Economic Benefits of Intensive Insulin Therapy in Critically Ill Patients: The TRIUMPH Project

(Economic Benefits of Intensive Insulin Therapy)

Archana R. Sadhu, M.D.¹ Alfonso C. Ang, Ph.D.² Leslie A. Ingram-Drake³ Dorothy S. Martinez, M.D.¹ Willa A. Hsueh, M.D.¹ Susan L. Ettner, Ph.D.²
1 Division of Endocrinology, Diabetes and Hypertension, Department of Medicine, David Geffen School of Medicine at UCLA
2 Division of General Internal Medicine and Health Services Research, Department of Medicine, David Geffen School of Medicine at UCLA
3 Departments of Human Genetics/Pathology and Laboratory Medicine, David Geffen School of Medicine at UCLA

Corresponding Author:

Archana R. Sadhu, M.D.
Division of Endocrinology, Diabetes and Hypertension
200 Medical Plaza, Suite #530
Los Angeles, CA 90095-7065
Email: asadhu@mednet.ucla.edu

Received 27 December 2007 and accepted 05 May 2008.

Additional information for this article can be found in an online appendix at http://care.diabetesjournals.org.

Copyright American Diabetes Association, Inc., 2008
**Objective:** Analyze the economic outcomes of a clinical program implemented to achieve strict glycemic control with intensive insulin therapy (IIT) in patients admitted to the intensive care unit (ICU).

**Research Design and Methods:** A difference-in-differences (quasi-experimental) study design was used to examine the associations of an intensive insulin therapy intervention with changes in hospital length of stay (ICU and total), costs (ICU and total) and mortality. Hospital administrative data was obtained for 6,719 adult patients admitted between 2003 and 2005 to one of five intervention or four comparison ICUs in a large academic medical center. Linear regression models with log transformations and appropriate retransformations were used to estimate length of stay (LOS) and costs; logistic regressions were used to estimate mortality.

**Results:** After adjusting for observable patient characteristics and secular time trends, the intervention was consistently associated with lower average glucose levels, and a trend towards lower LOS, costs and mortality. However, associations with resource use and outcomes were statistically significant in only ICU LOS, with an average reduction of 1.19 days of ICU care per admission. Other associations, while large in magnitude and in the hypothesized directions, were not estimated with sufficient precision to rule out other net effects. The associations with ICU days and costs were larger in magnitude than total days and costs.

**Conclusions:** A clinical team focused on hyperglycemia management for ICU patients can be a valuable investment with significant economic benefits for hospitals.
Increasing evidence supports implementation of intensive insulin therapy (IIT) in critical illness. Close links between hyperglycemia in hospitalized patients and poor clinical outcomes have been demonstrated in a variety of hospital settings such as critical illness, post cardiothoracic surgery, post organ transplant, stroke, trauma and even general medical wards. Furthermore, interventional studies have demonstrated significant reductions in morbidity and mortality when illness-related hyperglycemia is treated with IIT (1-5). As institutions strive to achieve better glucose control for these patients, they are faced with both clinical and financial obstacles.

Although the evidence for clinical benefits of strict glucose control in hospitalized patients with illness-related hyperglycemia is mounting, the financial benefits are less well-documented. Diabetic and non-diabetic patients with hyperglycemia have more complications and this results in longer hospital length of stay (LOS) and higher costs (6,7). In a retrospective analysis of cardiothoracic surgery patients with and without diabetes, each 50 mg/dL increase in glucose was associated with 0.76 more postoperative days, $2824 more inpatient hospital charges, and $1769 more inpatient hospital costs (6). In stroke patients, hyperglycemia over 130 mg/dL on admission was related to a one-day longer LOS and $1349 higher inpatient hospital charges (7). These increased costs were partially due to the known complications of hyperglycemia, e.g. nosocomial catheter-related bloodstream infection (8). When accounting for morbidities such as need for mechanical ventilation, dialysis, infections and other complications, the costs of untreated hyperglycemia could be substantial.

Therefore, intensive treatment of hyperglycemia may reduce morbidity, which can translate to reductions in hospital LOS and costs. In fact, the few studies of IIT treatment that included financial analysis have shown significant cost reductions. A post hoc analysis of the DIGAMI trial, which randomized patients with diabetes and myocardial infarction to intensive versus conventional glycemic control, estimated that IIT saved 16,900 Euros per life year gained (9). Similarly, a post hoc financial analysis of the 2001 Van den Berghe trial of surgical intensive care unit (ICU) patients, demonstrated a cost savings of 2638 Euros per patient in the IIT group (10). Finally, a before and after design of patients admitted to one mixed medical-surgical ICU estimated that IIT decreased ICU LOS by 0.3 days, and resulted in a cost savings of $1580 per patient for the entire hospitalization (11).

Although suggestive that IIT resulted in hospital cost savings, these studies were limited by their inability to distinguish effects of the intervention from secular time trends in hospital LOS, costs, and mortality, hence potentially confounding the estimated intervention effect. Moreover, only the last study was in a U.S. healthcare system. We seek to address these limitations by using a quasi-experimental study design to report the outcomes of a program dedicated for IIT in ICU patients at an academic U.S. medical center. Measures examined included mean glucose values, ICU LOS, total hospital LOS, ICU costs, total hospitalization costs, and inpatient mortality.
INTERVENTION

In January 2005, UCLA initiated a new clinical program, TRIUMPH (TaRgeted InsUlin therapy to IMProve Hospital outcomes). The goal was to achieve strict glucose control in accordance with the evidence-based practice supported by AACE Guidelines (12). Since UCLA has 9 different intensive care units, each with specialized patient populations, the program was implemented in several phases. Thus far, 5 of the 9 intensive care units have received the TRIUMPH intervention including the medical intensive care, coronary care, and cardiothoracic surgery units. These units were chosen based on previously published benefits in these patient populations (1-6). Medical directors of these units were offered the intervention and all of them willingly participated. The units that did not receive intervention included liver transplant, neurosurgery, trauma and other post-surgical units.

A multidisciplinary approach was used to develop new insulin therapy protocols and educate the physicians, nurses, pharmacists, and dieticians. The intravenous insulin therapy protocol was a modified version of the Markovitz protocol (13), and the subcutaneous insulin protocol incorporated basal, nutritional, and corrective insulin (14). In the TRIUMPH units, intravenous insulin infusion was initiated when the measured glucose was >140 mg/dL. Per the 2004 AACE guidelines, the recommended target glucose ranges were 80-110 mg/dL in the ICU setting and 80-110 mg/dL pre-prandial value with a maximal glucose < 180 mg/dL in the non-critical care setting (12). For the comparison units, glucose control was left to the discretion of those physicians and incorporated both intravenous insulin infusions and subcutaneous insulin therapy. However, these units did not utilize the TRIUMPH protocols and had varied glucose thresholds and target ranges.

The core TRIUMPH team consisted of an endocrinologist and a diabetes educator to oversee the management of patients on a daily basis from admission until discharge. Each patient admitted to an intervention ICU had glucose screening at regular intervals. If the glucose was greater than 140mg/dl and confirmed on a repeat measurement, the TRIUMPH intravenous insulin protocol was initiated. Subcutaneous insulin was also used when clinically appropriate. In most cases, the TRIUMPH team managed the glucose from admission to discharge.

RESEARCH DESIGN AND METHODS

Study design: The study cohort was all patients aged 18 and over who were admitted to one of five intervention or four comparison ICUs between 2003 and 2005 and who were discharged or died in the hospital by December 31, 2005 (N=6,719). The main analyses included all patients, but sensitivity analyses (N=5,787) excluded study patients who died prior to being discharged from the hospital.

To address potential confounding secular time trends in pre/post comparisons, we employed a quasi-experimental or "difference-in-differences" (DID) approach described by Goldman et al. (15,16). We compared the changes between the pre-intervention (2003-04) and post-intervention (2005) periods among patients discharged from intervention units with comparable changes among patients discharged from comparison units. Comparable changes means that the trajectories over time (i.e., the slope of the outcome as a function of
time) should be similar, even if the starting point (i.e., the intercept) is different. Secular time trends refers to any other changes that are occurring in the health care system (or this hospital in particular) that would have occurred even in the absence of the intervention. The DID estimate takes the average change over time and subtracts the portion that is likely attributable to secular time trends and not to the intervention per se. The validity of the estimated intervention effect relies on the assumption that (adjusting for observable patient characteristics) the underlying time trends in the outcomes would have been similar for the intervention and comparison unit patients in the absence of an intervention. However, the intervention effect is calculated net of the pre-existing differences, thus accounting for the possibility that the intervention patients may have started off at lower levels of utilization and costs. Because this study design accounts for secular time trends, it implicitly takes into account factors such as price inflation, changes in hospital wide financial practices, ICU procedural changes or other clinical practices not related to glucose management that can affect LOS, hospital costs and mortality.

**Outcome measures:** Glucose measurements were obtained from a database consisting of all point of care testing as well as serum glucose measurements from the laboratory. Hospital accounting records were used to obtain information on the total and direct variable costs, total and direct variable ICU costs, total and ICU LOS, and inpatient mortality. Total costs included direct variable, indirect variable, direct fixed, and indirect fixed. Direct costs were those charged specifically to a revenue-producing cost center; these costs were most closely related to providing patient care. Examples of direct departments are Nursing Units, Radiology, Clinical Labs, and Pharmacy. Indirect costs support patient care rather than providing patient care. Examples of indirect departments are Patient Escort, Nutrition, Administration, and Financial Services. Variable costs change when volume changes, whereas fixed costs do not change, at least for small changes in volume.

Although variable costs are the most relevant in the short run, an argument can be made for examining fixed costs as well. From the point of view of a capacity-constrained medical center, an important benefit of discharging patients earlier is the ability to use the beds for new patients, commonly referred to in hospital economics as "throughput." This benefit is implicitly taken into account when fixed costs are included in the analysis. The fixed costs are proxies for the true "opportunity cost" of the capital (including building space), that is, its value for other uses, such as serving other patients.

**Explanatory variables:** All regression models included an intercept and the following: patient’s sex; race; Latino ethnicity; age and its square; insurance type; indicators for complications prior to admission; baseline illness severity category (calculated by industry standard proprietary software, 3M APR-DRG, and based on Medicare All Patient Refined Diagnostic-Related Group system); a linear time trend for the year of admission; an indicator for type of unit (intervention vs. comparison); and, an interaction between indicators for admission time period (post- vs. pre-intervention) and type of unit. Patients were assigned to time periods and units based on their admission date and admission unit.
The linear time trend allows the outcome measures to change over time even in the absence of any intervention, due to secular trends in length of stay and costs. The indicator for type of unit allows the intervention units to start off at higher or lower levels than comparison units. The intervention effect is captured by the interaction between time period and type of intervention. For example, if costs increase over time for both the intervention and comparison units, then the cost increase between the pre- and post-intervention periods would have to be smaller for the intervention units than for the control units in order to conclude that the intervention was associated with a cost reduction. Conversely, if costs decline over time, then the cost decrease would have to be larger for the intervention units.

**Statistical analyses:** Chi-squared and Wilcoxon tests were used to examine differences in the demographic and clinical characteristics of the intervention and comparison patients. Due to the skewed distributions of the cost and LOS measures, these outcomes were log transformed in linear regressions and the estimates retransformed to calculate intervention effects on costs and LOS measured on the original scales. The regression-adjusted differences in cost and LOS associated with the intervention were calculated by predicting the value of a given outcome \( Y \) under four scenarios (intervention post-outcome, intervention pre-outcome, comparison post-outcome, comparison pre-outcome) and taking the “difference in difference”: 

\[
(\text{Y}_{\text{interv, post}} - \text{Y}_{\text{interv, pre}}) - (\text{Y}_{\text{comp, post}} - \text{Y}_{\text{comp, pre}})
\]

The sample mean of the difference-in-differences estimate was reported along with bias-corrected, empirical 95% confidence intervals, derived using 1000 bootstrap replicates with replacement (17). Statistical significance at the 5% level of Type I error was determined by examining whether the 95% confidence interval excluded zero.

In early analyses, we examined several alternative regression specifications that allowed more flexibility, e.g., models allowing each unit to have its own intercept. The specifications yielded findings consistent with the final specification, but due to concerns about overfitting and interpretability of the results, the most parsimonious specification was ultimately chosen. We also performed outlier analysis to see whether patients with extremely high resource use were skewing the results. Excluding the outliers did not notably influence our results, although in the end, we used log transformations for skewed outcomes to obtain more efficient estimates. Finally, we estimated random effects models to determine whether the conclusions were sensitive to possible clustering, i.e., within-unit correlation of the error terms. The intraclass correlation was very low and our conclusions did not change based on these estimates.

**RESULTS**

**Changes over time in the case-mix of intervention vs. comparison patients:** We first examined the changes in observed patient casemix between the pre- and post-intervention periods (Table 1). The rate of having any complications at admission declined from 4.1% to 2.3% over time within patients treated in the comparison units \((p=.01)\). Although the rate also declined among patients treated in intervention units (from 4.7% to 4.0%), the change was smaller and not significant. The only other
significant change was a slight increase between the pre- and post-period in the proportion of comparison unit patients with Medi-Cal insurance (p=.03).

Whether the patient had complications at admission was controlled in the regressions so this measure itself should not bias the comparisons. On the other hand, the more rapid decline in this rate over time among the comparison patients than among the intervention patients could mean that the comparison patients were becoming relatively healthier over time in ways that were not captured by our data. If so, then our study design may yield a conservative estimate of the intervention effects.

**Glucose measurements in the intervention and comparison units:** The mean glucose for each admission in each unit was calculated for the years 2004 and 2005. Only one pre-intervention year, 2004, was used due to the very large number of measurements. It was assumed that the year 2003 did not differ from 2004 since the clinical practice of glucose control was not different. Additionally, any bias would have been in the favor of the comparison units since the practice of strict glucose control was gaining more attention in these years even in the absence of a formal intervention. The reduction in mean glucose between the pre and post intervention year was 21.5 mg/dL in the intervention units. In the comparison units, the difference in mean glucose was 2.3 mg/dL. Regression models looking at associations of the intervention with changes in blood glucose during the patient stay using the same quasi-experimental study design also found large intervention effects.

**Unadjusted associations of the intervention with outcomes:** (Online Appendix Figures 1a-1g available at http://care.diabetesjournals.org.) The DID study design relies on the assumption that the time trends that would have occurred in the absence of any intervention are similar for the intervention and comparison patients. To examine the validity of this assumption, we plotted the unadjusted changes in the outcome measures during the pre-intervention period (2003 – 2004) separately for intervention vs. comparison patients. Overall, the pre-intervention time trends looked similar for the intervention and comparison patients. Where they did not, the pre-intervention trends looked worse for the intervention patients, e.g., lengths of stay and costs increased more rapidly over time and the mortality rate increased instead of declining. Therefore if anything, we expect that the DID estimate would suggest smaller intervention effects than the actual improvements in outcomes associated with the intervention, i.e., a conservative bias.

**Regression-adjusted associations of the intervention with the outcomes:** After adjusting for observable patient characteristics and confounding time trends using the DID approach, the intervention was consistently associated with lower resource use and better outcomes. However, the associations were statistically significant in only the ICU LOS, with an average reduction of 1.19 days of ICU care per admission (Column 2, Table 2). Not surprisingly, the associations of the intervention with direct variable cost were smaller in magnitude than its associations with the total cost measures. Interestingly, the magnitudes of the associations with the intervention were larger for ICU days and costs than for total LOS and costs, suggesting that
an increase in non-ICU utilization might have partially offset the decline in ICU use. The one statistically significant association, that of the intervention with ICU days, was quite large in magnitude. To put the magnitude of the reduction in ICU LOS of 1.19 days into context, the baseline mean ICU LOS of the entire intervention units group was 9.53 days (SD=16.74).

Excluding patients who died prior to discharge yielded associations that were smaller and not statistically significant (Column 3, Table 2). The resource use of the deceased patients was much higher than that of the non-deceased patients. The intervention was associated with an absolute reduction of 1.1% in mortality, compared with a baseline mortality rate of 14%. Even though this association did not reach statistical significance, it explains why the intervention effects on costs are greater when the deceased patients are included.

CONCLUSIONS

Using a difference-in-differences (or quasi-experimental) study design to account for the potential confounders inherent in pre-post comparisons, we found that a multidisciplinary approach to intensive glucose management of critically ill patients resulted in greater reductions in mean glucose values, while comparison patients had essentially no change in mean glucose from the year before to the year after the intervention was introduced. The intervention was also associated with a trend towards lower mortality and lower resource use such as ICU and total inpatient days, and all cost measures examined. Statistical significance was confined to the association with ICU days, but the effects on other outcomes were all in the same direction and large in magnitude (e.g., a reduction of $5231 in total ICU costs). These results suggest that the intervention might have had a broader influence, but that high variability in the outcome measures reduced our power to measure them with sufficient precision. Although we accounted for obvious costs related to delivering IIT such as increased nursing effort, glucose monitoring supplies, and insulin in the direct cost analysis, our current database did not allow us to identify specific components of clinical care that may be directly related to the observed savings in LOS and costs. This would undoubtedly be a useful area for future research. Effect sizes for the utilization and cost measures were reduced when patients who died (who tended to be more expensive) were excluded from the sample, suggesting that the effect of the intervention on inpatient resource use resulted in part from helping to keep patients alive, at least until discharge. This study is subject to certain limitations. Most notably, the intervention was studied in a single academic medical center, so results may not apply to other settings. Patients whose stays occurred in part prior to the intervention and in part following the intervention were assigned to the pre-intervention period. This measurement error may bias our estimates in a conservative direction. In the intervention units, IIT was implemented by the TRIUMPH clinical service under formalized protocols. The comparison units also used insulin therapy at the discretion of the physician but this was done on an individual basis and without the TRIUMPH protocols. However, this crossover should only lead to a conservative bias of our outcomes. Our DID study design also relies on the assumption that the secular time trends affecting the intervention and comparison
units are similar. If this assumption fails, then our estimates may be misleading. For example, if inflation increased costs in the comparison units to a greater degree than the intervention units, then we might overstate the association of the intervention with reductions in costs (although inflation per se would not affect associations with LOS). However, graphs of the pre-existing time trends suggests that if anything, the opposite was probably true, i.e., that the intervention units had worse trajectories of change over time and therefore the improvement in outcomes following the introduction of the intervention represented an even greater achievement. In any event, this DID assumption should be more valid than that of earlier pre-post study designs which did not take secular time trends into account at all.

We calculated a potential ICU cost savings of $5.5 million in the group of patients treated by the TRIUMPH team in the first year following the implementation of the intervention. At $5.0 million, the total cost savings was slightly less than ICU costs, but nevertheless substantial. The costs of setting up the program that were not already included in the analysis were limited to the salaries of a full-time endocrinologist and a diabetes educator. The costs of delivery of care (e.g., insulin, glucose meters and strips, nursing time, etc.) were already included in the cost measures. Thus the potential savings associated with the intervention appears to far outweigh the costs. As technological advances are made in the areas of automated, electronic protocols, continuous glucose sensors and insulin infusion devices, the costs of implementation may be even less. Furthermore, as physician extenders such as nurse practitioners and physician assistants are used to expand the service to treat larger numbers of ICU patients, the investment in the program will be small in comparison to the potential savings.

Our findings suggest that hospital administrators should seriously consider implementing a dedicated program for intensive glucose management in the ICU. As more knowledge is gained about the benefits of glucose control among non-critically ill patients, these programs might be expanded to this population as well. The per-patient cost savings may not be as impressive in this group, but the larger numbers of patients may allow the intervention to have a significant impact on hospital economics (1819). Further investigation is needed to determine the level of glucose control that is most beneficial in these patients and how the glucose management program can be tailored to ensure a favorable return on investment.

ACKNOWLEDGEMENTS

We are grateful for the efforts of Kaiding Zhu and Beth Tenpas in the UCLA Medical Center Financial Services Department for providing us with hospital accounting records. The TRIUMPH Clinical Program also received generous grant support from the UniHealth Foundation. An abstract of this study has been presented at the 67th Annual Meeting of the American Diabetes Association, Chicago, Illinois, 22-26 June 2007 and has been published in Diabetes, 56(Suppl 1): A313, 2007.
REFERENCES
1. Van den Berghe G, Wouters P, Weekers F, Verwaest C, Bruynickx F, Schetz M, Vlasselaers D, Ferinande P, Lauwers P, and Bouillon R. Intensive insulin therapy in critically ill patients. N Engl J Med 2001; 345(19):1359-67.
2. Krinsley, JS. Effect of intensive glucose management protocol on the mortality of critically ill adult patients. Mayo Clin Proc 2004; 79(8):992-1000.
3. Van den Berghe G, Wilmer A, Hermans G, Meersseman W, Wouters PJ, Milants I, Van Wijngaerden E, Bobbaers H and Bouillon R. Intensive insulin therapy in the medical ICU. N Engl J Med 2006; 354(5):449-61.
4. Fumary AP, Gao G, Grunkemeier GL, Wu Y, Zerr KJ, Bookin SO, Floten HS, and Starr A. Continuous insulin infusion reduces mortality in patients with diabetes undergoing coronary artery bypass grafting. J Thorac Cardiovasc Surg 2003; 125(5):1007-21.
5. Malmberg K, Ryden L, Efendic S, Werlitz J, Nicol P, Waldenström A, Wedel H, and Welin L. Randomized trial of insulin-glucose infusion followed by subcutaneous insulin treatment in diabetic patients with acute myocardial infarction (DIGAMI Study): effects on mortality at 1 year. J Am Coll Cardiol 1995; 26(1):57-65.
6. Estrada CA, Young JA, Nifong W, and Chitwood R. Outcomes and perioperative hyperglycemia in patients with or without diabetes mellitus undergoing coronary artery bypass grafting. Ann Thorac Surg 2003; 75(5):1392-98.
7. Williams LS, Rotich J, Qi R, Fineberg N, Espay A, Bruno A, Fineberg SE, and Tierney WR. Effects of admission hyperglycemia on mortality and costs in acute ischemic stroke. Neurology 2002; 59(1):67-71.
8. Blot SI, Depuydt P, Annemans L, Benoit D, Hoste E, De Waele JJ, Decruyenaere J, Vogelaers D, Colardyn F, and Vendewoude KH. Clinical and economic outcomes in critically ill patients with nosocomial catheter related bloodstream infections. Clin Infectious Dis 2005; 41(11):1591-98.
9. Almbrand B, Johannesson M, Sjostrand B, Malmberg K, Ryden L. Cost effectiveness of intense insulin treatment after acute myocardial infarction in the DIGAMI study. Eur Heart J 2000; 21(9):733-39.
10. Van Den Berghe G, Wouters P, Kesteloot K, Hilleman D. Analysis of healthcare resource utilization with intensive insulin therapy in critically ill patients. Crit Care Med 2006; 34(3):612-16.
11. Krinsley J, Jones R. Cost analysis of intensive glycemic control in critically ill adult patients. Chest 2006; 129(3):644-50.
12. Garber AJ, Moghissi ES, Bransome ED Jr., Clark NG, Clement S, Cobin RH, Furnary AP, Hirsch IB, Levy P, Roberts R, Van Den Berghe G, and Zamudio V. American College of Endocrinology position statement on inpatient diabetes and metabolic control. Endocr Pract 2004;10(1):77-82.
13. Markovitz LJ, Wiechmann RJ, Harris N, Hayden V, Cooper J, Johnson G, Harelstad R, Calkins L, and Braithwaite SS. Description and evaluation of a glycemic management protocol for patients with diabetes undergoing heart surgery. Endocr Pract 2002;8(1):10-18.
14. Clement S, Braithwaite S, Magee M, et al. Management of diabetes and hyperglycemia in hospitals. Diabetes Care 2002;27(2):553-90.
15. Goldman HH, Frank RG, Burnam MA, Huskamp HA, Ridgely MS, Normand SL, Young AS, Barry CL, Azzone V, Busch AB, Azrin ST, Moran G, Lichtenstein C, Blasinsky M. Behavioral health insurance parity for federal employees. N Engl J Med. 2006 Mar 30; 354(13):1378-86.
16. Cook TD, Campbell DT. Quasi-Experimentation: Design and Analysis Issues for Field Settings. Boston, MA, Houghton Mifflin Company, 1979
17. Mooney CZ, Duval RD. Bootstrapping: A Nonparametric Approach to Statistical Inference. Quantitative Applications in the Social Sciences No. 95. Newbury Park, CA, Sage Publications, 1993.
18. Olson L, Muchmore J, Lawrence B. The benefits of inpatient diabetes care: improving quality of care and the bottom line. Endocr Pract. 2006; 12 (Suppl 3): 35-42
19. Newton CA, Young S. Financial implications of glycemic control: results of an inpatient diabetes management program. Endocr Pract 2006;12 (Suppl 3): 43-48
Table 1. Characteristics of Study Population, by Intervention Status

| Characteristic          | Patients Treated in Intervention Units | Patients Treated in Comparison Units |
|-------------------------|----------------------------------------|--------------------------------------|
|                         | Pre-Intervention Period (N=2167)       | Post-Intervention Period (N=1058)    |
|                         | (SD=17.0)                              | (SD=17.6)                            |
|                         | Pre-Intervention Period (N=2406)       | Post-Intervention Period (N=1088)    |
|                         | (SD=17.3)                              | (SD=17.4)                            |
| Age                     | 61.2                                   | 61.1                                 |
|                         | .85                                    | .59                                  |
|                         | 54.7                                   | 54.1                                 |
|                         | .29                                    | .34                                  |
| Female                  | 38.4%                                  | 39.4%                                |
|                         | .59                                    | .06                                  |
|                         | 43.8%                                  | 42.1%                                |
|                         | .06                                    | .34                                  |
| Latino ethnicity        | 13.7%                                  | 11.2%                                |
|                         | .06                                    | .06                                  |
|                         | 21.1%                                  | 22.1%                                |
|                         | .29                                    | .49                                  |
| Race                    | Caucassian                             | 82.4%                                |
|                         | 79.9%                                  | .08                                  |
|                         | 79.8%                                  | .06                                  |
|                         | 79.9%                                  | .94                                  |
|                         | African-American                       | 6.5%                                 |
|                         | 7.8%                                   | .16                                  |
|                         | 7.5%                                   | .60                                  |
|                         | .60                                    | .61                                  |
|                         | Asian                                  | 7.7%                                 |
|                         | 8.3%                                   | .55                                  |
|                         | 8.9%                                   | .61                                  |
|                         | .61                                    | .62                                  |
|                         | Other                                  | 3.4%                                 |
|                         | 3.7%                                   | .69                                  |
|                         | 3.8%                                   | .62                                  |
|                         | Insurance                              | 41.8%                                |
|                         | 43.4%                                  | .39                                  |
|                         | 43.5%                                  | .55                                  |
|                         | 51.8%                                  | .35                                  |
|                         | Medicare                               | 46.2%                                |
|                         | 45.0%                                  | .52                                  |
|                         | 29.3%                                  | .13                                  |
|                         | 26.8%                                  | .03                                  |
|                         | Medi-Cal                               | 7.3%                                 |
|                         | 7.7%                                   | .67                                  |
|                         | 8.3%                                   | .07                                  |
|                         | 10.7%                                  | .07                                  |
|                         | Other                                  | 4.7%                                 |
|                         | 3.9%                                   | .31                                  |
|                         | 8.8%                                   | 2.3%                                 |
|                         | 10.7%                                  | .01                                  |
|                         | Complications at admission             | 4.7%                                 |
|                         | 4.0%                                   | .37                                  |
|                         | 4.1%                                   | .63                                  |
|                         | Medical Illness                        | 3.17                                 |
|                         | 3.24                                   | .07                                  |
|                         | 3.12                                   | .01                                  |
|                         | Severity Score                        | (SD = .86)                           |
|                         | (SD = .84)                             | (SD = .98)                           |
|                         |                                         | (SD = .94)                           |
Table 2. Association of Intervention with Changes in Costs, Length of Stay and Mortality

| Outcome                     | Change in Outcome (Deceased Patients Included) | Change in Outcome (Deceased Patients Excluded) |
|-----------------------------|-----------------------------------------------|-----------------------------------------------|
|                             | N= 6719                                       | N= 5787                                       |
| Total Costs                 | -$4,746 (-$10,509, $1,832)                    | -$2,957 (-$8,347, $2,692)                    |
| Direct Variable Costs       | -$2,210 (-$5,593, $1,584)                     | -$1,179 (-$4,409, $2,056)                    |
| Total ICU costs             | -$5231 (-$13,775, $3591)                     | -$2948 (-$11,184, $5500)                    |
| Direct variable ICU costs   | -$1143 (-$4096, $2068)                       | -$426 (-$3305, $2589)                       |
| Total days                  | -0.47 (-1.87, 1.02)                           | 0.31 (-0.87, 1.74)                          |
| ICU days                    | -1.19 (-1.93, -0.43)*                         | -0.73 (-1.48, 0.11)                         |
| Mortality                   | -.011 (-0.05, 0.03)                           | ---                                          |

Note: * denotes significance at p ≤ .05. 95% empirical, bias-corrected bootstrapped confidence intervals shown in parentheses. Estimates based on a linear regression with log transformation and appropriate retransformation algorithm (Duan 1983). All regressions control for the patient characteristics shown in Table 1, as well as for a squared age term, a linear time trend, an indicator for type of unit (intervention vs. comparison) and an interaction between indicators for time period (post- vs. pre-intervention) and type of unit.