Economic evaluation of the National Surgical Quality Improvement Program® (NSQIP®)

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IHE Report

Economic evaluation of the National Surgical Quality Improvement Program® (NSQIP®)

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Executive Summary

Introduction

Readily accessible, consistent, and comparable risk-adjusted data for individual sites and across Alberta in a form that surgeons, nurses, and anesthesiologists can use to understand and improve their performance is unavailable in our current systems. As such, a project involving a tool that could provide such data was piloted by Alberta Health Services (AHS), specifically using the American College of Surgeons National Surgery Quality Improvement Program® (NSQIP®). NSQIP® is a data collection, monitoring, and analysis instrument that supports quality improvement in the surgical domain. It uses standard definitions and a validated sampling strategy to provide robust risk-adjusted reports with benchmarked hospital performance, and to identify areas for improvement. There were five acute care facilities across all five AHS operational zones that adopted NSQIP® for the pilot project: Queen Elizabeth II Hospital (QEII), University of Alberta Hospital (UAH), Red Deer Regional Hospital (RDRH), Rockyview General Hospital (RGH), and Chinook Regional Hospital (CRH).

Objectives

The overall objective was to conduct an economic evaluation of the NSQIP® pilot project at each of the five sites listed above. The specific objectives were:

1. to identify quality improvement (QI) interventions/initiatives undertaken as a result of NSQIP® data recommendations, and additionally to understand whether the availability of data through NSQIP® has impacted the local QI culture.
2. to analyze the healthcare costs and savings associated with those interventions.

Methods

Both qualitative and quantitative approaches were applied for the economic evaluation. In the qualitative portion (specific objective #1), data were collected through a series of one-on-one interviews with the Surgical Clinical Reviewer at each of the pilot sites and focus group sessions with the NSQIP® teams. Focus group and interview questions were provided to participants in advance of the sessions, and notes were transcribed during and at the completion of each session.

In the quantitative portion (specific objective #2), a decision tree analytic modelling approach was utilized to estimate cost-savings of NSQIP® (from the start of NSQIP® to the end of 2017, under an AHS perspective) by comparing healthcare costs of intra- and post-operative events (within 30 days of surgery) of patients who underwent a surgery in the five pilot sites before and after a QI intervention resulting from a NSQIP® recommendation was implemented. From the model, the cost-savings of an intervention were estimated by the following formula:

$$\text{Gross cost-savings} = N * (p1 - p2) * \text{unit cost}$$

where N was the number of patients who underwent a surgery after the intervention, $p1$ was the probability of event occurrence before the intervention, $p2$ was the probability of event occurrence after the intervention, and unit cost is healthcare cost per event. To calculate the net cost-savings, we deducted the costs of NSQIP® and its interventions from the gross cost-savings.

Results

The qualitative results suggest that having access to valid and reliable clinical client outcome data through NSQIP® has had a positive impact on QI and QI culture at each of the pilot sites. Sites have reported that there is strong leadership commitment to QI from site administrators, surgeons, and anesthesiologists, and that access to NSQIP® data enabled the engagement of multidisciplinary teams of surgeons, anesthesiologists, nurses, and allied health professionals to review client outcomes and identify and implement QI initiatives.

The quantitative results show that the QI initiatives initiated by NSQIP® to reduce surgical events – including orthopedic surgical site infections (SSIs) in QEII and CRH, urology and gynecology urinary tract infections (UTIs) as well as orthopedic blood transfusions in RDRH, colorectal and urology SSIs in UAH, and cystectomy length of stay and readmissions in RGH – had significant impacts clinically and economically.

Specifically, at QEII, 143 SSIs were prevented for orthopedic patients, resulting in $6.5 million gross savings. At UAH, about 45 additional SSIs occurred in colorectal patients and 68 SSIs were prevented for urology patients, resulting in $0.07 million gross savings. At RDRH, 184 blood transfusions, 66 gynecology UTIs, and 36 urology UTIs were prevented, resulting in $3.4 million gross savings. At RGH, 840 hospital days and 26 readmissions were prevented for cystectomy patients, resulting in $1.3 million gross savings. At CRH, about three SSI events were prevented for orthopedic patients, resulting in $139,000 gross savings, in addition to $26,000 savings from switching from mini-bags to syringes of cefazolin. The total gross savings in all five sites were estimated at $11.4 million. Subtracting the total costs of NSQIP® and its interventions ($2.6 million) from the total gross savings, the net cost-savings of NSQIP® in the five sites were $8.8 million. The return on investment ratio was 4.3, meaning that every $1.00 invested in NSQIP® would bring $4.30 in returns. The sensitivity analysis showed that the probability for NSQIP® to be cost-saving was 95%.

Conclusion

NSQIP® had a positive impact on QI and QI culture at each of the pilot sites. A number of QI interventions were initiated and implemented as a result of NSQIP® data recommendations, and these interventions appear to be effective and cost-saving for Alberta Health Services. These cost-savings would be even larger if NSQIP® was prolonged in the pilot sites and/or expanded to other sites across the province.

Abbreviations

All abbreviations that have been used in this report are listed here unless the abbreviation is well known, has been used only once, or has been used only in tables or appendices, in which case the abbreviation is defined in the figure legend or in the notes at the end of the table.

ACS	American College of Surgeons
CI	confidence interval
CRH	Chinook Regional Hospital
NSQIP®	National Surgery Quality Improvement Program®
OR	operating room
QEII	Queen Elizabeth II Hospital
QI	quality improvement
RDRH	Red Deer Regional Hospital
RGH	Rockyview General Hospital
SCR	Surgical Clinical Reviewer
SSI	surgical site infection
UAH	University of Alberta Hospital
UTI	urinary tract infection

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1. Background

Within Alberta Health Services (AHS), there are approximately 288,000 surgical procedures performed in a main operating room (OR) across Alberta each year. Some of these procedures involve surgical complications that are preventable, and are significant and costly to both patients and the healthcare system. AHS spends approximately $1 billion on surgery-related activities annually, and yet, despite some collection of administrative data, there is limited clinical data on surgery-related activities to inform clinicians (and the system) as to how well they are performing. There is, therefore, opportunity for improvement, elimination of waste, better outcomes, and better experiences for surgical patients in Alberta and their families.

Readily accessible, consistent, and comparable risk-adjusted data for individual sites and across Alberta in a form that surgeons, nurses, and anesthesiologists can use to understand and improve their performance is unavailable in our current system. As such, a project involving a tool that could provide such data was piloted by AHS, specifically using the American College of Surgeons (ACS) National Surgery Quality Improvement Program® (NSQIP®). NSQIP® is a data collection, monitoring, and analysis instrument that supports quality improvement in the surgical domain. It uses standard definitions and a validated sampling strategy to provide robust risk-adjusted reports with benchmarked hospital performance, and to identify areas for improvement (*https://www.facs.org/quality-programs/acs-nsqip*).

There were five acute care facilities across all five AHS operational zones that adopted NSQIP® for the pilot project: Queen Elizabeth II Hospital (QEII) in Grand Prairie, University of Alberta Hospital (UAH) in Edmonton, Red Deer Regional Hospital (RDRH) in Red Deer, Rockyview General Hospital (RGH) in Calgary, and Chinook Regional Hospital (CRH) in Lethbridge. The expected benefits of adopting NSQIP® within these facilities specifically and AHS as a whole were as follows:

- Access to timely, risk-adjusted data will facilitate more targeted focus on improvement opportunities.
- Identification of problem areas will facilitate surgical teams to target change opportunities across the surgical continuum of care.
- Targeted change initiatives will lead to reduced rates of preventable complications, thus resulting in improved surgical outcomes, reduced morbidity rates, and reduced patient mortality.
- Decreasing surgical complications will reduce per capita healthcare costs.
- Decreasing complications/morbidity will lead to improved patient experience.
- Benchmarking and collaboration will be possible across sites within Alberta as well as between Canadian and American hospitals, and will lead to greater accountability for improving clinical outcomes.

2. Objectives

The overall objective was to conduct an economic evaluation of the NSQIP® pilot project at each of the five sites listed above. The specific objectives were:

1. to identify quality improvement (QI) interventions/initiatives undertaken as a result of NSQIP® data recommendations, and additionally to understand whether the availability of data through NSQIP® has impacted the local QI culture; and
2. to analyze the healthcare costs and savings associated with those interventions.

3. Methods

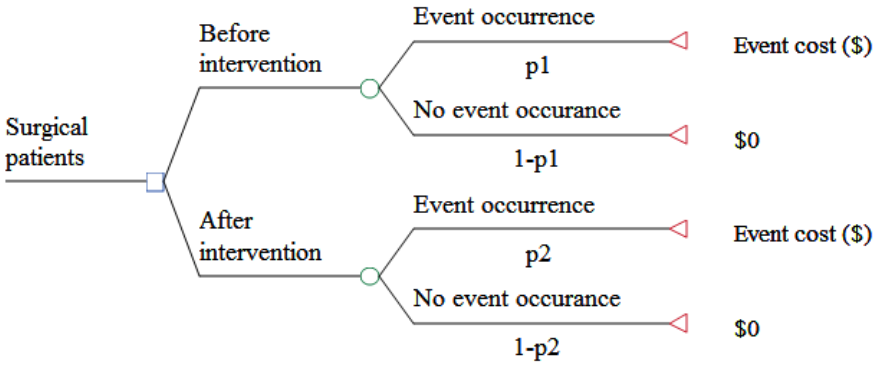
Both qualitative and quantitative approaches were applied for the economic evaluation. In the qualitative portion (specific objective #1), data were collected through a series of one-on-one interviews with the Surgical Clinical Reviewer (SCR) at each of the pilot sites and focus group sessions with the NSQIP® teams. Teams were typically comprised of an executive lead from the hospital, a surgical champion and an anesthesiologist champion, quality consultants, surgical managers, and an SCR. Focus group and interview questions were provided to participants in advance of the sessions, and notes were transcribed during and at the completion of each session. Copies of the interview and focus group guides are available in Appendix A.

Methods for the quantitative portion (specific objective #2) are detailed below.

3.1. Design

A decision tree analytic modelling approach was utilized to estimate health system cost-savings of NSQIP® by comparing healthcare costs of intra- and post-operative events (within 30 days of surgery) of patients who underwent a surgery in the five pilot sites before and after a QI intervention resulting from a NSQIP® recommendation was implemented (see Figure 1).

FIGURE 1: Model structure



From the model, the cost-savings of an intervention were estimated by the following formula:

$$\text{Gross cost-savings} = N * (p1 - p2) * \text{unit cost}$$

where N was the number of patients who underwent a surgery in the five pilot sites after the intervention, p1 was the probability of event occurrence (measured as the number of events divided by

the number of patients) before the intervention, p2 was the probability of event occurrence after the intervention, and unit cost was healthcare cost per event.

To calculate the net cost-savings, we deducted the costs of NSQIP® and its interventions from the gross cost-savings. We included the actual NSQIP® costs in 2015 and in 2016 and projected costs for 2017. Components of the intervention costs included salaries and benefits for staff (SCRs), stipends for physician champions, and costs for contracted services, education, travel, and others.

Because of variations (sites, types of surgery, interventions, events, and probability of event occurrence before/after an intervention) we analyzed the data by site, type of surgery, intervention, and event.

3.2. Perspectives

The evaluation was conducted from an AHS perspective, meaning it accounted for all costs and benefits to AHS, as well as all health impacts relevant to the patients.

3.3. Time Horizons

The time horizon for cost-savings was from the adoption of NSQIP® to the end of 2017.

3.4. Interventions and Outcomes/Events

3.4.1. Interventions

Based on NSQIP® data recommendations, different interventions were initiated by different sites, depending on indicators/areas that need to be improved in each site.

Queen Elizabeth II Hospital

At QEII, a bundle of interventions to reduce orthopedic surgical site infections (SSIs) has been implemented since January 2016. The bundle is comprised of best practice interventions proven to reduce SSIs, including:

- ensuring normothermia in orthopedic patients;
- ensuring antibiotics administered within 30 minutes of surgical incision time;
- ensuring redosing of antibiotics for surgical procedures over 3 hours in length;
- administration of tranexamic acid for all joint replacement surgeries; and
- limiting traffic in and out of the OR during procedures.

The activities implemented include:

- staff education (evidence for changes, review of documentation procedures, accountability);
- physician education and buy-in (for some initiatives);
- auditing of charts by the SCR with feedback on progress or problems;
- changes to charting procedures to improve accuracy; and
- staff buy-in and engagement to implement traffic limitation (driven and enforced by frontline staff).

University of Alberta Hospital

At UAH, a number of interventions to reduce colorectal and urology SSIs has been implemented since July 2016, including the following:

- Attention was brought to the General Surgery and Urology department surgeon heads about a renewed focus to reduce SSIs
- Monitoring inpatient hand hygiene rates
- A new plan to monitor the OR setting:
    - UAH site-specific closing bundle and protocol: A small sterile bundle of surgical instruments set aside (away from the active surgical field and contamination), to only be used in closing up the patient; General Surgery team leader has also put together a site-specific closing bundle protocol for the General Surgery ORs
        - March 1, 2017 to present time: Clinical educators perform randomized audits within the ORs
    - Skin prep timing: After the application of the chlorohexidine skin prep solution, surgeons are not to touch or cut skin to ensure the effectiveness of the skin prep solution (3 minutes are needed for the solution to dry and to be effective)
        - March 1, 2017 to present time: Clinical educators perform randomized audits within the ORs (timed the audits using timers)
    - Redosing antibiotics: For surgical cases longer than 3 hours, surgeons and anesthesiologists will work together to provide more antibiotics for patients based on their weight
    - Wound protectors: With the increasing laparoscopic surgical cases, surgeons are using more of a small plastic ring at the entry ports, in order to minimize bowel contaminations at the skin when closing
    - New antibiotic routines (started in April 2017):
        - Antibiotic irrigation: Prior to closing, some surgeons are starting to complete an antibiotic irrigation wash in the opened cavity
        - Oral pre-operative antibiotics: For elective patients, some surgeons are starting to prescribe an oral antibiotic course prior to their surgery

Red Deer Regional Hospital

At RDRH, interventions to reduce gynecology and urology urinary tract infections (UTIs) have been implemented since July 2015. These include the three following areas:

- sterile insertion technique/supplies in the OR;
- securement of the catheters post-operatively; and
- nursing staff education on the care of an indwelling catheter.

Orthopedic surgery blood utilization was also identified by the NSQIP® data as needing improvement at RDRH. A chart audit was completed to assess the current practices for blood transfusions in the orthopedic population. Through communication with the orthopedic surgeons and anesthetists,

support of best practices of transfusions for symptomatic or acute blood loss only was obtained. Since July 2016, best practices have been implemented.

Rockyview General Hospital

At RGH, an intervention to reduce cystectomy length of stay and readmissions (specifically, a radical cystectomy patient care pathway and order set) was developed and has been implemented since January 2016.

Chinook Regional Hospital

In CRH, several interventions to reduce hip and knee orthopedic SSIs have been implemented since February or May 2016. These include the following:

- The use of a pink sticker on all pre-op charts to indicate the exact time an antibiotic was given was introduced in February 2016. Compliance was measured for all joints; by April 2016, all joints were 100% compliant with the time given as per protocol.
- Since February 2016, patients were administered cefazolin via IV push by syringe, rather than by mini-bags.
- Normothermia education and the use of warming gowns for all elective hip and knee arthroplasty patients was introduced in May 2016. Monitoring and re-educating on the importance of maintaining normothermia within the OR and during post-anesthesia recovery were continued.
- Since May 2016, work was done through education with the surgical suite staff as well as the posting of signs on the doors of the orthopedic surgical suites to reduce traffic, maintain positive pressure within the suites, and ensure all doors are closed when needed. Traffic has reduced within the suites.
- Since May 2016, AQUACEL® Ag dressing was introduced for all elective hip and knee arthroplasty patients.

3.4.2. Outcomes/Events

Based on the interventions mentioned above, Table 1 presents the outcomes/events selected for this economic evaluation. We assumed that all other outcomes/events were unchanged before and after NSQIP®, as there were no interventions targeting them. Furthermore, we assumed that the interventions mentioned above solely resulted from NSQIP®; that is, if NSQIP® had not been implemented, those intervention would not have been initiated.

TABLE 1: Outcome/event by site and formulas to calculate cost-savings

Site Outcome/Event	N (I)	Difference in rates (=p1-p2) (II)	Number of events prevented (III=I*II)	Unit cost (IV)	Gross cost-savings (V=III*IV)
QEII					
Orthopedic SSI					
UAH					
Colorectal SSI					
Urology SSI					

Site Outcome/Event	N (I)	Difference in rates (=p1-p2) (II)	Number of events prevented (III=I*II)	Unit cost (IV)	Gross cost-savings (V=III*IV)
RDRH					
Orthopedic blood transfusion					
Gynecology UTI					
Urology UTI					
RGH					
Cystectomy LOS					
Cystectomy readmission					
CRH					
Orthopedic SSI					
Switching mini-bags to syringes of cefazolin					
Total					B
Costs of NSQIP® and interventions					C
Net cost-savings					**=B-C**

B: benefits; C: costs; CRH: Chinook Regional Hospital; LOS: length of stay; N: number of patients who underwent a surgery after the intervention; p1: probability of event occurrence before the intervention; p2: probability of event occurrence after the intervention; QEII: Queen Elizabeth II Hospital; RDRH: Red Deer Regional Hospital; RGH: Rockyview General Hospital; SSI: surgical site infection; UAH: University of Alberta Hospital; UTI: urinary tract infection

Data sources

N, p1, and p2 were retrieved from each pilot site's semi-annual reports, balanced scorecards, and/or SCRs.

Unit costs for SSIs, UTIs, and cystectomy length of stay and readmission were estimated by comparing patients with and without the events, from 2015/16 data provided by the AHS finance department. We included both direct (expenses directly associated with the provision of service, including direct staffing, supply, drug, sundry, and equipment costs, vacation accrual, and equipment depreciation) and indirect (administration and support overhead) costs.

The unit cost for orthopedic blood transfusion was retrieved from Ontario data (Freedman et al. 2008).

Since the marginal cost for hospital days of cystectomy shortened by the intervention was not available, we used the average cost per hospital day multiplied by the percentage of hotel cost (Thanh et al. 2016 and Lee et al. 2015). This is because the average cost per hospital day in an entire length of stay is lower than the cost per day in the first few days (when most medical procedures are done on patients), and higher than the cost per day in the last few days, which is very close to "hotel cost" (Drummond et al. 2005).

Since the unit costs for mini-bags and syringes of cefazolin specifically were not available, we used data on the costs of mini-bags used in six months compared to those of syringes used in six months, provided by the SCR at CRH.

Sensitivity analyses

Deterministic and probabilistic sensitivity analyses were both performed for the uncertainty of input parameters including N, p1, p2, and unit costs. In the deterministic sensitivity analysis, we performed a one-way sensitivity analysis (one variable varied at a time) and reported the results in a tornado diagram (that is, the most sensitive variable on top and the least at the bottom). The range of each variable was the 95% confidence interval (CI), or ±20% if the 95% CI was not available. In the probabilistic sensitivity analysis (all variables varied at a time), we ran 100,000 trials and reported the results in terms of the probability of NSQIP® being cost-saving. We used a normal distribution for numbers of patients, a beta distribution for rates/probabilities, and a gamma distribution for costs, as suggested by Briggs et al. (2006).

TreeAge Pro 2015 (*www.treeage.com/*) and MS Excel 2013 (*products.office.com/en-us/microsoft-excel-2013*) were used for analysis. All costs and savings were converted to 2017 Canadian dollars ($) using the Bank of Canada Inflation Calculator (*www.bankofcanada.ca/rates/related/inflation-calculator/*)

4. Results

4.1. Qualitative Results

The following section summarizes the results of the qualitative portion of the evaluation, which sought to identify QI interventions/initiatives undertaken as a result of NSQIP® data recommendations, and to understand whether the availability of data through NSQIP® impacted the local QI culture (specific objective #1).

4.1.1. Overall impressions of NSQIP®

The following section outlines the five pilot sites' overall impressions of NSQIP®.

NSQIP® provides valid and reliable clinical data that engages physicians and staff

Access to valid and reliable clinical data is surprisingly sparse in the health system. It seems that physicians, staff, and teams often spend a significant amount of their time questioning the validity of clinical and administrative data or determining how results will be measured. NSQIP® is reported by the pilot sites as offering valid and reliable patient outcome data. This appears to be the fundamental fact that allows teams to present physicians and staff with the results of their work, engage them in activities and interventions to improve their results, and track the success of these QI interventions over time.

> *"NSQIP® is probably the best way to make changes in the system."*
> - Participant

- **NSQIP® ensures accurate client outcome data is available** – All of the pilot sites reported the value in having access to accurate client outcome data. NSQIP® uses clinical information directly from the patient's medical record, not administrative data. It was suggested this ensures the data is reliable and valid, as administrative data can result in significant false positive or negative information. The following example was provided by one of the pilot sites:

  - When reviewing an administrative file, it may indicate a patient has an infection when a test is ordered to confirm this diagnosis. The coding required in administrative data results in false positive results, which impact the reliability of the data.

In NSQIP®, data is collected from clinical information throughout the patient's journey, including their experiences 30 days post-operatively. This provides the surgical team with data regarding outcomes beyond the patient's stay in hospital. The NSQIP® website (*www.facs.org/quality-programs/acs-nsqip/about*) states that:

> "studies show half or more of all complications occur after the patient leaves the hospital, often leading to costly readmissions. ACS NSQIP tracks patients for 30 days after their operation, providing a more complete picture of their care… concern for the patient doesn't stop at the hospital door, and [our] efforts to measure and track their care shouldn't either."

"Prior to NSQIP®, the only information we received was the quarterly reports from Infection Prevention Control, which are surveillance reports on infection rates in hip, knee, c-section, and bowel surgeries. This information is not robust enough to develop quality strategies for improvement. The NSQIP® [data] provides protocols that can be followed to make pointed changes in the areas of focus."

- Participant

One pilot site suggested that NSQIP® is critical to providing patient-centered care.

- **NSQIP® provides a mechanism to benchmark results against similar facilities** – All of the pilot sites were recognized as unique and appreciated that NSQIP® provides an opportunity to benchmark against facilities of similar scale and scope. Comparing dissimilar sites in Alberta to each other provides very little value, and doing so was recognized as a factor that would decrease engagement from physicians and the teams. Benchmarking the facilities, on the other hand provided the pilot sites with a clear indication of where there are opportunities for improvement.
- **NSQIP® presents data that is risk-adjusted** – Risk-adjusted data ensures that sites are able to compare the data regardless of the population being served by the procedure. Again, this was identified as a factor that influenced NSQIP® teams to present the data to stakeholders and engage them in conversations about the data's meaning and ability to influence outcomes.
- **NSQIP® data reports provide a structured approach for identifying opportunities for improvement** – The NSQIP® data reports that were regularly run by the SCRs identified areas where the sites were performing below benchmarked facilities. These reports provided direction in identifying priority areas for action, and provided ongoing feedback to the sites in terms of improvements related to the interventions implemented. This ongoing measurement and feedback was critical to the success of the NSQIP® pilot project.

The pilot sites consistently noted that there is an inherent assumption in the Alberta health system that the system is performing to the highest level possible and that physicians and care teams are doing the best job possible. While there is no doubt that everyone is well intentioned, providing teams with NSQIP® data helps identify where potential opportunities for improvement may exist, and raises awareness of the impact all care team members can have on patient outcomes. It was also suggested that the availability and reporting of data creates a Hawthorne effect; knowing that teams were monitoring data at the pilot sites was reported to improve charting and increase adherence to policies, procedures, and evidence-informed practice.

Access to reliable data is a catalyst for change

> *"While executive sponsorship is important, this is a grassroots initiative that drives change at the frontline and is very much patient-focused."*
>
> - Participant

One of the noted benefits of NSQIP® was that it engaged surgeons, anesthesiologists, and frontline providers to work together to discuss client outcomes and QI opportunities; NSQIP® data therefore highlights the importance of a comprehensive care team that supports a patient through their journey. In the past, it was reported that QI was often led by nursing and allied health professionals. As the NSQIP® teams included both a surgical champion and an anesthesiologist champion, the involvement of these roles was reported to drive change in a different way, with physicians engaged as key stakeholders in QI and conversations that consider the full patient journey. Furthermore, many of the pilot sites engaged multi-disciplinary teams to influence patient outcomes, involving pharmacy, nursing, individuals doing post-operative education, and family physicians, who are often the first point of contact after a hospital procedure. Access to the NSQIP® data and sharing of this information is reported to have created an increased awareness of QI; this increased awareness has all levels of staff interested in being involved in making positive changes and identifying opportunities for change.

- **NSQIP® data has influenced QI initiatives across the complete patient journey** – After pilot sites identified areas of focus based on their NSQIP® data, they undertook a process of developing a QI plan. QI interventions were not limited to changes in the OR or post-operative units. Reviewing NSQIP® data resulted in QI initiatives being undertaken across the full patient journey and, in some instances, interventions included primary care settings in the community. The following examples were provided of QI initiatives that focused outside of surgery:
    - At one pilot site, work was undertaken with pre-admission clinics to improve the information that was shared with patients, to ensure they had a clear understanding of their pre-operative procedures.
    - A review of catheter insertion practice was undertaken at one pilot site, and a number of opportunities for improvement to align with evidence-informed practice were identified. The NSQIP® team worked with the physicians and nurses to educate them on the proposed changes and to ensure they had the supplies necessary to follow the updated procedure. Additionally, the NSQIP® team developed and hung a poster to remind staff of the evidence-based procedures to be undertaken, support implementation of the changes, and hold everyone accountable for following them. The site indicated that nurses often referred to the poster when working with the physicians to remind them of the updated procedure.
    - In partnership with pharmacy, the NSQIP® team at one pilot site changed how certain medications were being administered to patients. Prior to NSQIP®, the site prepared and used mini-bags to administer cefazolin. They have now moved to a direct IV push by syringe.
    - Nurses at one of the sites brought forward the challenge they were having with catheter securement devices, which were falling off when a patient was diaphoretic or in the shower, often resulting in them not being used or not reapplied. A new securement device was sourced that requires alcohol for the adhesive to be removed. Feedback from the nurses suggests this device is a significant improvement.

- NSQIP® data identified an opportunity to improve surgical infection identification in primary care offices. Sites have worked to educate community physicians regarding infection diagnosis and, in one instance, have provided them with direct access to the surgeons in an effort to prevent readmissions to the hospital or the need for unnecessary testing or antibiotic use.

There is a strong belief among the sites that, in the absence of the NSQIP® data, the above initiatives would not have been undertaken.

4.1.2. Impact on quality improvement culture

Each of the sites was asked to comment on whether the NSQIP® pilot project has had a positive influence on QI culture at their site, and each reported a positive impact. The following section highlights five elements of continuous QI culture and changes resulting from the NSQIP® pilot project:

- **Leadership commitment** – The NSQIP® model in each of the sites included a surgical champion and an anesthesiologist champion, as well as an executive sponsor who was responsible for hiring the SCR. These leaders took a lead role in engaging their peers and the frontline staff in reviewing and understanding the NSQIP® data, determining and supporting the implementation of interventions, communicating progress, holding staff accountable, and leading change. Surgical and anesthesiologist champions provided significant support to the SCRs in coding and interpreting data, presenting the NSQIP® data, and engaging their colleagues. As stated by one anesthesiologist champion:

> *"In the past, QI used to be led by nurses and allied health professionals. NSQIP® is different because there are surgical and anesthesia leads. This drives change in a different way because a key set of stakeholders is involved."*
>
> - Participant

> "Traditionally, anesthesiologists have functioned on an island. They haven't worried about what happens before or after they are in the room with the patient. NSQIP® has given us the ability to educate the department about the vocabulary of quality improvement, standardization and measurement. As a result, people are more engaged in the system and see that they can play a supervisory role. We have created a safe surgery checklist to get more anesthesiologists involved in reducing infections."

It was outside of the scope of this evaluation to assess the commitment and engagement of the key leaders at each site. However, a number of the pilot sites indicated that engaged champions and executive sponsors contributed to changes in the QI culture at their site.

- **QI infrastructure** – The NSQIP® pilot project provided all of the sites with high quality patient outcome data, which enabled ongoing measurement and benchmarking; this data provided the most significant element of QI infrastructure. In addition to the availability of clinical data, the sites created internal

> *"NSQIP® has raised awareness among the staff that there are certain areas we are focused on and measuring. This measurement has increased awareness, engagement, and accountability. Contributes to the shift in culture when we all know that the numbers will be reviewed on a regular basis."*
>
> - Participant

QI teams and QI plans. After an area of focus was identified, the SCRs worked with the surgical and anesthesiologist champions and a variety of staff to identify and implement QI opportunities. In most of the sites, the SCRs took a lead role in bringing groups of frontline staff and physicians together to review results and identify and implement QI interventions.

Many of the sites noted that, prior to NSQIP®, quality was something that was talked about frequently but very little action was taken, and that the system lacked a structured approach and methodology for QI. While many sites reported having quality consultants/ coordinators, there was limited involvement from them in the NSQIP® QI initiatives. NSQIP® provided an infrastructure for ongoing QI at each of the sites.

"The NSQIP® pilot has significantly improved the QI culture at the hospital. Staff are starting to recommend changes that can be implemented and getting excited about making positive changes that influence patient outcomes and the patient experience. We have been focusing on creating a voice for staff so they can contribute to making positive changes in the workplace."

- Participant

- **Employee empowerment** – NSQIP® data successfully engaged surgeons, anesthesiologists, nurses, and allied health professionals in QI. A number of sites indicated that staff reached out to the SCRs directly to provide QI suggestions, such as the below example:

  > "I am starting to have staff email me directly about improvement opportunities. For example, a group of nurses attended a presentation and it included information about bed lesions and their connection to the mattresses being used on the unit and patient position. They have provided me with a copy of the presentation and are wondering if we can start collecting follow up data on bed lesions to understand if they start using this updated protocol whether it will decrease bed lesions among the patients."

  At one of the pilot sites, the surgical champion introduced the NSQIP® data to the residents and encouraged them to use the NSQIP® data and QI processes to meet their research project requirements. At this site, there is a desire to engage the next generation of physicians in QI and to ensure the culture of QI continues into the future.

- **Teamwork and collaboration** – The NSQIP® data provided the sites with tangible areas to focus on, taking the guesswork out of identifying performance expectations and measurement. Access to the data "makes it real for staff and it is tangible and they start thinking about how they can help." NSQIP® data also highlights the fact that all professionals interacting along the patient journey can make changes to improve quality outcomes. Most of the SCRs played a key role in raising awareness of the NSQIP® data, and in gathering teams to routinely brainstorm, solve problems, and implement QI projects. The executive sponsors and surgical and anesthesiologist champions have relied on these individuals to take a lead role in coordinating these key activities.

  "NSQIP® is an example of a project that has engaged a multi-disciplinary team and has crossed the whole site."

  - Participant

- **Continuous process improvement** – The NSQIP® teams worked with a variety of site stakeholders to review data, identify root problems, and engage in Plan-Do-Study-Act cycles.

This is evident through a review of their balanced scorecards, as well as the examples of the interventions they put in place to address low performing areas. One of the sites indicated that they have presented their NSQIP® data on poster boards and made them visible to staff, patients, and families. This site indicated they did this in an effort to be transparent and accountable for their results. Reporting results through the balanced scorecards is recognized as an important element of being accountable for QI efforts and investments.

4.1.3. Key learnings and considerations

Each of the pilot sites was provided an opportunity to provide advice to future sites regarding the implementation of NSQIP®. The following section highlights some of the key learnings and considerations if NSQIP® is expanded in the future.

Filling key NSQIP® roles

Most of the sites stressed the importance of carefully selecting the key NSQIP® roles. It was noted that, early in the project, the roles of these key positions were ill-defined. It was suggested that clearly-defined roles for the surgical and anesthesiologist champions and SCRs are particularly important.

An ideal surgical and/or anesthesiologist champion was defined as having the following qualities:

- a leader who is well respected among their colleagues;
- passionate about QI;
- able to read, interpret, and explain data; and
- able to present the data in an effort to engage peers in discussions regarding QI and QI processes.

An ideal SCR was defined as having the following background and qualities:

- experience on a surgical unit was seen as an asset;
- research experience and patience to conduct data gathering and entry; and
- strong leadership skills to bring stakeholders together, and to present and explain the NSQIP® data.

Project initiation requires investment

Feedback suggests that initiating NSQIP® at a site requires up to 12 months. The start-up phase of NSQIP® involves significant learning on the part of a site's SCR to understand how to read and code the data properly. While the training was valuable, all of the SCRs reported that significant time was used early in the project to learn to code the data and pull reports. Many of the SCRs indicated that they worked closely with the surgical and anesthesiologist champions to ensure coding and report interpretation was accurate.

Sites also suggested that there is a need to have 12 to 18 months' worth of data prior to determining areas of priority focus. In particular, it was noted that trying to make decisions after limited data entry resulted in reactions to monthly changes in the data rather than longer trends over time.

Lastly, all of the sites invested a significant amount of time building an awareness of NSQIP® and engaging peers and staff on-site in reviews of the data reports. Sites presented the NSQIP® data at existing meetings; however, all noted this engagement phase required significantly more work than anticipated. For example, it was noted that simply disseminating the NSQIP® reports did not result in

physician engagement; either the surgical or anesthesiologist champion needed to present the reports at meetings and engage physicians in discussions regarding their results and the need for improvement. It was noted that these early investments resulted in improved engagement and participation in QI at the sites.

SCRs are critical to the success of NSQIP®

Having a dedicated resource at each site to review charts, critically analyze clinical information, and consistently input data is essential to the successes realized at the pilot sites. While it is evident that a number of SCRs have a much broader role than data entry, the importance of having a dedicated resource in this position was stressed.

> *"The way the program is built with resources dedicated to data entry is important because we are not putting the work on existing resources with full workloads. It isn't something that someone is doing on the side of their desks. The SCR is a dedicated resource."*
>
> - Participant

The clinical data gathering and entry requirements for NSQIP® are significant. Most sites suggested they were under-resourced for the data entry requirements associated with NSQIP®. In addition to their roles of critically evaluating clinical information, entering data, and producing reports, many of the SCRs provided presentations of the data reports to teams and lead QI intervention teams.

All of the SCRs indicated that significant time was required to learn how to properly review charts and code, and to learn how to run reports and interpret the results. SCRs noted that previous experience in the OR or on a surgical unit assisted in reviewing charts, analyzing the clinical information, and inputting the data. SCRs consistently noted that attending the annual conferences and being able to connect with the other SCRs was extremely beneficial. The conferences provided them with hands-on opportunities to review charts and discuss coding, and access to other SCRs provided an opportunity to learn from others.

Role of the SCR in quality improvement

Teams suggested that the clinical information gathering, data entry, and reporting completed by the SCRs requires a significant amount of time, often limiting the amount of time they can dedicate to working with teams to develop and lead the implementation of their QI initiatives. The pilot sites suggested there may be a need to support NSQIP® sites with dedicated QI coordinators/leads/consultants who would be responsible for taking on these responsibilities in partnership with SCRs. It was noted that there has been a need to educate SCRs and NSQIP® teams about continuous QI cycles, balanced scorecards, and processes to identify root causes of issues. However, it should be noted that SCRs, due to their role in information gathering, data entry, and reporting, bring a depth of expertise to the QI cycle that is critical to ensuring the initiatives will have a positive impact. Working collaboratively with the QI coordinators/leads/consultants would be ideal.

NSQIP® proof of concept

NSQIP® provides a significant amount of surgical data. A number of pilot sites indicated they were overwhelmed early in the project when they were reviewing the significant amount of information available through NSQIP®. Pilot sites recommended that future sites begin their QI efforts by focusing on something small and ensure success, and then build from this success.

Patient follow-up impacts patient satisfaction

> *"We had patients rate their satisfaction and we saw a 36% improvement in self-reported satisfaction rate among patients."*
> - Participant

In an effort to support patient reported outcomes, NSQIP® requires a 30-day follow-up with patients. NSQIP® teams noted that this follow-up resulted in improvements in patient satisfaction. Patients reported that they felt cared for, heard, understood, and appreciated when contacted after leaving the hospital. SCRs reported that, in some instances, the follow-up calls provided an opportunity to address patient concerns and questions.

Consider creating a community of practice for SCRs

The SCRs frequently spoke of the value of connecting as a community to support both their roles in data entry and reporting, and QI. They believe providing a mechanism to meet face-to-face and virtually to problem solve, share success stories, and discuss QI interventions would be extremely beneficial. As one participant noted, "there are only so many ways things can go wrong, so there is an opportunity to learn from the other sites."

When asked to comment on future implementation of NSQIP® at other surgical sites, the SCRs also thought there may be value in having a provincial SCR who would be responsible for supporting SCRs as they learn their role and assisting them with their QI efforts.

Consider using a procedure-targeted approach

Sites spoke about the challenge in maintaining the 20% sample size required by NSQIP® and having to make changes to their sample sizes as a result. It was suggested that there may be value in using a procedure-targeted approach, similar to what has been adopted throughout British Columbia.

4.2. Quantitative Results

The following section summarizes the results of the quantitative portion of the evaluation, which sought to analyze the healthcare costs and savings associated with the QI interventions undertaken as a result of NSQIP® data recommendations (specific objective #2).

4.2.1. Model inputs

The probability of event occurrence before and after an intervention, number of patients after an intervention, and sources of data are shown by site in Table 2 below.

At QEII, the probability of SSI among orthopedic patients before the intervention was estimated at 4.35% (95% CI: 2.86, 6.31); this probability reduced to 1.9% (95% CI: 0.95, 3.38) after the intervention. The after intervention probability was calculated using 2016 data, as 2017 data was not yet available and we assumed that the probability would remain the same. As the intervention started in January 2016, all orthopedic patients in 2016 and 2017 were considered to be impacted. It was reported that there were 2,913 orthopedic patients at the hospital in 2016; as the 2017 number was not yet available, we assumed that it would be the same. Therefore, the total number of orthopedic patients in 2016 and 2017 after the intervention was estimated at 5,826. To account for the uncertainty, we varied it by ±20% for a sensitivity analysis.

At UAH, the probability of SSI occurrence in colorectal patients before and after the intervention was 9.26% (95% CI: 3.08, 20.3) and 14.81% (95% CI: 6.62, 27.12), respectively. The number of colorectal patients in 2016 was estimated at 540 (based on 54 patients in the NSQIP® sample, which was about 10% of all patients). As the intervention started in July 2016, the number of 2016 patients after the

intervention was 270 (=540/2). The number of colorectal patients in 2017 was assumed to be the same as in 2016, and therefore the total number of colorectal patients after the intervention in 2016 and 2017 was estimated at 810 (=270+540). To account for the uncertainty, we varied it by ±20% for a sensitivity analysis. Using a similar methodology, the probability of SSI occurrence in urology patients before and after the intervention were estimated at 3.03% (95% CI: 1.12, 6.48) and 0.55% (95% CI: 0.01, 3.02), respectively. The number of urology patients after the intervention was estimated at 2,730 (±20%).

At RDGH, from an unidentifiably individual dataset provided by the SCR, the probability of blood transfusion in orthopedic patients before the intervention (July 1, 2016) was estimated at 7.21% (95% CI: 5.50, 9.24); the after intervention probability was 3.58% (95% CI: 2.02, 5.84). The number of orthopedic patients after the intervention was estimated at 5,078, based on the number of orthopedic patients in the hospital per year of 3,385 (from 2015 data) and on a time duration of 1.5 years. Other interventions to reduce gynecology and urology UTIs started in July 2015 (approximately one year earlier than the intervention to reduce blood transfusions). The probability of UTI before the intervention was 2.65% (95% CI: 0.73, 6.64) for gynecology patients, and 2.80% (95% CI: 0.58, 7.98) for urology patients; the after intervention probability was 0.76% (95% CI: 0.09, 2.73) for gynecology patients, and 1.72% (95% CI: 0.36, 4.96) for urology patients. The number of patients after the intervention was 3,478 for gynecology and 3,285 for urology. These numbers were based on the numbers of gynecology and urology patients in the hospital per year (1,391 and 1,314, respectively, from 2015 data) and on a time duration (from the start of the interventions to the end of 2017) of 2.5 years. Note that we assumed that numbers of patients in 2016 and in 2017 were the same as in 2015. To account for the uncertainty, we varied the numbers of patients by ±20% for sensitivity analyses.

At RGH, interventions to reduce length of stay and readmissions for cystectomy patients started in January 2016. Length of stay before the interventions was 14 days, and after the interventions was 8 days. The probability of readmission before the interventions was 28.3% (95% CI: 16.79, 42.35), and after the interventions was 9.43% (95% CI: 3.13, 20.66). The number of cystectomy patients after the interventions was estimated at 140 (approximately 70 per year). To account for the uncertainty, we varied length of stay as well as the number of patients by ±20% for a sensitivity analysis.

At CRH, QI works were focused on SSIs in hip and knee orthopedic patients. The interventions to reduce hip and knee orthopedic SSI events started in February 2016. From a dataset provided by the SCR, the probability of hip and knee orthopedic SSI before the interventions was 1.11% (95% CI: 0.48, 2.18) and after the interventions was 0.84% (95% CI: 0.27, 1.95). Of note, the after intervention probability was calculated using data from January 1, 2016 to December 31, 2016, which included patients operated on one month before the start of the interventions; therefore, the impact of the interventions could be underestimated. The number of patients after the interventions (from February 2016 to the end of 2017) was estimated at 1,140 (595/12*23, where 595 was the number of patients in 12 months in 2016 as provided by the SCR, and the time duration was 23 months). To account for the uncertainty, we varied the number of patients by ±20% in a sensitivity analysis.

TABLE 2: Probability of event occurrence and number of patients by site

Input	Mean	Low	High	Data source/Note
QEII				
Probability of orthopedic SSI before intervention	4.35%	2.86%	6.31%	SAR for data period from January 1 to December 31, 2015
Probability of orthopedic SSI after intervention	1.90%	0.95%	3.38%	SAR for data period from January 1 to December 31, 2016
Number of orthopedic patients after intervention	5,826	(±20%)		Estimate (assumption)
UAH				
Probability of colorectal SSI before intervention	9.26%	3.08%	20.30%	SAR for data period from January 1 to December 31, 2015
Probability of colorectal SSI after intervention	14.81%	6.62%	27.12%	SAR for data period from July 1, 2016 to June 30, 2017
Number of colorectal patients after intervention	810	(±20%)		Estimate (assumption)
Probability of urology SSI before intervention	3.03%	1.12%	6.48%	SAR for data period from January 1 to December 31, 2015
Probability of urology SSI after intervention	0.55%	0.01%	3.02%	SAR for data period from July 1, 2016 to June 30, 2017
Number of urology patients after intervention	2,730	(±20%)		Estimate (assumption)
RDRH				
Probability of orthopedic blood transfusion before intervention	7.21%	5.50%	9.24%	Raw data from January 1, 2015 to June 30, 2016
Probability of orthopedic blood transfusion after intervention	3.58%	2.02%	5.84%	Raw data from July 1, 2016 to May 1, 2017
Number of orthopedic patients after intervention	5,078	(±20%)		Estimate (assumption)
Probability of gynecology UTI before intervention	2.65%	0.73%	6.64%	SAR for data period from July 1, 2014 to June 30, 2015
Probability of gynecology UTI after intervention	0.76%	0.09%	2.73%	SAR for data period from January 1 to December 31, 2016
Number of genecology patients after intervention	3,478	(±20%)		Estimate (assumption)
Probability of urology UTI before intervention	2.80%	0.58%	7.98%	SAR for data period from July 1, 2014 to June 30, 2015
Probability of urology UTI after intervention	1.72%	0.36%	4.96%	SAR for data period from January 1 to December 31, 2016
Number of urology patients after intervention	3,285	(±20%)		Estimate (assumption)

Input	Mean	Low	High	Data source/Note
RGH				
LOS in cystectomy patients before intervention	14 days	(±20%)		SCR (assumption)
LOS in cystectomy patients after intervention	8 days	(±20%)		SCR (assumption)
Probability of readmission in cystectomy patients before intervention	28.30%	16.79%	42.35%	SCR (based on sample size=53)
Probability of readmission in cystectomy patients after intervention	9.43%	3.13%	20.66%	SCR (based on sample size=53)
Number of cystectomy patients after intervention	140	(±20%)		Estimate (assumption)
CRH				
Probability of orthopedic (hip and knee) SSI before intervention	1.11%	0.48%	2.18%	Aggregated data from January 1 to December 31, 2015
Probability of orthopedic (hip and knee) SSI after intervention	0.84%	0.27%	1.95%	Aggregated data from January 1 to December 31, 2016
Number of orthopedic (hip and knee) patients after intervention	1,140	(±20%)		Estimate (assumption)

Note: Numbers of patients were from the intervention start to the end of 2017.

CRH: Chinook Regional Hospital; LOS: length of stay; QEII: Queen Elizabeth II Hospital; RDRH: Red Deer Regional Hospital; RGH: Rockyview General Hospital; SAR: semi-annual report; SCR: site clinical reviewer; SSI: surgical site infection; UAH: University of Alberta Hospital; UTI: urinary tract infection

The healthcare costs per event (unit costs) and data sources are shown below in Table 3. By comparing those who had and those who had not got an event (see Appendix B), the cost per orthopedic SSI event was estimated at $45,224 (95% CI: $38,827, $51,621), per colorectal SSI at $81,261 (95% CI: $72,998, $89,524), per urology SSI at $54,981 (95% CI: $44,292, $65,671), per gynecology UTI at $17,479 (95% CI: $15,103, $19,855), per urology UTI at $59,724 (95% CI: $54,063, $65,386), and per cystectomy readmission at $12,023 (95% CI: $8,206, $15,839). The unit cost of orthopedic blood transfusion was estimated at $904 (range: $723, $1,085); as this cost was unavailable from Alberta data, it was retrieved from Ontario data (Freedman et al. 2008) and then inflated to 2017 CA$. The marginal cost per day of cystectomy shortened by the interventions was also not available; to estimate this, we applied the percentage of hotel cost (43.5% [95% CI: 32.9%, 58.8%]) estimated by Lee et al. (2015) to the average cost per day ($2,708 [95% CI: $2,654, $2,762]) estimated from AHS financial data. All the ranges of unit costs as well as the range of hotel cost percentage were 95% CIs, except the unit cost of blood transfusion, which was assumed to vary by ±20%.

TABLE 3: Healthcare costs per event (unit costs, 2017 CA$)

Event	Cost per event			Data source
	Mean	Low	High	
Orthopedic SSI	$45,224.02	$38,827.48	$51,620.54	AHS financial
Colorectal SSI	$81,261.02	$72,997.96	$89,524.07	AHS financial
Urology SSI	$54,981.43	$44,292.01	$65,670.84	AHS financial

Event	Cost per event			Data source
	Mean	Low	High	
Blood transfusion for orthopedic patients	$ 903.93	$ 723.14	$ 1,084.72	Freedman et al.
Gynecology UTI	$17,478.98	$15,103.37	$19,854.59	AHS financial
Urology UTI	$59,724.27	$54,062.64	$65,385.89	AHS financial
Cystectomy readmission	$12,022.80	$ 8,206.14	$15,839.47	AHS financial
Average cost per hospital day for cystectomy	$ 2,707.79	$ 2,653.85	$ 2,761.72	AHS financial
Hotel cost as % of the average cost per hospital day	43.50%	32.90%	58.80%	Lee et al.

SSI: surgical site infection; UTI: urinary tract infection

As the unit cost per patient for mini-bags and syringes of cefazolin was not available, we estimated the savings of switching to syringes per year by comparing the total costs of mini-bags used in six months (before switching) with the total costs of syringes used in another six months (after switching) where data was available at CRH (see Table 4). On average, the cost of mini-bags used in six months was $10,370 and the cost of syringes used in six months was $3,578. Therefore, switching to syringes saved $6,792 per six months or $13,584 per year. To account for the uncertainty, we varied this cost by ±20% in a sensitivity analysis.

TABLE 4: Costs of mini-bags and syringes of cefazolin at CRH (2017 CA$)

Item/Size	6-month period			1-year period*
	Quantity	Unit cost	Total cost	
Before (January 1-June 30, 2016)				
1g bag	3,682	$ 1.17	$ 4,313.83	
2g bag	4,875	$ 1.24	$ 6,056.21	
Total			$10,370.04	$20,740.09
After (January 1-June 30, 2017)				
10mL syringe	2,456	$ 0.253	$ 621.37	
20mL syringe	6,513	$ 0.454	$ 2,956.90	
Total			$ 3,578.27	$ 7,156.54
Cost-savings (=Before-After)			**$ 6,791.77**	**$13,583.55**

Source: SCR at CRH

*1-year cost=6-month cost*2

Table 5 below shows the costs of NSQIP® by cost item and year. In 2015 and 2016, the total cost of NSQIP® was approximately $0.38 million and $1.22 million, respectively. In 2017, it was estimated at $1.04 million. Therefore, the total cost of NSQIP® for all three years was estimated at $2.64 million. Of this, salaries for the SCRs accounted for the largest share (48%), followed by contracted services (38%), benefits (11%), and other expenses (3%).

TABLE 5: Costs of NSQIP® (2017 CA$)

Item	2015	2016	2017	Total
Salaries	$ 215,310.50	$ 532,983.03	$ 522,337.73	$1,270,631.26
Benefits	$ 50,977.60	$ 118,426.47	$ 114,649.90	$ 284,053.97
Other contracted services	$ 109,650.00	$ 535,430.51	$ 349,309.54	$ 994,390.05
Other expenses	$ 1,891.04	$ 36,757.86	$ 53,378.34	$ 92,027.24
Total	$ 377,829.14	$1,223,597.87	$1,039,675.51	$2,641,102.53

Source: AHS financial

4.2.2. Outputs from the model

The base case cost-savings of NSQIP® are presented below in Table 6.

At QEII, approximately 143 SSIs were prevented for orthopedic patients by the interventions resulted from NSQIP®. With a unit cost of approximately $45,000 per orthopedic SSI, the program saved approximately $6.5 million in healthcare costs.

At UAH, about 45 additional SSIs occurred in colorectal patients, and 68 SSIs were prevented for urology patients. With a unit cost of $81,000 and $55,000, the program cost approximately $3.65 million for colorectal patients and saved $3.72 million for urology patients. Therefore, the total gross savings at UAH were $0.07 million.

At RDRH, 184 blood transfusions, 66 gynecology UTIs, and 36 urology UTIs were prevented. Multiplying these with their unit costs, the gross savings of these prevented events were respectively estimated at $0.2 million, $1.1 million, and $2.1 million. Therefore, the total gross savings at RDRH were $3.4 million.

At RGH, 840 hospital days and 26 readmissions were prevented for cystectomy patients. Multiplying these with their unit costs and then adding them together, the total gross savings at RGH were estimated at $1.3 million.

At CRH, about three SSI events were prevented for orthopedic patients, resulting in approximately $139,000 savings. Additionally, switching from mini-bags to syringes of cefazolin saved approximately $26,000. Therefore, the total gross savings at CRH were approximately $165,000.

The total gross savings for all five sites were estimated at $11.4 million. Subtracting the total costs of NSQIP® and its interventions ($2.6 million) from the total gross savings, the net cost-savings of NSQIP® were estimated at $8.8 million. The return on investment ratio was 4.3, meaning that every $1.00 invested in NSQIP® would bring $4.30 in return (in terms of cost-savings). Of note, as the data on the costs of NSQIP® by site were not available, the net cost-savings by site could not be calculated. However, even if the time horizon was by the end of 2016, NSQIP® was still cost-saving. Specifically, the net cost-savings of NSQIP® by the end of 2016 were estimated at $4.4 million, and the return on investment ratio was 3.7 (see Appendix C).

TABLE 6: Base case analysis results on cost-savings of NSQIP®

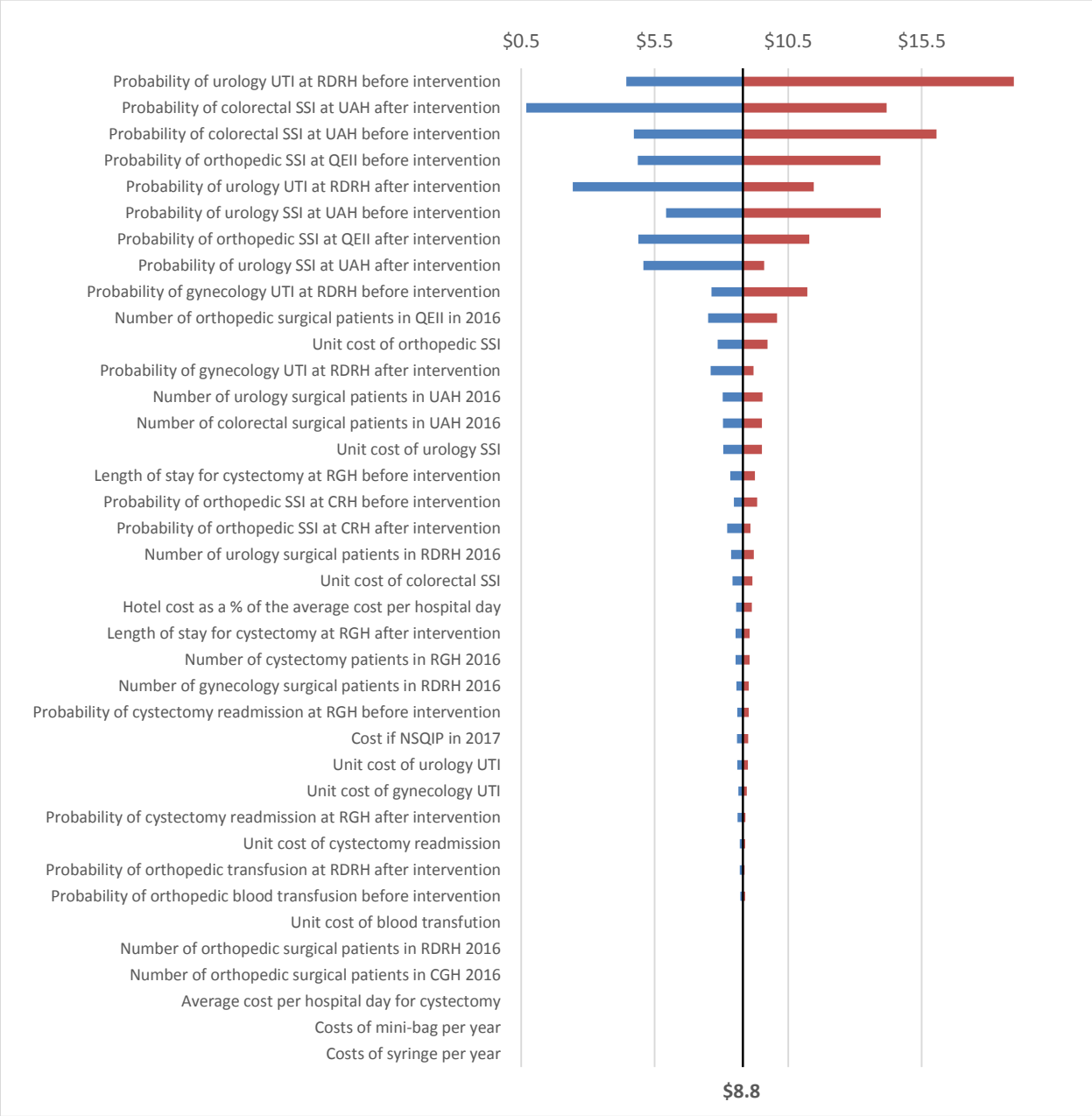
Site/Event	N (I)	Probability before (p1) (II)	Probability after (p2) (III)	Probability difference (IV=II-III)	Number of events prevented (V=I*IV)	Unit cost (VI)	Gross savings (VII=V*VI)
QEII							
Orthopedic SSI	5,826	0.0435	0.019	0.0245	142.7	$45,224	$ 6,455,141
UAH							
Colorectal SSI	810	0.0926	0.1481	-0.0555	-45.0	$81,261	-$ 3,653,089
Urology SSI	2,730	0.0303	0.0055	0.0248	67.7	$54,981	$ 3,722,462
RDRH							
Orthopedic blood transfusion	5,078	0.0721	0.0358	0.0363	184.3	$ 904	$ 166,606
Gynecology UTI	3,478	0.0265	0.0076	0.0189	65.7	$17,479	$ 1,148,802
Urology UTI	3,285	0.028	0.0172	0.0108	35.5	$59,724	$ 2,118,898
RGH							
Cystectomy LOS (days)	140	14	8	6	840.0	$ 1,178	$ 989,426
Cystectomy readmission	140	0.283	0.0943	0.1887	26.4	$12,023	$ 317,618
CRH							
Orthopedic SSI	1,140	0.0111	0.0084	0.0027	3.1	$45,224	$ 139,250
Switching mini-bags to syringes							$ 26,035
Total gross savings							**$11,431,150**
Total costs of NSQIP® and interventions for all sites from the start of NSQIP®							**$ 2,641,103**
Total net savings (=Total gross savings-Total costs of NSQIP® and interventions)							**$ 8,790,048**
Return-on-investment ratio (=Total gross savings : Total costs of NSQIP® and interventions)							**4.3**

CRH: Chinook Regional Hospital; LOS: length of stay; N: number of patients after interventions up to the end of 2017; QEII: Queen Elizabeth II Hospital; RDRH: Red Deer Regional Hospital; RGH: Rockyview General Hospital; SSI: surgical site infection; UAH: University of Alberta Hospital; UTI: urinary tract infection

The one-way sensitivity analyses results are shown below in Figure 2. The net cost-savings of NSQIP® varied from $1.0 million to $19.0 million. The five most sensitive variables were the probability of urology UTI at RDRH before intervention, the probability of colorectal SSI at UAH after intervention, the probability of colorectal SSI at UAH before intervention, the probability of orthopedic SSI at QEII before intervention, and the probability of urology UTI at RDRH after intervention. These would suggest areas on which the QI work should focus. The five least sensitive variables were costs of syringes, costs of mini-bags, average cost per hospital day for cystectomy, the number of orthopedic surgical patients in CGH after intervention, and the number of orthopedic

surgical patients in RDRH after intervention. The specific range of net cost-savings for every variable is shown in Appendix D.

FIGURE 2: Tornado diagram on variations of cost-savings (in millions)

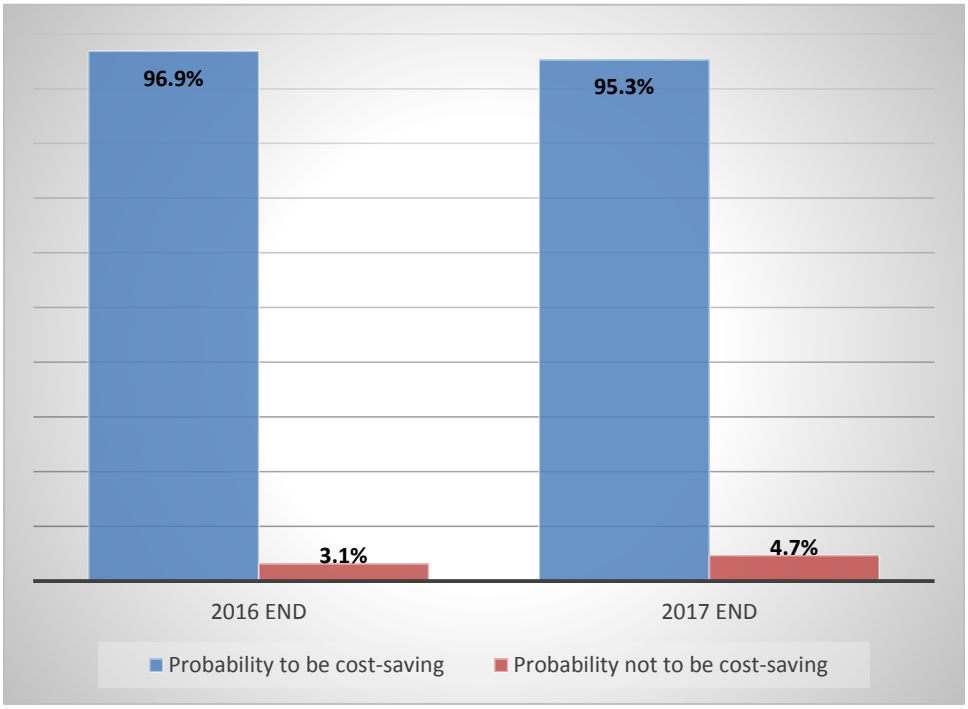


CRH: Chinook Regional Hospital; QEII: Queen Elizabeth II Hospital; RDRH: Red Deer Regional Hospital; RGH: Rockyview General Hospital; SSI: surgical site infection; UAH: University of Alberta Hospital; UTI: urinary tract infection

Figure 3 below shows the probability of NSQIP® to be cost-saving, in two separate scenarios. If the time horizon was by the end of 2017, the probability of NSQIP® to be cost-saving was 95%; if the time horizon was by the end of 2016, the probability was 96%. The longer the time horizon the lower

the probability of NSQIP® being cost-saving is because the probability of colorectal SSI at UAH increased after the intervention. This result would suggest that the intervention to reduce colorectal SSIs at this site needs to be improved.

FIGURE 3: Probability of NSQIP® to be cost-saving



5. Discussion

NSQIP® is not an intervention that can directly improve surgical outcomes. Rather, it is a database suggesting areas that need to be improved; based on its suggestions, QI interventions/initiatives can be initiated and implemented. Thus, it would not be useful to simply compare between sites with and without NSQIP®. As such, this study used both qualitative and quantitative methods to evaluate NSQIP® implementation in each of the five pilot sites in Alberta from 2015 to 2017. The qualitative method was to identify QI interventions/initiatives undertaken as the result of NSQIP® data recommendations, and to understand whether the availability of data through NSQIP® has impacted the local QI culture. The qualitative results suggest that having access to valid and reliable clinical client outcome data through NSQIP® has had a positive impact on QI and QI culture at each of the pilot sites. Sites reported that there is strong leadership commitment to QI from site administrators, surgeons, and anesthesiologists, and that access to NSQIP® data enabled the engagement of multidisciplinary teams of surgeons, anesthesiologists, nurses, and allied health professionals to review client outcomes and identify and implement QI initiatives. Consistently tracking and reporting this information over time revealed that the QI initiatives initiated through the NSQIP® pilot sites resulted in positive outcomes for the system and clients. The strength of the data collected for NSQIP® and the resulting reports are fundamental to successful QI.

The quantitative method was used to quantify the outcomes of the QI interventions/initiatives initiated through NSQIP® in terms of dollars. The results suggest that NSQIP® implementation in the

five pilot sites will result in $8.8 million in cost-savings by the end of 2017. The return-on-investment ratio is 4.3, meaning that $1.00 invested in NSQIP® would bring $4.30 in returns. The probability for NSQIP® to be cost-saving is 95%. Of note, these are results from five pilot sites, to the end of 2017; one can expect that the cost-savings would be larger if NSQIP® was prolonged in these sites and/or expanded to other sites across the province. This is not only because of the increase in patient volume, but also because of the increase in QI initiatives initiated by NSQIP® data recommendations. It is reported that the magnitude of QI increases with time in NSQIP® (Cohen et al. 2016).

Our results are supported by others in both Canada and the United States. For example, in British Columbia, it was reported that NSQIP® increases surgical patient satisfaction, prevents SSIs and pneumonia, and positively influences QI culture, communication, and quality of surgical care (Dempster 2014). In the United States, Cohen et al. (2016) studied 515 hospitals participating in NSQIP® between 2006 and 2013, and concluded that participation in NSQIP® is associated with reductions in adverse events after surgery. Hall et al. (2009) studied 118 hospitals participating in NSQIP® between 2005 and 2007, and concluded that NSQIP® hospitals appear to be avoiding substantial numbers of complications, improving care, and reducing costs. Hollenbeak et al. (2011) studied 2,229 general or vascular surgeries (of which 699 were after NSQIP®) and concluded that NSQIP® is cost-effective, and that its cost-effectiveness improves with greater duration participating in the program.

It should be noted that a few assumptions were made in this study. Firstly, it was assumed that the QI interventions implemented in the five pilot sites were initiated solely because of NSQIP®; in other words, if NSQIP® had not been used, these QI interventions would not have been implemented. Secondly, it was assumed that outcomes to which no interventions were specifically targeted remained unchanged. Thus, if there were any positive impacts from NSQIP® on such outcomes (e.g., the Hawthorne effect, where better outcomes are due to the awareness of being observed), then our cost-savings would be underestimated. On the other hand, if there were any negative impacts from NSQIP® on such outcomes (e.g., areas not receiving focus may inadvertently be neglected, making outcomes in those areas worse), then our cost-savings would be overestimated. Additionally, this study assumes that the impacts of QI interventions in 2016 continued to be the same in 2017 (because 2017 data were not available in most sites at the time of analysis to calculate the 2017 impacts). As the magnitude of QI increases with time in NSQIP® (Cohen et al. 2016 and Hollenbeak et al. 2011), our cost-savings are likely underestimated. Finally, the study assumes that, in a hospital, the characteristics of patients who underwent a specific type of surgery (e.g., orthopedic, urology, gynecology, or cystectomy) before the interventions are similar to the characteristics of those who underwent the same type of surgery after the interventions. It is believed that any uncertainties due to these assumptions are taken into consideration by sensitivity analyses. The one-way sensitivity analysis (one variable varied at a time) shows that the cost-savings of NSQIP® varies from $1 million to $19 million, and the probabilistic sensitivity analysis (all variables vary at a time) shows that the probability of NSQIP® to be cost-saving is high, at over 95%.

6. Conclusion

NSQIP® had a positive impact on QI and QI culture at each of the pilot sites. A number of QI interventions were initiated and implemented as a result of NSQIP® data recommendations, and these interventions appear to be effective and cost-saving for AHS. These cost-savings would be even larger if NSQIP® was prolonged in the pilot sites and/or expanded to other sites across the province.

Appendix A: Focus Group and Interview Guides

NSQIP Evaluation – Focus Group Questions

Thank you for agreeing to participate in the evaluation of the NSQIP pilot project. In order to understand the benefits realized from the implementation of NSQIP at the five pilot sites across the province Alberta Health Services (AHS) has engaged the Institute of Health Economics (IHE) to complete an economic evaluation. To supplement this economic evaluation qualitative data will be collected from each of the sites to identify planned and unplanned quality improvement initiatives undertaken and understand whether the availability of data through NSQIP has impacted the local quality improvement culture.

It is important that you understand that your participation is voluntary and all of the information that you provide will remain confidential. Notes will be taken during each of the focus group sessions and collated to identify common themes. The Surgical Strategic Clinical Network will be provided with the aggregate data, which will contain no identifiable comments or names.

The focus group sessions will be semi-structured in nature. The following questions will be used to guide the conversations:

1. Please introduce yourself and your role on the NSQIP team.
2. What are your overall impressions of NSQIP?
3. Do you feel that NSQIP has contributed to quality improvement at your site? How?
4. It is believed the NSQIP pilot has resulted in formal QI strategy development, but also informal QI improvements at your sites. Please describe the formal quality initiatives that have been driven by NSQIP and how you feel NSQIP has contributed or supported these initiatives.
5. Do you feel NSQIO has contributed to overall informal QI activities at your site? How?
6. How has the NSQIP pilot benefited you in your role?
7. Do you feel that NSQIP has had a positive influence on quality improvement culture? What changes have been realized and how has the pilot project contributed to these changes?
8. What of advice would you give future sites regarding the implementation and use of NSQIP?

NSQIP Evaluation – Surgical Clinical Reviewer Interview Guide

Thank you for agreeing to participate in the evaluation of the NSQIP pilot project. In order to understand the benefits realized from the implementation of NSQIP at the five pilot sites across the province Alberta Health Services (AHS) has engaged the Institute of Health Economics (IHE) to complete an economic evaluation. To supplement this economic evaluation qualitative data will be collected from each of the sites to identify planned and unplanned quality improvement initiatives undertaken and understand whether the availability of data through NSQIP has impacted the local quality improvement culture.

It is important that you understand that your participation is voluntary and all of the information that you provide will remain confidential. Notes will be taken during each of the SCR interviews and collated to identify common themes. The Surgical Strategic Clinical Network will be provided with the aggregate data, which will not have any identifiable comments or names.

The interviews conducted with each of the Surgical Clinical Reviewers will be semi-structured in nature. The following questions will be used to guide the conversations:

1. Can you provide an overview of your role as a Surgical Clinical Reviewer?

2. It is believed the NSQIP pilot has resulted in formal QI strategy development, but also informal QI improvements at your sites. Please describe the formal quality initiatives that have been driven by NSQIP and how you feel NSQIP has contributed or supported these initiatives.

3. Do you feel NSQIP has contributed to overall informal QI activities at your site? How?

4. How has the NSQIP pilot project influenced the following aspects of quality improvement culture:

    - **Leadership commitment** to quality improvement and a culture of quality
    - **Quality improvement infrastructure** (e.g. performance management system, quality improvement teams and improvement plans)
    - **Employee empowerment** (e.g. the awareness, knowledge, skills, resources and support to participate in quality improvement)
    - **Teamwork and collaboration** (e.g. teams have clearly defined performance expectations and gather routinely to brainstorm, solve problems, implement QI projects, and share lessons learned)
    - **Continuous process improvement** (e.g. there is a never-ending quest to improve processes by identifying root causes of problems and a process has been identified to support this work, e.g. Plan-Do-Study-Act [PDSA] cycles)

Appendix B: Unit Costs

TABLE B.1: Unit costs calculated using fiscal year 2015/16 data

Event	N	Mean	Std. Err.	Std. Dev.	95% Confidence Interval	
					Low	High
Colorectal surgery						
With SSI	34	$ 99,416.07	$ 15,670.73	$ 91,375.27	$ 67,533.73	$131,298.40
Without SSI	1,251	$ 19,552.66	$ 537.74	$ 19,019.45	$ 18,497.70	$ 20,607.63
Difference		$ 79,863.41	$ 4,139.50		$ 71,742.47	$ 87,984.34
*Difference in 2017 CA$**		*$ 81,261.02*	*$ 4,211.94*		*$ 72,997.96*	*$ 89,524.07*
Orthopedic surgery						
With SSI	33	$ 60,144.27	$ 10,054.71	$ 57,759.89	$ 39,663.50	$ 80,625.04
Without SSI	1,837	$ 15,698.07	$ 390.92	$ 16,755.09	$ 14,931.36	$ 16,464.77
Difference		$ 44,446.21	$ 3,205.39		$ 38,159.69	$ 50,732.72
*Difference in 2017 CA$**		*$ 45,224.02*	*$ 3,261.48*		*$ 38,827.48*	*$ 51,620.54*
Gynecology surgery						
With UTI	27	$ 24,915.74	$ 3,529.66	$ 18,340.64	$ 17,660.42	$ 32,171.05
Without UTI	2,211	$ 7,737.38	$ 124.55	$ 5,856.40	$ 7,493.14	$ 7,981.62
Difference		$ 17,178.36	$ 1,190.58		$ 14,843.61	$ 19,513.11
*Difference in 2017 CA$**		*$ 17,478.98*	*$ 1,211.41*		*$ 15,103.37*	*$ 19,854.59*
Urology surgery						
With UTI	29	$ 69,214.33	$ 12,907.99	$ 69,511.66	$ 42,773.51	$ 95,655.15
Without UTI	1,829	$ 10,517.26	$ 295.11	$ 12,621.04	$ 9,938.46	$ 11,096.05
Difference		$ 58,697.07	$ 2,837.10		$ 53,132.82	$ 64,261.32
*Difference in 2017 CA$**		*$ 59,724.27*	*$ 2,886.75*		*$ 54,062.64*	*$ 65,385.89*
With SSI	9	$ 68,186.51	$ 23,186.64	$ 69,559.92	$ 14,718.01	$121,655.00
Without SSI	666	$ 14,150.71	$ 546.71	$ 14,108.85	$ 13,077.23	$ 15,224.18
Difference		$ 54,035.80	$ 5,350.44		$ 43,530.23	$ 64,541.37
*Difference in 2017 CA$**		*$ 54,981.43*	*$ 5,444.08*		*$ 44,292.01*	*$ 65,670.84*
Cystectomy						
Average cost per hospital day	989	$ 2,661.21	$ 27.01		$ 2,608.21	$ 2,714.22
*Average cost in 2017 CA$**		*$ 2,707.79*	*$ 27.48*		*$ 2,653.85*	*$ 2,761.72*
Average cost per readmission	77	$ 11,816.02	$ 1,883.35		$ 8,065.00	$ 15,567.05
*Average cost in 2017 CA$**		*$ 12,022.80*	*$ 1,916.31*		*$ 8,206.14*	*$ 15,839.47*

*2017CA$ = 2015/16CA$ * 0.75 * 1.02 + 2015/16CA$ * 0.25 * 1.01. As fiscal year 2015/16 was from April 1, 2015 to March 31, 2016, we estimated that 75% of data was from 2015 and 25% from 2016. According to Bank of Canada, 1.00 CA$ in 2015 was equal 1.02 CA$ in 2017 and 1.00 CA$ in 2016 was equal to 1.01 CA$ in 2017

SSI: surgical site infection; UTI: urinary tract infection.

Appendix C: Cost-Savings of NSQIP®

TABLE C.1: Cost-savings of NSQIP® by the end of 2016

Site/Event	N (I)	Probability before (p1) (II)	Probability after (p2) (III)	Probability difference (IV=II-III)	Number of events prevented (V=I*IV)	Unit cost (VI)	Gross savings (VII=V*VI)
QEII							
Orthopedic SSI	2,913	0.0435	0.019	0.0245	71.4	$ 45,224	$3,227,570
UAH							
Colorectal SSI	270	0.0926	0.1481	-0.0555	-15.0	$ 81,261	-$1,217,696
Urology SSI	910	0.0303	0.0055	0.0248	22.6	$ 54,981	$1,240,821
RDRH							
Orthopedic blood transfusion	1,693	0.0721	0.0358	0.0363	61.4	$ 904	$ 55,535
Gynecology UTI	2,087	0.0265	0.0076	0.0189	39.4	$ 17,479	$ 689,281
Urology UTI	1,971	0.028	0.0172	0.0108	21.3	$ 59,724	$1,271,339
RGH							
Cystectomy LOS (days)	70	14	8	6	420.0	$ 1,178	$ 494,713
Cystectomy readmission	70	0.283	0.0943	0.1887	13.2	$ 12,023	$ 158,809
CRH							
Orthopedic SSI	545	0.0111	0.0084	0.0027	1.5	$ 45,224	$ 66,598
Switching mini-bags to syringes							$ 12,452
Total gross savings							**$5,999,422**
Total costs of NSQIP® and interventions for all sites from the start of NSQIP®							***$1,601,427***
Total net savings (=Total gross savings-Total costs of NSQIP® and interventions)							**$4,397,995**
Return-on-investment ratio (=Total gross savings : Total costs of NSQIP® and interventions)							**3.7**

CRH: Chinook Regional Hospital; LOS: length of stay; N: number of patients after interventions up to the end of 2016; QEII: Queen Elizabeth II Hospital; RDRH: Red Deer Regional Hospital; RGH: Rockyview General Hospital; SSI: surgical site infection; UAH: University of Alberta Hospital; UTI: urinary tract infection

Appendix D: Ranges of Cost-Savings by Variable

TABLE D.1: Ranges of cost-savings by variable

Variable	Range	Low Value	High Value
Probability of urology UTI at RDRH before intervention	0.0058 to 0.0798	$ 4,434,536	$18,952,909
Probability of colorectal SSI at UAH after intervention	0.0662 to 0.2712	$ 687,430	$14,180,823
Probability of colorectal SSI at UAH before intervention	0.0308 to 0.203	$ 4,722,284	$16,056,733
Probability of orthopedic SSI at QEII before intervention	0.0286 to 0.0631	$ 4,864,268	$13,954,161
Probability of urology UTI at RDRH after intervention	0.0036 to 0.0496	$ 2,433,355	$11,458,289
Probability of urology SSI at UAH before intervention	0.0112 to 0.0648	$ 5,923,151	$13,968,474
Probability of orthopedic SSI at QEII after intervention	0.0095 to 0.0338	$ 4,890,616	$11,293,062
Probability of urology SSI at UAH after intervention	0.0001 to 0.0302	$ 5,082,595	$ 9,600,584
Probability of gynecology UTI at RDRH before intervention	0.0073 to 0.0664	$ 7,623,011	$11,215,296
Number of orthopedic surgical patients in QEII in 2016	(±20%)	$ 7,499,020	$10,081,076
Unit cost of orthopedic SSI	$38,827 to $51,621	$ 7,857,329	$ 9,722,764
Probability of gynecology UTI at RDRH after intervention	0.0009 to 0.0273	$ 7,592,620	$ 9,197,295
Number of urology surgical patients in UAH 2016	(±20%)	$ 8,045,555	$ 9,534,540
Number of colorectal surgical patients in UAH 2016	(±20%)	$ 8,059,430	$ 9,520,666
Unit cost of urology SSI	$44,292 to $65,671	$ 8,066,331	$ 9,513,764
Length of stay for cystectomy at RGH before intervention	(±20%)	$ 8,328,316	$ 9,251,780
Probability of orthopedic SSI at CRH before intervention	0.0048 to 0.0218	$ 8,465,130	$ 9,341,892
Probability of orthopedic SSI at CRH after intervention	0.0027 to 0.0195	$ 8,217,574	$ 9,084,021
Number of urology surgical patients in RDRH 2016	(±20%)	$ 8,366,268	$ 9,213,827
Unit cost of colorectal SSI	$72,998 to $89,524	$ 8,418,582	$ 9,161,514
Hotel cost as a % of the average cost per hospital day	0.329 to 0.588	$ 8,548,946	$ 9,138,053
Length of stay for cystectomy at RGH after intervention	(±20%)	$ 8,526,201	$ 9,053,895
Number of cystectomy patients in RGH 2016	(±20%)	$ 8,528,639	$ 9,051,457
Number of gynecology surgical patients in RDRH 2016	(±20%)	$ 8,560,288	$ 9,019,808
Probability of cystectomy readmission at RGH before intervention	0.1679 to 0.4235	$ 8,596,312	$ 9,026,536
Cost if NSQIP in 2017	(±20%)	$ 8,582,113	$ 8,997,983
Unit cost of urology UTI	$54,063 to $65,386	$ 8,589,185	$ 8,990,911
Unit cost of gynecology UTI	$15,103 to $19,855	$ 8,633,911	$ 8,946,184
Probability of cystectomy readmission at RGH after intervention	0.0313 to 0.2066	$ 8,601,025	$ 8,896,089
Unit cost of cystectomy readmission	$8,206 to $15,839	$ 8,689,219	$ 8,890,877
Probability of orthopedic transfusion at RDRH after intervention	0.0202 to 0.0584	$ 8,686,321	$ 8,861,647
Probability of orthopedic blood transfusion before intervention	0.055 to 0.0924	$ 8,711,564	$ 8,883,219
Unit cost of blood transfusion	(±20%)	$ 8,756,727	$ 8,823,369

Variable	Range	Low Value	High Value
Number of orthopedic surgical patients in RDRH 2016	(±20%)	$ 8,756,727	$ 8,823,369
Number of orthopedic surgical patients in CGH 2016	(±20%)	$ 8,762,198	$ 8,817,898
Average cost per hospital day for cystectomy	$2,654 to $2,762	$ 8,770,338	$ 8,809,754
Costs of mini-bag per year	(±20%)	$ 8,782,097	$ 8,797,998
Costs of syringe per year	(±20%)	$ 8,787,305	$ 8,792,791

CRH: Chinook Regional Hospital; LOS: length of stay; QEII: Queen Elizabeth II Hospital; RDRH: Red Deer Regional Hospital; RGH: Rockyview General Hospital; SSI: surgical site infection; UAH: University of Alberta Hospital; UTI: urinary tract infection

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Author Contribution Statements

Nancy Zuck contributed to study design, data analysis and interpretation, and writing the qualitative portion of the report.

Thanh Nguyen contributed to study design, data analysis and interpretation, and writing the quantitative portion of the report, as well as combined qualitative and quantitative portions into the final version for publication.