# Using the National Surgical Quality Improvement Program and the Tennessee Surgical Quality Collaborative to Improve Surgical Outcomes

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**BACKGROUND:** Led by the Tennessee Chapter of the American College of Surgeons, in May 2008 a 10-hospital collaborative was formed between the Tennessee Chapter of ACS, the Tennessee Hospital Association, and the BlueCross BlueShield of Tennessee Health Foundation. We hypothesized that by forming the Tennessee Surgical Quality Collaborative using the National Surgical Quality Improvement Program (NSQIP) system to share surgical process and outcomes data, overall patient surgical outcomes would improve.

**STUDY DESIGN:** All NSQIP data from the 10-hospital collaborative for the time periods January to December 2009 (period 1) and January to December 2010 (period 2) were collected. Data on 20 categories of postoperative complications and 30-day mortality were compared between periods. Complication comparisons and hospital costs associated with complications were calculated per 10,000 procedures. Statistical analysis was performed by Z-test.

**RESULTS:** There were 14,205 total surgical cases in period 1 and 14,901 surgical cases in period 2. Between periods (per 10,000 cases) there were significant improvements in superficial surgical site infections (−19%, $p = 0.0005$), on ventilator longer than 48 hours (−15%, $p = 0.012$), graft/prosthesis/flap failure (−60%, $p < 0.0001$), acute renal failure (−25%, $p = 0.023$), and wound disruption (−34%, $p = 0.011$). Although mortality (per 10,000) was higher in period 2 (237.6 vs 232.3), no statistical difference was noted. Net costs avoided between these periods were calculated as $2,197,543 per 10,000 general and vascular surgery cases.

**CONCLUSIONS:** Data organization and scrutiny are the initial steps of process improvement. Participation in our regional surgical quality collaborative resulted in improved outcomes and reduced costs. Although the mechanisms for these changes are likely multifactorial, the collaborative establishes communication, process improvement, and frank discussion among the members as best practices are identified and shared and standardized processes are adopted. (J Am Coll Surg 2012;xx:xxx. © 2012 by the American College of Surgeons)

Surgery has long been a rapidly evolving field that has been affected by multiple factors including information technology, improved understanding of anatomy and physiology, and maturation of health care systems. As the rapid changes have slowed into a plateau phase, the focus is shifting from development and application of novel procedures to the standardization of outcomes. The current era of surgery depends heavily on complex health care delivery systems that must remain plastic in order to optimize outcomes. Although constantly minimizing practice variability by using practice management guidelines has been advocated and is deeply ingrained into current health care delivery models,[1] implementation of evidence-based medicine is frequently dependent on local culture and resources. There is rarely a "one-size-fits-all" solution that solves some of the

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**Abbreviations and Acronyms**

| | | |
|---|---|---|
| ACS NSQIP | = | American College of Surgeons National Surgical Quality Improvement Program |
| DVT | = | deep venous thrombosis |
| ROI | = | return on investment |
| RR | = | relative risk |
| SSI | = | surgical site infection |
| TSQC | = | Tennessee Surgical Quality Collaborative |

complex systems problems faced in modern surgical practice.

Arguably, one significant historical barrier to process improvement was the lack of reliable data from which to draw conclusions and change processes. The development of sophisticated systems to collect surgical data began with the National Veterans Surgical Risk Study.[2] Process improvements based on these data have been shown to considerably reduce morbidity and mortality.[3] This has since developed into the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP), which is a well-validated tool that collects risk-adjusted data intended to drive quality initiatives.[4] Although there is clear benefit to the use of these data on a national level to help establish benchmarks and comparisons, regional surgical quality groups have also shown significant improvements in surgical outcomes by sharing data and auditing practice patterns.[5,6]

In 2008, a regional surgical quality collaborative was formed in the state of Tennessee using infrastructure similar to that of the Michigan Surgical Quality Collaborative.[7] Led by the Tennessee chapter of the American College of Surgeons, funding from Blue Cross/Blue Shield of Tennessee was used to create a 10-hospital Tennessee Surgical Quality Collaborative (TSQC). We hypothesized that by forming the TSQC using the ACS NSQIP system to share surgical processes and outcomes data, overall patient surgical outcomes would improve.

## METHODS

The TSQC used an interrupted time-series study to examine trends in surgical outcomes among the 10-hospital group during 2 phases: January 2009 through December 2009 (period 1) and January 2010 through December 2010 (period 2). We used several outcomes measurements. The primary outcome was postoperative complications. Secondary outcomes included 30-day mortality and hospital costs associated with postoperative complications.

TSQC consists of 10 member hospitals: Erlanger Hospital (Chattanooga, TN), Vanderbilt University Hospital (Nashville, TN), St Francis Hospital (Memphis, TN), Baptist Memorial Hospital (Memphis, TN), Cookeville Regional Medical Center (Cookeville, TN), Jackson Madison County General Hospital (Jackson, TN), Johnson City Medical Center (Johnson City, TN), Methodist University Hospital (Memphis, TN), Parkwest Medical Center (Knoxville, TN), and the University of Tennessee Medical Center (Knoxville, TN). These 10 institutions perform approximately 25% of the entire general and vascular surgical interventions performed annually within the state.[8] Using the infrastructure of the ACS NSQIP and data use agreements among the participating parties, the Tennessee Hospital Association serves as the coordinator for the collaborative and has confidential access to the TSQC performance data. Although the collaborative was chartered in 2007, an initial 18-month period was used to finalize grant funding, identify and recruit the 10 participating hospitals, and establish the appropriate personnel (RN abstractor, surgeon champion, CEO) within each system. Appropriate data collection among the entire collaborative began in earnest in January 2009.

Demographic and risk factor data including age, race, American Society of Anesthesiologists (ASA) classification, risk factors, body mass index, diabetes mellitus (insulin and noninsulin dependent), smoking status and functional health status before surgery, COPD, previous cardiac surgical history, hypertension requiring medication, and dialysis status were derived from the NSQIP dataset provided by each institution with the TSQC, compared between period 1 and period 2, as well as to the NSQIP population during period 2. The primary outcome of postoperative complication was defined as any of the 21 postoperative occurrences by the NSQIP: acute renal failure, bleeding/transfusions, cardiac arrest requiring cardiopulmonary resuscitation, coma longer than 24 hours, deep incisional skin and soft tissue infection (surgical site infection [SSI]), deep venous thrombosis (DVT)/thrombophlebitis, graft/prosthesis/flap failure, myocardial infarction, postoperative ventilatory support greater than 48 hours, peripheral nerve injury, pneumonia, pulmonary embolism, progressive renal insufficiency, stroke/cerebrovascular accident, superficial incisional skin and soft tissue infection (SSI), sepsis, unplanned intubation, urinary tract infection, wound disruption, organ/deep space SSI, and septic shock. Thirty-day mortality was considered as a secondary outcome. Hospital costs per event were applied using the ACS NSQIP Return on Investment (ROI) calculator, normalized to savings per 10,000 procedures, and used the differences between period 1 and period 2.[9,10] Sensitivity analysis of the event cost levels was assessed using

**Table 1.** Comparison between the TSQC Surgical Population and the National NSQIP Population

| | TSQC | | NSQIP |
|---|---|---|---|
| **Variable** | **1/1/09 – 12/31/09** | **1/1/10 – 12/31/10** | **1/1/10 – 12/31/10** |
| n | 14,205 | 14,901 | 312,240 |
| Age, y | 56 | 56.5 | 56 |
| Race, % | | | |
| White | 79.5 | 72.6 | 77.2 |
| Black or African American | 18.6 | 17.6 | 9.3 |
| ASA classification, % | | | |
| ASA 1 – no disturb | 5.1 | 5.2 | 9.4 |
| ASA 2 – mild disturb | 34.4 | 34.5 | 45.0 |
| ASA 3 – severe disturb | 48.6 | 49.1 | 38.4 |
| ASA 4 – life threat | 11.2 | 10.9 | 6.7 |
| ASA 5 – moribund | 0.6 | 0.3 | 0.3 |
| ASA 6 – brain death | 0.0 | 0.0 | 0.0 |
| Emergency case, % | 11.4 | 11.2 | 11.5 |
| Risk factors, % | | | |
| Cases with 0 risk factors | 20.1 | 20.6 | 30.0 |
| Cases with 1 risk factors | 26.3 | 26.7 | 29.4 |
| Cases with 2 risk factors | 19.2 | 18.8 | 17.6 |
| Cases with 3 risk factors | 11.8 | 11.5 | 9.4 |
| Cases with 4 risk factors | 7.5 | 8.1 | 5.3 |
| Cases with 5+ risk factors | 15.1 | 14.3 | 8.2 |
| Body mass index, kg/m$^2$ | 30.2 | 30.6 | 29.9 |
| Diabetes mellitus, % | | | |
| Noninsulin | 12.0 | 12.1 | 9.3 |
| Insulin | 9.0 | 8.2 | 5.7 |
| Current smoker within 1 year, % | 26.8 | 25.8 | 19.7 |
| Functional health status before surgery, % | | | |
| Total dependent | 2.6 | 2.4 | 1.5 |
| History of severe COPD | 6.9 | 8.0 | 4.9 |
| Previous cardiac surgery | 8.9 | 7.9 | 5.4 |
| Hypertension requiring medication | 56.4 | 57.1 | 46.4 |
| Currently requiring or on dialysis | 3.4 | 3.5 | 1.6 |

ASA, American Society of Anesthesiologists; NSQIP, National Surgical Quality Improvement Program; TSQC, Tennessee Surgical Quality Collaborative.

Monte Carlo method of simulation. All completed cases were included in the analysis. Collaborative-wide aggregate postoperative rate improvement significance was identified using the Z-test.

## RESULTS

Overall, the TSQC submitted caseloads in periods 1 and 2 were 14, 205 and 14, 901, respectively, with a 4.9% rise in the latter dataset. The TSQC patient population had greater burden of preoperative risk factors than the national comparison (Table 1). In terms of preoperative risk, the TSQC group had a higher proportion of American Society of Anesthesiologists class 4 or 5 and more patients with 3 or more preoperative risk factors. Comorbidities such as diabetes, COPD, dialysis-dependent renal disease, previous cardiac surgery, hypertension, and dependent functional status were more common in the TSQC group as well.

Postoperative occurrences per time period (normalized per 10,000 cases) are listed in Table 2. Significant improvement in period 2 postoperative occurrences was identified in acute renal failure (75.3 vs 56.4, −25.1%, p = 0.0227), graft/prosthesis/flap failure (45.8 vs 18.1, −60.5%, p < 0.0001), ventilator greater than 48 hours (293.6 vs 250.3, −14.7%, p = 0.0116), SSI (357.6 vs 289.9, −18.9%, p = 0.0005), and wound disruption (90.8 vs 59.7, −34.3%, p = 0.011). An increase in complications in period 2 (normalized per 10,000 cases) was identified in DVT/thrombophlebitis in period 2 (66.2 vs 89.3, 34.9%, p = 0.0126), pneumonia (224.6 vs

**Table 2.** Postoperative Occurrences by Time Period

| Postoperative occurrences | Postoperative occurrences per 10,000 procedures 2009 | 2010 | Change, % |
|---|---|---|---|
| Acute renal failure* | 75.3 | 56.4 | −25.1 |
| Cardiac arrest requiring CPR | 55.6 | 51.7 | −7.0 |
| Coma > 24 h | 5.6 | 5.4 | −3.6 |
| Deep incisional SSI | 93.6 | 76.5 | −18.3 |
| DVT/thrombophlebitis* | 66.2 | 89.3 | 34.9 |
| Graft/prosthesis/flap failure† | 45.8 | 18.1 | −60.5 |
| Myocardial infarction | 62.0 | 59.1 | −4.7 |
| On ventilator > 48 h* | 293.6 | 250.3 | −14.7 |
| Organ/space SSI | 157.7 | 181.2 | 14.9 |
| Peripheral nerve injury | 2.8 | 2.0 | −28.6 |
| Pneumonia* | 224.6 | 276.5 | 23.1 |
| Progressive renal insufficiency | 52.8 | 55.0 | 4.2 |
| Pulmonary embolism | 34.5 | 39.6 | 14.8 |
| Sepsis | 216.8 | 193.9 | −10.6 |
| Septic shock | 108.4 | 125.5 | 15.8 |
| Stroke/CVA | 28.3 | 26.8 | −5.3 |
| Superficial incisional SSI† | 357.6 | 289.9 | −18.9 |
| Unplanned intubation | 181.6 | 166.4 | −8.4 |
| Urinary tract infection† | 164.7 | 233.5 | 41.8 |
| Wound disruption* | 90.8 | 59.7 | −34.3 |
| Mortality | 232.3 | 237.6 | 2.3 |
| Total general and vascular surgery cases | 14,205 | 14,901 | |

*$p < 0.05$.
†$p < 0.001$.
CVA, cerebrovascular accident; DVT, deep venous thrombosis; SSI, surgical site infection.

276.5, 23.1%, p = 0.0023), and urinary tract infections (164.7 vs 233.5, 41.8%, p < 0.00001) (Table 2).

For skin and soft tissue infections, there was a significant aggregate improvement in overall morbidity from period 1 to period 2 although the decrease in individual morbidity type reached significance for superficial incisional SSI only. This includes the decline in deep incisional SSI (93.6 vs 76.5, relative risk [RR] 0.82, 95% CI 0.63 to 1.06 and superficial incisional SSI (357.6 vs 289.9, RR 0.81, 95% CI 0.71 to 0.92), while organ/space SSI increased (157.7 vs 181.2, RR 1.15, 95% CI 0.96 to 1.38), for an overall reduction in cases from period 1 to period 2 of 603.3 to 546.9 cases (normalized by 10,000 cases) and an RR reduction of approximately 10% (RR 0.906, 95% CI 0.82 to 0.99) (Table 3). There was no significant increase in mortality within the TSQC from period 1 to period 2 (RR 1.023, 95% CI 0.88 to 1.19).

When the financial model was applied to the outcomes data there appeared to be an overall program savings from period 1 to period 2 of $4,476,515. Based on the ACS NSQIP ROI calculator for each significantly changed postoperative occurrence, the benefits were derived per unit cost. In this model all data were normalized as net savings per 10,000 procedures. For acute renal failure the unit cost was $28, 359, with a net savings of $535,985. Graft/prosthesis/flap failure unit cost was $14,851, with a net savings of $411,373. Ventilator greater than 48 hours unit cost was $27,654, for a net savings of $1,197,418. The SSI unit cost was $27,631, with a net savings of $1, 870,619. Wound disruption unit cost was $14,827, with a net savings of $461,120. The total normalized savings from period 1 to period 2 was $4,476,515 (Table 4).

Although a net improvement was identified, there were 3 areas in which outcomes worsened in the later period. These included DVT, pneumonia, and urinary tract infections, as described above. DVT unit cost was $10,804, with a net cost of $249,572. Pneumonia unit cost was $22,097, with a net cost of $1,146,834. Urinary tract infection unit cost was $12,828 and net cost was $882,566. Using the NSQIP ROI calculator, the total increased costs incurred by these complications was $2,278,972 from period 1 to period 2. When net costs over the comparison periods were subtracted from net savings incurred by avoiding complications, the overall savings were $2,197,543.

Sensitivity analysis[11] showed that for each event cost, simulation from zero to the upper end of the distribution resulted in a positive y-intercept for net savings at an event cost of zero, ranging from just above zero to $326,000. Net savings increased with higher event costs for events with a reduced second period rate, and net savings declined with higher event costs for events with an increased second period rate. Event cost distribution specification was based on the distribution of length of stay for cases with postoperative complications. Simulation of the NSQIP ROI model, including both increased and reduced event rate complications, resulted in 84.5% of the iterations of net savings being greater than zero.

## DISCUSSION

NSQIP has shown in previous work that participation in a systems-based approach to medical care will lead to significant reduction in postoperative occurrences.[12,13] The TSQC has identified several areas of postoperative morbidity improvement over the 2-year period of involvement in the ACS NSQIP. These areas of improvement include acute renal failure, graft failure, ventilator use, and SSI/wound disruption. The reason for such a dramatic change, however, is not readily apparent. As was identified in the landmark VA-NSQIP study

**Table 3.** Surgical Site Infections

| Postoperative occurrence | Postoperative occurrences per 10,000 procedures, n | | Relative risk (95% CI) |
|---|---|---|---|
| | 2009 | 2010 | 2010 compared with 2009 |
| Deep incisional SSI | 93.6 | 76.5 | 0.82 (0.63–1.06) |
| Organ/space SSI | 157.7 | 181.2 | 1.15 (0.96–1.38) |
| Superficial incisional SSI* | 357.6 | 289.9 | 0.81 (0.71–0.92) |
| All SSIs* | 603.3 | 546.9 | 0.91 (0.82–0.99) |

*$p < 0.05$.
SSI, surgical site infection.

in 1998,[3] these changes may be attributed to process improvement secondary to increased scrutiny of surgical intervention when incorporated in a quality improvement program, or to the Hawthorne effect, as was noted in the cardiac surgery programs of New York State during the 1990s with the advent of public reporting.[9,14,15]

TSQC identified areas of significant improvement in care ranging from an approximate 15% reduction in patients ventilated more than 48 hours to a 60% reduction in graft/prosthesis failure. Also included in this are significant improvements in acute renal failure, skin/soft tissue infection, and wound disruption. Although improved reductions in areas such as skin/soft tissue infection, wound disruption, and ventilator dependence may be attributable to identification of a problem, and associated rapid change in practice based on evidence-based medicine,[16] it is unlikely that the reduction of renal and reconstructive graft failures are attributable to such measures. These improvements may be a byproduct of observation and novel realization of a problem that was not thought to exist before involvement in NSQIP.

The obvious cost savings associated with the initiation of a quality improvement program collaborative and the effect this may have on the consumers and vendors was initially described by the Michigan Surgical Quality Collaborative (MSQC), with the added observation that an approximate 2% reduction in overall morbidity would be effective in supporting any quality collaborative.[6] Although there were some increases in morbidity identified within the TSQC after the second year of involvement, namely DVT, pneumonia, and urinary tract infections, the overall morbidity reduction led to a projected cost savings of approximately $2 million per 10,000 cases within the first 2 years of formation. Although projections of overall morbidity improvement may slow in the ensuing several years, as was initially identified by the VA-NSQIP studies, this cost containment is substantial and implies the ability of such a collaborative to be self-supportive.

The sensitivity analysis shows that event cost levels and the event rates determine the magnitude of savings. Whether net savings are positive for any program is more likely to be dependent on the changes in event rates rather than event cost. In this study, event costs near zero did not change the direction of net savings, which remained positive although small.

The limitation of this study is that the reason for improvement is not readily obvious. It is our belief that participation in a quality improvement program will initially have some manner of Hawthorne effect, as each institution becomes aware of its flaws and attempts to remedy them. There must also be an added benefit of discussion at the

**Table 4.** Financial Model

| Postoperative occurrence | Occurrences per 10,000 procedures, n | | Unit costs, $ | Net savings per 10,000 procedures, $ |
|---|---|---|---|---|
| | 2009 | 2010 | | |
| Acute renal failure | 75.3 | 56.4 | 28,359 | 535,985 |
| Graft/prosthesis/flap failure | 45.8 | 18.1 | 14,851 | 411,373 |
| On ventilator > 48 h | 293.6 | 250.3 | 27,654 | 1,197,418 |
| Superficial incisional SSI | 357.6 | 289.9 | 27,631 | 1,870,619 |
| Wound disruption | 90.8 | 59.7 | 14,827 | 461,120 |
| Full year 2010 savings | | | | 4,476,515 |
| Full year 2010 costs | | | | 2,278,972 |
| Net savings | | | | 2,197,543 |

SSI, surgical site infection.

local level with a jury of one's peers, which enables a frank discussion without repercussion.

## CONCLUSIONS

Developing a collaborative that allows the sharing of information without institutional retribution may have led to some of the improvements and successes identified within the group. Future analysis and implementation of improvement strategies in a prospective fashion will help to determine whether the potential cost savings are sustainable.

### Author Contributions

Study conception and design: Cofer, Guillamondegui, Gunter, Gibson, Hines, Martin, Cecil, Clarke
Acquisition of data: Guillamondegui, Gunter, Cecil, Clarke, Martin, Cofer
Analysis and interpretation of data: Cecil, Clarke, Martin, Cofer, Guillamondegui, Gunter, Hines, Gibson
Drafting of manuscript: Guillamondegui, Gunter, Cecil
Critical revision: Cofer, Martin, Hines, Gibson, Cecil, Guillamondegui, Gunter, Clarke

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