Achieving and Sustaining Zero
Preventing Surgical Site Infections After Isolated Coronary Artery Bypass With Saphenous Vein Harvest Site Through Implementation of a Staff-Driven Quality Improvement Process

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Background: Surgical site infections (SSI) increase morbidity and mortality, hospital costs, length of stay, readmissions, and risk of litigation and may impact a facility’s reputation.

Methods: Through implementation of a Six Sigma, interdisciplinary team process and the Contextual Model for change engaged all stakeholders. A total of 44 perioperative processes were evaluated, with 15 processes ultimately altered. Revisions involved identifying inconsistent implementation of procedures and standardizing processes, as well as utilizing new suture techniques and products including disposable electrocardiogram leads and pacing wires, antibiotic-coated sutures, and silver-impregnated midsternal dressings.

Results: In isolated coronary artery bypass grafting with donor-site procedures, an incidence of 3.74 per 100 procedures was reduced to 0.7 and ultimately to 0. No patients who underwent coronary artery bypass grafting developed a deep sternal wound infection in over 30 months and 590 procedures, resulting in an estimated cost savings of more than $600,000, from May 2012 through December 2014.

Conclusions: A significant reduction in deep sternal wound infections was achieved by working at all levels of the organization through a multidisciplinary approach to create sustained change. Using real-time observations for current practices, areas for improvement were identified. By engaging frontline staff in the process, ownership of the...
outcomes and adherence to practice change were promoted. The result was a dramatic, rapid, and sustainable improvement in the prevention of deep sternal wound infection.

Keywords: Coronary artery bypass grafts, Surgical site infection, Quality Improvement Process, Six Sigma

Surgical site infections (SSIs) increase patient mortality and morbidity, readmissions, length of stay, hospital costs, and litigation, as well as impact a hospital’s reputation.1,2 Despite multiple studies, evidence-based changes in practice, and implementation of prevention bundles, SSIs continue to complicate the recovery of post-coronary artery bypass graft (CABG) patients.1,2 Deep sternal wound infections (DSWIs) cause an even greater burden due to the need for additional surgeries, advanced wound treatment, and long-term antibiotic therapy.4 The reported occurrence of DSWI is 0.4% to 4% with early or in-hospital mortality reported to vary between 10% and 47%.5 The excess cost of 1 DSWI incident is estimated to be $17,944 with an average extended length of stay of 25.7 days.6

**SETTING**

This single institution’s Quality Improvement Process (QIP) initiative was conducted at a 350-bed regional medical center, which performs approximately 250 isolated CABGs with donor-site procedures per year. The project was completed in partnership with VHA Georgia and the VHA Hospital Engagement Network, an alliance established in the 2012 Centers for Medicare & Medicaid Services initiative, “Partnership for Patients,” to provide synergistic services, information exchange, and collaborative initiatives to help member organizations.7,8

**THE QUALITY IMPROVEMENT PROCESS**

This QIP was initiated in 2011 when the incidence of 3.74 DSWIs after isolated CABG was identified as higher than the National Healthcare Safety Network benchmark of 2.55.9 According to the Joint Commission, when a facility’s performance on key indicators such as SSI increases above national standards, quality improvement projects to gather and analyze processes and outcomes data should be implemented. The data should then be used to make improvements where needed, and follow-up data collection should ascertain that the implemented changes accomplished the proposed goals.10-13 To determine the cause of poor outcomes, the use of sophisticated tools such as rapid process improvement (including Lean Six Sigma, fact-based, systematic, data-driven problem-solving methodologies and change management) is recommended.10-13

Evidence-based practice is the goal; however, translating evidence into practice is a complex process. Best-evidence guideline implementation must be supported by intensive multidisciplinary efforts to ensure adherence.1,14 Accordingly, to engage staff and ultimately promote adoption of required change, a multidisciplinary team of cardiothoracic surgeons, nurses from each patient contact area, infection-prevention nurses, environmental services, home health care, and support personnel were assembled and met biweekly to ensure timely communication and collaboration. The goal set was to decrease the annual rate of DSWIs from 3.74 infections per 100 procedures to 1.61 infections in order to bring the CABG rate below the national benchmark, a 40% reduction, over the next year. Key nonclinical stakeholder input was solicited including the chief executive officer, chief medical officer, quality officer, materials management, and cardiovascular and operating room (OR) directors. This extensive input resulted in full support for the project.

Both Six Sigma and Contextual Model process improvement methodologies were utilized to allow for rapid adoption of interventions designed to reduce infection rates as quickly as possible.

Six Sigma is a set of techniques and tools for process improvement that utilizes a systematic approach to solve complex problems. It is a highly organized process for the structured analysis of data based on a 5-step methodology: define, measure, analyze, improve, and control (DMAIC). In the first step, a problem or improvement opportunity is defined, and clear, measurable goals are established. During the measure phase, data are collected regarding the current process. In analysis, the root causes for variations and areas for improvement are determined. In the improvement phase, focus is on addressing the root causes and using evidence-based practice to standardize processes. The control phase utilizes tools such as standardized forms, preprinted order sets, and new or revised policies to sustain changes. DMAIC was chosen as an improvement methodology because it is a structured, analytical, and logical approach to problem solving with a strong organizational framework for its implementation.10,11

The Contextual Model for change is a repetitive, nonlinear process that focuses on people, processes, and...
environment. The model consists of 4 parts: user research, analysis, prototyping, and implementation. Key to the process is investigation into current practice by direct observation of the processes in real time. Analysis includes identifying patterns, inconsistencies, and areas for improvement using the information from the observations. Prototyping involves developing and trialing interventions appropriate to the setting. The implementation phase involves using the successful interventions to create lasting change.7,15

Consistent with the recommendations in the 2014 Updates to the Compendium in Preventing Hospital-Acquired Infections,16 the Contextual Model for change engages frontline staff to identify and make changes resulting in not only appropriate interventions but also buy-in by staff leading to compliance and sustained improvements. By utilizing both change models, quantitative and qualitative data were obtained, resulting in a more complete picture.

METHODOLOGY USED IN THE QIP

Define/Research
The QIP was designed to include all patients undergoing isolated CABG with donor site regardless of elective, urgent, or emergent surgery status and American Society of Anesthesiologists risk index classification. Two analytical processes were utilized to identify current processes that might be contributing to a high infection rate: a retrospective chart review of all DSWI cases and observation of the current surgical processes. The retrospective chart review identified 16 DSWIs between January 2011 and May 2012.

Based on a review of literature, 28 key variables and similarities between cases were examined. (Audit criteria are summarized in Table 1.) The only common variables included body mass index greater than 30 kg/m², hemoglobin A1c (HbA1c) greater than 5.7, and inpatient status. This knowledge led to greater scrutiny of all processes involved in preparing inpatients for surgery.

MEASURE
The second step was to examine the actual surgical processes as they occurred. The practice keys to SSI risk were identified through a review of best-practice guidelines and peer-reviewed literature. A preliminary flowchart was developed to map the current process. Utilizing the flowchart, multiple observations were conducted in each patient point of care, including preadmission testing, preoperative short stay, OR, cardiac intensive care unit (CICU), and cardiovascular step-down unit. Observers were instructed not to evaluate compliance with existing protocols but to learn the process as it actually happens. Observers were guided by the chart review criteria in Table 1.

ANALYSIS
Following the initial observation period, the multidisciplinary team created a more detailed process map (flowchart) of preoperative, intraoperative, and postoperative care (Figure).

The revised flowchart reflected the actual processes of patient care. Inconsistencies in practice and practices that varied from evidence-based guidelines were identified on the flowchart based on the assumption that these practices would be the ones most likely to cause the increased rate of infection.

In many ways, the flowchart was the central foundation of this improvement initiative. It identified the actual processes and allowed for the development of evidence-based solutions.

### TABLE 1 Chart Review Criteria

<table>
<thead>
<tr>
<th>Age</th>
<th>Postoperative Day 1 Blood Glucose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Postoperative day 2 blood glucose</td>
</tr>
<tr>
<td>Discharge disposition</td>
<td>First case of the day</td>
</tr>
<tr>
<td>Discharge prior to diagnosis of deep sternal wound infection</td>
<td>Operating room</td>
</tr>
<tr>
<td>Length of stay</td>
<td>History of diabetes</td>
</tr>
<tr>
<td>No. of days in hospital prior to surgery</td>
<td>Body mass index</td>
</tr>
<tr>
<td>Surgeon</td>
<td>Creatinine on admission</td>
</tr>
<tr>
<td>Duration of surgery</td>
<td>History of hypertension</td>
</tr>
<tr>
<td>No. of blood products received</td>
<td>History of chronic obstructive pulmonary disease</td>
</tr>
<tr>
<td>American Society of Anesthesiologists class</td>
<td>History of peripheral vascular disease</td>
</tr>
<tr>
<td>Re-explore</td>
<td>Current smoker</td>
</tr>
<tr>
<td>Temperature on admission to unit</td>
<td>On insulin infusion postoperatively</td>
</tr>
<tr>
<td>Hemoglobin A1c</td>
<td>Preoperative methicillin-resistant Staphylococcus aureus screen positive</td>
</tr>
<tr>
<td>Day-of-surgery blood glucose</td>
<td>Operating room personnel</td>
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</tbody>
</table>

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Figure. Flowchart developed by the multidisciplinary team based on observation.
flow of events and facilitated the comparison of the current process to the ideal process. The flowchart revealed redundant or unnecessary work, unexpected complexities, and practice variations. The team was then able to pinpoint where simplification and/or standardization was possible. The flowchart also facilitated team building among the departments and staff involved. By placing a copy of the flowchart in the OR and cardiac intensive care unit, an ongoing conversation began, encouraging frontline staff engagement and allowing inquiry without judgment. Staff reviewed the flowchart to ensure accuracy and placed notes to ask questions and offer suggestions. The flowchart also served to educate all parties involved on the complete process. Completing the flowchart process broke through traditional silos of communication, promoting interdisciplinary collaboration in order to come to a consensus on each step of the process.

**IMPROVEMENTS AND STANDARDIZATION**

Forty-four processes were investigated based on the analysis of the flowchart. Recommended guidelines to prevent SSIs were largely adhered to, although the following 3 inconsistencies needed to be addressed.

First, hair removal was done by clipping outside the OR, as recommended in the Surgical Care Improvement Project (SCIP) Guidelines, but where initial hair removal was inadequate, touch-ups were done in the OR. In addition, all female patients were being clipped in the OR because the OR technicians who saw patients preoperatively for preparation were all male. Evidence-based practice was implemented with requisite staffing changes so that all patients undergo hair removal in preoperative short stay without exception. All relevant staff were reeducated in this requirement and the procedure for hair removal.

Second, methicillin-resistant *Staphylococcus aureus* (MRSA) SSIs prevention strategies were examined. Methicillin-resistant *S. aureus* SSIs are more commonly associated with cardiothoracic surgical procedures. In absence of universal surveillance, routine administration of topical nasal mupirocin has been recommended. Optimal decolonization regimen is unclear, but a standardized regimen of mupirocin (eg, twice a day for 5 days) is reasonable. Although more recent guidelines recommend a more targeted approach based on actual MRSA contamination determined by universal surveillance, universal decolonization of high-risk cardiac surgery patients was well established at time of implementation of this protocol. Previously, mupirocin nasal ointment was prescribed for all patients preoperatively; however, those patients seen in the physician’s office received 3 days of the medication prior to surgery, whereas those in the hospital received 5 days. A standard protocol of 5 days of mupirocin nasal ointment was implemented through preprinted order sets distributed both in the hospital and the doctors’ offices.

Third, glycemic control is well established as reducing the risk of SSI. According to the STS workforce 2012 updates, HbA1c levels should be obtained prior to surgery on diabetic patients. A glucose concentration of 180 mg/dL is reasonable to maintain post-operatively. Glycemic control is best achieved with a continuous insulin infusion. Chart review revealed that 11 of 16 patients had an HbA1c greater than 6.5% preoperatively and that the use of insulin drips to ensure glycemic control was being implemented inconsistently. Procedures were changed to ensure that patients with a history of diabetes and/or an HbA1c greater than 6.5% were admitted the night before surgery and placed on an insulin drip.

Implementation occurred through the use of preprinted orders distributed to the doctors’ offices. Subsequently, this protocol was changed to initiate the insulin drip in the preoperative area as supported by the 2009 Society of Thoracic Surgeons workforce. The SCIP guidance on postoperative glycemic control was already in effect.

In addition to the standardization of current practices, new evidence-based practices were implemented during the project. These interventions were broken down into equipment, processes, and patient education as summarized in Table 2. The following is a discussion of the 6 most notable changes.

First, the chart review revealed that all patients who developed a DSWI prior to the initiative in 2011 were inpatients preoperatively. The SCIP Guidelines support administration of vancomycin within 2 hours before incision for high-risk procedures. Cardiac procedures and inpatients

<table>
<thead>
<tr>
<th>TABLE 2</th>
<th>New Practices Implemented</th>
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</thead>
<tbody>
<tr>
<td>Processes</td>
<td>Equipment</td>
</tr>
<tr>
<td>Suture technique</td>
<td>Braided triclosan-coated suture</td>
</tr>
<tr>
<td>Midsternal dressing care</td>
<td>Silver-impregnated midsternal dressing</td>
</tr>
<tr>
<td>Insulin infusion protocol</td>
<td>Disposable electrocardiogram leads</td>
</tr>
<tr>
<td>Preoperative vancomycin for inpatients</td>
<td>Disposable pacer wires</td>
</tr>
<tr>
<td>Chlorhexidine gluconate mouthwash administered until discharge</td>
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</table>
are both at high risk for MRSA\(^{18}\); therefore, a standard protocol was implemented for a 1-time vancomycin dose administered 2 hours prior to incision for any patient in the hospital for 48 hours or more. Although guidance regarding vancomycin administration is more restrictive in subsequent guidelines, the protocol was well supported in the literature at the time of the study.

Second, the insulin infusion protocol was revised to require any patient on epinephrine and/or vasopressin be placed on an insulin infusion to prevent hyperglycemia.

Third, a new trend toward use of antibiotic-impregnated sutures was reviewed. All surgical wounds are contaminated with skin flora to some degree at closure; therefore, limiting or reducing the microbial burden within the wound at time of closure should be a focus of SSI reduction efforts.\(^3\)

After investigation, a polyglactin 910 braided suture with triclosan, a broad-spectrum antibiotic, was adopted to replace the monofilament noncoated suture that was being utilized. Triclosan is reported to reduce the growth of bacteria by inhibiting their fatty acid synthesis and is effective against the most common organisms that cause SSIs: \(S\) \(aureus\), \(Staphylococcus epidermidis\), methicillin-resistant \(S\) \(aureus\), and methicillin-resistant \(S\) \(epidermidis\).\(^{22}\) Use of this suture is reported to result in the active inhibition of these organisms at the surgical site and reduce the risk of infection. Although antimicrobial sutures came to the market with little evidence, studies supporting their efficacy in reducing SSI mounted quickly. Now, 30 studies and 2 meta-analyses support this clinical benefit.\(^{20,22,23}\) However, guidelines currently vary on this recommendation.\(^1\)

Fourth, the closing technique was changed from a running suture to an interrupted suture on the distal fascia. This resulted in a more secure closure of the distal incision so that if one suture breaks, the remaining sutures will hold the wound edges together.\(^{24}\) In addition, microorganisms are less likely to travel along a series of interrupted sutures.\(^{24}\)

Fifth, a standardized approach to sternal incision care was implemented utilizing a soft silicone silver-impregnated dressing, which replaced the prior gauze dressing approach. Gauze dressings remain the standard choice for many types of surgical incisions despite the lack of evidence supporting their efficacy.\(^{25}\) However, traditional tape and gauze dressings are not impermeable to bacteria.\(^{26}\) Even absent infection, the presence of bacteria in the wound extends the inflammatory phase, delays collagen synthesis, slows epithelialization, and delays healing.\(^{27}\) Several postsurgical recommended guidelines now recommend a protective, insulating dressing that is impermeable to microorganisms.\(^{2,28}\)

Wounds treated with silver show fewer signs of inflammation and heal faster.\(^3,25\) Although antibiotic resistance is a well-documented concern in management of surgical infection, report of human resistance to silver is rare.\(^3\) The placement of silver dressings over incision sites at the time of primary closure has been demonstrated to lower SSI rates in cardiovascular and orthopedic procedures.\(^3,25,29\)

Silver is bactericidal and fungicidal with antimicrobial properties against such organisms as \textit{Pseudomonas aeruginosa}, \textit{S aureus}, methicillin-resistant \textit{S aureus}, vancomycin-resistant \textit{Escherichia coli}, and \textit{Candida albicans}.\(^{30,31}\)

The self-adhesive soft silicone multilayer silver dressing utilized readily adheres but does not stick to the incision, thus preventing trauma to the healing incision.\(^{32}\) The soft silicone may also be lifted and adjusted without losing adherent properties, allowing for assessment of the incision without changing the dressing. The silver-impregnated foam releases silver ions in a continued and controlled manner to protect the incision from opportunistic organisms for up to 7 days.\(^{32}\) The soft silicone silver-impregnated dressing works to prevent infections by reducing bacterial burden, protecting the surrounding skin, preventing trauma and pain associated with dressing changes, and optimizing the local healing environment.\(^3,30-32\)

Sixth, in addition to the use of a silver-impregnated dressing, the dressing change protocol was standardized to cover the midsternal incision for 7 days or the duration of hospitalization instead of the previous practice of keeping the dressing in place for only 48 hours. This was done to prevent exogenous contamination and promote undisturbed healing.\(^{2,27,33}\)

After the first 24 hours, the dressing is pulled back to assess the incision, then reapplied. The dressing is changed prior to 7 days only if it is soiled or becomes insecure. The process for replacing the dressing was changed from aseptic to sterile technique.\(^{34,35}\) New policies, preprinted orders, and staff education were completed to ensure standard procedures across all shifts.

\section*{RESULTS}

In isolated coronary artery bypass (CABG) with donor site procedures, a 3.74 incidence per 100 procedures was reduced to 0.7 and ultimately to zero. During the study period, 262 isolated CABG procedures with saphenous vein donor-site procedures were performed. Two patients developed DSWI within the first 2 months of the study. This resulted in an incidence rate of 0.7 per 100 procedures, surpassing the targeted goal of reducing the DSWI rate to 1.61 infections per 100 patients. Most notably, zero midsternal SSIs have occurred since May 2012.

Using Association for Professionals in Infection Control and Epidemiology Cost of Healthcare-Associated Infections calculator, the total excess cost of SSIs at Athens Regional Medical Center was $250 965 with 136 excess hospital days in the year 2011.\(^7\) With the implementation of new practices and standardization of processes and products, the incidence of SSIs was reduced to zero with a cost avoidance of $606 498 with 377 excess hospital days avoided as of December 2014.
CONCLUSION
A significant reduction in DSWIs was achieved by working at all levels of the organization through a multidisciplinary approach to create sustained change. Using real-time observations for current practices, areas for improvement were identified. By engaging frontline staff in the process, ownership of the outcomes and adherence to practice change was promoted. The result was a dramatic, rapid, and sustainable improvement in the prevention of DSWI.

COMMENTS
A bundled approach to SSI reduction is the recommended approach. When multiple interventions are implemented at the same time, it is difficult to identify which specific changes were effective in reducing the infection rate. It is possible that through the focus on infection prevention itself techniques were influenced, resulting in improved compliance with standard practices; however, the dramatic and sustained reduction in SSIs supports the efficacy of this bundle of interventions. Further research should be conducted to identify the effects of single interventions.

References

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