as well as organizational factors (Rogers 2003; Greenhalgh, Robert et al. 2004). Rogers found that 5 key attributes of innovations (relative advantage, compatibility, complexity, trialability, and observability) explained approximately 49% to 87% of the variance in the rate of adoption of innovations. Greenhalgh et al. identified key components for the diffusion of innovation in health service delivery which included the 5 innovation attributes identified by Rogers as well as organizational-level factors including communication channels, organizational antecedents for innovation, organizational readiness for change, the implementation and routinization process, and the wider environment.

Baylor Scott & White Health (BSWH) North, formerly Baylor Health Care System, was awarded a grant from the Agency for Healthcare Research and Quality in 2012 to implement and evaluate the implementation of the ABCDE bundle in ICUs in different BSWH settings including tertiary, community, and rural hospitals. Two implementation strategies were used to rollout the ABCDE bundle to study ICUs. The basic strategy involved the modification of the electronic health record (EHR) to facilitate bundle implementation and documentation while the enhanced strategy included EHR modification plus additional bundle training, clinical champions, and staff participation in bundle implementation efforts.

We previously evaluated the effect of the two ABCDE bundle implementation strategies (basic vs. enhanced) on bundle adherence (Appendix A). We found that ICUs in the basic intervention group had lower ABCDE bundle adherence rates than ICUs in the enhanced intervention group in the pre-period (25% vs. 38%) but achieved higher

levels of adherence (63% vs. 55%) in the post-period. These findings were contrary to our hypothesis that ICUs receiving the enhanced intervention strategy would achieve a greater increase in bundle adherence compared to ICUs receiving the basic intervention strategy. The objective of this mixed methods study was to determine how to facilitate adoption, implementation, and routinization of the ABCDE bundle. Guided by Rogers' theoretical framework for diffusion of innovations and Greenhalgh et al.'s theoretical framework for diffusion of innovations in health service delivery, we conducted a comparison analyses among ICUs and between the basic and enhanced intervention groups to identify barriers and enabling factors for successful implementation of the ABCDE bundle practices.

Methods

Study Setting

Baylor Scott & White Health (BSWH), is one of the largest non-profit health care systems in the United States including 43 hospitals, >500 patient care sites, >6,000 affiliated physicians, 34,000 employees and an accountable care organization. The ABCDE bundle was implemented in the 12 ICUs of 6 BSWH North hospitals. This mixed methods study examined ABCDE bundle implementation in 8 of these ICUs, including 6 medical/surgical, 1 cardiac, and 1 trauma unit in 6 different hospitals which included an urban tertiary referral center, 4 community hospitals, and a rural hospital. We intentionally selected a sample of ICUs with heterogeneity in size, staffing, and patient populations in order examine the effectiveness of bundle implementation across settings.

The study was approved by the Baylor Research Institute and the Tulane University Biomedical IRBs.

Implementation Strategies

As previously described (Appendix A), we used two implementation strategies (basic and enhanced) to facilitate bundle implementation. The basic strategy involved the modification of the EHR (Collinsworth, Masica et al. 2014). The EHR (Allscripts™) for all BSWH North hospitals was modified in July of 2013 to facilitate uptake and documentation of ABCDE bundle elements. Changes included the addition of structured data fields for the documentation of ABCDE bundle eligibility and delivery of bundle processes and the addition of an "ABCDE" tab in the existing Patient Care Viewer to promote quick viewing of bundle elements received by individual patients. ICUs in the basic intervention groups were notified of these changes by the BSWH information services team per standard protocol and did not receive any additional communication or training from study staff.

The enhanced intervention included a multifaceted implementation strategy targeting physician, nursing, and allied health staff. ICUs assigned to the enhanced intervention group received additional ABCDE bundle training and implementation tools, had designated bundle champions, and participated in the development of the structured EHR documentation and ABCDE performance reports. Implementation tools included posters and pocket cards describing the bundle components and step-by-step guides for performing sedation delirium assessments. Enhanced intervention sites received these interventions to facilitate ABCDE bundle use and documentation in the 7 months preceding and 12 months following EHR modification.

Sampling

We included 8 of the 12 study ICUs in the mixed methods analysis. We selected at least 1 ICU from each of the 6 hospital sites in the basic and enhanced intervention groups. For the 2 hospitals with both medical/surgical and coronary care ICUs, we only included the medical/surgical ICUs. For the tertiary hospital with 5 ICUs we included 1 medical/surgical, 1 trauma, and 1 coronary care unit, in order to compare bundle implementation across different types of units.

The sampling frame included nurses, nurse managers, physician bundle champions and leaders, and respiratory, physical, and occupational therapists from these ICUs. The number of full-time equivalent (FTE) nurses per ICU ranged from 16 to 84. The number of FTE respiratory therapists and physical/occupational therapists ranged from 1 to 4. Enhanced intervention sites had 1 appointed physician bundle champion, and we scheduled interviews with ICU physician leaders in the basic intervention ICUs. As the ABCDE bundle was primarily a nurse-driven intervention and there were significantly greater numbers of nurses per ICU unit, we planned for our stratified sample to include more nurses than other care providers.

Before we recruited participants to participate in the interviews and surveys, the project manager for the study met with the nurse managers of all the study ICUs to complete an environmental scan in order to gather information about ICU characteristics and staffing and to formulate a strategy for the identification of interview participants and the conduct of interviews. Through our conversations with the nurse managers, we determined that the limited availability and/or willingness of nurses, respiratory and physical/occupational therapists to participate in interviews before and after shifts and the

unpredictable schedules of ICU care providers would serve as substantial barriers to the recruitment of participants and the conduct of the study. In order to overcome these barriers we decided to obtain a convenience sample of nurses and respiratory, physical, and occupational therapists by going to ICU units during the day shift and asking care providers who were not engaged in patient care activities to participate. We scheduled these visits with the nurse managers of each unit and the respiratory and physical therapy managers at each facility and visited ICUs on different days and at different times to ensure representation from different shifts. We contacted physician champions/leaders by email and phone and scheduled interviews with those who indicated they would be willing to participate. Interviews were conducted in each ICU until saturation was achieved, as determined through daily discussions with the interview teams to identify potential gaps in data and topics for clarification and the simultaneous coding of interview responses.

Recruitment and Consent

The interview teams met with potential respondents in private conference rooms on the ICU floors to explain the study and obtain consent for participation in an interview and a brief survey. We obtained a waiver of informed consent from the IRB, as we felt a signed consent form posed a threat to participant anonymity. Respondents were given a cover letter describing the study and asked to consent verbally to participate in interviews with audio recording and a brief survey.

Instruments

Study instruments included the environmental scan, interview guides and a survey. We created the environmental scan questionnaire (Appendix B1) by modifying an existing site visit form from a national diabetes evaluation(Robert Wood Johnson Foundation 2010). The questionnaire included questions pertaining to the characteristics, staffing, and working environment of the ICU and key staff involved in ABCDE bundle implementation. Interviews were conducted with an interview guide (Appendix B2). We developed separate interview guides for ICUs in the basic and enhanced intervention groups. The 6-part guide for the 5 ICUs that received the enhanced intervention contained 24 questions pertaining to: 1) the role of the respondent in the ICU and regarding ICU processes of care, 2) ABCDE bundle adoption, 3) characteristics of the bundle, 4) organizational-level factors influencing ABCDE bundle implementation, 5) implementation and routinization of the bundle, and 6) other factors that may have facilitated or hindered bundle implementation efforts. The guide for the 3 ICUs that received the basic intervention contained the same questions as the enhanced intervention interview guide plus an alternative set of questions for respondents who indicated that they were not familiar with the ABCDE bundle, as ICUs in the basic intervention group were only given EHR tools and were not provided with ABCDE bundle education or training by the study team. The alternative questions pertained to current ICU processes for delirium prevention, detection, and management; experience with and current quality improvement projects; and attitudes of ICU staff and leadership regarding innovation. Questions were open-ended to allow respondents to fully explain their perceptions of the ABCDE bundle and implementation process. We pre-tested the interview guides with

members of the research staff and 2 nurses, one who was familiar with ABCDE bundle implementation and one who was not and revised the guides based on their feedback.

Following the interview, interviewees were asked to complete a brief paper-based survey designed to further assess perceptions of the bundle and bundle implementation (Appendix B3). This instrument was based on a survey developed by Helfrich et al. and contained questions about the organizational factors within the ICU and attributes of the ABCDE bundle (Helfrich, Savitz et al. 2007). We examined bundle attributes based on the 5 qualities identified by Rogers as key drivers of innovation: relative advantage, compatibility, complexity, trialability, and observability (Rogers 2003). For example, respondents were asked about the advantages of bundle use and the visibility of bundle benefits. Items were assessed on a 5-point Likert scale. The survey was used to augment data collected from the interviews and its psychometric properties were not formally assessed.

Data Collection

The environmental scan, semi-structured interviews, and surveys were conducted between July and October of 2014. The project manager for the study conducted the environmental scan through in-person meetings with the nurse managers of the study ICUs. ICU staff interviews were conducted by 4 interview teams consisting of 2 researchers each in private conference rooms on ICU floors. One researcher conducted the interview while the other researcher took notes in a Microsoft Access database designed specifically for the study. Interviews were audio recorded with the consent of the respondents.

After each interview session, the research team reviewed the notes and clarified responses by listening to the audio recordings. Survey responses were entered into an Access database and verified by a member of the study team. All researchers attended 2 webinars on qualitative interviewing and data collection conducted by experts from the High Value Healthcare Collaborative and completed two practice interviews. Interview notes from the practice interviews were compared with the interview script and across interview teams to ensure that data was collected accurately and reliably.

Data Analysis

Two researchers analyzed interview responses using a shared codebook (Appendix B4). The researchers created the codebook by developing pre-set codes based on the research questions and themes from the literature and creating emerging codes based on interview responses. The researchers coded the interviews in Microsoft Access by creating a coding form featuring drop-down menus with the pre-set and emerging codes. To ensure consistency in coding, both researchers coded three of the same interviews and compared coding schemes to ensure that both researchers were interpreting and applying the codes in a consistent manner. The minor differences in coding styles that were detected were resolved via discussion between the 2 researchers. The researchers were in constant communication during the coding process and discussed the creation of emerging codes and any other questions regarding interpretation to ensure agreement between researchers,

We used thematic content analysis to identify thematic patterns from narrative responses (Miles and Huberman 1994). Following identification and description of the themes and their underlying relationships from the interview data as a whole, we

conducted a comparison analyses among ICUs and between the basic and enhanced intervention groups to identify barriers to and enabling factors for successful implementation of the ABCDE bundle practices based on key components of Rogers' and Greenhalgh et al.'s theoretical framework for diffusion of innovation: perceptions of the ABCDE bundle, organizational factors influencing bundle implementation, the implementation and routinization process, and barriers to implementation. Survey data were analyzed using independent t-tests in SAS version 9.3 (SAS Institute, Inc. Cary, NC).

Results

Characteristics of the interview and survey respondents are shown Table 2. A total of 84 respondents completed both the interviews and surveys, 32 from the basic intervention group and 52 from the enhanced intervention group. All of the nurses and respiratory, physical, and occupational therapists that we approached agreed to participate. Two of the 8 physicians we contacted declined to participate. Approximately 68% of the respondents were nurses and nurse managers, 12% were physical or occupational therapists, 7% were physicians, and 13% were respiratory therapists. Respondents were between 20-69 years of age. Most respondents were female (70%) had >10 years of experience (60%).

Perceptions of the ABCDE Bundle

All respondents, with the exception of 2 respondents from one ICU in the basic intervention group (ICU B) were familiar with the ABCDE bundle. Regardless of intervention group, most respondents agreed that using the ABCDE bundle helped them provide "best care" for patients compared to the status quo. Respondents indicated that

relative advantages of the bundle included improved care delivery and standardized care. As one respiratory therapist explained,

> The bundle is a tool. It is a way to check to make sure everybody is doing things consistently. To me it is a checklist and helps us to become successful. As long it is in a bundle, we are supposed to do everything, and we are more apt to use it. It is just like an order set. It is a tool to promote consistency, continuity of care, and also standardization.

Some care providers indicated that the bundle gave them more confidence and autonomy in treating patients. One nurse from a basic intervention ICU commented, “It makes people more confident in their decision making regarding the readiness of the patient for extubation.” Another nurse from a basic intervention ICU commented, “There are guidelines, which is good. It provides steps you can go by. That's the biggest advantage. You're using nursing judgment at the same time as you're using guidelines.”

Respondents thought that use of the bundle led to patients receiving less sedation, spending less time on the ventilator, and achieving improved outcomes such as reduced incidence of delirium, morbidity, and mortality. As one nurse from a basic intervention ICU commented, “The bundle has improved patient outcomes because we are more aware of the risk of delirium. We really sit down with the doctors and try to figure out what we can do for each patient with respect to their medication and other things.” A nurse supervisor commented, “It decreases patient mortality and length of stay. It's better overall care for patients. I've seen that in practice.” Although some respondents said that the benefits of the bundle were not directly observable, they still believed that use of the bundle improved patient care. One nurse from an enhanced intervention ICU explained, “Mobilizing people seems to result in fewer complications, although I'm not sure if I've observed that firsthand.” Another nurse explained, “My gut feeling is that we are

probably decreasing the length of ventilator time, but I don't know that we have any data to support that."

Most of the respondents felt that the bundle was not overly complex, but required more coordination among providers. A staff nurse from a basic intervention ICU commented, "It's not that complex. It can be complex to coordinate with the respiratory therapists. For mobility you have to sometimes coordinate with physical therapy or occupational therapy." One physical therapist explained, "The practice isn't complex. If you adhere to the bundle exactly as it's presented, it can seem daunting at first to remember each step, but once you repeat it as part of your practice, you get the hang of it and it's not too bad." Respondents felt that delirium screening with the CAM-ICU and initiation of early mobility were the most complex elements of the bundle. Most respondents agreed that the ICU bundle was compatible with current workflow. However, many respondents thought the bundle did not have the potential for reinvention as they felt the purpose of the bundle was to provide standardized care and should not be modified.

According to the survey given to the interviewees (Table 3), the ABCDE bundle had characteristics that Rogers found to be associated with more rapid adoption, specifically in terms of its simplicity, relative advantage, and compatibility. Respondents from ICUs in the basic intervention group rated the bundle more favorably on all characteristics than respondents from ICUs in the enhanced intervention group, but the differences between groups were not significant when compared using independent t-tests.

Organizational Factors Influencing Bundle Implementation

In the interviews, members of basic intervention ICUs, particularly respondents from ICU C, cited strong leadership; good working relationships among nurses, physicians, respiratory therapists, and physical therapists prior to bundle implementation; good communication; and sufficient resources as organizational factors that facilitated bundle implementation. Although a few respondents from both intervention groups said that they were aware of external efforts to promote the ABCDE bundle from the literature or critical care nursing organizations, most felt the push for bundle implementation came from BSWH and ICU leadership. In the survey, respondents from ICUs in the basic intervention group were significantly more likely to agree that their ICU encouraged innovation and new ways of providing care and rewarded creativity.

Implementation and Routinization Process

In the interviews, ICU staff reported that they used a variety of implementation strategies to promote bundle use (Table 4). Leaders of ICUs in the enhanced intervention group were asked to implement the ABCDE bundle as part of a federally-funded study. Respondents from these ICUs indicated that they attended trainings provided by ABCDE bundle experts from Vanderbilt as part of the study, had clinical champions that promoted bundle adoption, and were given visual aids such as posters describing the ABCDE bundle and pocket cards with the CAM-ICU scoring systems. Most respondents indicated that these ICUs had also appointed super-trainers, to be the ABCDE bundle content and training experts for the floor. The bundle was implemented in a piecemeal fashion in 2 of the enhanced intervention hospitals, which respondents felt facilitated implementation and uptake. ICUs in the enhanced intervention group were eventually provided with a

DART report to track ABCDE bundle adherence, but respondents indicated that the DART report did not always function correctly and was not accurate. Most of the respondents from both intervention groups indicated that the bundle had become a routine and accepted part of care delivery. Respondents from two ICUs in the basic intervention group cited the fact that daily, multidisciplinary rounds included discussions about the ABCDE bundle and which patients were eligible as evidence of the routinization of the bundle within the unit.

Leaders of ICUs in the basic intervention group said that they learned about the bundle through participation in the BSWH system wide critical care council or ventilator mortality team or continuing education. In one basic ICU, a staff nurse had implemented the ABCDE bundle as part of her participation in ASPIRE, BSWH's nurse advancement program. Some respondents did note that they felt they had been "left out" of bundle implementation efforts after learning about other sites participation in the study through system wide councils. Following the EHR modifications, ICUs in the basic intervention group initiated their own bundle implementation strategies including formal trainings, use of clinical champions and super-trainers, piecemeal implementation of bundle elements, verbal and email reminders, and visual aids. Respondents from 2 ICUs said that the units utilized a huddle board that contained up-to-date information regarding which patients met bundle eligibility criteria. One ICU was also able to draw on one of its own nurses' personal experiences with delirium as an ICU patient and used a video of her describing the acute and lasting effects of delirium to educate staff. Two ICUs monitored compliance with the ABCDE bundle and provided feedback to staff. As one respondent explained, "We kind of follow the nurses and make sure the things happen and make sure

are documented and charted appropriately." Respondents also noted that ICU managers provided strong leadership and were a driving force in bundle implementation. One nurse explained, "It was our manager who was pushing it through, and we are doing it and we are going to do it the best."

Respondents in basic intervention ICUs felt that the bundle had become routinized through incorporation into daily huddles and daily assessment schedules. As one nurse explained,

> We discuss it at our meetings and every morning, we have a huddle before our shift starts. We discuss our candidates for delirium screening, who has a positive or negative ICU-CAM, who is ready to move, and who is ready to do the spontaneous breathing. At 10 A.M., we meet with physical therapists and respiratory therapists and decide who we will focus on for early mobility and spontaneous breathing trials.

One ICU had integrated the bundle into unit orientation, so all new staff would be taught the bundle as standard of care.

Barriers

The most common barrier to ABCDE bundle implementation reported by respondents in the interviews was EHR documentation Although some respondents felt that the EHR streamlined ABCDE bundle adherence by providing a structured checklist of bundle elements, many respondents indicated that they were unsure of how to document certain bundle elements or there were too many different places where they needed to document the bundle. Other frequently cited barriers were staff shortages, time constraints and lack of coordination among care providers. Many respondents indicated that it was difficult to administer the bundle when the nurse to patient ratio exceeded 1:2

and that often there were very few physical therapists assigned to ICUs to assist with early mobility.

Most respondents in both intervention groups indicated that the bundle was complex in the sense that it involved a change in culture and the coordination of nurses, physicians, respiratory therapists, and physical therapists to conduct awakening and breathing trials and early mobility. Many nurses said the most challenging piece was incorporating the early mobility, and they did not have a clear understanding of when nursing should be responsible for mobility and when a physical therapist should be consulted. As one nurse in a basic intervention ICU stated, “I would see the biggest challenge would be nursing's ability to decide when they truly need to have physical medicine intervene with the patient.” In the past ICU patients were often kept sedated and immobilized and a few respondents expressed fear of patient harm, particularly in performing early mobility, with this change in ICU culture and practice. One physician working in an enhanced intervention ICU explained,

> I think there was a fear of turning off a drip entirely that patients would become agitated and begin to pull their lines out, and then I think there was a fear of possible harm with a nurse trying to mobilize a patient alone, without help.

The trauma unit, in particular, felt it was difficult to apply bundle criteria to its patients due to the nature of their injuries. In addition, respondents in both intervention groups indicated that they were involved in a variety of quality improvement efforts including reducing blood stream infections, pressure ulcers, and ventilator mortality, and it was difficult to make the ABCDE bundle a priority. One nurse from an enhanced intervention ICU said,

> Whenever you add something new, it feels overwhelming to nurses because we have so much already - core measures, Foley care… getting your routine done with all these added steps can be daunting.

Leaders of the implementation efforts in the three ICUs of the tertiary hospital felt that implementation in these hospitals was difficult due to the size of the ICUs, the existing culture, and difficulties obtaining buy-in and transferring ownership. As one physical therapist explained, "It is a fairly slow adoption process here. The adoption might take a while since it is a large hospital in addition to the culture here."

Discussion

All ICUs experienced significant improvements in ABCDE bundle adherence in the year following implementation of the EHR modifications. Contrary to our hypothesis, ICUs that were in the basic intervention group achieved higher levels of ABCDE bundle adherence than ICUs in the enhanced intervention group and had the greatest change from pre- to post- periods. We thought providing sites with structured education and training, clinical champions, and other bundle implementation tools before and after the implementation of the EHR would lead to better routinization of the bundle and higher levels of adherence than provision of EHR tools alone. However leaders of the ICUs in the basic intervention group learned about the ABCDE bundle through system wide councils and continuing education and launched bundle implementation efforts of their own with greater success. Differences in organizational factors, facility size, engagement of ICU managers, and routinization efforts likely contributed to observed differences in adherence rates.

Similar to trends observed in studies examining the use of other types of care bundles in the ICU, such as those for prevention of central line infections (Wall, Ely et al.

2005; Pronovost, Needham et al. 2006), we found that bundling ABCDE care processes facilitated their implementation and use. ICU staff viewed the bundle as a standardized approach to care that gave them specific guidelines for treatment of critically ill patients and increased their autonomy and confidence in care delivery. The majority of respondents in all ICUs believed that use of the bundle was advantageous as it represented best care for patients and was compatible with the way they felt care should be delivered. They also thought that use of the bundle resulted in improved outcomes for patients, including observable benefits such as reduced length of stay.

Given the favorable impression of the bundle across sites, much of the variation in adherence is likely attributable to differences in organizational factors and routinization efforts. By chance, the ICUs that were selected as the basic intervention group appeared to be more conducive to innovation. These ICUs were smaller, with the exception of the rural hospital ICU, and one ICU had a closed staffing model which may have made created more familiarity among staff and better working relationships. In addition, the ICUs in the basic intervention group may have provided higher quality of care and/or had leadership that was more supportive of quality improvement initiatives as the average number of central line-associated blood stream (CLABSI) and catheter-associated urinary tract (CAUTI) infections, our proxy measure for ICU quality, was lower in these hospitals. Respondents in the basic intervention groups did frequently cite strong leadership as a driver of bundle implementation; however, we did not observe differences in the quality of ICU leadership between basic and enhanced intervention ICUs based on the leadership domain score of a patient safety culture survey administered to all hospital staff in August 2013. The success of basic intervention ICUs

largely may be due to the fact that the managers of these ICUs chose to pursue ABCDE bundle implementation and were personally vested in the bundle's success rather than having the bundle forced on them as part of a study. Also, some respondents from basic intervention ICUs indicated they had been left out of the study and seemed determined to outperform study ICUs.

As far as differences in implementation and routinization, basic intervention ICUs were successful in establishing performance measurement and feedback and held staff accountable for bundle use and documentation while the enhanced group ICUs were still waiting for accurate performance reports from the study team at the time of the interviews. ICUs in the basic intervention group had taken additional steps to routinize and sustain bundle use such as going over which patients needed to receive the bundle during daily huddles and incorporating bundle training into unit orientation.

We did observe major increases in bundle adherence in both groups immediately following the EHR modifications. The training provided to enhanced ICUs in the 9 months prior to the EHR modifications may have been ineffective without supporting EHR tools, and these ICUs may have performed better had the training been structured around how to use the EHR to facilitate bundle workflow and how to properly document bundle adherence. Although some respondents in most ICUs said the EHR documentation was time consuming and presented a barrier to bundle adoption, there were fewer of these complaints among respondents who were in the basic intervention group.

Our findings are similar to those reported in other studies of ABCDE bundle implementation. In a pilot study involving 4 ICUs, Carrothers et al. found that structural

characteristics of the ICU including an organization-wide patient safety culture, and ICU culture of quality improvement, effective project leadership, access to training and hands-on support from nurse champions/super-users, and use of the EHR to document ABCDE interventions facilitated the rate of bundle implementation (Carrothers, Barr et al. 2013). Excessive turnover of project and ICU leadership, staff morale issues, lack of respect among disciplines, and knowledge deficits were barriers to implementation. Balas, et al. found that implementation of the bundle in 5 ICUs was facilitated by the performance of daily, interdisciplinary rounds, engagement of key implementation leaders, sustained and diverse educational efforts, and the bundle's quality and strength. Barriers to implementation included intervention-related issues (timing of trials, fear of adverse events), communication and care coordination challenges, knowledge deficits, workload concerns, and documentation burden (Balas, Burke et al. 2013). Despite the fact that the 8 sites included in our study had some site-specific challenges, we observed the facilitators and barriers to ABCDE bundle implementation across sites were similar to those in the aforementioned studies. These findings reiterate the need for engaged leadership, supporting resources and ongoing training, EHR tools, and multidisciplinary communication and rounding to drive the adoption and routinization of the ABCDE bundle.

Limitations

This study had several limitations that may have biased our assessment of bundle adoption, implementation and routinization in study ICUs. A major limitation was that leadership in ICUs in the basic intervention group learned about the enhanced intervention through the systemwide critical care council. This unintended exposure

resulted in contamination which made it difficult to determine the impact of the EHR modification alone on bundle implementation for ICUs in the basic intervention group. Secondly, this study was based on Rogers' and Greenhalgh et al.'s frameworks for diffusion of innovation and for diffusion of innovations in health service delivery, and we may have only elicited important factors pertaining to the implementation and adoption of the ABCDE bundle that were congruent with Rogers' or Greenhalgh et al.'s model. We also may have failed to account for underlying differences among ICUs that may have influenced bundle adoption. Although, we tried to mitigate sampling bias by recruiting interview and survey respondents on different days and on different times, the use of convenience sampling may have prevented us from obtaining a representative sample of ICU staff. Other potential limitations include a small number of respondents per ICU, recall bias, and hesitance of respondents to reveal their true feelings about bundle implementation.

Conclusion

The ABCDE bundle is a viable strategy for improving quality of care and outcomes for ICU patients. Implementation of the bundle can be facilitated through the use of traditional quality improvement approaches such as engagement of clinical champions, EHR tools, and timely feedback on process performance to frontline clinical care providers. Bundle implementation and routinization can be accelerated if managers or front line staff have a vested interest in improving care and prioritize and drive bundle use. Focusing resources on improving EHR tools that support bundle implementation before training ICU staff on bundle use and documentation may be a more streamlined and effective implementation and education strategy. However, it appears that a

structured implementation strategy must be used in conjunction with EHR tools to improve and sustain bundle uptake and ultimately improve patient care and outcomes.

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Table 1. Characteristics of Participating ICUs

	Basic Intervention				Enhanced Intervention					
ICU	**A**	**B**	**C**	**Overall**	**F**	**G**	**H**	**I**	**L**	**Overall**
Hospital Type	Community	Community	Community		Tertiary	Community	Rural	Tertiary	Tertiary	
ICU Type	Med/Surg	Med/Surg	Med/Surg		Med/Surg	Med/Surg	Med/Surg	Cardiac	Trauma	
# of Beds	16	14	16		24	19	6	24	37	
Daily Census	11	10.8	12		22	12.5	5	13	35	
% Bundle Adherence										
Pre	0.24	0.24	0.16	0.25	0.44	0.42	0.25	0.38	0.37	0.38
Post	0.65	0.67	0.70	0.63	0.57	0.62	0.68	0.55	0.52	0.55
Difference	0.41	0.43	0.54	0.38	0.13	0.20	0.43	0.17	0.15	0.17

Table 2. Characteristics of Interview and Survey Participants

n (%)	Overall n = 84	Basic n = 32	Enhanced n = 52
Occupation			
Nurse	50(60)	19 (60)	31 (60)
Nurse Manager	7 (8)	3 (9)	4 (8)
Physical/Occupational Therapist	10 (12)	4 (13)	6 (11)
Physician	6 (7)	3 (9)	3 (6)
Respiratory Therapist	11 (13)	3 (9)	8 (15)
Gender			
Male	25 (30)	13 (41)	12 (23)
Female	59 (70)	19 (59)	40 (77)
Age			
20-29	14 (17)	3 (9)	11 (21)
30-39	25 (30)	12 (37)	13 (25)
40-49	18 (21)	9 (28)	9 (17)
50-59	21 (25)	6 (19)	15 (29)
60-69	2 (2)	0 (0)	2 (4)
Experience (Years)			
0-2	9 (11)	3 (9)	6 (12)
3-5	15 (18)	6 (19)	9 (17)
6-10	8 (10)	2 (6)	6 (12)
>10	50 (60)	21 (66)	29 (56)

Table 3. Results of the Implementation Survey

	Basic			Enhanced[a]					Overall	Basic	Enhanced	*p*-value
ICU	**A**	**B**	**C**	**F**	**G**	**H**	**I**	**L**				
Number of Respondents	11	12	9	10	11	6	11	8	84	32	52	
Climate of ICU (5 point Likert scale, 5 = greater agreement with statement)												
Innovation is encouraged	4.45	4.42	4.89	3.20	4.00	4.67	4.27	4.25	4.25	4.56	4.05	0.0025*
Creativity is rewarded	4.09	4.33	4.89	3.80	4.45	4.33	4.09	3.63	4.15	4.40	4.00	0.0095*
Physicians are receptive to new ways of providing care	2.73	3.67	4.56	3.50	3.91	3.83	3.55	3.50	3.60	3.59	3.60	0.9912
Nurses are receptive to new ways of providing care	4.00	3.75	4.56	3.70	4.18	4.17	4.18	3.50	3.96	4.06	3.90	0.3290
Managers are receptive to new ways of providing care	4.27	4.58	5.00	4.00	4.18	4.83	4.27	4.38	4.39	4.59	4.27	0.0368*
Staff are given training when new ways of providing care are introduced	4.09	4.58	4.67	4.30	4.09	4.50	4.55	4.25	4.38	4.44	4.35	0.5274
New ways of providing care are encouraged	4.45	4.50	4.67	3.90	4.36	4.50	4.36	4.50	4.37	4.62	4.21	0.0025*
Perceptions of ABCDE Bundle (5 point Likert scale)												
Simplicity: How easy or difficult is it to use the ABCDE Bundle? (Difficult = 1, Easy = 5)	4.64	4.42	4.44	4.40	4.36	4.33	4.27	4.38	4.37	4.50	4.29	0.2057
Relative Advantage: Is the ABCDE bundle better or worse than the care processes you used before? (Worse = 1, Better = 5)	4.45	3.92	4.44	4.90	3.64	4.83	3.36	4.38	4.07	4.25	3.96	0.6755
Compatibility: How compatible is the ABCDE bundle with the way you feel care should be provided to critical care patients? (Incompatible =1, Compatible = 5)	4.82	3.67	4.78	4.60	3.55	4.83	3.55	4.38	4.10	4.38	3.92	0.5031
Trialability: To what extent can the ABCDE bundle be experimented with on a limited or trial basis? (With Difficulty =1, Easily = 5)	4.45	3.33	4.11	3.90	2.73	4.67	3.00	4.63	3.60	3.94	3.38	0.4189
Observability: How visible to you are the benefits of the ABCDE bundle? (Not Visible =1, Very Visible = 5)	4.55	3.25	4.44	4.40	3.18	4.50	3.18	4.25	3.73	4.03	3.54	0.4625
Potential for Reinvention: How easy or difficult is it to customize or adapt the ABCDE bundle to fit within current care processes or to better meet patient needs? (Difficult = 1, Easy = 5)	4.27	2.92	4.33	4.00	3.00	4.50	3.36	3.75	3.55	3.78	3.40	0.5691

[a]6 respondents worked in multiple ICUs in the tertiary facility and were excluded from the unit-level analysis

*p<0.05

Table 4. Organizational Factors and Implementation and Routinization Tactics Supporting ABCDE Implementation and Barriers to Bundle Use

	Basic Intervention			**Enhanced Intervention**				
ICU	A	B	C	F	G	H	I	L
Organizational Factors								
Strong leadership	x	x	x					
Adequate resources	x		x					
Good working relationship with physical therapists (PTs)			x					
Good working relationship with respiratory therapists (RTs)			x					
Good working relationship between doctors and nurses			x			x		
Good communication			x					
Closed ICU with dedicated physicians			x					
Implementation and Routinization Tactics								
Formal training	x	x	x	x	x	x	x	x
Clinical champion(s)	x		x	x	x	x	x	
Regular meetings	x	x						
Super-trainers	x		x	x		x	x	x
Monitoring and feedback	x		x		x			
Multidisciplinary rounds/huddles	x	x	x		x	x		
Huddle board	x		x					
Bundle part of routine schedule/daily assessment	x	x	x			x		
Reminders	x		x		x	x		
Implementation of 1 bundle element at a time	x	x	x		x	x		
Bundle part of orientation	x							
Visual aids (posters, pocket card)	x		x	x	x	x	x	
Personal testimony	x							
Barriers								
Staff turnover					x			
EHR documentation	x		x	x	x		x	x
Shortage of staff					x	x		
Time constraints					x	x	x	
Lack of coordination among providers	x	x			x			
Culture change	x			x				
Lack of training						x	x	x
Competing priorities/initiatives		x						
Fear of patient harm			x	x				

APPENDIX B1. ENVIRONMENTAL SCAN DATA COLLECTION TOOL

Site Visit Planning Form – Enhanced Intervention ICUs

We are planning a visit to ***(name of ICU)*** to assess quality improvement efforts related to the prevention and treatment of delirium, including the use of the ABCDE Bundle. As the primary contact for your ICU, we ask that you take a few minutes to answer the following questions. Your responses will assist us in making the best use of our time together. We thank you for your time and look forward to our visit.

Please describe the size of your ICU

a. Number of beds:
b. Daily census:
c. Number of nurse FTEs:

2. Has the ABCDE bundle been fully implemented in your ICU?

☐ **Yes** ☐**No**

If no, what steps need to be taken to reach full implementation?

3. What, if any, staffing changes have been made to implement the program?

4. Please describe any challenges or barriers to ABCDE bundle implementation that have been encountered.

5. Please describe any other challenges that the ICU encountered over the past year that may have impacted delivery of care. (Examples: high staff turnover, new leadership, or lack of resources).

6. Please describe any other quality improvement initiatives the ICU has implemented from 2012-2014 and any observed impact on patient outcomes.

7. Please identify the key people who have led ABCDE bundle implementation efforts in your ICU. We will select a sample of these individuals and work with you to set up a time to meet with them during our visit.

Name	**Role (ex. ICU Director, Nurse Champion, Trainer, etc.)**	**Phone**

8. Please list the names of the nurses who work in the ICU on a regular basis. We will select a sample of these individuals and work with you to set up a time to meet with them during our visit.

Name	**Typical Shift (Day, Night, Weekend)**

9. Please list the names of some of the physicians who regularly oversee the care of ICU patients. We will select a sample of these individuals and work with you to set up a time to meet with them during our visit.

Name	**Specialty**

10. Please list the names of the respiratory therapists who provide care in your ICU. We will select a sample of these individuals and work with you to set up a time to meet with them during our visit.

Name

11. Please list the names of the physical therapists that provide care in your ICU. We will select a sample of these individuals to interview and work with you to set up a time to meet with them during our visit.

Name

12. Is there anything else you would like for us to know before the visit that may help us better understand the implementation and use of the ABCDE bundle in you ICU?

13. Is there a conference room or private area that we may reserve at your facility in order to conduct interviews during our visit?

☐ **Yes Please specify location:**
☐ **No**

14. Is there a particular day of the week and/or time of the day that would be best for conducting interviews with clinical personnel?

Site Visit Planning Form – Basic Intervention ICUs

We are planning a visit to ***(name of ICU)*** to assess quality improvement efforts related to the prevention and treatment of delirium. As the primary contact for your ICU, we ask that you take a few minutes to answer the following questions. Your responses will assist us in making the best use of our time together. We thank you for your time and look forward to our visit.

---

1. Please describe the size of your ICU.
   a. Number of beds:
   b. Daily census:
   c. Number of nurse FTEs

2. Have you implemented the ABCDE Bundle in your ICU? **If No, skip to question 5.**

3. What, if any, staffing changes were made to facilitate bundle implementation?

4. Please describe any challenges or barriers to ABCDE bundle implementation that have been encountered. **Skip to question 6.**

5. Please describe the current standard of care for delirium prevention and treatment in your ICU.

6. Please describe any quality improvement initiatives for delirium or any other condition(s) that have taken place in your ICU from 2012-2014.

7. What impact, if any, did these initiatives have on patient outcomes?

8. Please describe any challenges or barriers to implementation of quality improvement efforts in the ICU.

9. Please describe any other challenges that the ICU encountered over the past year that may have impacted delivery of care. (Examples: high staff turnover, new leadership, or lack of resources).

10. Please identify the key people who lead ABCDE bundle implementation efforts (or other quality improvement efforts if the bundle has not been implemented) in your ICU. We will select a sample of these individuals and work with you to set up a time to meet with them during our visit.

Name	**Role (ex. ICU Director, Nurse Champion, Trainer, etc.)**	**Phone**

11. Please list the names of the nurses who work in the ICU on a regular basis. We will select a sample of these individuals and work with you to set up a time to meet with them during our visit.

Name	**Typical Shift (Day, Night, Weekend)**

12. Please list the names of some of the physicians who regularly oversee the care of ICU patients. We will select a sample of these individuals and work with you to set up a time to meet with them during our visit.

Name	**Specialty**

13. Please list the names of the respiratory therapists who provide care in your ICU. We will select a sample of these individuals and work with you to set up a time to meet with them during our visit.

Name

14. Please list the names of the physical therapists that provide care in your ICU. We will select a sample of these individuals to interview and work with you to set up a time to meet with them during our visit.

Name

15. Is there anything else you would like for us to know before the visit that may help us better understand how care is delivered in your ICU?

16. Is there a conference room or private area that we may reserve at your facility in order to conduct interviews during our visit?

☐ **Yes** **Please specify location:** ☐ **No**

17. Is there a particular day of the week and/or time of the day that would be best for conducting interviews with clinical personnel?

APPENDIX B2. INTERVIEW GUIDES

IBID INTERVIEW GUIDE – ENHANCED INTERVENTION ICUS

[Notes to facilitator:

All instructions to the interviewers are in square brackets. Do not read these statements aloud. Please check the recording equipment prior to starting the interview.

Suggested script for the interviewer (introduction, transitions, and questions) appears in italics. The main questions in each section are numbered. Interviewer should read and understand topic areas and questions prior to starting the interview. Interviewer should try to cover all questions in protocol.

Question phrasing is *suggested*. This is a discussion. Interviewer should phrase questions in a way that s/he is comfortable speaking.

Follow-up questions may be employed to more fully explore the topic area. If interviewer believes the concept has been covered s/he may skip follow-up question.

Probes are optional. If interviewer believes the respondent has not fully engaged or answered the main or follow-up question s/he may use one or more of the "probes" to further investigate and engage respondents. For convenience of the interviewer, these optional questions will be listed below the main question stem.]

[Begin by reading the introduction script:]

Good morning. My name is [INTERVIEWER NAME], and I am with the Baylor Scott & White Center for Clinical Effectiveness. I'd also like to introduce [NOTETAKER NAME] who will be taking notes, so that we can make sure to keep track of what you said and represent your opinions accurately. As you may know, the Baylor Scott & White Center for Clinical Effectiveness received a grant from the Agency for Healthcare Research and Quality (AHRQ) to implement the ABCDE bundle for delirium prevention and evaluate how the bundle was implemented and the impact of the bundle on patient outcomes. I will be interviewing you today regarding delirium prevention and management practices in the ICU. I have given you a cover letter explaining the purpose of this interview and informing you that participation in the interview constitutes consent. You may refuse to answer any question or quit the interview at any time. Do we have your permission to tape this conversation to help us with note taking? We respect that you might not want to be identified, and we won't use your name in any written reports; the transcripts of the

interview will not contain your name and recordings will be destroyed once transcribed. There are no right or wrong answers to the questions I will ask.

We anticipate the interview will take 30-45 minutes. Are there any questions before I begin?

[Start the recording device.]

This is [INTERVIEWER NAME]. This is interview [INTERVIEW NUMBER] on [TODAY'S DATE].

[Begin to ask questions.]

[PART 1: ICU Roles and Involvement in Decisions Regarding ICU Processes of Care]

[The first question is a "warm-up;" we would like to understand the general role of the respondent in the ICU.]

1. ***Okay, first I would like for you to briefly describe your role in the ICU.***

   Probes: *What types of activities do you perform on a typical day?*

2. ***Are you generally involved in decisions about the adoption of new care processes or technologies for the management of patients in the intensive care unit (ICU)?***

[If the response is "No," skip to question 3]

Follow-up: *How do you generally make these decisions?*

Probes: *Are these decisions influenced by:*

a) *Recommendations by respected colleague or opinion leader*
b) *Consensus of ICU staff*
c) *Reported research studies in the literature*
d) *Care guidelines from a respected source*
e) *Research study of own patients*
f) *Recommendations by a professional organization*
g) *Own practice experience*

[PART 2: The ABCDE Bundle]

3. *Will you describe the elements of the ABCDE bundle?*

4. ***When was the ABCDE bundle introduced to you?***

5. ***How did you learn about the ABCDE bundle?***

   Probes:
   a) Was there a meeting to introduce it?
   b) Did you receive a written notice of the bundle?
   c) Did your supervisor tell you about it?
   d) Did you learn about the bundle at a training session?

6. ***Have you adopted the bundle? If so, how would you describe the process of bundle adoption?***

   Probes:
   a) Did you adopt certain bundle elements first?
   b) Did certain people adopt the bundle before others?
   c) Did other ICU personnel encourage you to adopt the bundle?

   Follow-up: *How long ago did you adopt the bundle?*

[PART 3: Characteristics of the ABCDE Bundle]

Relative Advantage

7. *What are the advantages of the ABCDE bundle compared to standard of care?*

   Probes:
   a) Do you think that the bundle positively impacts the delivery of care? If so, how?
   b) Do you think that the bundle positively impacts patient outcomes? If so, how?

8. What are the disadvantages of the ABCDE bundle compared to standard of care?

   Probes:
   a) Do you think that the bundle negatively impacts delivery of care? If so, how?
   b) Do you think that the bundle negatively impacts patient outcomes? If so, how?

Complexity/Simplicity

9. *How would you describe the complexity of the ABCDE bundle?*

   Probes:
   a) Are there any particular components of the bundle that are difficult to implement?

b) *Do certain elements of the bundle require more collaboration with other staff than others?*

Compatibility

10. *How do you feel the ABCDE bundle fits with your current workflow and processes of care?*

    Probes:

    a) *Which, if any, of the bundle elements were already a part of your workflow prior to implementation?*
    b) *Are there any aspects of your job that make it difficult to implement a new bundle?*

Observability

11. *What benefits related to the delivery of patient care and patient outcomes have you observed that you would attribute to the implementation of the bundle?*

12. *Have you observed any negative effects?*

Potential for Reinvention

13. *How have you customized the bundle to fit within your current workflow?*

[Part 4. Organizational-level Factors Influencing ABCDE Bundle Implementation]

Communication

14. *How was information about the ABCDE bundle communicated to you? How effective was this means of communication?*

Organizational Antecedents for Innovation

15. *How would you describe the attitudes of ICU staff and management and Baylor Scott & White regarding innovation?*

    Probes:

    a) *Are people usually willing to try new approaches to care?*
    b) *What types of resources are available to support new initiatives?*

Organizational Readiness for Change

16. *How would you describe the ICU's readiness to adopt the ABCDE bundle?*

    Probes:

    a) *What resources and support for the bundle were available?*
    b) *Did you feel pressure from leadership or staff to improve the status quo?*
    c) *Had the ICU engaged in similar quality improvement initiatives before bundle implementation?*

The Wider Environment

17. *What, if any, factors other than internal pressure from ICU or Baylor Scott and White leadership influenced ABCDE bundle adoption?*

    Probes:
    a) *Where there any local or national policy initiatives that influenced bundle adoption?*
    b) *Are you aware of any professional organizations that are encouraging bundle adoption?*

[Part 5. Implementation and Routinization of the ABCDE Bundle]

18. ***How did the ICU implement the ABCDE bundle?***

    Probes:
    a) *What key activities took place to support bundle use?*
    b) *Was there a formal implementation process?*

19. ***What challenges arose in implementing the ABCDE bundle?***

    Probes:
    a) *Was there a lack of acceptance by:*
        1) *physicians*
        2) *nurses*
        3) *respiratory therapists*
        4) *physical therapists*
        5) *ICU leadership*
    b) *Was there a fear of patient harm?*
    c) *Was there a lack of training?*
    d) *Was there a shortage of resources?*
    e) *Did staff face time constraints?*
    f) *Was the bundle incompatible with other ICU initiatives?*
    g) *Was there a lack of coordination among care providers?*
    h) *Was there a fear of potential occupational hazards associated with awakening and mobilizing patients?*

20. ***What organizational-level factors supported the ABCDE bundle implementation?***

    Probes:
    a) *Did a clinical champion assist with implementation efforts?*
    b) *Did you receive support from hospital/ICU leadership?*
    c) *Did you receive appropriate training and education?*
    d) *Did you have personal or organizational experience with implementing new initiatives?*
    e) *Did you have sufficient staffing resources?*

f) *Did the culture of the ICU support innovation?*
g) *Was there good communication among care providers?*
h) *Did the bundle fit with other organizational goals or programs?*
i) *Was it helpful to have the ABCDE elements incorporated in the EHR (critical care flowsheet)?*
j) *Did you feedback regarding bundle compliance rates and was this feedback helpful?*

21. ***How does the ABCDE bundle fit with the way you or the other staff think care should be provided in the ICU?***

22. ***Is the ABCDE bundle a routine and accepted part of the way that care is delivered to patients in your ICU?***

    Probes:
    a. *If not, why do you think that is the case?*

    b. *If so, what changes have you had to make in order for the ABCDE bundle to become an accepted and routine part of the management of critically ill patients?*

        1) *Did you make changes to your workflow?*
        2) *Did you make staffing changes?*
        3) *Did you make changes to policies?*
        4) *Did you make changes to your training processes?*
        5) *Did you make changes to information systems/ electronic health record?*
        6) *Did your relationships with other care providers change?*

[Part 6. Other]

23. ***Is there anything else we should know about the ABCDE bundle and how it was implemented and adopted in your ICU? Did we miss anything?***

24. ***What other quality initiatives were implemented in the ICU from 2012-2014 and how did these initiatives impact patient care and outcomes?***

[Thank the respondent for his/her participation.]

Thank you for agreeing to talk to us today. We have a brief survey consisting of 8 questions that we would like you to complete to help us gather a few more details about your role at Baylor Scott & White and in the implementation of the ABCDE bundle. Would you be willing to complete this?

Again, thank you for your time and your willingness to provide us with feedback.

IBID INTERVIEW GUIDE – BASIC INTERVENTION ICUS

[Notes to facilitator:

All instructions to the interviewers are in square brackets. Do not read these statements aloud. Please check the recording equipment prior to starting the interview.

Suggested script for the interviewer (introduction, transitions, and questions) appears in italics. The main questions in each section are numbered. Interviewer should read and understand topic areas and questions prior to starting the interviews. The interviewer should try to cover all questions in protocol.

Question phrasing is *suggested*. This is a discussion. Interviewer should phrase questions in a way that s/he is comfortable speaking.

Follow-up questions may be employed to more fully explore the topic area. If interviewer believes the concept has been covered s/he may skip follow-up question.

Probes are optional. If interviewer believes all or the respondent has not fully engaged or answered the main or follow-up question s/he may use one or more of the "probes" to further investigate and engage respondents. For convenience of the interviewer, these optional questions will be listed below the main question stem.]

[Begin by reading the introduction script:]

Good morning. My name is [INTERVIEWER NAME]. I will be interviewing you today regarding delirium prevention and management practices in the ICU. I'd also like to introduce [NOTETAKER NAME] who will be taking notes, so that we can make sure to keep track of what you said and represent your opinions accurately. As you may know, the Baylor Scott & White Center for Clinical Effectiveness received a grant from the Agency for Healthcare Research and Quality (AHRQ) to examine delirium in ICUs. Today, we have asked you to talk to us about any delirium prevention and management strategies you may have implemented in your ICU. We intend to use the information gained from this interview to inform the implementation of a bundled care process for delirium in other Baylor Scott & White ICUs. I have given you a cover letter explaining the purpose of this interview and informing you that participation in the interview constitutes consent. You may refuse to answer any question or quit the interview at any time. Do we have your permission to tape this conversation to help us with note taking? We respect that you might not want to be identified, and we won't use your name in any written reports; the transcripts of the interview will not contain your name and recordings will be destroyed once transcribed. We want to hear your honest opinions. There are no right or wrong answers to the questions I will ask.

We anticipate the interview will take 30-45 minutes. Are there any questions before I begin?

[Start the recording device.]

This is [INTERVIEWER NAME]. This is interview [INTERVIEW NUMBER] on [TODAY'S DATE].

[Begin to ask questions.]

[PART 1: ICU Roles and Involvement in Decisions Regarding ICU Processes of Care]

[The first question is a "warm-up;" we would like to understand the general role of the respondent in the ICU.]

1. ***Okay, first I would like for you to briefly describe your role in the ICU.***

   Probes: *What types of activities do you perform on a typical day?*

2. ***Are you generally involved in decisions about the adoption of new care processes or technologies for the management of patients in the intensive care unit (ICU)?***

[If the response is "No," skip to question 3]

Follow-up: *How do you generally make these decisions?*

Probes: *Are these decisions influenced by:*

a) *Recommendations by respected colleague or opinion leader*
b) *Consensus of ICU staff*
c) *Reported research studies in the literature*
d) *Care guidelines from a respected source*
e) *Research study of your own patients*
f) *Recommendations by a professional organization*
g) *Own practice experience*

<u>[PART 2: The ABCDE Bundle]</u>

3. ***Are you familiar with the ABCDE bundle? If yes, will you describe the elements of the bundle?***

   [IF NO, SKIP TO QUESTION 25]

4. ***When was the ABCDE bundle introduced to you?***

5. ***How did you learn about the ABCDE bundle?***

   Probes:
   a) Was there a meeting to introduce it?
   b) Did you receive a written notice of the bundle?
   c) Did your supervisor tell you about it?
   d) Did you learn about the bundle at a training session?

6. ***Have you adopted the bundle? If so, how would you describe the process of bundle adoption?***

   Probes:
   d) Did you adopt certain bundle elements first?
   e) Did certain people adopt the bundle before others?
   f) Did other ICU personnel encourage you to adopt the bundle?

   Follow-up: *How long ago did you adopt the bundle?*

[PART 3: Characteristics of the ABCDE Bundle]

Relative Advantage

7. *What are the advantages of the ABCDE bundle compared to standard of care?*

   Probes:
   a) Do you think that the bundle positively impacts the delivery of care? If so, how?
   b) Do you think that the bundle positively impacts patient outcomes? If so, how?

8. What are the disadvantages of the ABCDE bundle compared to standard of care?

   Probes:
   a) Do you think that the bundle negatively impacts delivery of care? If so, how?
   b) Do you think that the bundle negatively impacts patient outcomes? If so, how?

Complexity/Simplicity

9. *How would you describe the complexity of the ABCDE bundle?*

   Probes:
   a) Are there any particular components of the bundle that are difficult to implement?
   b) Do certain elements of the bundle require more collaboration with other staff than others?

Compatibility

10. *How do you feel the ABCDE bundle fits with your current workflow and processes of care?*

    Probes:
    a) *Which, if any, of the bundle elements were already a part of your workflow prior to implementation?*
    b) *Are there any aspects of your job that make it difficult to implement a new bundle?*

Observability

11. *What benefits related to the delivery of patient care and patient outcomes have you observed that you would attribute to the implementation of the bundle?*

12. *Have you observed any negative effects?*

Potential for Reinvention

13. *How have you customized the bundle to fit within your current workflow?*

Part 4. Organizational-level Factors Influencing ABCDE Bundle Implementation]

Communication

14. *How was information about the ABCDE bundle communicated to you? How effective was this means of communication?*

Organizational Antecedents for Innovation

15. *How would you describe the attitudes of ICU staff and management and Baylor Scott & White regarding innovation?*

    Probes:
    c) *Are people usually willing to try new approaches to care?*
    d) *What types of resources are available to support new initiatives?*

Organizational Readiness for Change

16. *How would you describe the ICU's readiness to adopt the ABCDE bundle?*

    Probes:
    d) *What resources and support for the bundle were available?*
    e) *Did you feel pressure from leadership or staff to improve the status quo?*
    f) *Had the ICU engaged in similar quality improvement initiatives before bundle implementation?*

The Wider Environment

17. *What, if any, factors other than internal pressure from ICU or Baylor Scott and White leadership influenced ABCDE bundle adoption?*

Probes:

c) Where there any local or national policy initiatives that influenced bundle adoption?
d) Are you aware of any professional organizations that are encouraging bundle adoption?

[Part 5. Implementation and Routinization of the ABCDE Bundle]

18. ***How did the ICU implement the ABCDE bundle?***

Probes:

c) What key activities took place to support bundle use?
d) Was there a formal implementation process?

19. ***What challenges arose in implementing the ABCDE bundle?***

Probes:

a) Was there a lack of acceptance by:
    1) physicians
    2) nurses
    3) respiratory therapists
    4) physical therapists
    5) ICU leadership
b) Was there a fear of patient harm?
c) Was there a lack of training?
d) Was there a shortage of resources?
e) Did staff face time constraints?
f) Was the bundle incompatible with other ICU initiatives?
g) Was there a lack of coordination among care providers?
h) Was there a fear of potential occupational hazards associated with awakening and mobilizing patients?

20. ***What organizational-level factors supported the ABCDE bundle implementation?***

Probes:

k) Did a clinical champion assist with implementation efforts?
l) Did you receive support from hospital/ICU leadership?

m) *Did you receive appropriate training and education?*
n) *Did you have personal or organizational experience with implementing new initiatives?*
o) *Did you have sufficient staffing resources?*
p) *Did the culture of the ICU support innovation?*
q) *Was there good communication among care providers?*
r) *Did the bundle fit with other organizational goals or programs?*
s) *Was it helpful to have the ABCDE elements incorporated in the EHR (critical care flowsheet?)*
t) *Did you receive feedback regarding bundle compliance rates and was this feedback helpful?*

21. ***How does the ABCDE bundle fit with the way you or the other staff think care should be provided in the ICU?***

22. ***Is the ABCDE bundle a routine and accepted part of the way that care is delivered to patients in your ICU?***

Probes:

c. *If not, why do you think that is the case?*

d. *If so, what changes have you had to make in order for the ABCDE bundle to become an accepted and routine part of the management of critically ill patients?*

7) *Did you make changes to your workflow?*
8) *Did you make staffing changes?*
9) *Did you make changes to policies?*
10) *Did you make changes to your training processes?*
11) *Did you make changes to information systems/ electronic health record?*
12) *Did your relationships with other care providers change?*

[Part 6. Other]

23. ***Is there anything else we should know about the ABCDE bundle and how it was implemented and adopted in your ICU? Did we miss anything?***

24. ***What other quality initiatives were implemented in the ICU from 2012-2014 and how did these initiatives impact patient care and outcomes?***

[Thank the respondent for his/her participation.]

Thank you for agreeing to talk to us today. If there is anything else you'd like for us to know that we didn't talk about today, you can contact Ashley Collinsworth via email Ashley.Collinsworth@baylorhealth.edu or phone 214.265.3611.

We have a brief survey consisting of 8 questions that we would like you to complete to help us gather a few more details about your role at Baylor Scott & White and in the implementation of the ABCDE bundle. Would you be willing to complete this?

Again, thank you for your time and your willingness to provide us with feedback.

[End recording.]

<u>Questions for Respondents Who Are Not Familiar with the ABCDE Bundle</u>

25. ***Can you describe any care processes that are in place to detect and/or prevent delirium in ICU patients?***

26. ***Can you describe what protocols currently exist in the ICU for:***
    a) *sedation vacations*
    b) *ventilator weaning*
    c) *delirium assessments*
    d) *physical therapy*

27. ***What other quality improvement initiatives were implemented in the ICU between 2012 and 2014 and how did these impact patient care?***

    [IF THE RESPONDENT REPORTS THAT NO OTHER QUALITY INITIATIVES HAVE BEEN IMPLEMENTED, SKIP TO QUESTION 31.]

28. ***What were some of the challenges you encountered in implementing these projects?***

    Probes:
    a) *Was there a lack of acceptance by:*
        1) *physicians*
        2) *nurses*
        3) *respiratory therapists*
        4) *physical therapists*
        5) *ICU leadership*
    b) *Was there a fear of patient harm?*
    c) *Was there a lack of training?*
    d) *Was there a shortage of resources?*
    e) *Did staff face time constraints?*
    f) *Was there a lack of coordination among care providers?*

29. ***What organizational factors facilitated the implementation of these projects?***

    Probes:
    a) Did a clinical champion assist with implementation efforts?
    b) Did you receive support from hospital/ICU leadership?
    c) Did you receive appropriate training and education?
    d) Did you have personal or organizational experience with implementing new initiatives?
    e) Did you have sufficient staffing resources?
    f) Did the culture of the ICU support innovation?
    g) Was there good communication among care providers?
    h) Were modifications made to the electronic health record?
    i) Did you receive feedback on your performance?

30. ***How did these quality initiatives affect patient care and outcomes?***

31. ***How would you describe the attitudes of ICU staff and management and Baylor Scott & White regarding innovation and the resources available to support new initiatives?***

32. *How interested would you and the ICU staff be in implementing a new care process to reduce patient risk of delirium? What barriers might you encounter?*

33. *Is there anything else we should know pertaining to the delivery of care in ICU related to the prevention and management of delirium?*

[Thank the respondent for his/her participation.]

Thank you for agreeing to talk to us today. We have a brief survey consisting of 8 questions that we would like you to complete to help us gather a few more details about your role at Baylor Scott & White. Would you be willing to complete this?

Again, thank you for your time and your willingness to provide us with feedback.

[End recording.]

APPENDIX B3. SURVEY

Key Informant Questionnaire

1. **In general, how would you describe your tendencies to adopt new ideas and innovations?**

1☐ I am eager to adopt new ideas even when they seem daring and risky. I can cope with a high degree of uncertainty regarding whether an idea or innovation will be a success or failure.

2☐ I seek advice and information about ideas and innovations prior to adopting them. I am willing to promote new ideas and lead adoption efforts once I have tested and evaluated the innovation.

3☐ I often deliberate for some time before adopting new ideas. I am more willing to adopt an innovation if someone else has tested the idea and leads adoption efforts.

4☐ I tend to be skeptical and cautious about innovations or new ideas. I may adopt a new idea if I am pressured by my peers to do so and much of the uncertainty regarding the innovation or idea has been resolved.

5☐ I am often suspicious of or resistant to innovations or new ideas. I may adopt an innovation once I am certain the innovation will not fail or once everyone else has adopted it.

2. **Please answer the following questions based on the climate of the ICU you work in or manage.**

		Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
a.	Innovation is encouraged without fear of punishment if the innovation does not work	1	2	3	4	5
b.	Creativity is rewarded	1	2	3	4	5
c.	Physicians are receptive to new ways of providing care	1	2	3	4	5
d.	Nurses are receptive to new ways of providing care	1	2	3	4	5

e.	Managers are receptive to new ways of providing care	1	2	3	4	5
f.	Staff are provided with training when new ways of providing care are introduced	1	2	3	4	5
g.	New ways of providing care are encouraged	1	2	3	4	5

3. **Thinking about the ABCDE bundle, please complete the following items by circling the best response. Please respond in terms of your own perceptions. Circle "Not Applicable" if you are not familiar with the bundle.**

a. How easy or difficult is it to use the ABCDE Bundle?

1 2 3 4 5 X
Difficult Easy Don't Know/Not Applicable

b. Is the ABCDE bundle better or worse than the care processes you used before?

1 2 3 4 5 X
Worse Better Don't Know/Not Applicable

c. How compatible is the ABCDE bundle with the way you feel care should be provided to critical care patients?

1 2 3 4 5 X
Incompatible Compatible Don't Know/Not Applicable

d. To what extent can the ABCDE bundle be experimented with on a limited or trial basis?

1 2 3 4 5 X
With Difficulty Easily Don't Know/Not Applicable

e. How visible to you are the benefits of the ABCDE bundle?

1 2 3 4 5 X
Not Visible Very Visible Don't Know/Not Applicable

f. How easy or difficult is it to customize or adapt the ABCDE bundle to fit within current care processes or to better meet patient needs?

1 2 3 4 5 X
Difficult Easy Don't Know/Not Applicable

4. **What is your occupation?**

1☐ Administrator
2☐ Nurse
3☐ Nurse Manager
4☐ Nurse Practitioner
5☐ Physical Therapist
6☐ Physician
7☐ Respiratory Therapist
8☐ Other_____

5. **Gender**

1☐ Female
2☐ Male

6. **Age**

1☐ 20-29 years
2☐ 30-39 years
3☐ 40-49 years
4☐ 50-59 years
5☐ 60-69 years
6☐ 70-79 years

7. **How many years of work experience do you have in your current occupation?**

1☐ 0-2 years
2☐ 3-5 years
3☐ 6-10 years
4☐ >10 years

APPENDIX B4. INTERVIEW CODING SCHEME

Categories/Questions	**Codes**
	Preset codes are designated by plain text. Emerging codes are designated by **bold text.**
1. Briefly describe your role in the ICU	1.1 Supervisor/manager role 1.2 Provide patient care 1.3 Day shift 1.4 Night shift 1.5 Weekend shift
2. Adoption Decisions How do you make decisions about the adoption of new care processes or technologies in the ICU?	2.1 Colleague/opinion leader recommendation 2.2 ICU staff suggestions 2.3 Literature/current research 2.4 Care guidelines 2.5 Own research 2.6 Professional organization recommendation 2.7 Own practice experience 2.8 Recommendation by BSWH/ICU leadership **2.9 Evidence based medicine/best practices** **2.10 Other hospitals/health systems** **2.11 Critical Care Council**
ABCDE Bundle	
3. Will you describe the elements of the bundle?	3.1 Correctly described all elements 3.2 Correctly described some elements 3.3 Could not describe any elements 3.4 Not familiar with the term ABCDE bundle
4. When was the bundle introduced to you?	4.1 <6 months ago 4.2 6-11 months ago 4.3 1 year ago 4.4 1.5 years ago 4.5 2 years ago 4.6 Don't know **4.7 Nursing School** **4.8 Have always used**

5. Learning about the Bundle How did you learn about the ABCDE bundle?	5.1 Meeting 5.2 Written notice 5.3 Supervisor told about 5.4 Training **5.5 Email** **5.6 Visual Aids** **5.7 Partnership council** **5.8 Clinical champions** **5.9 Other BSWH sites** **5.10 Nursing School** **5.11 Critical Care Council** **5.12 Other council** **5.13 Orientation**
6. Process of Bundle Adoption How would you describe the process of bundle adoption?	6.1 Adoption 6.1.1 Yes, have adopted 6.1.2 No, have not adopted 6.1.3 Have somewhat adopted 6.1.4 Have always used the bundle 6.2 Adoption of elements 6.2.1 All elements at once 6.2.2 SAT first 6.2.3 SBT first 6.2.4 Delirium screening first (CAM-ICU) 6.2.5 Early mobility first 6.3 Adoption by staff 6.3.1 Some staff adopted earlier 6.3.2 Encouraged by other staff 6.4 Difficulties with 6.4.1 SAT 6.4.2 SBT 6.4.3 Delirium screening (CAM-ICU) **6.4.4 Mobility** **6.5 Process of adoption** **6.5.1 Long and slow** **6.5.2 Easy** **6.5.3 Challenging**
Characteristics of the ABCDE Bundle	
7. Relative Advantage What are the advantages of the ABCDE bundle compared to standard of care?	7.1 Improved care delivery 7.2 Coordinated care 7.3 Improved provider communication 7.4 Patients off the vent sooner 7.5 Patients receive less sedation 7.6 Patients more likely receive delirium screening 7.7 Patients receive physical therapy

	sooner **7.8 Improved patient outcomes** **7.9 Reduced morbidity** **7.10 Reduced mortality** **7.11 Reduced LOS** **7.12 Transfer out of ICU sooner** **7.13 More efficient care delivery** **7.14 Standardized care**
8. What are the disadvantages of the ABCDE bundle compared to standard of care?	8.1 Time consuming 8.2 Difficult to implement 8.3 Fear of patient harm **8.4 No disadvantages** **8.5 Requires more documentation** **8.6 Requires more staff** **8.7 Requires more coordination**
9. Complexity/Simplicity How would you describe the complexity of the bundle?	9.1 Simple 9.2 Complex **9.2.1 Requires more coordination** **9.2.2 Requires more documentation** **9.2.3 Requires additional training** **9.2.4 Difficult to document** **9.3 Not overly complex** **9.4 Depends on personnel** **9.5 Some elements are complex** **9.5.1 CAM-ICU** **9.5.2 Early mobility**
10. Compatibility How do you feel the ABCDE bundle fits with your current workflow and processes of care?	10.1 Fits with current workflow 10.2 Does not fit with current workflow 10.3 Made workflow modifications
11. Observability What benefits related to the delivery of patient care and patient outcomes have you observed that you would attribute to the implementation of the bundle?	11.1 No observed benefits 11.2 Improved patient care 11.2.1 Coordinated care 11.2.2 Improved provider communication 11.2.3 Patients off the vent sooner 11.2.4 Patients receive less sedation 11.2.5 Patients more likely receive delirium screening 11.2.6 Patients receive physical therapy sooner 11.2.7 Staff more autonomous 11.3 Improved patient outcomes 11.3.1 Decrease in delirium incidence 11.3.2 Decrease in delirium duration

	11.3.3 Decrease in coma days 11.3.4 Decrease in length of stay 11.3.5 Decrease in mortality
12. Have you observed any negative effects?	12.1 No negative effects 12.2 Negative effects 12.2.1 Patient harm **12.2.2 Staff stress** **12.2.3 Unhappy staff**
13. Potential for Reinvention How have you customized the bundle to fit within your current workflow?	13.1 No changes to the bundle
Organizational-level Factors Influencing ABCDE Bundle Implementation	
14. Communication How was information about the ABCDE bundle communicated to you? How effective was this means of communication?	14.1 Communication channels 14.1.1 Meetings 14.1.2 Written notice 14.1.3 Supervisor told about 14.1.4 Training **14.1.5 Visual aids** **14.1.6 Email** **14.1.7 Councils** **14.1.8 Word of mouth** **14.1.9 Roundings** **14.1.10 Huddles** 14.2 Effectiveness of communication 14.2.1 Not effective 14.2.2 Somewhat effective 14.2.3 Effective 14.2.4 Very effective
15. Organizational Antecedents for Innovation How would you describe the attitudes of ICU staff and management and Baylor Scott & White regarding innovation?	15.1 Attitudes 15.1.1 Willing to try new care approaches 15.1.2 Hesitant to try new care approaches 15.1.3 Unwilling to try new care approaches
16. Organizational Readiness for Change How would you describe the ICU's readiness to adopt the ABCDE bundle?	16.1 Resources 16.1.1 Leadership 16.1.2 Time 16.1.3 Appropriate staffing **16.1.4 Education/training** 16.2 Pressure from leadership 16.3 Quality improvement experience

17. The Wider Environment What, if any, factors other than internal pressure from ICU or Baylor Scott and White leadership influenced ABCDE bundle adoption?	17.1 Local initiatives 17.2 National policy initiatives 17.3 Promotion by professional organizations **17.4 Use in other hospitals**
Implementation and Routinization of the ABCDE Bundle	
18. How did the ICU implement the ABCDE Bundle?	18.1 Key activities 18.1.1 Trainings 18.1.2 Regular communication 18.1.3 Monitoring and feedback **18.1.4 Meetings** **18.1.5 Superusers** **18.1.6 Collaboration with other providers** **18.1.7 Visual aids** **18.1.8 Order sets** **18.2 Implementation process** **18.2.1 Formal** **18.2.2 Informal** **18.3 Adoption of elements** **18.3.1 All elements at once** **18.3.2 SAT first** **18.3.3 SBT first** **18.3.4 Delirium screening first (CAM-ICU)** **18.3.5 Early mobility first** **18.4 Difficulties with** **18.4.1 SAT** **18.4.2 SBT** **18.4.3 Delirium screening (CAM-ICU)** **18.4.4 Mobility** **18.5 Process of adoption** **18.5.1 Long and slow**
19. What challenges arose in implementing the ABCDE bundle?	19.1 Lack of acceptance by 19.1.1 physicians 19.1.2 nurses 19.1.3 respiratory therapists 19.1.4 physical therapists 19.1.5 ICU leadership 19.2 Fear of patient harm 19.3 Lack of training

	19.4 Staff shortages 19.5 Time constraints 19.6 Incompatible with other ICU initiatives 19.7 Lack of coordination among care providers 19.8 Fear of occupational hazards **19.9 Staff turnover** **19.10 Lack of accountability** **19.11 Lack of knowledge about bundle** **19.12 Need for retraining** **19.13 EHR documentation** **19.14 Competing priorities/initiatives** **19.15 Culture change** **19.16 No challenges** **19.17 Consistent use of the bundle** **19.18 Lack of a clear protocol** **19.19 Lack of order set**
20. What organizational-level factors supported the ABCDE bundle implementation?	20.1 Clinical champion 20.2 Support from hospital/ICU leadership 20.3 Appropriate training/education 20.4 Experience implementing new initiatives 20.5 Sufficient staffing resources 20.6 Culture supports innovation 20.7 Good provider communication 20.8 Bundle fit with other organizational goals 20.9 ABCDE elements incorporated in the EHR 20.10 Feedback regarding bundle compliance rates **20.11 Nurse educator** **20.12 Supertrainers**
21. How does the ABCDE bundle fit with the way you or the other staff think care should be provided in the ICU?	21.1 Aligns well 21.2 Does not align well
22. Is the ABCDE bundle a routine and accepted part of the way that care is delivered to patients in your ICU? e. If not, why do you think that is the case?	22.1 Routinization 22.1.1 Yes 22.1.2 No 22.1.3 Somewhat/Making progress 22.2 If no, why not?

f. What changes have you had to make in order for the ABCDE bundle to become an accepted and routine part of the management of critically ill patients?	22.3 Changes 22.3.1 Workflow changes 22.3.2 Staffing changes 22.3.3 Changes to policies 22.3.4 Changes to training 22.3.5 Changes to EHR 22.3.6 Changes in relationships with other care providers **22.3.7 Change in protocol/processes** **22.3.8 Incorporated into rounding** **22.3.9 Staff held accountable for bundle use** **22.3.10 Routine auditing** **22.3.11 Multidisciplinary huddles** **22.3.12 Change in culture**
Other	
23. Is there anything else we should know about the ABCDE bundle and how it was implemented and adopted in your ICU? Did we miss anything?	
24. What other quality initiatives were implemented in the ICU from 2012-2014 and how did these initiatives impact patient care and outcomes?	24.1 Other Initiatives 24.1.1 CLABSI 24.1.2 Vent mortality 24.1.3 Foley catheter 24.1.4 CAUTI **24.1.5 HAPU/pressure ulcer** **24.1.6 VAP** **24.1.7 HELP study** **24.2 No other initiatives** **24.3 Don't know** **24.4 Core measures**

APPENDIX C. EVALUATING THE COST-EFFECTIVENESS OF THE ABCDE BUNDLE: IMPACT OF BUNDLE ADHERENCE ON INPATIENT AND 1-YEAR MORTALITY, QUALITY OF LIFE, AND COSTS OF CARE

Abstract

Objective: To determine the impact of ABCDE (Awakening and Breathing Coordination, Delirium monitoring/management, and Early exercise/mobility) bundle adherence on inpatient and 1-year mortality, quality-adjusted life years (QALYs), and costs of care.

Design: Two-year, prospective, quasi-experimental study conducted between July 2012 and June 2014.

Setting: 12 adult ICUs in 6 hospitals belonging to a large, integrated healthcare delivery system. Hospitals included a large, urban tertiary referral center, 4 community hospitals, and a rural hospital. ICUs included medical/surgical, trauma, neurological and cardiac care units.

Patients: 2501 patients, 18 years of age or older, with an ICU stay >24 hours, who were on a ventilator for more than 24 hours and less than 14 days.

Interventions: The ABCDE bundle consisted of several individual evidence-based critical care processes (spontaneous awakening trials, spontaneous breathing trials, delirium screening, and early mobility). Different strategies were employed to improve bundle adherence in study ICUs including modification of the electronic health record

(EHR) and training sessions, use of clinical champions, and staff participation in bundle implementation efforts.

Measurements and Main Results: Using propensity score-adjusted regression models we found that patients with high ABCDE bundle adherence (≥60%) had significantly decreased odds of inpatient mortality (OR 0.40) and slightly higher costs ($1,877) of inpatient care. The incremental cost effectiveness ratio (ICER) of high bundle adherence was $18,770 (95% CI: $13,750-$21,705) per life saved and $1,341 per life year saved. A Markov model was used to estimate the potential effect of improved bundle adherence on health care costs and QALYs in the year following ICU admission. High bundle adherence was associated with a 0.05 increase in QALYs, a $939 increase in cost, and an ICER of $17,792 per QALY.

Conclusions: The ABCDE bundle appears to be a cost-effective means to improve delivery of care and patient outcomes in the ICU.

Background

The provision of critical care is associated with high rates of morbidity and mortality and is a major source of health care expenditures in the United States and other developed countries (Cuthbertson, Roughton et al. 2010). Approximately 35% to 80% of patients in the Intensive Care Unit (ICU) develop delirium as a complication of care (Flinn, Diehl et al. 2009; Skrobik 2011). Patients undergoing mechanical ventilation are particularly susceptible to the condition, as the analgesics, sedatives, and hypnotics that are frequently used in ICUs to achieve patient comfort are often deliriogenic (Banerjee, Girard et al. 2011; Hipp and Ely 2012). ICU-acquired delirium is independently associated with increased cognitive and physical impairment, mortality, hospital length of stay (LOS), and health care costs (Inouye, Schlesinger et al. 1999; Ely, Gautam et al. 2001; Milbrandt, Deppen et al. 2004; Lundstrom, Edlund et al. 2005; Inouye 2006; Pisani, Murphy et al. 2007; Vidan, Sanchez et al. 2009; Pandharipande, Girard et al. 2013; Reston and Schoelles 2013). Leslie et al. found that the additional costs of care attributable to delirium ranged from $16,303 to $64,421 per patient and from $38 to $152 billion dollars annually in the United States alone (Leslie and Inouye 2011).

New cost-effective strategies for the prevention and management of delirium are needed to achieve the triple aim of health care defined as improved delivery of care and patient outcomes at a reduced cost. The ABCDE (Awakening and Breathing Coordination, Delirium Monitoring and Management, and Early Exercise and Mobility) bundle has been proposed as an interdisciplinary, multi-component patient safety intervention to reduce incidence of delirium in ICUs by improving collaboration among clinical team members, standardizing care processes, and breaking the cycle of

oversedation and prolonged ventilation (Girard, Pandharipande et al. 2008; Vasilevskis, Ely et al. 2010; Vasilevskis, Pandharipande et al. 2010; Balas, Vasilevskis et al. 2012; Balas, Burke et al. 2013; Hipp, Ely et al. 2013). The bundle consists of spontaneous awakening trials (SATs) to decrease the use of sedation, spontaneous breathing trials (SBTs) to wean patients off mechanical ventilation faster, coordination of awakening and breathing trials to maximize benefits of SATs and SBTs, delirium screening and treatment, and early progressive mobility to decrease ICU-acquired muscle weakness. Individually, these interventions have been associated with reductions in incidence and duration of delirium and improved patient outcomes such as shorter duration of mechanical ventilation, shorter ICU and hospital LOS, improved functional outcomes, and improved survival (Girard, Kress et al. 2008; Schweickert, Pohlman et al. 2009; Vasilevskis, Ely et al. 2010; Brummel and Girard 2013). In the one study examining the effectiveness of the ABCDE bundle, Balas et al. observed significant reductions in delirium incidence and ventilator days and a significant increase in the number of patients who were mobilized out of bed during their ICU stay.

No published studies have examined the cost-effectiveness of the ABCDE bundle. The objective of this study was to determine the impact of ABCDE bundle adherence inpatient mortality, quality of life, and costs of care. We used a Markov model with estimates obtained from the literature to estimate the potential effect of improved ABCDE bundle adherence on health care costs and QALYs in the year following ICU admission.

Methods

Study Setting

Baylor Scott & White Health (BSWH) includes 43 hospitals, >500 patient care sites, >6,000 affiliated physicians, 34,000 employees and an accountable care organization and is one of the largest non-profit health care systems in the United States. This study included patients treated in the 12 ICUs of 6 BSWH North (previously Baylor Health Care System) hospitals. The hospitals included a large, urban tertiary referral center, 4 community hospitals, and a rural hospital. ICUs included medical/surgical, trauma, neurological, and cardiac care units.

Patients

All patients who were admitted to study ICUs from July 2012 – June 2014 who met the ABCDE bundle inclusion criteria were included in the analysis. Patients were eligible to receive the bundle if they were 18 years of age or older, had an ICU admission lasting more than 24 hours, and were on a ventilator for more than 24 hours and less than 14 days. Patients were excluded if they were on comfort care; were awaiting a transfer order to a non-ICU bed; were never on the ventilator; had a primary diagnosis of brain tumor, mental disorder, stroke, intracranial injury, or poisoning by drugs, medicinal and biologic substances based on ICD-9 classification; or had an hospital stay greater than 30 days.

Intervention

The ABCDE bundle incorporates several individual evidence-based critical care processes (SATs, SBTs, delirium screening, and early mobility) into a single, integrated package. As critically ill patients may be clinically unstable (labile blood pressures or

oxygenation status), safety screens are performed to determine appropriateness of specific care processes for each patient. The number of care processes a patient is eligible for on a given day depends on whether or not the patient is ventilated and passes the appropriate screening criteria. Different strategies were employed to improve bundle adherence in the study ICUs. The electronic health record (EHR) for all study ICUs (Allscripts™) was modified in July 2013 to facilitate uptake and documentation of ABCDE bundle elements. Seven of the study ICUs received additional ABCDE bundle training and implementation tools before and after the EHR modification, had designated bundle champions, and participated in the development of the structured EHR documentation and ABCDE performance reports.

Study Design

We used a prospective, quasi-experimental design to examine differences in bundle adherence on inpatient outcomes and costs. We then conducted a cost-effectiveness analysis using a Markov model built in TreeAge Pro to estimate differences in 1-year costs and QALYs for patients with low and high levels of bundle adherence.

Outcome Measures

We examined differences in incidence of delirium, in-hospital mortality, discharge status, and direct costs of hospital care among patients with varying levels of bundle adherence. ABCDE bundle adherence for each patient was calculated as the total number of care processes the patient received divided by the total number of care processes the patient was eligible for during the course of the patient's ICU stay. Patients who were on a ventilator were eligible to receive all 5 bundle elements (provided they met the safety screening criteria) every day they remained in the ICU and were on the

ventilator. Patients who were not on a ventilator were eligible to receive 3 bundle elements (SAT, CAM-ICU, and early exercise) every day they remained in the ICU and were not on a ventilator. We also estimated differences in costs and QALYs for patients with low and high bundle adherence in the year following ICU admission.

Data Sources

Process measures related to ABCDE bundle adherence were collected from the EHR. Patient demographic and outcomes data were collected from the EHR and BSWH administrative databases. The cost of inpatient care was calculated as the direct care cost for each patient and was obtained from the BSWH TRENDSTAR database. These costs included the costs of any additional patient services associated with application of the ABCDE bundle. The cost of ABCDE bundle implementation was approximately $165,000 and included salary support (1.65 FTEs) for the project lead, project manager, clinical champions, IT personnel for EHR modifications, and data analysts and the cost of trainings and visual aids. These costs were considered sunk costs and were excluded from the cost calculation. Costs were adjusted to 2012 dollars using the medical component of the consumer price index (United States Department of Labor 2014).

Post-acute care costs were estimated from 2012 Medicare average payments for patients receiving care from home health services, skilled nursing facilities, inpatient rehabilitation facilities, and long-term care hospitals (Medicare Payment Advisory Committee 2014). One-year mortality rates and quality adjusted life years (QALYs) based on discharge status were obtained from a one-year prospective cohort study of 817 critically ill patients aged 18 years of age or older who received mechanical ventilation

for ≥ 48 hours in the medical, general surgical, trauma, and neurological ICUs of an academic tertiary care medical center (Cox, Carson et al. 2007; Cox, Carson et al. 2007).

Statistical Analysis

We conducted a univariate analysis to examine unadjusted differences in patient characteristics and delirium incidence, inpatient mortality, inpatient costs, and discharge status between patients with high and low bundle adherence. We compared differences in continuous variables and outcomes that did not violate normality assumptions with independent t-tests. We compared differences in categorical variables and outcomes using Chi-square and Fisher's exact tests.

Due to the fact that patients with greater severity of illness and risk of mortality were more likely to have low levels of bundle adherence, a propensity score adjustment approach was used to reduce the impact of selection bias on the association between bundle adherence and the outcomes of interest. The propensity score, the conditional probability of a patient having high bundle adherence, was determined from a multivariable logistic regression model. Covariates included ICU, age, sex, race, ethnicity, insurance status, APR-DRG Severity and Risk of Mortality scores, Charlson Comorbidity Index, Acute Physiology and Chronic Health Evaluation II (APACHE II) score, ventilator days, ICU length of stay, alcohol use, smoking status, pre-existing dementia, month of ICU admission, and ICU quality. These variables were included based on findings in the literature and evidence that some nurses are reluctant to apply the bundle out of fear of harming patients, particularly those who are frail or may be agitated and/or aggressive when they wake up. We calculated a quality score for each ICU as a proxy measure to control for differences in the quality of care provided in ICUs.

The score was calculated as the average number of central line associated blood stream (CLABSI) infections and catheter associated urinary tract (CAUTI) infections divided by the number of line/catheter days per 1,000 patient days. CLABSI and CAUTI are common infections in critical care units that can be prevented through proper management of central lines and catheters, and the Centers for Medicare and Medicaid have selected these infection rates as critical care quality measures for 2015 (Centers for Disease Control and Prevention 2014; Centers for Disease Control and Prevention 2014).

Propensity score-adjusted effects of bundle adherence on delirium incidence, inpatient mortality, and discharge status were modeled using logistic regression. A generalized linear model with a log link function and a gamma distribution was used to model direct costs due the highly skewed nature of hospital cost data. All statistical analyses were conducted using SAS®. Statistical significance was indicated at the $\alpha < 0.05$ level.

Cost-effectiveness Analysis

We calculated potential patient life years saved by estimating the number of life years lost for each person who died in the study. Life expectancy was projected based on the age and sex of the patient using the Social Security Administration's actuarial life tables for 2010 (U.S. Social Security Administration), discounted based on the five-year survival for patients discharged from ICUs compared to the general population (Wright, Plenderleith et al. 2003). The number of life years saved was calculated as the difference in projected life expectancy and the age of the patient at the time of death.

We used recycled predictions to estimate the effect of high versus low adherence on incidence of delirium, hospital LOS, inpatient mortality, discharge status and inpatient

costs (Glick, Doshi et al. 2007). High bundle adherence was defined as receiving ≥60% of bundle elements, based on the average level of adherence obtained in sites following ABCDE bundle implementation efforts. We varied this threshold from 50% to 70% as a sensitivity analysis. Outcomes were predicted from the modeled equations based on two scenarios: 1) every patient had high adherence to the ABCDE bundle; and 2) every patient had low adherence to the ABCDE bundle. The difference between these two predictions constituted the predicted mean differences in delirium incidence, hospital length of stay, inpatient mortality, discharge status, and direct inpatient costs between patients who had high and low levels of ABCDE bundle adherence. We generated 1,000 bootstraps of this process to estimate 1) the mean differences in these outcomes and 2) the standard errors of these statistics.

The estimates obtained from the bootstraps for inpatient mortality, direct costs, and discharge status for both high and low adherence groups were used as inputs in the Markov model for the cost-effectiveness analysis along with the 1-year mortality risks, QALYs, and costs of care obtained from the literature (Figure 1). Life expectancy estimates for the Markov model for the patients who died in the year following discharge were based on LOS averages for Medicare patients discharged to nursing facilities, inpatient rehabilitation centers, and long term acute care facilities. We assumed a life expectancy of 30 days for patients who died after being discharged home or to home health. We calculated the one-year incremental cost effectiveness of high ABCDE bundle adherence as the ratio of incremental health care costs in the year following ICU admission to the incremental effects (QALYs).

Results

Patient Characteristics

A total of 2501 eligible patients received care in the 12 study ICUs from July 2012-June 2014. After excluding patients who had missing data or were eventually transferred to other acute care hospitals or facilities, 1648 (71%) patients had low (<60%) adherence to ABCDE bundle processes, and 674 (29%) had high (≥60%) adherence. There were no differences in patient demographics between the two groups (Table 1). Mean patient age ranged from 59.8-60.8 years. Both groups had a higher percentage (54%-57%) of male patients. The patient population in both groups was approximately 65% white, 28% black, 2% Asian, and 4% other; 12% of patients were Hispanic. Over half of the patients (53%) were on Medicare. There were significant differences (p <.001) between groups in severity of illness and risk of mortality. More patients in the low adherence group had APR-DRG Severity and Risk of Mortality scores of 4, indicating that patients in the low adherence group were sicker than patients in the high adherence group. The average APACHE II score was also significantly higher in patients in the low adherence group, indicating greater illness severity. There were no differences between groups in delirium risk factors including surgical patients, pre-existing dementia, alcoholism, and smoking.

Unadjusted Outcomes

The comparison of unadjusted outcomes and costs by level of bundle adherence is shown in Table 2. Patients with higher bundle adherence were more likely to be diagnosed with delirium (35% vs. 27%, $p < 0.001$) compared to patients with lower adherence. Inpatient mortality was significantly lower in the high adherence group (8%)

than in the low adherence group (20%). There was a statistically significant difference in discharge status between groups. Patients in the high adherence group were more likely to be discharged home (42% versus 35%), to a rehabilitation facility (12% versus 10%), and to a skilled nursing facility (17% versus 14%). Patients in the high adherence group also had slightly longer average hospital LOS (0.42 days) and higher direct costs of care ($2406), but these differences were not statistically significant.

Risk-adjusted Outcomes

After risk-adjustment using propensity scores, patients with bundle adherence ≥ 60% were still more likely to be diagnosed with delirium; however, this effect was no longer statistically significant (Table 3). Higher levels of bundle adherence continued to be associated with decreased odds of mortality (OR = 0.40). Similar to the unadjusted results, patients with higher levels of bundle adherence had increased odds of being discharged home, to home health, a long term care facility, inpatient rehabilitation, and to a skilled nursing facility. However, only the increase in odds of being discharged to an inpatient rehabilitation facility was statistically significant. Hospital LOS and direct costs remained slightly higher in patients with bundle adherence ≥ 60%, after risk adjustment.

When we varied the bundle adherence threshold from 50% to 70%, we found that patients who received ≥ 50% of bundle elements were much more likely to be diagnosed with delirium, but this difference declined as the threshold increased. Greater bundle adherence was associated with reduced odds of inpatient mortality, but this reduction decreased from 0.72 to 0.56 as bundle adherence threshold increased. Patients with bundle adherence ≥ 50% had much greater odds of being discharged home or to home health, and although these trends persisted as the bundle adherence threshold increased,

the effect of increased bundle adherence was no longer statistically significant. The effect of bundle adherence on hospital LOS remained statistically significant, with LOS increasing from 0.37 to 0.56 as bundle adherence was varied from 50% to 70%. Direct costs were higher for patients with higher levels of adherence, but we did not observe statistically significant differences in costs at any level of bundle adherence.

The mean effect of ABCDE bundle adherence ≥ 60% on inpatient mortality and costs obtained from the bootstrap analysis was a reduction in mortality (19% versus 9%) and a $1,877 increase in direct inpatient costs (Table 4). Potential life years saved, based on the adjusted life-expectancy calculation for all patients in the study population who died, was estimated at 14 years per patient. Based on the estimated differences in mortality and cost, the incremental cost effectiveness ratio (ICER) was calculated as $18,770 per life saved and $1,341 per life year saved (Table 5). The 95% confidence interval per life saved calculated by applying Fieller's method to the estimates from the bootstrap replications was $13,750-$21,705. The estimated impact of ABCDE bundle adherence ≥ 60% on 1 year QALYs and costs of care obtained from the Markov model based on the inputs listed in Table 6 was an 0.05 increase in QALYs and a $939 increase in costs (Table 7). Based on these differences the ICER was calculated as $17,792 per QALY.

Discussion

We investigated the impact of ABCDE (Awakening and Breathing Coordination, Delirium monitoring/management, and Early exercise/mobility) bundle adherence on inpatient and 1-year mortality, quality of life, and costs of care for patients admitted to 12 ICUs over a two year period. During this time period, overall bundle adherence

improved from 34% to 57%. However, there was variation in performance rates among units and between groups receiving different intervention strategies. There were also significant differences in patient characteristics between patients with low and high levels of bundle adherence. Patients who had lower levels of bundle adherence were significantly more likely to have greater severity of illness and risk of mortality as indicated by differences in APACHE II and APR-DRG Severity of Illness and Risk of Mortality scores.

The ABCDE bundle has been proposed as a strategy in ICUs to reduce delirium, which has been independently associated with increased mortality, hospital length of stay (LOS), and health care costs (Inouye, Schlesinger et al. 1999; Ely, Gautam et al. 2001; Milbrandt, Deppen et al. 2004; Lundstrom, Edlund et al. 2005; Inouye 2006; Pisani, Murphy et al. 2007; Vidan, Sanchez et al. 2009; Pandharipande, Girard et al. 2013; Reston and Schoelles 2013). We found that improved adherence to the ABCDE bundle was associated with increased incidence of delirium. However, we believe this increase is due to a detection bias, as patients with higher levels of bundle adherence were more likely to be regularly screened for delirium. We also found that greater adherence to the bundle was associated with decreased incidence of coma which may have unmasked patients with delirium.

Despite the observed increase in delirium in patients with higher levels of bundle adherence, we found that the risk-adjusted odds of mortality were considerably lower (OR = 0.40). The observed decrease in mortality resulted in an increased likelihood of patients with high bundle adherence being discharged home and to long term care facilities, inpatient rehabilitation, and skilled nursing facilities. Hospital LOS and direct

costs were higher for patients with higher levels of bundle adherence, but we observed improvements in other outcomes for patients with higher bundle adherence such as reduced ventilator days, increased percentage of coma and delirium free days, and greater likelihood of being mobilized out of bed, which may translate into better long term outcomes and reduced cost for patients with ICU stays.

The results of the cost-effectiveness analysis indicate that use of the ABCDE bundle is a cost-effective strategy for reducing morbidity and mortality in ICU patients. Based on the differences in inpatient mortality and costs, the ICER for high adherence to the ABCDE bundle was $18,770 per life saved and $1,341 per life year saved. The estimated ICER for high bundle adherence in the year following hospital admission was $17,792 per QALY. These estimates are well below the threshold of $50,000 per life-year or QALY frequently used as to assess the cost-effectiveness of health interventions in the United States (Grosse 2008).

No other published studies have examined the cost-effectiveness of the ABCDE bundle. Awissi et al. examined the cost-effectiveness of a multifaceted care processes for management of sedation, analgesia, and delirium (Awissi, Begin et al. 2012). Although the incidence of delirium remained the same between groups, the mean total costs of an ICU hospitalization (in 2004 Canadian dollars) decreased from $6,213 in the control group to $5,280 in the group of ICU patients treated with a sedation, analgesia, and delirium management protocol (p = .02). The duration of mechanical ventilation was shorter for patients in the treatment group, and the approximately $1,000 reduction in costs in this group was primarily due to an average one day reduction in LOS. Analgesic, sedative, and antipsychotic drug use was also lower in the treatment group, which slightly

contributed to observed reductions in cost. Although we found greater adherence to the ABCDE bundle to be associated with an increase rather than a decrease in inpatient costs, we have found evidence that use of bundle can improve care and outcomes for ICU patients and save lives.

Limitations

This study has several limitations. Due to the fact that this was a quasi-experimental study and not a randomized controlled trial, differences in patient characteristics may have influenced bundle adherence rates, potentially overestimating the impact of improved bundle adherence on patient outcomes, particularly the observed reduction in mortality. This bias may have been due to improper application of bundle inclusion criteria, poor documentation, or differences in the provision of care for patients who were severely ill and had a high risk of mortality. We attempted to control for this selection bias and reduce potential endogeneity by using a propensity score risk-adjustment approach to estimate the conditional probability of a patient having high bundle adherence. However, risk-adjustment can only account for observed confounders and does not ensure a balanced distribution of covariates between patients with low and high bundle adherence. In addition, all patients in this study were critically ill, and it is difficult to differentiate levels of illness severity and mortality within this population with existing measures. In the one published study examining the effectiveness of the ABCDE bundle, Balas et al. also observed a great reduction in mortality following bundle implementation (OR = 0.56); however the study included <300 patients, and this reduction was not statistically significant (p = .09).

Because we did not have data for patients beyond their inpatient stay, we chose to model the impact of ABCDE bundle adherence on 1-year outcomes based on 1-year mortality and QALY estimates obtained from another study. The patient population of that study was similar to our patient population in that it included critically ill patients aged 18 years of age or older who received mechanical ventilation for ≥ 48 hours in the medical, general surgical, trauma, and neurological ICUs of a tertiary care medical center, but patients were 5 years older on average and predominantly white. While we excluded patients who were on the ventilator for >14 days, the other study included 114 (14%) patients who were ventilated for ≥ 21 days. Because the study included patients with prolonged mechanical ventilation who are likely to have higher severity of illness and risk of mortality, the mortality estimates obtained from the study likely overestimated the 1-year mortality risk and underestimated QALYs. In addition our basic Markov model did not account for readmissions and transitions other than from hospital to home/discharge facility and from discharge facility to home or death.

Due to the fact that patients with low bundle adherence may not have been routinely screened for delirium, and the incidence of delirium was likely underestimated for this group, we could not conduct a valid assessment of the impact of the ABCDE bundle on incidence of delirium and the impact of delirium on patient costs and outcomes. Prevention of delirium could result in potential gains in QALYs as the development of ICU-acquired delirium has been associated with increased cognitive and physical impairment in both the short and long term (Pandharipande, Girard et al. 2013).

Another limitation of this study is the fact that bundle adherence remained relatively low for the majority of patients, as only 29% of patients received >60% of

bundle elements. Greater adherence may lead to improved outcomes. We did, however, observe reductions in mortality in patients with higher levels of bundle adherence at a threshold of 50% adherence and did not see additional improvements when the threshold was increased to 70%, suggesting that even low levels of bundle adherence may lead to improved outcomes or that patients with a high risk of mortality are unlikely to receive bundle elements. We also did not examine what lead to differences in costs between patients with low and high levels of bundle adherence. These costs are likely due to increases in LOS and additional physical therapy consults that may have been received with higher bundle adherence.

Conclusion

Based on our findings, the ABCDE bundle appears to be a cost-effective means to improve delivery of care and patient outcomes in the ICU. Although we did not observe a decrease in delirium with improved bundle adherence and our observed decreases in mortality are likely overestimated, there is growing evidence that consistent use of the ABCDE bundle can improve patient outcomes, including reducing the risk of mortality. Further research is needed to obtain better estimates of the impact of the ABCDE bundle on the incidence of delirium and the long-term cost-effectiveness of the bundle in terms of survival and quality of life for patients admitted to the ICU.

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Figure 1. Markov Tree

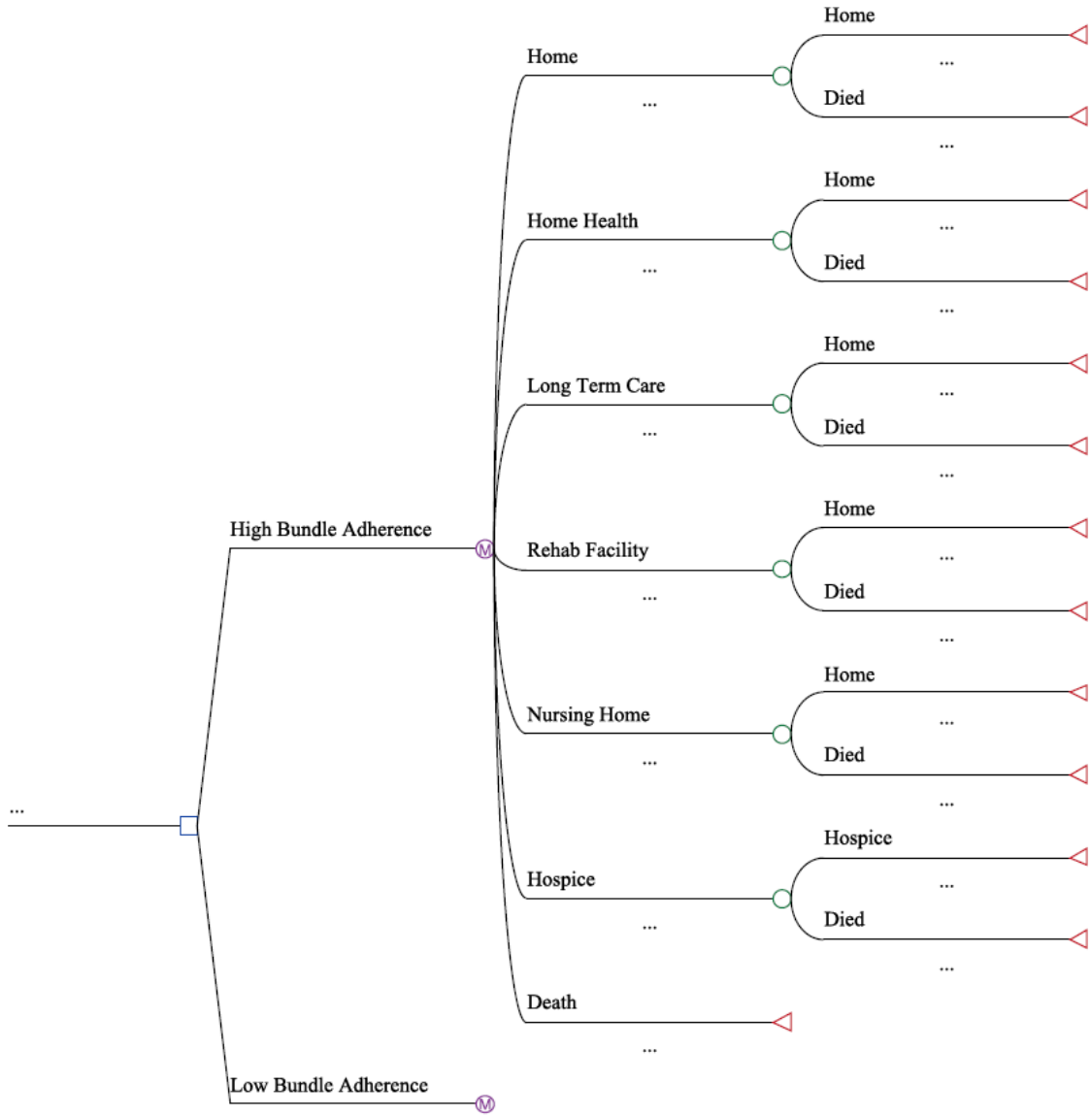

Table 1. Characteristics of Patients Admitted to Study ICUs

	Bundle Adherence		
	<60% *n =1648*	≥60% *n=674*	*p*-value
Age, mean (SD)	60.1 (15.3)	60.6 (15.8)	0.4830
Gender (male), n (%)	899 (54)	383 (57)	0.3175
Race, n (%)			
White	1057 (64)	448 (66)	0.1078
Black	476 (29)	184 (27)	
Asian	40 (2)	23 (3)	
Other	75 (5)	19 (3)	
Ethnicity, n (%)			
Hispanic	221 (13)	81 (12)	0.2526
Insurance, n (%)			
Private	224 (13)	97 (15)	0.8405
Medicare	877 (53)	357 (53)	
Medicaid	84 (5)	26 (4)	
Other federal	133 (8)	55 (8)	
Self-pay	199 (12)	83 (12)	
Other	137 (8)	56 (8)	
Risk Factors, mean (SD)			
Charlson Comorbidity Index, mean (SD)	4.57 (2.78)	4.65 (2.84)	0.5331
APR DRG Severity, n (%)			
1	1 (.1)	1(.2)	<.0001*
2	9 (.6)	8 (1)	
3	165 (10)	113 (17)	
4	1472 (89)	552 (82)	
APR-DRG Mortality Risk, n (%)			
1	6 (.4)	4 (.6)	<.0001*
2	40 (2)	20 (3)	
3	341 (21)	206 (31)	
4	1260 (77)	444 (66)	
APACHE II Score, mean (SD)	18.87 (6.64)	18.15 (6.30)	0.0167*
Surgical, n (%)	294 (18)	118 (18)	0.8492
Dementia, n (%)	117 (7)	56 (8)	0.3216
Alcohol, n (%)	55 (3)	22 (3)	0.9287
Current Smoker, n (%)	349 (21)	140 (21)	0.6701

*$p < 0.05$

Table 2. Comparison of Outcomes and Costs by Bundle Adherence (Unadjusted Results)

Bundle Adherence Threshold			
	<60% Adherence n=1648	≥60% Adherence n=674	*p*-value
Delirium incidence *n* (%)	449 (27)	235 (35)	0.0003*
Inpatient mortality *n* (%)	337 (20)	51 (8)	<.0001*
Discharge status *n* (%)			
Home	569 (35)	280 (42)	<.0001*
Home health	126 (8)	51 (8)	
Hospice	105 (6)	47 (7)	
Long term care facility	116 (7)	47 (7)	
Inpatient rehabilitation facility	169 (10)	84 (12)	
Skilled nursing facility	226 (14)	114 (17)	
Length of stay, mean (SD)	12.66 (6.77)	13.08 (6.72)	0.1723
Direct cost of inpatient care ($), mean (SD)	30,636 (32,654)	33,042 (34,128)	0.1079

*$p < 0.05$

Table 3. The Unadjusted and Adjusted Effect of Bundle Adherence on Outcomes

Bundle Adherence Threshold	**≥50%**		**≥60%**		**≥70%**	
	Unadjusted (95% CI) n = 1253	Adjusted (95% CI) n = 1069	Unadjusted (95% CI) n = 1648	Adjusted (95% CI) n = 674	Unadjusted (95% CI) n = 1969	Adjusted (95% CI) n = 353
Delirium incidence (OR)	1.68 (1.40-2.01)*	1.31 (1.06-1.61)*	1.43 (1.18-1.73)*	1.21 (0.98-1.50)	1.05 (0.82-1.34)	0.98 (0.76-1.28)
Inpatient mortality (OR)	0.25 (0.20-0.33)*	0.28 (0.21-0.37)*	0.32 (0.23-0.43)*	0.40 (0.29-0.55)*	0.32 (0.21-0.50)*	0.44 (0.28-0.69)
Discharge status (OR)						
Home	1.48 (1.25-1.75)*	1.33 (1.09-1.62)*	1.34 (1.12-1.62)*	1.16 (0.94-1.42)	1.40 (1.11-1.76)*	1.17 (0.91-1.49)
Home health	1.17 (0.86-1.59)	1.44 (1.00 -2.07)*	0.99 (0.71-1.39)	1.13 (0.77-1.66)	1.15 (0.76-1.73)	1.33 (0.85-2.08)
Hospice	1.19 (0.85-1.64)	0.99 (0.67-1.44)	1.10 (0.77-1.57)	0.95 (0.64-1.40)	0.84 (0.52-1.36)	0.75 (0.45-1.25)
Long term care facility	1.14 (0.83-1.57)	1.33 (0.92-1.94)	0.99 (0.70-1.40)	1.11 (0.75-1.64)	0.77 (0.47-1.24)	0.84 (0.50-1.41)
Inpatient rehabilitation facility	1.07 (0.82-1.38)	1.24 (0.91-1.70)	1.25 (0.94-1.65)	1.38 (1.01-1.90)*	1.28 (0.91-1.80)	1.38 (0.95-2.00)
Skilled nursing facility	1.40 (1.11-1.77)*	1.25 (0.96-1.64)	1.28 (1.00-1.64)*	1.16 (0.88-1.53)	1.24 (0.91-1.68)	1.08 (0.78-1.50)
Length of stay (days)	0.26 (0.10-0.42)*	0.37 (0.24-0.52)*	0.26 (2.34-2.51)*	0.46 (0.30-0.61)*	0.26 (0.10-0.42)*	0.56 (0.38-0.73)*
Cost difference ($)	$2757 (-30-5546)	$840 (-2419 -4100)	$2406 (-655-5467)	$1815 (-1613-5243)	-$261 (-4132-3609)	$952 (-3201-5107)

*$p < 0.05$

Table 4. Risk-adjusted Bootstrap Estimates

Outcomes	<60% Adherence	≥60% Adherence
Delirium incidence *n* (%)	0.28	0.32
Inpatient mortality *n* (%)	0.19	0.09
Length of stay	12.54	13.45
Discharge status *n* (%)		
Home	0.36	0.39
Home health	0.07	0.08
Hospice	0.07	0.07
Long term care facility	0.07	0.08
Inpatient rehabilitation facility	0.10	0.13
Skilled nursing facility	0.14	0.16
Direct cost of inpatient care, mean (standard error)	$30,820 (90)	$ 32,697 (165)

Table 5. Cost-effectiveness of High versus Low Bundle Adherence in Terms of Inpatient Costs and Survival

	Cost Per Patient	Incremental Cost	Inpatient Survival Rate	Incremental Effectiveness	Cost/ Effectiveness	ICER
Low bundle adherence (< 60%)	$30,820		.81		$38,049	
High bundle adherence (≥60%)	$32,697	$1,877	.91	.10	$35,930	$18,770

Table 6. Input Variables for Markov Model

	Base Case	Range	Data Source
Costs			
Hospital			
High adherence	$32,697	32,532-32,862	BSWH Trendstar Database
Low adherence	$30,820	30,730-30,910	BSWH Trendstar Database
Discharge Disposition			
Home	$0		
Home health	$2,677		(MEDPAC 2014)
Long term acute care (LTAC)	$39,493		(MEDPAC 2014)
Skilled nursing facility	$17,667		(MEDPAC 2014)
Inpatient rehabilitation facility	$17,995		(MEDPAC 2014)
Hospice	$11,852		(MEDPAC 2014)
Utilities (QALYs)			
Hospital	0.60	0.50-0.76	(Cox, Carson et al. 2007)
Home	0.66	0.60-0.76	(Cox, Carson et al. 2007)
Home health	0.66	0.60-0.76	(Cox, Carson et al. 2007)
Long term acute care	0.64	0.60-0.76	(Cox, Carson et al. 2007)
Skilled nursing facility	0.63	0.60-0.76	(Cox, Carson et al. 2007)
Inpatient rehabilitation facility	0.66	0.60-0.76	(Cox, Carson et al. 2007)
Utilities (QALEs)			
Hospice	0.29		(Cox, Carson et al. 2007)
Mortality Rate			
Hospital			
High adherence	0.09	0.08-0.09	BSWH Administrative Data
Low adherence	0.19	0.19-0.20	BSWH Administrative Data
Home	0.30	25-50%	(Cox, Carson et al. 2007)
Home health	0.30	25-50%	
Long term acute care	0.25	18-58%	(Cox, Carson et al. 2007)
Skilled nursing facility	0.21	5-40%	(Cox, Carson et al. 2007)
Inpatient rehabilitation facility	0.05	2-29%	(Cox, Carson et al. 2007)
Length of Stay (Days)			
Hospital			
High adherence	13.45		BSWH Administrative Data
Low adherence	12.54		BSWH Administrative Data
Home health	30		(MEDPAC 2014)
Long term acute care	26.2		(MEDPAC 2014)
Skilled nursing facility	39		(MEDPAC 2014)
Inpatient rehabilitation facility	12.9		(MEDPAC 2014)

Table 7. Cost-effectiveness of High versus Low Bundle Adherence in Terms of 1-Year Care Costs and QALYs

	Cost per Patient	Incremental Cost	QALYs	Incremental Effectiveness	Cost/ Effectiveness	ICER
Low bundle adherence (< 60%)	$41,127		0.44		$94,542	
High bundle adherence (≥60%)	$42,066	$939	0.49	0.05	$86,232	$17,792