The New Zealand Surgical Site Infection Improvement (SSII) Programme: a national quality improvement programme reducing orthopaedic surgical site infections

Arthur J Morris, Sally A Roberts, Nikki Grae, Richard Hamblin, Carl Shuker, Alan F Merry

ABSTRACT

AIMS: The New Zealand Surgical Site Infection Improvement (SSII) Programme was established in 2013 to reduce the incidence of surgical site infections (SSI) in publicly funded hip and knee arthroplasties in New Zealand hospitals.

METHODS: The programme pursued a three-pronged strategy:

1. Surveillance of SSI with a nationwide system
2. Promotion of consistent adherence to evidence-based practices proven to reduce SSI
3. Monitoring and publicly reporting changed practice and outcome data.

RESULTS: Between quarter 3 2013 and quarter 4 2016 there has been a nationwide increase in compliance with all process measures: correct timing for antibiotic prophylaxis; use of the recommended antibiotic in the recommended dose and alcohol-based skin antisepsis.

The SSI rate in hip and knee arthroplasties has shown a significant improvement. The nationwide median rate has fallen to 0.91% since June 2015, compared with 1.36% during the baseline period of April 2013 to March 2014 ($p<0.01$). This equates to approximately 55 fewer infections between August 2015 and June 2017, savings of NZD$2.2 million in avoided treatment and avoided disability-adjusted life years (DALYs) of NZD$5 million.

CONCLUSIONS: The introduction of a nationwide SSI reduction programme for hip and knee arthroplasties resulted in an increase in compliance across the country with best practice that was associated with a reduction in incidence of SSI since June 2015 from the baseline period of April 2013 to March 2014, sustained to June 2017.

Healthcare-associated infections (HAI) are associated with significant morbidity and mortality.[1,2] Surgical site infections (SSI) are the second most frequent type of HAI in European countries, the US and other similar high-income countries such as New Zealand.[3] Patients experiencing an SSI have longer stays in hospital, increased mortality and higher healthcare-related costs when compared to those without SSI.[4] Patients exposed to surgery carry twice the overall HAI burden compared to those

NZMJ 27 July 2018, Vol 131 No 1479
ISSN 1175-8716

www.nzma.org.nz/journal

patients not exposed to surgery; almost half attributable to SSI.[5] Local Auckland data from the late 1990s estimated that the annual cost of HAI for surgical and medical admissions to all hospitals in New Zealand was NZD$137 million.[4] Active surveillance and reporting of HAI is associated with a significant reduction in HAI events.[6] Moreover, surveillance and reporting of SSI leads to a mean reduction in their incidence.[7–18] An independent cost-benefit analysis conducted in 2011 suggested a contemporary surveillance programme and dissemination of the results was highly likely to lead to significant reductions in SSI rates in New Zealand, and that a reduction in rates of approximately 8% a year was possible.[19]

Due to the evidence for significant patient benefit and reduced healthcare costs, a national SSI surveillance programme was established in 2013. As described previously in this journal, the New Zealand Surgical Site Infection Improvement Programme, known as the SSII Programme, was instituted by the Health Quality & Safety Commission (the Commission) with an initial focus on hip and knee arthroplasties, now expanded to cardiac procedures.[20] The programme adopted an evidence-based three-pronged approach to reduce the incidence of surgical site infections in New Zealand, consisting of surveillance of surgical site infections via a nationwide surveillance system and data warehouse called National Monitor; promotion of nationwide adherence to specific evidence-based practices proven to reduce the incidence of SSI; and monitoring and reporting of changed practice and its effects on outcomes.

This study set out to determine the magnitude of improvement, if any, since institution of the programme. We report results from July 2013 until June 2017.

Method

The purpose, background, structure and rationale for the NZ SSII Programme have been described previously in this journal.[20] Full details of the methods, data collection forms, definitions and interventions are available on the Commission's website.[21]

The SSII Programme is ongoing and has a three-pronged approach to reduce the incidence of SSI in New Zealand. In summary, these are:[20]

1. *Surveillance*: establishing a nationwide surveillance system and data warehouse called National Monitor, hosted by Canterbury DHB, initially targeting hip and knee arthroplasties, and expanded since 2015 to include selected cardiac surgery procedures;
2. *Practice change*: promoting consistent adherence to evidence-based practices proven to reduce the incidence of SSI; and,
3. *Monitoring changed practice and its effects*: measuring and providing feedback on the implementation of these best practices, and their effects on the rate of SSI. This includes an estimate of the value to the system, and to patients, due to effects on outcomes.

We briefly consider each of these strategies in turn.

Surveillance

SSI surveillance for publicly funded hip and knee arthroplasty in New Zealand hospitals utilises National Monitor, a data warehouse developed by ICNet, provider of infection prevention and control surveillance software to surveillance programmes in the UK, the US, Australia, Scotland and Wales.[22] Trialled with eight DHBs in a development phase in early 2013, National Monitor was rolled out to remaining DHBs in July 2013.[20]

Only DHB-funded procedures, performed in either the DHB or other facility on a DHB contract, are included. Privately funded procedures performed in private surgical hospitals are not included in the surveillance. The US Centers for Disease Control and Prevention's (CDC) National Healthcare Safety Network (NHSN) definitions for SSI are used.[20,23] These provide precise definitions of a surgical site infection and their classifications (superficial, deep and organ space) and make clear appropriate exclusions.[21,24]

Due to the availability of different systems in DHBs, some DHBs use an electronic surveillance system for case identification, but the majority of DHBs use either a manual or hybrid system containing both electronic and manual components. To ensure that all eligible procedures are included in the surveillance, multiple sources of data are reviewed, including patient management systems, operating theatre records and emergency theatre records. Potential SSI cases are identified by surveillance of readmissions within 30 and 90 days after any specified hip and knee arthroplasty procedures funded by the DHB (including those in a private setting). Data capture takes place via hospital patient management systems using New Zealand's unique patient identifier, the national health index (NHI) number, as well as review of microbiology results, and liaison with operating room and ward staff, infectious disease physicians and microbiologists. Some DHBs also have the ability to run reports identifying patients that have admissions longer than the average length of stay to further review for infection.

The NHI allows linkage of all encounters with a health provider, including inpatient, outpatient and community-based care as well as readmissions.

Patient records of all potential cases are reviewed to determine if NHSN SSI definitions are met. Bacteraemia cases, for example, are also reviewed to determine if cases meet SSI criteria. Precision in definition is essential to having a consistent dataset that can allow comparison over time. Cellulitis, for example, does not in itself count as an SSI, and SSIs following manipulation of the operative site (such as aspiration of a hematoma, for example) are excluded from the definition of SSIs, as the course of infection is no longer clear. In situations of uncertainty the SSII Programme clinical lead or infection prevention and control (IPC) nurse specialist seeks further information from the operating surgeon. SSIs resulting from procedures performed at other hospitals are communicated by IPC staff for appropriate attribution and learning for quality improvement.[24] The SSI minimum dataset is completed for procedures that fulfil the NHSN criteria for SSI and are uploaded onto the online form in National Monitor by the data transfer team member. SSI data are submitted by DHBs each quarter, and independent data checks are made by the national SSII Programme team for anomalies and/or incomplete information to increase comprehensiveness of the database. Any additional information needed is requested from IPC staff at DHBs.

Training on application of the NHSN definitions included formal training at programme outset, as well as ongoing regular case review sessions at regional meetings and direct support from project team members. DHB IPC staff work with multidisciplinary teams at their organisations to ensure SSI case review is thorough and in line with definitions.

The feedback portion of surveillance results is crucial to reducing SSI rates. Surveillance reports subsequently generated are disseminated widely, to the expert faculty group, heads of orthopaedic departments, IPC staff and senior leadership at all DHBs, and published on the Commission's website.

Data elements recorded within National Monitor and detailed information on definitions, data collection, validation and quality assurance protocols are available in the Orthopaedics Surgery Implementation Manual (http://www.hqsc.govt.nz/assets/Infection-Prevention/Surgical-Site-Infection-Surveillance/SSII-implementation-manual-Apr-2016.pdf).[25]

Practice change

A three-fold package of evidence-based interventions was implemented by the programme.

1. Administration of the right antibiotic in the right dose at the right time—evidence recommends ≥2g of cefazolin intravenously for routine antibiotic prophylaxis for hip and knee replacements (≥1.5g dose of cefuroxime is an acceptable alternative).[25] For primary procedures prophylaxis should be administered as a single dose within 60 minutes before the initial incision ("knife to skin") is made.[20] This is in line with the World Health Organization (WHO) Surgical Safety Checklist[26] item that checks if antibiotic prophylaxis has been given within the 60 minutes before knife to skin.
2. Skin antisepsis—ensuring that appropriate skin antisepsis before incision takes place: evidence recommends a preparation including 70% alcohol (eg, chlorhexidine gluconate/alcohol or povidone-iodine/alcohol solution).[27]
3. Clipping not shaving—ensuring that clipping of hair overlying surgical wound sites is standard practice, avoiding shaving.[20]

Supporting practice change

To improve staff uptake, engagement and awareness, we implemented multi-pronged approaches to engage healthcare workers and encourage their active participation in surveillance and quality improvement activities.

A clinician with expertise in IPC was appointed as the national clinical lead of the SSII Programme to facilitate progress of the programme and provide regular updates to various stakeholders. Expert faculty groups were formed; these are multi-disciplinary teams comprised of surgeons, anaesthetists, perioperative nurses and IPC nurses from across New Zealand. The clinical lead also participates in peer-to-peer conversations with doctors around the country, via grand rounds, for example, and by invitation.

We conducted a national campaign around SSI prevention, including provision of a series of webinars focused on surveillance methods, quality improvement interventions and engaging consumers. This campaign also developed and distributed posters, patient education brochures and videos.

A quality improvement advisor was designated as a resource for the national SSII Programme to work with individual DHBs to progress quality improvement activities. A 12-month Quality Improvement Facilitator course was offered to an IPC nurse from each DHB with a specific focus on SSI reduction. This course included face-to-face learning sessions, regional meetings and monthly webinars that provide training in quality-improvement methodologies and tools. Each participant conducted an SSI-related project at their DHB and learnings and ideas were shared among this group throughout the course.

Monitoring changed practice and its effects

The programme measures and reports the effects of compliance with the process measures below on one outcome measure: surgical site infections per 100 hip and knee procedures for orthopaedic surgery. Compliance with process measures is calculated from the National Monitor dataset, and collectively these measures are known as a Quality and Safety Marker (QSM)[28] and are publicly reported quarterly by DHB on the Commission's website.[29]

Process measures

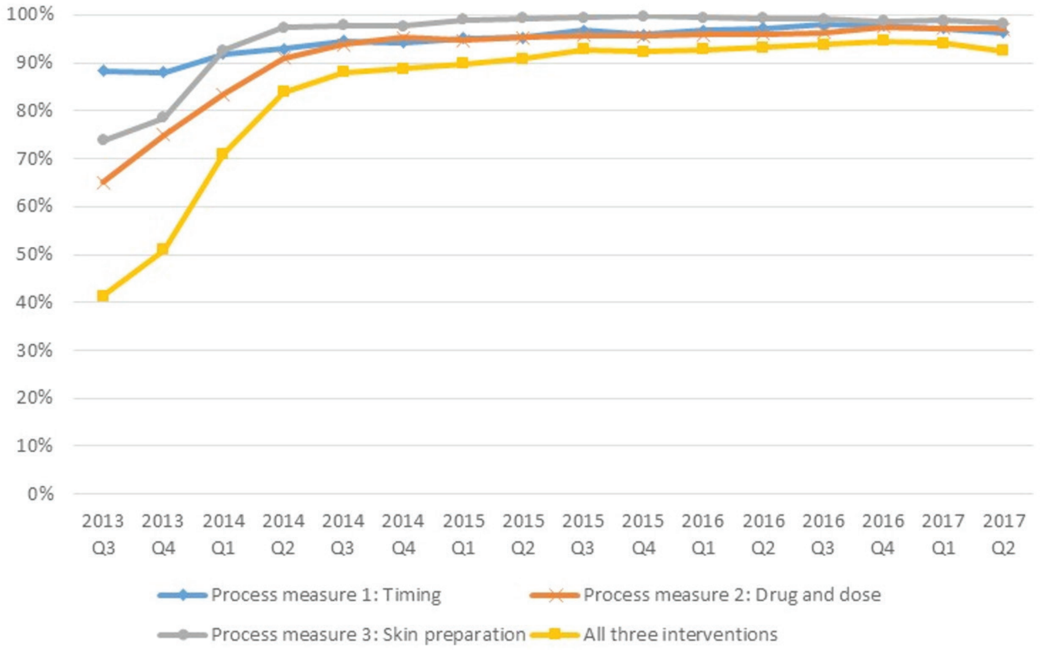
1. Correct timing for antibiotic prophylaxis—was the antibiotic given within 60 minutes before knife to skin in all primary procedures? The QSM target is 100%.
2. Right antibiotic in the right dose—was cefazolin ≥2g used? (Cefuroxime ≥1.5g is also acceptable). To allow for instances of beta-lactam allergy, the QSM threshold is 95%.
3. Appropriate skin antisepsis—has a 70% alcohol/chlorhexidine or 70% alcohol/povidone-iodine solution been used? This should always occur, so the QSM target is 100%. (Due to continual high compliance with 99% or more procedures meeting the threshold every surveillance quarter, this measure was retired in the last quarter of 2016).[30]

Outcome measure

The main outcome measure collected and monitored by the programme is proportion of SSI per 100 procedures for total hip and total knee arthroplasties, including revision procedures, where the SSI is defined as superficial, deep incisional or joint space, occurring in hospital (in hospital refers to an infection occurring during the initial admission or requiring readmission within 30 days (superficial) or within 90 days (deep and organ space) post-operation). Infection rates are monitored using statistical process control (SPC) and results presented as run charts, or run charts with limits, known as control charts.[31,32]

Estimates of the value of reducing SSI are part of the Commission's measurement of this programme. The additional cost of treating an SSI in hip and knee replacements has been estimated at between NZD$40,000 and NZD$112,000.[4,20,33] Quantification of the value of an avoided SSI to the patient is necessarily approximate. However, SSI have been estimated to cost the patient 0.5 disability-adjusted life years (DALYs).[34] (The DALY combines the likely shortening of life (years of life lost) with the loss of quality of life (years of life disabled) to measure the effect on individuals and populations of specific illnesses and harms.[35,36]) The current New Zealand estimate of the Value of a Statistical Life (VoSL) is $4 million (based on what New

Figure 1: Compliance with the three SSI prevention interventions for publicly funded hip and knee replacement procedures, by quarter (Q), 2013 to 2017.



Zealanders state they are willing to pay in improving roads to save a life). Using methodology from the Accident Compensation Corporation (ACC) to calculate the value of a year of healthy life (or avoided DALY) from this figure, each avoided DALY provides NZD$181,000 worth of value.[37] Hence each avoided surgical site infection provides approximately NZD$90,000 of value for each patient.

More detailed results covering these and other aspects of the programme are published in quarterly reports, the most recent covering the programme through to September 2017.[38]

Results

Change in practice

The QSM indicators show that for all three process measures there has been an increase in compliance between quarter 3 2013 and quarter 4 2016 (see Figure 1). Currently, more than 90% of hip and knee replacement patients receive all three interventions, up from 40% at the commencement of the programme.

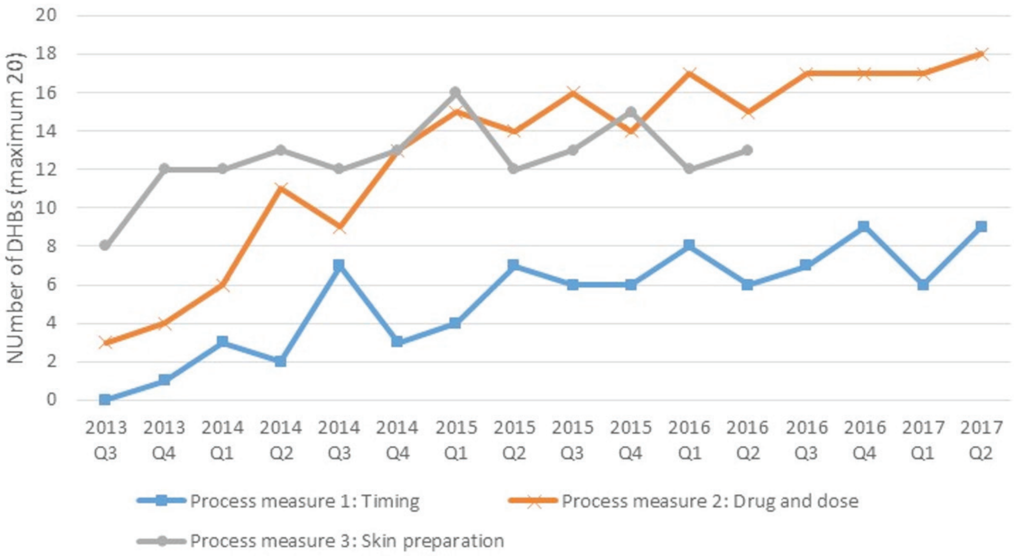
Documentation of the right antibiotic in the right dose was, at greater than 98%, high from programme outset, and the majority of improvement was due to improved compliance. While non-documentation of timing was higher initially at 8%, this fell significantly over the first five quarters to 2.5%. Failure to document the use of skin preparation fell in the first five quarters from 1.3% to 0.2%. From then improvement in compliance was due to increasing intervention adherence.

The number of DHBs achieving the nationally mandated thresholds for the three QSM process measures have increased over the period of the study (see Figure 2).

Change in outcome measure: reduction in SSI rate over time

The median surgical site infection rate has shown a significant improvement, dropping to 0.91% since June 2015, compared with 1.36% during the baseline period of April 2013 to March 2014. Figure 3 shows the change in SSI rate in "p chart" format. There is a shift in overall rate from the third quarter 2015, ie, from August 2015, identified by a run of six consecutive points below the initial median rate.[39,40] This special cause variation in the infection rate was sustained from June 2015 to March 2017. The likelihood of this occurring by chance is <0.01.

Figure 2: Number of DHBs (maximum 20) achieving nationally mandated thresholds for achievement of the three QSM process measures, by quarter, 2013 to 2017.



The majority—approximately 66%—of SSIs in the data were deep and organ space.

The two "spikes" in February and September 2016 are higher outliers, which indicate one-time occurrences of a special cause (more than three standard deviations from the mean). The reasons for these two special cause variations are difficult to ascertain, but examination of the September DHB-level data shows the number of SSI increased by one or two cases in seven DHBs compared with their baseline levels of zero or one case per month.

During the period of the study there was no reduction in the proportion of patients included in the analysis who were identified as morbidly obese (body mass index (BMI) ≥40) (see Figure 4).

Figure 3: Run chart showing proportion of hip and knee replacement surgeries which had a surgical site infection by month, New Zealand, 2013–16.

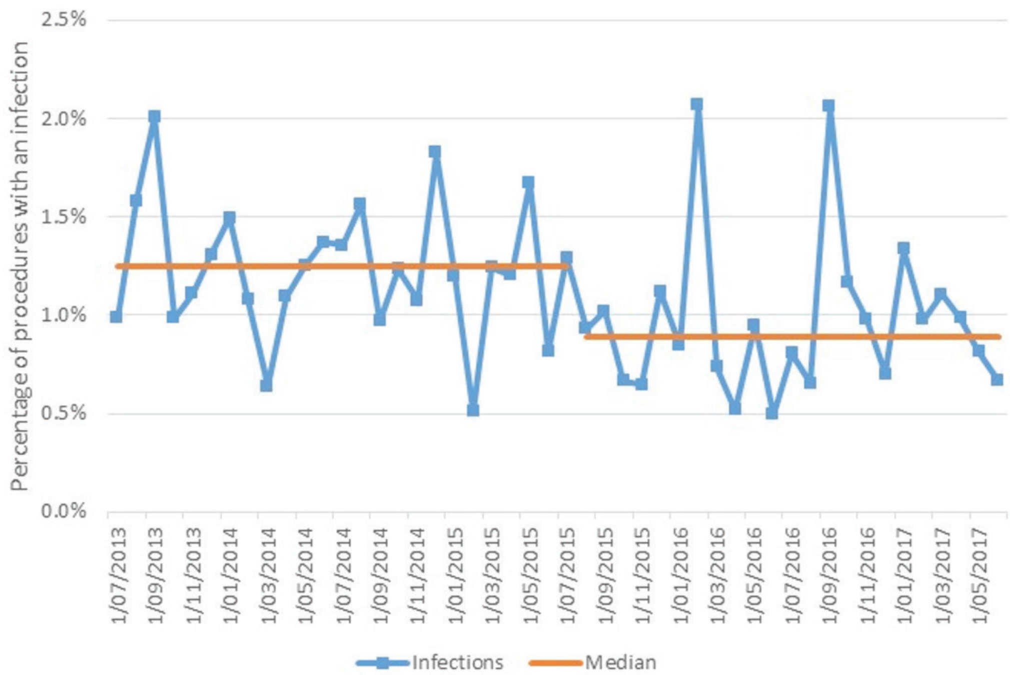
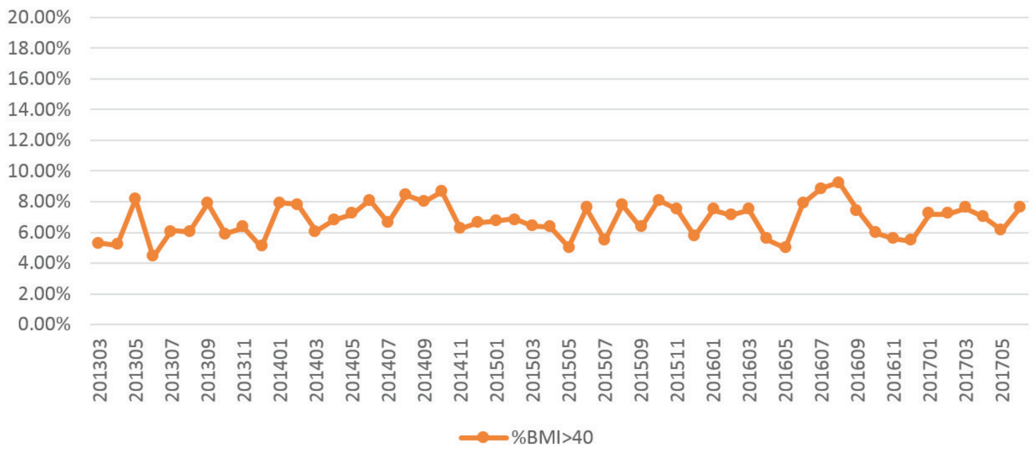


Figure 4: Proportion of patients with BMI ≥40, by quarter, March 2013–June 2017.



The reduction in the SSI rate to 0.91% equates to approximately 55 fewer infections between August 2015 and June 2017. There were 30 fewer observed SSI in the 2015/2016 financial year than we would expect from the baseline data (a 24% reduction), and 25 fewer observed SSI in the 2016/2017 financial year (a 19% reduction on baseline data). This reduction equates to, conservatively, savings of NZD$2.2 million in avoided treatment for the period,[4] and avoided DALYs of NZD$5 million.

To further test this apparent shift, a difference in proportion test on the SSI rate pre- and post- the shift point in August 2017 was conducted and showed a statistically significant reduction (odds ratio 0.78, 95% confidence interval 0.65–0.94, p=0.01) (see Table 1).

Discussion

The introduction of the SSII Programme has resulted in an increase in compliance with three key process measures, associated with a reduction in the proportion of hip and knee replacement surgeries that had an SSI from August 2015. This reduction has been sustained to June 2017. The median SSI rate has shown a significant improvement, dropping to 0.91% since June 2015, compared with 1.36% during the baseline period of April 2013 to March 2014 (p<0.01).

This result is in line with international findings. SSI surveillance involves the collection and provision of reliable data allowing clinicians to make meaningful comparisons between local incidence rates and national benchmarks, and to monitor changes in local rates over time. Strong international evidence from the Netherlands, Germany and France among others has shown that the monitoring and reporting of SSIs is associated with a mean reduction in their incidence.[7–18] As Krukowski and Bruce concluded in 2008, "it has been clear for almost three decades that the routine collection and dissemination of rates of surgical site infection results indirectly in a worthwhile reduction."[7] Surveillance serves to inform and prompt the needed actions, but these actions must be implemented for improvement to occur. The universal, standardised application of practices proven to reduce the incidence of SSIs is required to see nationwide improvement in infection rates. Before promotion of the interventions of the SSII Programme there had been inconsistent

Table 1: Surgical site infection rates before and after run chart shift point (August 2017).

	Number of SSI	Number of operations	% SSI	Odds ratio (95% confidence interval) Before =1.0		p value
Before	252	20,536	1.23%			
After	195	20,352	0.96%	0.78	(0.65-0.94)	0.01

implementation of clinical practices associated with a reduction in SSI throughout New Zealand—eliminating unjustified variation in practice is a key element of quality improvement.[41,42] The QSM indicators show that for all process measures there has been an increase in compliance with expected best practice to the extent that this is now nearly universal across public hospitals in New Zealand. Further, in excess of 90% of hip and knee replacement patients now receive all three interventions, an increase from 40% in the third quarter of 2013. The use of these best practice interventions has effectively been undertaken as a "bundle"[43] by New Zealand hospitals. The increasing proportions of local units meeting these performance thresholds demonstrates that this improving compliance with good practice was seen across the country as unwarranted variation decreased.

Estimates of value are always approximate but using conservative estimates from the literature suggests the reduced number of approximately 55 SSI cases in hip and knee arthroplasty in New Zealand between August 2015 and June 2017 has contributed to savings of NZD$2.2 million in avoided treatment. However, as Grimer and colleagues note, deep infection following an arthroplasty is not only expensive to manage, it is a "disaster for the patient".[44] Understanding the financial benefits of avoiding infection is important but can obscure the harm and trauma caused to the individual if this is not quantified as well. Estimates using VoSL and ACC methodologies of reduced SSI in New Zealand hip and knee arthroplasty patients yields an estimate of avoided DALYs of NZD$5 million between August 2015 and June 2017.

Limitations

Infection rates have been analysed using statistical process control (SPC) approaches. SPC is a statistical technique with origins in manufacturing and industry, developed from the work of Walter Shewhart and W Edwards Deming from the 1920s onwards.[45] These approaches are now widely used in healthcare,[39,40,46] quality improvement projects,[31,32,47] IPC[48,49] and SSI reduction.[50,51,52] SPC is a useful approach to monitoring the effects of improvement interventions and has the advantages in allowing quicker identification of trends and more timely decision making.[31,32] Subsidiary before-and-after analyses support the reduction in SSI rate (see Table 1).

Not all the reduction in the SSI rate may be due to the greatly improved compliance with best practice. Other changes in practice following dissemination and discussion of local SSI surveillance data may have occurred, such as improved patient temperature control, theatre clothing, control of theatre traffic, wound dressing policy, weight reduction before surgery and health practitioner hand hygiene, all of which have the potential to reduce SSI. The potential effects of changes in casemix and proportion of patients presenting with higher BMI over the period of the study was examined in light of recent findings of a statistically significant association between higher patient BMI and early periprosthetic joint infection following total hip and knee arthroplasty (BMI ≥40kg/m^2 odds ratio 5.62, 95% CI 2.25-14.0).[53] Figure 4 shows that there has been no decrease in the proportion of patients with BMI ≥40kg/m^2, indicating that the reduction in SSI is not a reflection of reduced risk.

The reasons for the two special cause variations are difficult to ascertain, but examination of the September DHB-level data shows the number of SSI increased by one or two cases in seven DHBs compared with their baseline levels of zero or one case per month. Closer examination of the SSIs in these outlier months does not point to any obvious reason for the two peaks. There do not appear to be more high-risk patients in these months, and the relative proportions of the type of SSI (superficial, deep, organ space) are identical to the period as a whole. Revision procedures accounted for 8% of all procedures included in the analysis.

Strengths

The NHI linkage across all encounters with a health provider, including inpatient, outpatient and readmissions, has strengthened our ability to capture cases.

Where to next?

The data showing a 24% reduction in observed SSI in the 2015/2016 financial year, and the 19% reduction in the 2016/2017 financial year, compare favourably with the 2011 cost-benefit analysis finding that a reduction in rates of approximately 8% a year was possible.[19] This is an ongoing programme and the challenge now is to maintain these gains. New Zealand SSI rates are still double those seen in the UK and we need to consolidate and build on this initial success.[54] The most commonly isolated pathogen and cause of SSI globally and in New Zealand is *Staphylococcus aureus*,[55,56] accounting for about 30% of orthopaedic SSI identified in New Zealand patients, and coagulase-negative staphylococci about 13%.[57,58] The SSII Programme is currently working on nationwide implementation of a standardised anti-staphylococcal bundle derived from a Royal Australasian College of Surgeons (RACS) systematic review and meta-analysis[59] and endorsed by the Strategic Infection Prevention & Control Advisory Group (SIPCAG).[60]

The SSII Cardiac Programme has also observed opportunities to improve prophylaxis, particularly timing. *S. aureus* is also the common pathogen isolated and interventions to reduce *S. aureus* infections will also benefit cardiac patients. It is probable that the orthopaedic and cardiac findings on prophylaxis and skin preparations are occurring in other surgical specialties. Our hope is that, by showing how practice can change and result in better patient outcomes, other surgical teams will utilise the methods proven to work here to reduce the risk of SSI in their patients.

Conclusion

These data show that the introduction of a nationwide SSI reduction programme for primary hip and knee arthroplasties in New Zealand resulted in an increase in compliance across the country with expected best practice, that was associated with a reduction in incidence of SSI from a median of 1.36% during the baseline period of April 2013 to March 2014 to 0.91% since June 2015; a reduction sustained to June 2017.

Competing interests:

Richard Hamblin and Carl Shuker report affiliation with Health Quality & Safety Commission during the conduct of the study. Arthur Morris states that he is the Clinical Lead for the NZ Surgical Site Infection Improvement Programme. Sally Roberts is the National Clinical Lead for Health Quality and Safety Commission Infection Prevention and Control Programme. Alan Merry reports affiliation with Safer Sleep LLC, from null, outside the submitted work; and is Chair of Board of Health Quality and Safety Commission in New Zealand.

Acknowledgements:

We recognise the vital involvement of IPC staff in all DHBs who made the SSII Programme happen. Without their dedication and meticulous data collection, monitoring practice change and its impact on patient outcomes would not have been possible. We appreciate the support for the programme of the Infection Prevention and Control Nurses College of the New Zealand Nurses Association. We also acknowledge the important contributions of New Zealand surgeons and anaesthetists, and their teams, who have embraced the changes and interventions of the programme, as well as the local DHB quality, safety and risk staff for their support. Our gratitude also goes to the members of the expert faculty group for their expertise and time, and to the CEOs of New Zealand DHBs for their forward-thinking support for public reporting of performance.

Author information:

Arthur J Morris, Clinical Microbiologist, Auckland City Hospital, Auckland; Clinical Lead, NZ SSII Programme; Sally A Roberts, Clinical Microbiologist, Auckland City Hospital, Auckland; Clinical Lead, Health Quality & Safety Commission Infection Prevention and Control Programmes; Nikki Grae, Infection Prevention & Control Specialist, Infection Prevention & Control Programme, Health Quality & Safety Commission, Wellington; Richard Hamblin, Director, Health Quality Intelligence, Health Quality & Safety Commission, Wellington; Carl Shuker, Principal Advisor, Publications, Health Quality & Safety Commission, Wellington; Alan F Merry, Chair of the Board of the Health Quality & Safety Commission, Head of the School of Medicine and Specialist Anaesthetist, Auckland City Hospital, Auckland.

Corresponding author:

Alan F Merry, Anaesthesiology, The University of Auckland, Private Bag 92019, Auckland 1142. a.merry@auckland.ac.nz

URL:

http://www.nzma.org.nz/journal/read-the-journal/all-issues/2010-2019/2018/vol-131-no-147927-july-2018/7644

REFERENCES:

1. World Health Organisation (WHO). Report on the burden of endemic health care-associated infection worldwide. Geneva: WHO, 2011. http://apps.who.int/iris/handle/10665/80135
2. Astagneau P, L'Heriteau F, Daniel F, et al. Reducing surgical site infection incidence through a network: results from the French ISO-RAISIN surveillance system. J Hospital Infect. 2009 Jun; 72(2):127–34.
3. World Health Organisation (WHO). Global guidelines on the prevention of surgical site infections, Geneva: WHO, 2016. http://www.who.int/gpsc/ssi-guidelines/en/
4. Gow N, McGuinness C, Morris AJ, et al. Excess cost associated with primary hip and knee joint arthroplasty surgical site infections: a driver to support investment in quality improvement strategies to reduce infection rates. NZ Med J 2016; 129(1432):51–8.
5. Sax H, Uçkay I, Balmelli C, et al. Overall burden of healthcare-associated infections among surgical patients. Results of a national study. Ann Surg. 2011 Feb; 253(2):365–70.
6. Haley RW, Culver DH, White JW, et al. The efficacy of infection surveillance and control programs in preventing nosocomial infections in US hospitals. Am J Epidemiol 1985; 121(2):182–205.
7. Krukowski ZH, Bruce J. Commentary: Controversies in NICE guidance on surgical site infection. BMJ. 2008 Oct 28; 337:a2120.
8. Haley RW, Culver DH, White JW, et al. The efficacy of infection surveillance and control programs in preventing nosocomial infections in US hospitals. Am J Epidemiol. 1985 Feb; 121(2):182–205.
9. Olson MM, Lee JT Jr. Continuous, 10-year wound infection surveillance. Results, advantages, and unanswered questions. Arch Surg. 1990 Jun; 125(6):794–803.
10. Geubbels EL, Mintjes-de Groot AJ, van den Berg JM, de Boer AS. An operating surveillance system of surgical-site infections in The Netherlands: results of the PREZIES national surveillance network. Preventie van Ziekenhuisinfecties door Surveillance. Infect Control Hosp Epidemiol. 2000 May; 21(5):311–8.
11. Segers P, de Jong AP, Kloek JJ, Spanjaard L, de Mol BA. Risk control of surgical site infection after cardiothoracic surgery. J Hosp Infect. 2006 Apr; 62(4):437–45.
12. Geubbels EL, Nagelkerke NJ, Mintjes-De Groot AJ, et al. Reduced risk of surgical site infections through surveillance in a network. Int J Qual Health Care. 2006 Apr; 18(2):127–33.
13. Gastmeier P, Geffers C, Brandt C, Zuschneid I, Sohr D, Schwab F, et al. Effectiveness of a nationwide nosocomial infection surveillance system for reducing nosocomial infections. J Hospital Infect. 2006 Sep; 64(1):16–22.
14. Barwolff S, Sohr D, Geffers C, Brandt C, P VR, Halle H, et al. Reduction in surgical site infections after Caesarean delivery using surveillance. J Hosp Infect. 2006 Oct; 64(2):156–61.
15. Brandt C, Sohr D, Behnke M, et al. Reduction of surgical site infection rates associated with active surveillance. Infect Control Hosp Epidemiol. 2006 Dec; 27(12):1347–51.
16. Rioux C, Grandbastien B, Astagneau P. Impact of a six-year control programme on surgical site infections in France: results of the INCISO surveillance. J Hosp Infect. 2007 Jul; 66(3):217–23.
17. Manniën J. Evaluation of the surveillance of surgical site infections within the Dutch PREZIES network: Centre for Infectious Disease Control, National Institute for Public Health and the Environment, Bilthoven, The Netherlands. 2008.
18. Carlet J, Astagneau P, Brun-Buisson C, Coignard B, Salomon V, Tran B, et al. French national program for prevention of health-care-associated infections and antimicrobial resistance, 1992–2008: positive trends, but perseverance needed. Infect Control Hosp Epidemiol. 2009; 30(8).
19. Hefford M, Black M, Wyatt S. Cost benefit analysis of the proposed national surgical site infection surveillance and response programme. Sapere Research Group, 2011. http://www.hqsc.govt.nz/assets/Infection-Prevention/Surgical-Site-Infection-Surveillance/SSI-cost-benefit-analysis-May-2011.pdf
20. Morris AJ, Panting AL, Roberts SA, et al. A new surgical site infection improvement programme for New Zealand: early progress. N Z Med J. 2015 May 15; 128(1414):51–9.
21. Health Quality & Safety Commission. Surgical Site Infection Improvement Programme. Resources. http://www.hqsc.govt.nz/our-programmes/infection-prevention-and-control/projects/surgical-site-infection-improvement/resources/

22. Baxter International. ICNet. http://www.icnetplc.com/
23. Centres for Disease Control and Prevention. (2015). Procedure-associated Events. www.cdc.gov/nhsn/PDFs/pscManual/9pscSSIcurrent.pdf?agree=yes&next=Accept
24. Health Quality & Safety Commission. Surgical Site Infection Improvement Programme. Publications and resources relating to the Surgical Site Infection Improvement Programme. http://www.hqsc.govt.nz/our-programmes/infection-prevention-and-control/projects/surgical-site-infection-improvement/resources/
25. Health Quality & Safety Commission. Orthopaedics Surgery Implementation Manual. http://www.hqsc.govt.nz/assets/Infection-Prevention/Surgical-Site-Infection-Surveillance/SSII-implementation-manual-Apr-2016.pdf
26. Perry W, Civil I, Mitchell S, Shuker C, Merry AF. Reducing perioperative harm in New Zealand: the WHO Surgical Safety Checklist, briefings and debriefings, and venous thrombembolism prophylaxis. N Z Med J. 2015 Oct 30; 128(1424):54–67.
27. Health Quality & Safety Commission. Surgical Skin Antisepsis Preparation Intervention Guidelines. February 2014. http://www.hqsc.govt.nz/assets/Infection-Prevention/Surgical-Site-Infection-Surveillance/SSII-skin-antisepsis-preparation-intervention-guidelines-Feb-2014.pdf
28. Health Quality & Safety Commission. Quality and Safety Markers (QSMs) April–June 2017. Surgical site infection improvement. http://www.hqsc.govt.nz/our-programmes/health-quality-evaluation/projects/quality-and-safety-markers/qsms-april-june-2017/#[SSI]
29. Health Quality & Safety Commission. Quality & Safety Markers. http://www.hqsc.govt.nz/our-programmes/health-quality-evaluation/projects/quality-and-safety-markers/
30. Health Quality & Safety Commission. Quality and Safety Markers (QSMs) October–December 2016. Surgical site infection improvement. http://www.hqsc.govt.nz/our-programmes/health-quality-evaluation/projects/quality-and-safety-markers/qsms-october-december-2016/#[SSI]
31. Thor J, Lundberg J, Ask J, et al. Application of statistical process control in healthcare improvement: systematic review. Qual Saf Health Care. 2007 Oct; 16(5):387–99.
32. Benneyan JC, Lloyd RC, Plsek PE. Statistical process control as a tool for research and healthcare improvement. Qual Saf Health Care. 2003 Dec; 12(6):458–64.
33. Jenks PJ, Laurent M, McQuarry S, Watkins R. Clinical and economic burden of surgical site infection (SSI) and predicted financial consequences of elimination of SSI from an English hospital. J Hosp Infect. 2014 Jan; 86(1):24–33.
34. Cassini A, Plachouras D, Eckmanns T, et al. Burden of Six Healthcare-Associated Infections on European Population Health: Estimating Incidence-Based Disability-Adjusted Life Years through a Population Prevalence-Based Modelling Study. PLoS Med. 2016 Oct 18; 13(10):e1002150.
35. Health Quality & Safety Commission. A Window on the Quality of New Zealand's Health Care 2017. http://www.hqsc.govt.nz/our-programmes/health-quality-evaluation/publications-and-resources/publication/2921/
36. Ministry of Health. 2016. Health Loss in New Zealand 1990–2013: A report from the New Zealand Burden of Diseases, Injuries and Risk Factors Study. Wellington: Ministry of Health.
37. O'Dea D, Wren J. 2010. NZ Estimates of the total social and economic costs of "all injuries" and the six priority areas respectively, at June 2008 prices: technical report prepared for NZIPS Evaluation. ACC: Wellington.
38. Health Quality & Safety Commission. Surgical Site Infection Improvement Programme: National Orthopaedic Report 1 July-30 September 2017. http://www.hqsc.govt.nz/our-programmes/infection-prevention-and-control/publications-and-resources/publication/3238/
39. Perla RJ, Provost LP, Murray SK. The run chart: a simple analytical tool for learning from variation in healthcare processes, BMJ Qual Saf. 2011 Jan; 20(1):46–51.
40. Anhøj J, Olesen AV. Run charts revisited: a simulation study of run chart rules for detection of non-random variation in health care processes. PLoS One. 2014 Nov 25; 9(11):e113825.
41. Dartmouth Atlas of Health Care. Key Issues. http://www.dartmouthatlas.org/keyissues/
42. Health Quality & Safety Commission. Atlas of Healthcare Variation.

http://www.hqsc.govt.nz/our-programmes/health-quality-evaluation/projects/atlas-of-health-care-variation/

43. Merry AF, Hamblin R. Partnership and rigor in improving patient care. N Z Med J. 2015 Sep 4; 128(1421):7–10.

44. Grimer R, Ludman L. Further opinion. Comment on: Willis-Owen CA, Konyves A, Martin DK. Factors affecting the incidence of infection in hip and knee replacement: an analysis of 5277 cases. J Bone Joint Surg Br. 2010 Aug; 92(8):1128–33.

45. Shewhart WA. Statistical method from the viewpoint of quality control. Mineola, NY: Courier Dover, 1986; 155.

46. Benneyan JC. Use and interpretation of statistical quality control charts. Int J Qual Health Care 1998; 10:69–73.

47. Carey R, Lloyd R. Measuring Quality Improvement in Healthcare: A Guide to Statistical Process Control Applications. ASQ Press, Milwaukee, WI, 2001.

48. Benneyan JC. Statistical quality control methods in infection control and hospital epidemiology, part I: Introduction and basic theory. Infect Control Hosp Epidemiol 1998; 19:194–214.

49. Curran E, Harper P, Loveday H, et al. Results of a multicentre randomised controlled trial of statistical process control charts and structured diagnostic tools to reduce ward-acquired meticillin-resistant Staphylococcus aureus: the CHART Project. J Hosp Infect 2008; 70:127–35.

50. Baker AW, Haridy S, Salem J, et al. Performance of statistical process control methods for regional surgical site infection surveillance: a 10-year multicentre pilot study. BMJ Qual Saf. 2017 Nov 24. pii: bmjqs-2017-006474. doi: 10.1136/bmjqs-2017-006474. [Epub ahead of print]

51. Dyrkorn OA, Kristoffersen M, Walberg M. Reducing postcaesarean surgical wound infection rate: an improvement project in a Norwegian maternity clinic. BMJ Qual Saf 2012; 21:206–10.

52. Ng WK, Awad N. Performance improvement initiative: prevention of surgical site infection (SSI). BMJ Qual Improv Rep. 2015 May 12; 4(1). pii: u205401.w3279.

53. Jung P, Morris AJ, Zhu M, et al. BMI is a key risk factor for early periprosthetic joint infection following total hip and knee arthroplasty. N Z Med J. 2017 Sep 1; 130(1461):24–34.

54. Public Health England. Surveillance of surgical site infections in NHS hospitals in England, 2016 to 2017. Public Health England, December 2017. http://www.gov.uk/government/uploads/system/uploads/attachment_data/file/666465/SSI_annual_report_NHS_hospitals_2016-17.pdf

55. Saadatian-Elahi M, Teyssou R, Vanhems P. Staphylococcus aureus, the major pathogen in orthopaedic and cardiac surgical site infections: a literature review. Int J Surg. 2008 Jun; 6(3):238–45.

56. Cantlon CA, Stemper ME, Schwan WR, et al. Significant pathogens isolated from surgical site infections at a community hospital in the Midwest. Am J Infect Control. 2006 Oct; 34(8):526–9.

57. Discussion paper: Anti-staphylococcal bundle to reduce surgical site infections in orthopaedic and cardiac surgery. November 2016. http://www.hqsc.govt.nz/assets/Infection-Prevention/Surgical-Site-Infection-Surveillance/SSIIP-discussion-paper-anti-staph-bundle-to-reduce-SSIs-Nov-2016.pdf (accessed 24 March 2017).

58. Health Quality & Safety Commission. Infection Prevention & Control. Anti-staphylococcal bundle to reduce surgical site infections in orthopaedic and cardiac surgery Feedback summary of discussion paper and next steps. March 2017. http://www.hqsc.govt.nz/assets/Infection-Prevention/PR/SSIIP_anti_staph_bundle_to_reduce_SSIs_feedback_summary_and_next_steps.pdf

59. Royal Australasian College of Surgeons (RACS). Systematic Review of Surgical Site Infections in Cardiac and Orthopaedic Surgery. 12 August 2016. http://www.hqsc.govt.nz/assets/Infection-Prevention/PR/S_aureus_SSIIP_Systematic_review_Aug_2016_FINAL.pdf

60. Health Quality & Safety Commission. Infection Prevention & Control. Update on reducing Staphylococcus aureus related SSI collaborative. 25 Sep 2017. http://www.hqsc.govt.nz/our-programmes/infection-prevention-and-control/news-and-events/news/3063