ELECTRONIC MONITORING SYSTEMS FOR HAND HYGIENE COMPLIANCE IN BRITISH COLUMBIA

Evaluation of effectiveness and cost-effectiveness of electronic hand hygiene monitoring with aggregate feedback in British Columbia and budget impact.

HEALTH TECHNOLOGY ASSESSMENT REPORT

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List of Abbreviations

AMS	activity monitoring system
ARO	Antimicrobial Resistant Organisms
BC	British Columbia
BCCSSS	BC Clinical and Support Services Society
CADTH	Canadian Agency for Drugs and Technologies in Health
C. diff.	*Clostridium difficile*
Canada 4	Canadian 4 Moments of Hand Hygiene
CDI	Clostridium difficile infection
CEAC	Cost-effectiveness acceptability curve
CNISP	Canadian nosocomial infection surveillance program
CPO	Carbapenemase-producing organisms
EMS	electronic monitoring system
FHA	Fraser Health Authority
HAI	hospital-acquired infections
HCAI	health care-associated infections
HCP	health care providers
HHMT	hand hygiene monitoring technologies
HHO	hand hygiene opportunities
HTA	health technology assessment
HTR	Health Technology Review
ICER	Incremental cost-effectiveness ratio
IHA	Interior Health Authority
ISPOR	International Society for Pharmacoeconomics and Outcomes Research
MOH	Ministry of Health
MRSA	methicillin-resistant Staphylococcus aureus
NHA	Northern Health Authority
OR	Odds ratio
PHAC	Public Health Agency of Canada
PHC	Providence Health Care
PHSA	Interior Health Authority
PICNet	Provincial Infection Control Network of BC
PPV	positive predictive value
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RR	Relative ratio
VCH	Vancouver Coastal Health
VCHA	Vancouver Coastal Health Authority
VIHA	Vancouver Island Health Authority
WHO	World Health Organization
WHO 5	World Health Organization's 5 Moments of Hand Hygiene

Executive Summary

The purpose of this health technology assessment (HTA) is to summarize the available evidence on the effectiveness of electronic group hand hygiene (HH) monitoring systems (not individual HH monitor) and to analyze the cost-effectiveness and budget impact of implementing an electronic monitoring system (EMS) with aggregate feedback versus direct observation (DO) audit based on the Canadian 4 moments for HH, which is the current standard of practice in British Columbia (BC).

Due to several factors, the specific focus of this work is on the impact of EMS on methicillin-resistant Staphylococcus aureus (MRSA). MRSA is the most commonly reported health care acquired infection, with a more established association with HH practices in addition to having available local data allowing simulations, and is also on a rising trend in the province since 2011. Therefore, MRSA is a more reasonable focus for assessing the effect of implementing EMS.

Across Canada, the use of EMS was identified in Newfoundland and Labrador and Ontario; however, there are no identified written policies limiting or guiding the use of different systems, and therefore seems to be a choice that is made by the individual hospital administrative teams. Two group monitoring systems were identified: DebMed and Gojo Smartlink.

The key factors leading to the implementation of EMS in Ontario were identified to be due to difficulties in capturing real-time data for compliance, the perception that the DO method was biased and flawed, which therefore was generating unrealistic high compliance rates, alongside the criteria for the health care team to have an open mind to challenge the

validity of the DO method and criticize their own practices. Compliance rates measured by EMS were significantly lower (i.e., worse) than those measured via DO. The most important challenge for the implementation of EMS is the added cost, as the Province continues to mandate DO for reporting compliance.

The perceived benefits of implementing an EMS are that it continuously measures HH compliance, is less subject to biases and flaws, and interferes less with workflow and patient care. It may also reduce auditor turnover, free up human resources for quality improvement initiatives, and provide a more accurate and transparent compliance rate to the public. The negative aspects of implementing an EMS was reported to be the lack of confidence in the methods which the monitors use to capture and calculate compliance, the fact that EMS cannot provide qualitative data to support quality improvement initiatives such as identifying in which moments or situations HH opportunities are missed, and also not being able to provide immediate education to staff in the event of a missed HHO. Immediate education is believed to be most effective in changing behaviour.

Patients are quite aware of the HH practices during their admissions and observe inconsistencies among health care providers. However, they interfere very little in HH practices, either due to their great trust in the health care providers' judgment or for fear of disturbing their relationship with their providers and suffering consequences on their care provision. When a health care infection is acquired, the impact on those patients' lives is substantial and enduring with great social and mental impact (fear, anxiety, depression, social isolation) that last long after the treatment of the infection per se.

DebMed EMS has validation studies against direct observation and video surveillance using the WHO 5 Moments and Canada 4 Moments to measure HH opportunities. Gojo EMS has one validation study for two moments (room entry and exit) performed in single occupancy rooms. No studies are available for Gojo comparing with Canada 4 Moments or adjusting for multiple-bed rooms.

The available evidence about EMS is limited to interrupted time series that did not apply the appropriate trend analysis to the design (four conference proceedings and two published studies). Five studies using DebMed reported a wide range in the positive impact on HH compliance (5% to 20% absolute improvement in compliance rates). One study using Gojo examined the effect on compliance with or without additional interventions (EMS in both arms) and despite not using the appropriate trend analysis, visual compliance improved in both groups. Overall multiple co-interventions were reported in three studies, so the effect size on compliance improvement cannot be solely attributed to periodic feedback with the EMS data. Before-and-after MRSA infection rates were reported in four studies using DebMed systems; in all of them, as compliance increased, infections rates decreased. However, only one study performed a correlation analysis and reported a confirmation of a negative correlation ($r=-0.373$.) between MRSA infection rate and HH compliance. No cost-effectiveness studies of the EMS were found.

In a cost-consequence analysis tailored for BC, the best available evidence suggests that the addition of EMS to the current audit process for monitoring HH compliance will increase the overall cost; therefore, costs avoided with MRSA treatment and reduced DO are unlikely to outweigh the total cost of implementing EMS at the current prices. The cost estimates were most

sensitive to the effect of improving compliance, the price of the EMS, the cost of MRSA cases (infections and colonizations), and especially the effect of improved compliance in reducing infections, which have not yet been rigorously studied in the medical literature. The scenarios where EMS potentially looks more efficient entail a dramatic price reduction ($[redacted] per bed per year), or a considerably higher cost of treating MRSA cases than the costs published in the literature.

Under the status quo, BC will spend approximately $1 million per year to perform direct observations in both acute and residential care facilities. At current prices, the implementation of EMS would raise the cost of monitoring HH to $8.3 million per year in the initial two years and $7.4 million in subsequent years. According to the available published evidence, the additional cost of monitoring HH by EMS at current prices is not offset by costs avoided from a reduction in either MRSA cases (approximately $297,000 per year) or less direct observation audits (approximately $718,300 per year after phase-in period).

If the included MRSA costs in the sensitivity analysis (Alberta costs) are proven accurate, and a significant (75%) price reduction is negotiated, the EMS could avoid costs in acute care settings (− $18.5 million) but would still incur incremental costs in residential care ($929,000) over 10 years, and there is a moderate chance (50-60%) to offset the investment across the BC health care system to change the standard of auditing and reporting compliance.

There is a considerable degree of uncertainty in the model, in large part because the effectiveness estimates were generated from observational studies. Simultaneous adoption and empirical evaluation of the technology in realistic settings with appropriate study designs and statistical analysis are highly recommended and can help explore the benefits of the technology

and reduce the uncertainty. Perhaps starting in selected areas (compliance and infection rates outliers) to optimize research resources.

It is important to note that this cost-consequence analysis included only MRSA cases because of the lack of quality evidence of the effect of the improvement in compliance on other types of infections from EMS studies (or in general). However, it seems plausible that improved compliance to HH will improve other infection rates beyond MRSA, though it was not feasible to evaluate the spillover effects within this analysis. The model also does not incorporate the effects of additional quality improvement interventions the health authorities might choose to implement (education programs, targeted audits, awareness campaigns, etc.), if the feedback with the EMS data alone (expected to show drastically lower compliance) does not motivate change in behaviour. It is difficult to predict and measure the effect of future interventions that might arise, given that health authorities may tailor them according to their teams' capacity, behaviour and other polices in place.

Chapter 1 Background and Problem

1.1 Purpose of this health technology assessment

The purpose of this health technology assessment (HTA) is to summarize the available evidence on the effectiveness of electronic group HH monitoring systems and to analyze the cost-effectiveness and budget impact of implementing an electronic monitoring system (EMS) with aggregate feedback versus direct observation (DO) audit, which is the current standard of practice in British Columbia (BC).

This report includes evidence on the efficacy and cost-effectiveness of implementing an EMS compared with conducting DO audits, and a cost-effectiveness analysis and budget impact analysis of potential cost reduction associated with fewer DO audits if an EMS is implemented in BC. It also includes a summary of key stakeholder perspectives about EMS, and what they consider positive and negative factors for the implementation of an EMS. Patient experiences with the current HH practices and health care-associated infections (HCAI) from published literature are also reported, as are patient interviews and stakeholder reports.

The specific focus of this work is on the impact of EMS on methicillin-resistant *Staphylococcus aureus* (MRSA). MRSA is one of the most commonly reported infections in BC and Canada. There is some evidence showing that an increase in HH compliance would decrease the MRSA infection rate. (1-6)

1.2 Policy question and research objectives

1.2.1 Primary policy question or decision problem to be answered by this HTA

Are EMS effective in improving HH compliance, reducing health care-associated infection rates, and decreasing costs with HH compliance measurement and monitoring? And if yes, is the EMS system cost-effective, and what would be the budget implications of implementing this technology in BC?

1.2.2 Primary research questions to be answered by this HTA

Background questions

- What are the most important HCAI in BC and what is their burden (rates, costs, consequences for the patients and health care system)?
- What are the patterns of care once those HCAI happen?
- How is HH compliance defined and measured in BC?

Questions on effectiveness and cost-effectiveness

- Is improved HH compliance known to decrease HCAI? And what is the effect size?
- What EMS are currently available in Canada and how do they operate?
- What is the evidence of the accuracy and validity of EMS that provide aggregate feedback in measuring HH compliance compared with DO audits?
- What is the evidence of the effectiveness and cost-effectiveness of EMS that provides aggregate feedback on improving HCAI rates, hand wash compliance, and costs with monitoring compared with DO audits?

- How cost-effective is the EMS from DebMed (if no other effective option) compared with DO audits in BC?

Questions on cost and budget impact

- What are the known costs for maintaining DO audit in BC (data from Ministry of Health, health authorities, Provincial Infection Control Network (PICNet), etc.)?
- What is the budget impact of implementing the EMS from DebMed (if no other effective option is available) in all acute and residential care facilities throughout BC compared with DO audits (the current standard)?

1.3 Background information

1.3.1 Burden of HCAI

The Public Health Agency of Canada (PHAC) monitors and reports the number of new cases of health care-associated infection annually. (7) *Clostridium difficile* (*C. diff.*), MRSA, vancomycin-resistant enterococci, and carbapenem-resistant gram negative bacilli are included in their report.

The Provincial Infection Control Network of BC (PICNet) maintains the reports of HCAI (also called hospital-acquired infections (HAI)) that include infections caused by C. *diff.*, MRSA, and Carbapenemase-producing organisms in BC. (8) *C. diff.* and MRSA infections were two of the most commonly reported HCAI in Canada and in BC, contributing to 96% of new HCAI cases reported in 2014 in Canada and 98.5% of new HCAI cases reported in 2015–16 in BC (Table 1).

Table 1. New HCAI cases reported in BC and Canada. (7, 9)

HCAI	new cases reported in BC (2015–16)	Percentage	new cases reported in Canada (2014)*	Percentage
CDI	2,893	45.6%	2,847	28.2%
MRSA colonization and infection	3,358	52.9%	7,083	67.8%
VRE	NR	NA	294	2.8%
CPO	94	1.5%	66	0.6%
CRE	NR	NA	147	1.4%
CRA	NR	NA	7	<0.1%

Note: CDI = *Clostridium difficile* infection; CPO = Carbapenemase-producing organisms; CRA = Carbapenem-resistant Acinetobacter; CRE = Carbapenem-resistant Enterobacteriaceae; HCAI = Health care-associated infections; MRSA = methicillin-resistant *Staphylococcus aureus*; VRE = vancomycin-resistant enterococci.
*Only 60 major hospitals across Canada reported HCAI numbers to PHAC; not all HCAI cases in Canada were accounted for in the report.

The *C. diff.* infection rates in acute care facilities have fallen from 6.6 per 10,000 patient days in 2011 to 4.4 per 10,000 patient days in 2014 across Canada. In BC, the *C. diff.* infection rate of new cases was similar to the Canadian average at 4.9 per 10,000 patient days in the third quarter of 2015/16, and shows a declining trend over the longer term (Table 2). (9, 10)

The Canadian MRSA infection rate has been declining in the last few years. It decreased from 3.64 per 10,000 patient days in 2008 to 2.89 per 10,000 patient days in 2014. (10) The colonization rates decreased from 8.52 to 7.27 per 10,000 patient days in 2009 to 2014. (7) In BC, the MRSA rate of new cases (infections and colonizations combined) in acute care facilities is at 4.9 per 10,000 patient days (Table 2) and shows an upward trend over the past five years. (9-11)

Table 2. Highlights of surveillance results in BC health care facilities, 2015/2016. (11)

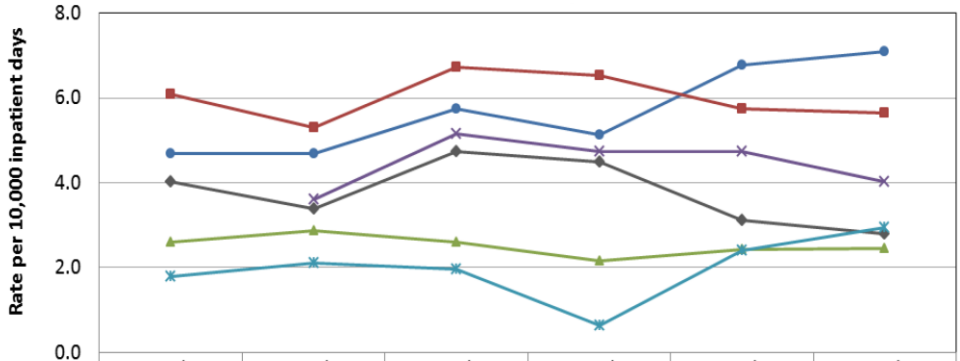
Indicators	2015/16	Compared to 2014/15	Long-term trend
***Clostridium difficile* infection (CDI)**[a]			(from 2009/10)
Total number of cases identified	2,893	⇧	⇩
Number of new CDI associated with the reporting facility	1,443	⇧	⇩
Provincial rate of new CDI associated with the reporting facility and 95% confidence interval[b]	4.9 (4.6-5.1)	⬆	⬇
Methicillin-resistant *Staphylococcus aureus* (MRSA)[a]			(from 2010/11)
Total number of cases newly identified	3,358	⇧	⇧
Number of new MRSA associated with the reporting facility	1,569	⇧	⇧
Provincial rate of new MRSA associated with the reporting facility and 95% confidence interval[b]	4.9 (4.7-5.2)	⇧	⬆
Carbapenemase-producing organisms (CPO)[a]			(from 2014/15[c])
Number of new cases	94	N/A	N/A
Hand Hygiene Compliance (HCC)			(from 2010/11)
Percent compliance in acute care facilities	83.2%	⬆	⬆
Percent compliance in residential care facilities	83.6%	⬆	N/A[d]

Notes: ⇧⇩ statistically non-significant or not applicable; ⬆⬇statistically significant
a. includes cases identified in acute care facilities only; b. per 10,000 inpatient days; c. for the period from July 18, 2014 to March 31, 2015; d. provincial public reporting started in 2014/15

The MRSA and *C. diff.* infection rates in the last six years within each BC health authority can be found in Figure 1 and

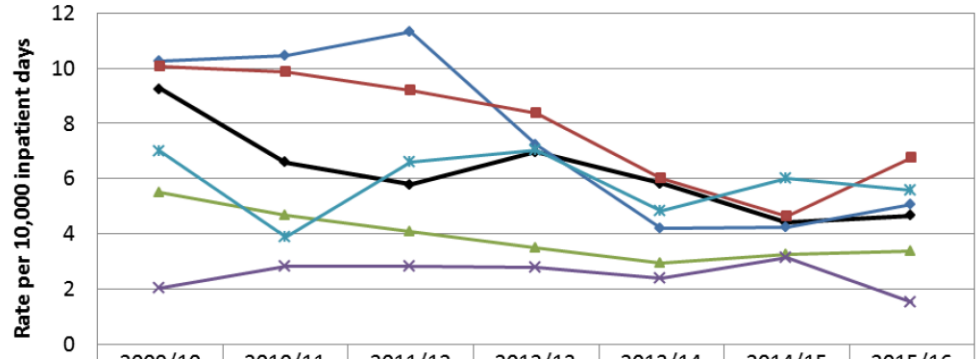
Figure 2. (9) These figures illustrate that the upward trend of MRSA in the province overall is driven primarily by increases at Fraser Health Authority and Provincial Health Services Authority. For *C. diff.* infection, the data suggest that the trend has been declining over five years at all health authorities, noting some specific year-to-year variation during this period.

Figure 1. Rate of newly identified MRSA colonization or infection in reporting acute care facilities within health authority. (9)



	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16
IHA	4.0	3.4	4.7	4.5	3.1	2.8
FHA	4.7	4.7	5.8	5.1	6.8	7.1
VCHA	6.1	5.3	6.7	6.5	5.7	5.6
VIHA	2.6	2.9	2.6	2.2	2.4	2.5
NHA		3.6	5.2	4.7	4.7	4.0
PHSA	1.8	2.1	2.0	0.6	2.4	2.9

Figure 2. Rate of new or relapse *C. diff.* infection in reporting acute care facilities within each BC health authority. (9)



	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16
IHA	9.2	6.6	5.8	7.0	5.8	4.4	4.7
FHA	10.3	10.5	11.3	7.2	4.2	4.3	5.1
VCHA	10.0	9.9	9.2	8.4	6.0	4.7	6.8
VIHA	5.5	4.7	4.1	3.5	2.9	3.3	3.4
NHA	2.1	2.8	2.8	2.8	2.4	3.1	1.5
PHSA	7.0	3.9	6.6	7.0	4.8	6.0	5.6

The mortality rate of MRSA blood infection in hospital patients was found to be 22.1% in a study that examined 10 European hospitals. (12) The all-cause mortality rate 30 days after a positive MRSA blood infection culture was 25.1% in Canada; however, not all MRSA occurs in the blood and is more common in the skin. The attributable mortality rate in 30 days after first positive *C. diff.* infection test was 4% in 2014, according to PHAC. (7) In BC, 2.8% of patients diagnosed with *C. diff.* infection in 2015/16 were admitted to the intensive care unit, 0.8% developed toxic megacolon, and 0.8% received a partial or total colectomy. (9)

1.3.2 Cost to treat HCAI

HCAI consume a substantial amount of resources in the health care system. Infected patients stay in the hospital an average of five days longer than other patients. (12) One study found that patients with MRSA infections require even longer stays, with an average of 26 days of isolation per patient in addition to other precautionary measures, treatment, and surveillance. (13) A U.S. study of 120 Veterans' hospitals found that extra length of stay attributable to *C. diff.* infection was 0.75 days for mild to moderate cases, and 4.11 days for severe infections. (14) A business case commissioned by PICNet in 2011 estimated that among the 17,918 cases of HCAI (including *C. diff*, MRSA, VRE, central line-associated blood stream infection, and surgical site infection) in BC acute care facilities in the 2007/08 fiscal year, treatment cost was approximately $274,212,248, based on cost data derived from Canadian literature and applied to the incidence and admission rates from the health authorities. (15) This study estimated the annual cost of HCAI in BC as $331,712,164 in 2014/2015 (Table 3) and

that a 5% decrease in all HCAI could avoid approximately $63 million in treatment costs over four years. (15)

Table 3. Estimated Costs of Health care-Associated Infections in BC by Fiscal Year. (15)

Health Care Associated Infection	2010/11	2011/12	2012/13	2013/14	2014/15	5-Year Total
Clostridium difficile	$4,623,769	$4,762,483	$4,905,357	$5,052,518	$5,204,093	$24,548,220
Methicillin-resistant Staphylococcus aureus / Vancomycin-resistant Enterococci	$50,460,446	$51,974,259	$53,533,487	$55,139,492	$56,793,676	$267,901,360
Blood Stream Infection	$115,236,392	$118,693,483	$122,254,288	$125,921,917	$129,699,574	$611,805,654
Surgical Site Infection	$124,401,354	$128,133,395	$131,977,396	$135,936,718	$140,014,820	$660,463,683
Total Cost of HAI	**$294,721,961**	**$303,563,620**	**$312,670,528**	**$322,050,644**	**$331,712,164**	**$1,564,718,917**

1.3.3 Risk factors, diagnosis, and treatment of *C. diff* infection

C. diff. infection is caused when the bacteria enters the body through the mouth and grows in the bowel, producing toxins and causing diarrhea. Patients with the highest risk are those who do not have enough "good" bacteria in their digestive tract, which typically includes patients with other underlying diseases, patients with weakened immune systems, those patients who have had long-term stays at either acute or residential care units, patients who are aged 65 years or more, and patients who have previously used antibiotics. (16) A 2013 review suggested that prolonged antimicrobial therapy, underlying comorbidity, and exposure to health care environment and personnel were three of the top risk factors for both newly acquired and relapse of *C. diff.* infection. (17) Research has shown that *C. diff.* spores can survive on surfaces for months, so proper antimicrobial stewardship and environmental disinfection may also play an important role in preventing *C. diff.* infection. (18)

In BC, *C. diff.* infection is diagnosed when any of the following are confirmed:

- The presence of diarrhea (three liquid or loose stools within a 24-hour period)

- Idiopathic toxic megacolon plus laboratory confirmation of the presence of *C. diff.* toxin A and/or B
- Diagnosis of typical pseudomembranes on sigmoidoscopy or colonoscopy
- Histological/pathological diagnosis of *C. diff.* infection with or without diarrhea. (19-21)

Testing should only be performed on diarrheal stool. Repeated testing during the same episode of infection or testing for asymptomatic patients (to check for the eradication of infection) is not recommended, and is discouraged unless ileus due to *C. diff.* infection is suspected. Routine testing and treatment for asymptomatic carriers is not proven to be effective and is not recommended. (19-21)

Treatment is determined on an individual patient basis. Most moderate cases (low severity of symptoms) do not usually require antibiotic treatment, but in cases with severe symptom, antibiotics may be required. (16)

1.3.4 Prevalence, definition, and treatment for MRSA infections

MRSA is defined as *Staphylococcus aureus* bacteria that are resistant to antibiotics such as methicillin, penicillin, amoxicillin, or other antibiotics commonly used to treat *S. aureus* and other bacterial infections. *S. aureus* infection is relatively common (10–30 per 100,000 person year); however, only a proportion of these infections may be attributed to MRSA (7.4 per 100,000 person year). (22) MRSA is primarily spread through skin-to-skin contact, via other surfaces or objects that may be contaminated, or self-contamination due to existing open wounds on the patient's body. It is important to note that MRSA can be classified as either an

infection or colonization, where infection is the presence of signs and symptoms, while colonization is simply the presence or colonization of MRSA on the body. Hospitalized or long-term care patients with weakened immune systems or underlying comorbidities are at a higher risk of more severe MRSA infections. (23, 24)

In BC, the case definition for MRSA must meet the criteria of "laboratory identification of MRSA" (24). Patients must be admitted to the reporting facility for acute care, must be a new case of MRSA, either infection or colonization, as an inpatient in the reporting facility with no known history of MRSA in any BC acute care facilities. MRSA cases are further classified into five categories based on the date of MRSA identification and the patient's health care history in the last 12 months (24):

- Health care-associated with current admission to the reporting facility
- Health care-associated with previous encounter with the reporting facility
- Health care-associated with another health care facility
- Community-associated
- Unknown

The population under MRSA surveillance is inpatients admitted to acute care facilities in BC. MRSA cases in residential care facilities are not being reported to PICNet at this time.

MRSA infection can be diagnosed by laboratory identification by any of the following:

a) Any *S. aureus* culture from any specimen that tests oxacillin-resistant by standard susceptibility testing methods

b) A positive result for penicillin binding protein 2a, by molecular testing for mecA

c) Positive results of specimens tested by other validated polymerase chain reaction tests for MRSA. (24)

MRSA skin infection does not usually require antibiotic treatment. More severe MRSA infections, such as bloodstream infections or lung infections, can be treated with vancomycin or other similar antibiotics. (23)

Contact precaution, including good HH practice, is at the forefront of MRSA prevention. (25) It may also be beneficial to instruct patients to remind health care providers (HCP) that MRSA precautions should be taken. (23)

Interviewed front-line HCP also stated that patients are currently screened by a nasal and/or rectal swab for HCAI upon hospital admission or transfer from other health care facilities. In the event of an outbreak, patients in proximity to or in contact with an infected patient will undergo further tests with the help of the infection control practitioners on the team.

1.3.5 Infection prevention and hand hygiene practice

In the nineteenth century, Dr. Ignaz Semmelweis proposed the theory that the hands of HCP could be the medium for the transmission of infection. (26) This is now an accepted scientific fact. (27, 28) Multiple national and regional studies have been published showing that improved HH practices might be associated with lowering health care-associated infection rates. (2-6) However, none of these studies use EMS, and since all the studies examined the implementation of multiple quality improvement interventions, in which improving HH was only one component, the decline in HCAI cannot be solely attributed to the improvement of HH

compliance. Pittet 2000's landmark study showed that an increase in HH compliance due to a HH promotion program was associated with a decrease in MRSA infection. (1)

Antibiotics are effective in treating *C. diff.* and MRSA infections. However, since bacteria may develop new resistance to current effective treatments, and only a few antibiotics (such as vancomycin) remain effective on drug-resistant strains, preventive measures play an important role in the complex model of infection prevention programs. Given that *C. diff.* and MRSA infections are two of the most common HCAI in Canada (9), and their incidence rates are reported by the provincial surveillance program every year, they can serve as reasonable indicators of the effectiveness of any component of an infection control program, such as a new HH monitoring system.

That said, a recent systematic review showed that patients who had *C. diff.* colonization at admission had a much higher risk of developing *C. diff.* infection during their hospital stay compared with patients without colonization at admission (risk ratio 5.86 95% CI 4.21-8.16, risk difference 18.4%, 21.8% vs 3.4%). (29) This evidence suggested that a significant proportion of patients who developed *C. diff.* infection in the hospital were colonized before admission. In this group of patients, improvement in HH practice are unlikely to influence the risk of developing *C. diff.* infection. In addition, studies showed that alcohol rub was not effective in preventing the transfer of *C. diff.* spores from contaminated hands, while hand washing with soap significantly reduced the number of colony-forming units on contaminated hands. (30, 31) Therefore, the 2012 PHAC recommendation stated that hand washing should be performed with soap rather than alcohol rub to prevent the spread of *C. diff.* (27) An auditor can ensure that the HCP uses soap with proper hand washing technique; an EMS could neither

differentiate between using soap or alcohol nor determine if proper hand washing technique is used. (Please see section 1.3.7 for a detailed description of how an EMS operates). As such, *C. diff* is likely not the best condition for review with respect to EMS. In contrast, a landmark study, mentioned above, showed the impact of improvements in HH compliance on MRSA infection rate. (1) It would thus appear that MRSA infection rate is a more reasonable focus for assessing the effect of implementing EMS.

1.3.6 Hand hygiene compliance auditing and related issues

HH remains one of the top priorities in the prevention of HCAI in most developed countries. The World Health Organization (WHO) recommends that national infection prevention programs should include essential components such as adequate staff education and training, ensuring the availability of proper equipment and material for infection control, accurate surveillance of outbreaks, and regular monitoring of HH compliance and timely feedback as well as a quality assurance program with clear goals. (28, 32) HH compliance comprises many of these essential components, such as education and training, monitoring and feedback, and quality assurance programs. HH monitoring is not just a performance measurement. It is also believed that if HCP are made aware of their unit's performance, they may seek to increase their HH compliance. Therefore, HH monitoring can be viewed as part performance measurement and part intervention.

Accreditation Canada requires HH monitoring for all hospitals and other medical care facilities. (33) The standard used to measure HH compliance is DO. In DO, a trained auditor observes the HCP in a unit and records the number of HH opportunities and the number of

observed HH events. The current guideline for HH audit establishes the number of HH opportunities based on the Canadian Four Moments of HH (Canada 4), which is a modified version of the WHO 5 Moments: (28, 33)

- Before initial contact with the client or their environment
- Before a clean/aseptic procedure
- After body fluid exposure risk
- After touching a client or their environment

A HH event means that a health care worker cleans their hand by washing with soap or alcohol-hand sanitizer gel when a HH opportunity occurs. HH compliance is a simple ratio of the number of observed events and the number of opportunities that occurred during the observation.

$$\text{Hand Hygiene Compliance } (\%) = \frac{\text{Number of observed hand hygiene events}}{\text{Number of hand hygiene opportunities}} \times 100\%$$

The key to reliable data lies with accurate observation or estimation of HH opportunities (denominator) and an accurate detection of events (numerator).

The WHO recommends that a minimum of 200 observations is required per reporting cycle per site. PICNet's guideline for HH auditing in BC (34) is based on this recommendation. The BC guideline mostly follows the WHO recommendations for how auditors should audit:

- Record only those observations done during routine care, not during urgent/emergent situations (e.g., code blue, patient fall).

- When observing, stand near the point of care in a way that will not disturb care activities. The auditor may move to follow an HCP, but needs to respect patient privacy (e.g., being respectful to patient care delivery and not looking inside a drawn curtain).
- Spend the minimum mandated time per each audit session (20 minutes, + 10 minutes depending upon the level of activity in the care area).
- Observe several HCP simultaneously if the auditor is confident they can observe the complete sequence of events.
- Avoid observing an individual HCP more than six times during any one audit session.
- Attempt to achieve a representative HCP sample as possible in each care area and each audit session.

1.3.6.1 Current hand hygiene auditing process in BC

In BC, there are four different groups of auditors performing DO audits: self-auditors, infection control practitioners, dedicated auditors, and co-op students. Self-audits are conducted by employees, usually nurses or care aides, trained to audit their own units as part of their workload. Infection control practitioners may also conduct audits as part of their workload within the facility where they are housed or at a different facility; they do not directly work in the units under audit, so they are not described as self-auditors. Dedicated auditors can be either trained health care or non-health care professionals dedicated to conducting audits in units where they do not have a clinical or care delivery role. Like dedicated auditors, co-op students are trained auditors, usually with a background in the field of sciences, conducting audits in units where they have no clinical or care delivery role. The mode of audit is not

restricted to any one type of auditor, and each facility can choose the type of auditor most convenient and feasible to conduct mandated DO audits.

The identity of auditors is not usually concealed, and HCP can identify when they are being audited. Table 4 shows the proportion of the varying modes of audit within the different health authorities: Fraser Health Authority, Interior Health Authority, Northern Health Authority, Providence Health Care, Provincial Health Services Authority, Vancouver Coastal Health Authority, and Vancouver Island Health Authority. Modes of audit may vary between acute care facilities and residential care facilities. (35)

Table 4. Modes of audit within health authorities.

	IHA	FHA	VCH	PHC	PHSA	VIHA	NHA
Acute Care							
SA							
ICP							
CS							
DA							
Residential Care							
SA							
ICP							
CS							

Note: CS = co-op students; DA = dedicated auditors; FHA = Fraser Health Authority; ICP = infection control practitioner; IHA = Interior Health Authority; NHA = Northern Health Authority; PHC = Providence Health Care; PHSA = Provincial Health Services Authority; SA = self-auditors; VCHA = Vancouver Coastal Health Authority; VIHA = Vancouver Island Health Authority.

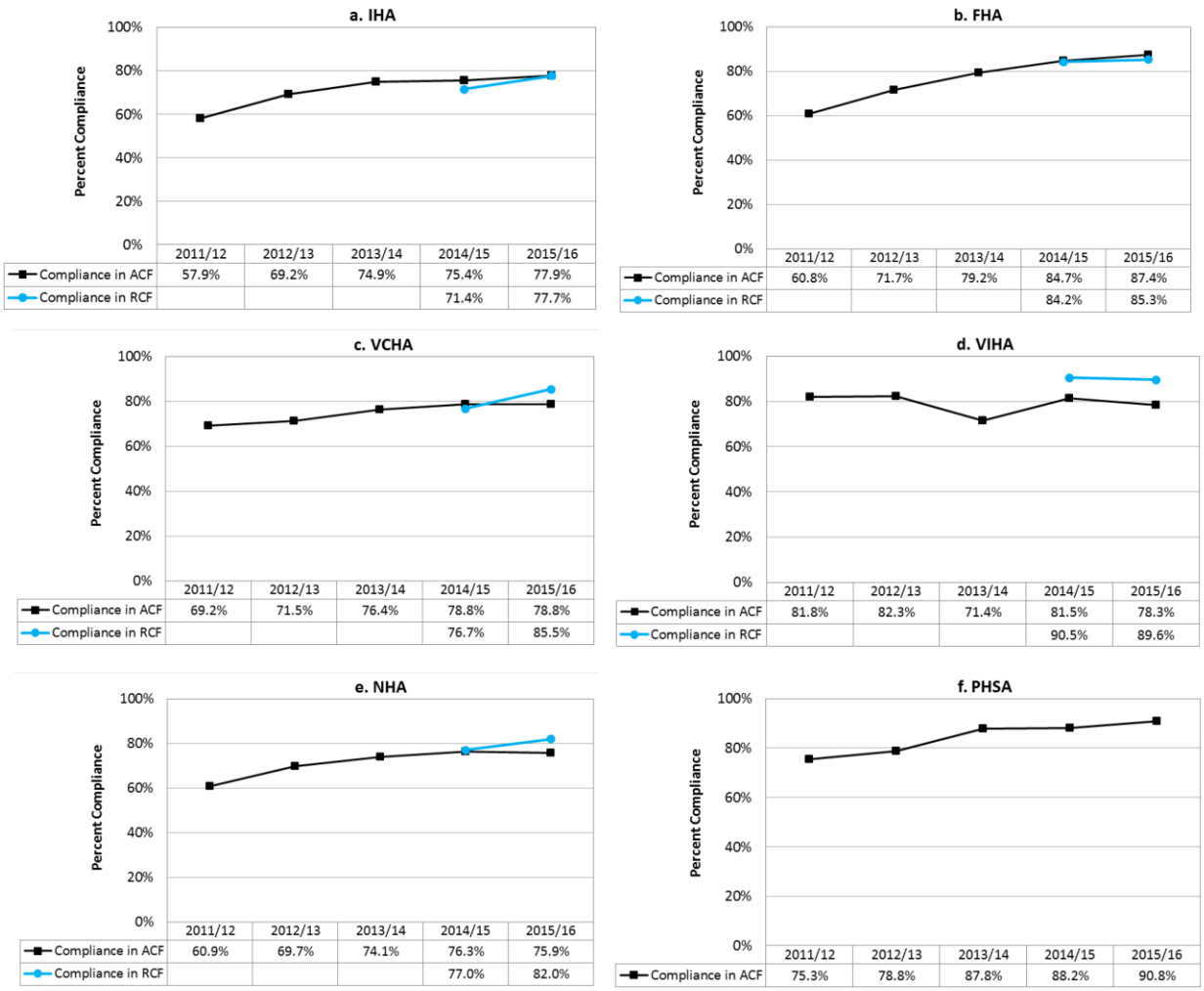
The number of observations per audit differs throughout the health authorities, averaging approximately [redacted] and [redacted] observations per hour in acute and residential care units, respectively (Table 5**Error! Reference source not found.**). (35) As mandated by the BC Ministry of Health, all health authorities report their compliance rate quarterly. A common decision by the health

authorities, as revealed in interviews with key infection control personnel, is to conduct audits per unit for every fiscal period (13 in total), and aggregate the reported compliance at the quarter mark. The reporting method also varies by health authority; some use software for data entry and others manually collect the data at each audit. PHC compliance data is aggregated into the VCHA compliance reports, but their mode of auditing and HH initiatives are entirely different and independent from VCHA's.

The HH compliance rates measured by DO are published by PICNet for each health authority. (36) Compliance ranges from 70% to 95% (Figure 3).

The hand hygiene compliance rate by DO in Alberta was 80% in 2016. (37) The hand hygiene compliance rate in Mount Sinai Hospital (Toronto) ranged from 83% to 90% measured by DO, however, the compliance measured by EMS was ranged from 21% to 39% in the same units during the same period of time. (38)

Figure 3. Hand hygiene compliance rate in acute care and residential care facilities within each BC health authorities. (9, 34)



Note: ACF: Acute care facility; RCF: Residential care facility. There are no residential care facilities in PHSA

Note: FHA = Fraser Health Authority; IHA = Interior Health Authority; NHA = Northern Health Authority; PHSA = Provincial Health Services Authority; VCHA = Vancouver Coastal Health Authority; VIHA = Vancouver Island Health Authority.
Note: Providence Health Care has an independence auditing process but the data from Providence was aggregated with Vancouver Coastal Health Authority.

A costing exercise carried out with the individual health authorities for this HTA revealed a wide range of resources employed to conduct HH auditing (Table 5**Error! Reference source not found.**). They varied depending on the volume of observations performed, type of professionals chosen as auditors, training requirements, travel requirements, and supporting software and equipment (software licences, iPads, etc.).

Total annual costs for the auditing process ranged by health authority, from approximately $[redacted] to $[redacted], noting of course this is a total and is thus in part dependent on the number of facilities in a given health authority. The main costs for the current auditing process are auditor and management time (managers perform audits in some health authorities). When distributing the individual health authority total costs by their volume of observation performed in the last year, the average cost per observation ranged from $[redacted] to $[redacted] in acute care facilities, and from $[redacted] to $[redacted] in residential care facilities. Thus, not only is there variation in the type of audit method by health authority, there is also considerable variation in the cost of these activities. Details from the costing exercise are shown in Appendix A.

Table 5. Yearly costs of measuring and reporting hand hygiene compliance by direct observation in BC. 566,013

Yearly Costs of Measuring and Reporting Hand Hygiene Compliance by direct observation in BC							
	IHA	FHA	VCH	# PHC	PHSA	VIHA	NHA
Overall							
Total costs	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Average cost per Observation performed	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
ACF Portion							
Total costs	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Average cost per Observation performed	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
RCF Portion							
Total costs	[redacted]	[redacted]	[redacted]	[redacted]	No RCF	[redacted]	[redacted]
Average cost per Observation performed	[redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]

Note: ACF = acute care facilities; FHA = Fraser Health Authority; IHA = Interior Health Authority; NHA = Northern Health Authority; PHC= Providence Health Care; PHSA = Provincial Health Services Authority; RCF = residential care facilities; VCH = Vancouver Coastal Health Authority (excluding Providence Health Care); VIHA = Vancouver Island Health Authority. NA = not available; health authority did not provide data, expert opinion, or validation of assumptions.

Note: This cost exercise was based on expert opinion of the estimated number of observations performed per hour, type of professionals employed in the process, and other resources. We then calculated auditors' time and applied the health authorities' salary schedule to estimate costs, except for PHC, who have some observational data.

PHC costing exercise mostly based on an internal observation study measuring resource utilization (auditor hours, number of observations, admin and management time, travel expenses)

1.3.6.2 Potential biases and limitation of DO

Using DO to assess HH compliance presents some limitations and biases. Visual auditing is labour intensive and subject to a variety of potential biases, likely generating inflated compliance rates that can give HCP a false sense of security and a belief that there is no need for improvement. A major limitation of DO is that auditors only observe a unit for a short period of time during a weekday and record only a snapshot of activities. It is estimated that this only captures about 0.5% to 1.7% of total HH opportunities during a regular work day. (39) Another limitation is that HCP may change their behaviour while under observation. This possible change in behaviour due to the awareness of being studied or watched is known as the Hawthorne effect. (40) The Hawthorne effect on HH compliance under DO has been estimated to be between 20 to 40%. (41) Srigley 2014 studied the Hawthorne effect by comparing the number of dispenser events per hour when the auditor was present to other times during the day. (42) They found that the average usage per dispenser was more than triple when auditors were on site (3.75 events per hour versus 1.07 event per hour, $p<0.0001$). Auditor training could also vary from facility to facility, and the form used by auditors might also vary tremendously. This creates variations in the standard of audit, which makes comparing compliance problematic. (43)

A further bias that could impact the result of DO audits is observer bias, which specifically impacts compliance measurement where the audits are conducted by staff working at the same facility or unit, known as self-auditing. It is defined as “when outcome assessments are systematically influenced by the assessors’ conscious or unconscious predispositions” to report higher compliance rates than are actually observed. (44) Although observer bias is

present in all modes of DO audits for HH, self-audited sites are subject to a higher potential bias effect compared with sites with independent auditors, and are estimated to inflate the reported compliance rates by approximately 20%. (44)

We acknowledge other potential factors may also influence the level of reported compliance. The combination of these known potential biases affects the level of reported compliance rates measured by DO. In this report, all mentions of the term *bias* in the discussion of HH compliance refer to the combination of effect of all potential biases.

In summary, HCAI is a significant burden to the BC health care system and is a preventable harm to patients in hospital. *C. diff.* infection and MRSA are the most commonly reported HCAI, with MRSA showing a rising trend. HH is still one of the most important tools for preventing HCAI; its monitoring is recommended by WHO, required for accreditation in Canada, and mandated by the Ministry of Health (MOH). DO is the current standard for auditing in BC, but modes of audit and resources employed to perform the observations vary greatly between and within health authorities. The intrinsic limitations of DO also influence its quality and reliability, creating a need to seek alternatives to monitor HH.

1.3.7 Definition of technologies under assessment

HH monitoring technologies are classified into three groups based on their mode of operation:

- EMS that provide reminders (any mechanism to alert HCP to wash their hands immediately when the monitor identifies an opportunity for washing) without feedback (data report);

- Electronic or video monitoring systems (EMS/VMS) that provide aggregate (group) feedback without reminders;
- EMS that provides individual feedback and reminders.

This HTA focuses on a non-video group EMS that provides aggregated feedback without reminders. This system monitors the HH activity within a unit without interfering with daily work flow. It provides feedback to the manager of the unit via email or online interface. The manager can then discuss the report with staff to help improve HH practices (more detail in section 1.3.8). Electronic HH monitoring technologies, when used as a complement to DO, may help mitigate the potential limitations and biases of DO, generate more accurate rates of HH compliance, expand the scope of current auditing coverage, and free up infection prevention personnel for other important duties such as staff education. (41, 45)

An EMS could potentially help address the limitations of DO in several ways:

- EMS monitors HH around the clock, capturing the HH opportunities and events missed by DO.
- EMS counts HH events in the background, without any visual indication to HCP that they are being monitored, which could minimize the Hawthorne effect.

EMS uses a standard measurement for HH, thereby minimizing variation in standard of audit.

However, determining the impact of EMS also has its own challenges. There is substantial complexity in implementing, evaluating, and comparing these devices against each other. (45) Common limitations include the lack of validation compared with compliance from DO or video surveillance, differences in the calculation of compliance, study designs that do not

allow for the assessment of Hawthorne effect, and lack of power to evaluate the effect on HCAI reduction. EMS is also not able to assess HH technique or whether a HH event occurs at the appropriate moment.

Compliance measurement and an accountability framework for ongoing monitoring of HH compliance rates by DO was the Auditor General of BC's first recommendation to the Ministry in a 2010 report. (46) It is important to note that fully withdrawing from DO is not an option, and EMS does not completely replace DO. The expectation is to decrease the need for audits and identify facilities or units in need of other interventions to improve compliance (i.e., visual audit with a qualitative focus to investigate non-compliance to specific moments or within specific teams or HCP classes, educational and training interventions, etc.). In BC, important implementation barriers to be considered include costs, the privacy of patients or HCP when using video monitoring systems, badge systems that single out individuals in the workplace, and systems that would require replacing the existing soap and alcohol dispensers. Within the current pricing structure for emerging systems, the resource impact to the provincial health care system is potentially significant. For these reasons, only the group monitoring system with aggregated feedback is being considered at this time. Eligible EMS must not interfere with the daily clinical operation of the unit. The sensors must operate without any change of routine or training of staff. The HH events should be detected automatically, without any input from staff other than using the soap and alcohol dispensers. The DebMed group monitoring systems and the Gojo Smartlink activity monitoring system (AMS) are the two systems that fit these requirements.

1.3.8 Mode of operation of eligible EMS

The DebMed group monitoring system contains wireless soap and hand sanitizer dispenser counters, a hub and modem, and a computer server that provides web-based reports in the form of a percentage. HH compliance is measured by the number of soap and alcohol units dispensed on a 24/7 basis. DebMed calculates the HH compliance index by dividing the number of events captured by dispenser sensors (numerator) by the number of expected HH opportunities (HHO) (denominator). HHO are estimated based on the algorithm developed during the HOW2 study (47) that takes into account patient acuity, number of patients, and nurse–patient ratio. The basic algorithm can be adjusted for individual units and updated at the end of each day using the nurse–patient ratio specific to each unit. This seems to allow for less opportunity to artificially inflate results, as compliance rates are calculated one day after the measured soap and alcohol use. The report can be provided daily, weekly, or monthly.

The Gojo Smartlink AMS contains activity counters, dispenser actuation counters, data receivers, a server, and a digital monitor. The activity counters are mounted on the doorway of each patient room, and detect the number of entries and exits. The number of entries and exits provide the denominator of the compliance equation, which only captures two of the four moments in the guidelines described above. The number of events counted in the dispensers provides the numerator of the compliance equation. HCP do not need to use a single dispenser as all dispensers within the unit are counted the same. However, dispenser events outside of the unit will not be captured and included in the numerator.

BC Ministry of Health and health authorities are especially interested in evaluating the DebMed EMS, for several reasons:

- The compliance rate is based on broader criteria of HH opportunity (WHO 5 moments), patient load, nurse–patient ratio rather than entry and exit from patient room (Gojo), and it captures 24/7 compliance rather than cross-sectional data.
- All the existing soap and alcohol dispensers in BC residential and acute care units are by DebMed.
- A pilot study is under way in Northern Health Authority to compare compliance rates measured by the DebMed system with the rates measured by the provincial HH compliance audit. It has been indicated that this study may be published within the next year; however, this may be subject to change.

The BC Ministry of Health, PICNet, and the provincial HH working group requested a coordinated, evidence-informed assessment of the costs, benefits, and feasibility of implementing an EMS that provides aggregate feedback in BC health authorities. The evaluation is not limited to the DebMed system, but will only consider systems that can offer equivalent measurements, monitoring, and reporting and have shown proof of validation. All health authorities are interested in assessing the merits of available technologies and, if supported by evidence, bringing preferred options forward to collectively negotiate better pricing.

1.4 Structure of report

This report contains the Canadian jurisdictional scan (Chapter 2), stakeholder perspectives (Chapters 3 and 4), clinical effectiveness review (Chapter 5), economic evaluation (Chapter 6) and budget impact analysis (Chapter 7).

Chapter 2 Jurisdictional Scan

Summary

Five Canadian jurisdictions responded to the request for information. Two Provinces informed the use of EMS. Newfoundland informed an ongoing trial, but only Ontario provided detailed information on the use of EMS.

Eight sites in Ontario were identified to have implemented an EMS: DebMed is used at Sunnybrook, Mount Sinai Hospital, the Hospital for Sick Children, St. Michael's Hospital, Toronto General Hospital, and Lakeridge Health; Gojo Smartlink is used at St. Joseph's Health Centre and Surrey Place Centre.

No written policy limiting or guiding the use of different systems was found. It seems that the choice of manufacturer and monitoring system is made by individual hospital administrative teams.

The driving factors leading to the implementation of EMS were difficulties in capturing real-time data for compliance and team readiness to challenge the DO method (high levels of compliance were perceived as unrealistic and DO perceived as biased and flawed).

Compliance rates measured by EMS were significantly lower (i.e., worse) than those measured via DO. The initial reaction of the health care teams was to doubt the new method, but after three to six months, they accepted the reality of low compliance rates and engaged in hand hygiene quality improvement initiatives.

The most important challenge for the implementation of EMS is the added cost, as the Province continues to mandate DO. The question then becomes whether the added value is worth the additional cost.

2.1 Objectives

To outline policies from across Canada regarding the use of EMS to measure HH compliance, the current state of technology use across Canada, and feasibility of implementation.

2.2 Methods

An environmental scan of the use of this technology in the Canadian provinces and territories was conducted by communicating with a contact person for each jurisdiction.

The Canadian Agency for Drugs and Technologies in Health (CADTH) liaison officers across Canada were contacted, with initial communication by the BC CADTH liaison officer. The intergovernmental relations network was also contacted, with communication done by policy

analysts from the BC Ministry of Health. A Snowball sampling scheme was used, with follow up with the responders as necessary. The manufacturers were also contacted by the UBC research team. Individual interviews with facilities that have implemented EMS were conducted by the UBC researchers and incorporated in this report. Interviews were focused on two main areas of interest:

1. What are the benefits, barriers, and challenges in successful implementation of EMS?
2. What has been the difference between the DO and EMS HH compliance measurements?

For the two competing manufacturers under consideration, DebMed and Gojo, the main questions of interest were:

1. Is the EMS designed for individual or group monitoring?
2. What method is used to measure HH events and opportunities?
3. Which moments of HH can be measured with the promoted EMS?
4. Are validation studies available?
5. Clarification on other technical considerations (e.g., environmental impact, operational challenges, costs, etc.).

2.3 Results

Newfoundland and Labrador, Nova Scotia, Ontario, Prince Edward Island, and Saskatchewan responded to the request for information. None of these provinces have a written policy guiding the use of the technology. Nova Scotia, Prince Edward Island, and Saskatchewan indicated that they currently do not have this technology and are not considering it at this time.

Newfoundland & Labrador has a pilot project on EMS, ongoing since 2014, motivated by the time and resource consumption required to perform DO and potential bias of the DO method. Their study focuses on whether the implementation of EMS will improve compliance and reduce HAI, and its perceived acceptability to front-line HCP. The preliminary results of this study are expected to be published later in 2017. It was not clear which EMS is being piloted.

Facilities in Ontario that have implemented an EMS include Sunnybrook, Mount Sinai Hospital, the Hospital for Sick Children, St. Michael's Hospital, Toronto General Hospital, and Lakeridge Health, who opted for DebMed system, and St. Joseph's Health Centre and Surrey Place Centre, who opted for the Gojo Smartlink. Five sites provided detailed information about their experiences with their EMS implementation.

Some hospitals started looking for alternatives to DO after predictive analyses of their compliance rate trends showed that they would quickly surpass the 90% compliance mark. The reason for the switch to EMS was the clear understanding that DO audits were, as one respondent put it, "extremely flawed" because of the Hawthorne effect and observer bias, resulting in two major problems. First, it was difficult to get buy-in from managers and HCP for improvement initiatives, and it started to undermine HCP's beliefs about the impact of HH on infection rates. Second, the cost burden and labour intensity of DO audits (training, auditors' time, turnover, etc.) was proving to be unsustainable. There is also a very high turnover of auditors as personal tension can arise between the auditors and staff. The overall inclination to implement an EMS seems to be due to a consensus that, despite the number of staff hours and resources invested in DO, the compliance rates were not valuable because of flaws in the method compromising reliability and validity of the results. The next logical step to these

leadership teams seemed to be implementing an EMS. Participating hospitals wanted to be at the forefront of testing the benefits and feasibility of this new technology. Selection of units to install EMS was based on the understanding that it was much harder to conduct DO audits in fast-paced units (units with a high volume of patients, contact with body fluids, and invasive procedures). These units reported a high level of HCP team willingness for quality improvement and readiness to incorporate new measurement systems.

The province of Ontario still mandates DO audits as the gold standard to measure and report compliance rates, so EMS data is not being used to produce the official reports; rather, it is used for quality improvement initiatives. For this reason, the cost of implementing EMS was added to the existing cost of conducting DO audits, making a hospital-wide implementation financially prohibitive. There were two main advantages identified in conducting DO simultaneously alongside EMS: the qualitative data derived from DO audits can be used to create quality improvement initiatives, and the education moments during audits leads to real changes in HH practices and the emergence of peer champions to advocate for improving HH compliance.

2.3.1 DebMed system

Some infection control experts believed that an EMS that monitors individual HCP is essentially more useful because it can include individual data, provide immediate feedback in response to a missed HH moment, and improve accountability. However, implementation of such systems has proven to be problematic. The interviewed experts stated that individualized monitoring systems (such as those using badges) were significantly more expensive than group monitors, and it was difficult to get HCP to wear the badges. Many HCP intentionally did not

wear their badges, and visitors and physicians conducting rounds travelled between units, giving an inaccurate number of HHO. There were also ethical concerns expressed by hospital leadership, since HCP could neither opt out nor provide consent to wear these badges. While individual badges may drive better accountability, group monitoring is a better option, taking all challenges into consideration. While no system is perfect in measuring the WHO 5 Moments of HH, DebMed was claimed by the infection control experts to be the closest measurement to real compliance measured by WHO 5 Moments, with the added benefit that it can be fitted to any brand of dispensers (e.g., Purell dispensers).

The most important barriers of implementation identified by users were cost and the need for contracts to ensure privacy and to include a definition of data ownership to avoid issues with unethical breaches of information. Another major challenge was the need to work with DebMed to ensure that volume/acuity metrics resulted in correct calculation of rates, which required several validation tests. Compliance rates measured by the EMS in Ontario showed a drastic difference from those measured by DO, which resulted in a surge of resistance and doubt by staff and front-line workers about the validity of the algorithm used to estimate expected HHO. Careful and consistent communication was required to re-engage staff in improving HH behaviour and increasing overall HH compliance which seemed to require three to six months to be noticed.

In one of the Ontario hospitals, the overall rate of compliance increased after the EMS was implemented, even in units where the technology was not used. It is not possible to compare the compliance rate from units that used EMS to other units due to the difference in baseline compliance rate, but the direction and magnitude of changes in compliance are similar

in both groups; this precludes the Hawthorne effect and observer bias as being the sole reasons for improved compliance rates.

In another facility, it was reported that no changes in behaviour were observed after the implementation of EMS, partly because the introduction of this system coincided with many other organizational factors such as changes in policy, management, personnel, etc. This facility has seen an overall decrease in reported HAI, but the leadership team is reluctant to attribute this improvement solely to an increase in HH compliance or the implementation of EMS. HAI rates are multifactorial, and the use of an EMS to report compliance still needs to be accompanied by quality improvement initiatives.

In some facilities, implementing an EMS enabled a change in the duties of auditors, from performance measurement to education of staff and improvements in hand wash techniques. The fact that the EMS does not report compliance rates for specific HCP groups was not seen as a disadvantage. Existing literature shows that the differences in compliance between HCP classes are well established. Overall, the facilities stated that implementation of EMS as a complement to qualitative DO audits reinforced positive behaviour, halted the “blame game,” and built a stronger team in their facilities. If facilities can decrease the workload of auditing by using EMS, more hospital resources could be re-directed to other quality improvement initiatives.

2.3.2 Gojo Smartlink EMS

In the two Ontario facilities that implemented the Gojo Smartlink EMS suggested the implementation was seamless because of the excellent clinical support provided by the manufacturer. As part of the implementation process, Gojo investigated the proportion of

expected HHO attributed to staff versus others (such as family or visitors), and established that the clear majority of HH opportunities were generated from staff contact with patients, which is a common measurement concern for some infection control experts when implementing monitors instead of DO. The contract between a given facility and the manufacturer includes a one-time fee for all hardware, installation, setup, repairs and replacements, maintenance, and troubleshooting. Additional costs include batteries that need to be changed every one to two years. It was noted by the users that measuring compliance with the EMS drastically changed the reported HH compliance rates. At first, this generated push-back from staff who attributed the low compliance numbers to other contributing factors, but after a few months, the staff stopped criticizing these numbers and began to implement specific changes in daily care delivery to better HH practices. Compliance rates reported with this EMS, as compared with DO audits, were found to be much more realistic by the leadership of the facilities.

One interviewed site provides specialized clinical services and is not required to report HH compliance via DO as mandated by the provincial government. They are required by Accreditation Canada to provide proof of HH monitoring, but with no specification on the type of monitoring, which allowed this facility to switch almost completely to an EMS. They do still conduct complementary DO audits every six months for validation and quality improvement purposes, which is less frequent than before the implementation of EMS.

According to the facility, the primary reason for the switch to EMS in this site was the low compliance rates observed, and the lack of staff to conduct direct visual audits which is extremely labour intensive. Many of the staff at this facility are not clinicians and therefore not trained in patient care, so there was a desire to change the culture, behaviour, and education

level around HH. In the preliminary trial for the EMS, staff was not notified about the implementation of EMS, and compliance rates were quite low. Upon closer assessment of the results, the leadership of the facility found some limitations with the data generated by the system, which identifies HH opportunities by entrance and exit from the patient room (or established patient zone). One of the sensors was placed in a heavy traffic area, where those passing by might not actually have any clinical interaction with the patients at the centre, resulting in a falsely high number of HH opportunities (inflating the denominator) and low compliance, which was not accurate. This problem was also found during weekends and nights, whereby the movement of cleaning staff recorded an inflated number of HH opportunities when no clinical activity was taking place and no HH events were registered.

The facility approached Gojo about these issues and was given support and instructions to manipulate certain variables on the EMS software which, though still not completely accurate, produced much more realistic compliance reports. The facility considered their experience successful and opted for another one-year contract. During the implementation of the EMS, the centre invested and reinforced informational campaigns and continuing education programs (co-interventions) even after seeing a gradual improvement in compliance. No data on the effect of EMS on the reduction of any HAIs is available for this site.

2.4 Summary

Within the respondent jurisdictions, there is no written policy limiting the coverage or guiding the use of EMS to measure HH compliance. The driving factors leading to the implementation of EMS were the difficulty in capturing real-time data for compliance in fast-paced care units (i.e., those with a high volume of patients, a high probability of contact with

body fluids, and invasive procedures) and units whose teams were ready and willing to incorporate different measurements for quality improvement. Moreover, the trends and high levels of compliance rates reported by DO was perceived as not reflecting true compliance and HH practices, due to potential measurement biases and flaws in the DO process.

Compliance rates measured by EMS were significantly different from those measured via DO, which resulted in many of the staff and HCP questioning the validity and reliability of EMS in detecting and measuring HH opportunities and events. Careful and consistent communication was needed to increase the staff's confidence in the credibility of the EMS. For example, in one facility it took three to six months for staff to stop questioning the validity of data and re-engage in efforts to change HH practices and increase compliance.

In hospitals where an EMS was implemented, trends of improvement were demonstrated to be similar, even extending to units where EMS was not implemented. There seems to be a consensus among the respondents of our jurisdictional review that DO should complement EMS to validate results, investigate specific issues with compliance, change behaviour, provide educational moments, increase awareness about the importance of HH, and provide information to targeted individuals.

A unanimous and important challenge for the implementation of EMS was cost, because it added to the existing costs of DO audit reporting, which was still mandatory for most hospitals. Introducing an EMS could allow for less frequent DO audits and in a more targeted way, which would allow facilities to re-allocate resources to other quality improvement activities rather than data collection.

Chapter 3 BC Context and Other Stakeholders Perspectives

Summary

The perceived benefits of implementing an EMS are that it continuously measures hand hygiene compliance, is less subject to biases and flaws, and interferes less with workflow and patient care. It may also reduce auditor turnover, free up human resources for quality improvement initiatives, and provide a more accurate and transparent compliance rate to the public.

The negative aspects of implementing an EMS fall into three main areas of concern: (1) lack of confidence in methods that include only room entry and exit in calculating the number of hand hygiene opportunities; (2) the EMS provides no qualitative data, such as identifying which moments are missed most often and in what situations, to support quality improvement initiatives; (3) the EMS cannot provide immediate education to staff in the event of a missed HHO. Immediate education is believed to be most effective in changing behaviour.

Cost added to the audit process is a major concern among all health authorities.

3.1 Objective

To understand the BC experience of HH DO auditing and monitoring technologies from the perspective of directors, managers, auditors, and HCP who have undergone a HH audit (i.e., auditees).

3.2 Methods

During March and April 2017, we conducted phone and email interviews with 28 key stakeholders:

- 16 directors and HH managers
- 7 HCP conducting HH audits, in four different categories or roles:
    - infection control practitioners
    - self-auditors (staff from the same facility being audited)
    - dedicated auditors
    - co-op students

- 3 auditees (nurses)
- 2 manufacturer representatives (DebMed and Gojo)

Key stakeholders were recruited through referral and snowball sampling, having been identified as having knowledge about available HH monitoring technologies (HHMT) and being qualified to answer the questions related to HH compliance and efficacy of existing systems. Sampling incorporated auditors' and auditees' perspectives from both rural and urban centres, as well as acute and residential care units. Personnel from all BC health authorities were interviewed. The participants included individuals with experience or knowledge of EMS and professionals working in the field of HHMT. Feedback was summarized, aggregated, and anonymized so no personally identifiable information was included.

A semi-structured interview guide was developed for the interviews, and certain questions were identified as appropriate for the specific role of each stakeholder. This guide evolved as questions were refined to reflect what had been learned from previous interviews.

3.3 Findings

3.3.1 Potential target population and implementation concerns

BC has 8,432 acute care beds accommodating more than 3 million inpatient days over the last four years, with an upward trend in some health authorities (Table 6 and Table 7). BC also has 9,455 residential care beds. (48) Occupancy data for residential care facilities is not available, but most residential care units operate at full capacity; vacancies are rare and are quickly filled.

Table 6. Bed capacity in acute and residential care by health authority.

	IHA	FHA	VCHA	PHSA	VIHA	NHA	Total
ACF	1,369	2,845	1,853	249	1,561	555	8,432
RCF	2,520	1,505	2,557	0	1,793	1,080	9,455

Note: ACF = acute care facilities; FHA = Fraser Health Authority; IHA = Interior Health Authority; NHA = Northern Health Authority; PHSA = Provincial Health Services Authority; RCF = residential care facilities; VCHA = Vancouver Coastal Health Authority; VIHA = Vancouver Island Health Authority.

Table 7. Inpatient days history in acute care facilities by health authority.

	IHA	FHA	VCHA	PHSA	VIHA	NHA	Total
2012/2013	490,192	1,058,007	649,935	91,920	552,172	183,943	3,026,169
2013/2014	498,970	1,070,889	666,382	93,078	571,018	188,174	3,088,511
2014/2015	544,906	1,094,219	659,261	87,601	577,378	190,608	3,153,973
2015/2016	494,954	1,127,448	676,337	81,393	598,271	191,554	3,169,957

Note: FHA = Fraser Health Authority; IHA = Interior Health Authority; NHA = Northern Health Authority; PHSA = Provincial Health Services Authority; VCHA = Vancouver Coastal Health Authority; VIHA = Vancouver Island Health Authority.

The health authorities interviewed generally reported that they would be open to trying out an EMS, but were hesitant to accept implementation in all units and facilities. Rather, they would prefer to have EMS in units that would benefit most from a reduction in DO audits (e.g., long-term residential units that require more time to conduct the mandated number of observations per audit), or units that experience frequent disease outbreaks. They felt that a prioritization exercise in the future would help to identify the most suitable units to receive EMS, due to both the high cost of implementation and the uncertainty associated with capturing the correct number of HH opportunities and events.

To supplement and validate the data from the EMS, they recommended doing complementary DO audits to obtain specific qualitative data about which moments are missed opportunities, what classes of HCP are non-compliant, and any extenuating circumstances specific to each unit and environment in question (e.g., higher flow of visitors, caregivers, etc.). However, if they were confident in the validity and efficacy of the EMS, and if it were proven to

reduce the costs associated with DO audits (primarily in the number of hours staff spend conducting and organizing audits), interviewees would not object to switching to the EMS system and reducing DO audits to the minimum required to validate EMS data and support quality and intervention initiatives.

Interviewees would also be more inclined to implement an EMS if the provincial government negotiated bulk purchasing and chose EMS manufacturers that sell other HH products such as soap and alcohol sanitizers (e.g., companies like Gojo and DebMed, who manufacture Purell and Deb HH products, respectively) to facilitate contract negotiations and decrease overall costs, as opposed to manufacturers that only provide monitors.

3.3.2 Expected benefits of EMS expressed by interviewees

3.3.2.1 Benefits for the health authorities

Hospital leaders are hopeful that an EMS can provide more reliable and valid results that are less subject to biases than DO and could allow a decrease in the frequency (and thus cost) of audits. Two main areas of potential cost avoidance identified were a decrease in staff hours and other resources employed in DO auditing and a reduction in the rates of HAI and the associated costs by increasing overall HH compliance, specifically in areas of highest risk (e.g., acute care or postsurgical units). It might also reduce the time and cost for auditors to travel between facilities in remote areas.

The EMS could also avoid staff conflict during the monitoring process. Entry level auditing staff have reported incidents of senior staff's resistance to comply during a non-compliance event as well as verbal insults and rude response from non-compliant staff. This

type of encounter can demoralize entry level monitors and diminish the greatest strength of DO, on-the-spot quality assessment and education.

The turnover rate of auditors was high in many facilities across BC; demoralized staff unwilling to continue as auditors and auditors transferring to other facilities increase the need for training and re-training. Non-dedicated auditors do not usually receive extra pay or benefits for auditing; it is often added to their regular duties in the unit. Observations are often interrupted when auditors need to perform patient care or other priority duties. Hospital leaders thought EMS might mitigate these challenges related to DO audits.

EMS could also provide around-the-clock monitoring, whereas DO audits were usually conducted during daytime hours. This would provide a more comprehensive assessment of the performance in a unit. It would also minimize the burden of time and cost for slow-paced units to accumulate enough observed events for DO requirement.

3.3.2.2 Benefits to the general target population

There is evidence that HH is important to reduce HCAI, and that increased compliance in HH is an important area of focus. However, experts in the field agree that there is a lack of quality evidence of the attributable effect of compliance to HCAI because of the many confounding variables in this area of research. An observed decrease in HCAI has been associated with an increase in HH compliance, and although this effect cannot be directly attributed to HH monitoring alone, DO auditors observed that monitoring HH has in fact improved HH practices. Improved HH has the potential to prevent infection, decrease the burden of disease in patients recovering from other comorbidities or procedures, maintain patient well-being, reduce harm, and promote faster recovery.

3.3.2.3 Benefits to disadvantaged population

This technology is not directly intended for specific marginalized or disadvantaged populations. However, residential care patients seem to be more vulnerable to HCAI and experience a greater impact on their quality of life. PICNet data shows that adults 65 years and older with prolonged hospital stays, intensive care stays, underlying diseases, weak immune systems, and history of antibiotic usage are more prone to acquire HCAI, especially *C. diff.* infection. (16, 23) Residential care patients usually meet five of these six criteria. Furthermore, the treatment of antibiotic-resistant infections such as MRSA may be more difficult in areas that lack resources (e.g., long-term facilities, rural areas).

3.3.2.4 Non-health benefits

For HCP, EMS can minimize the inconvenience of being observed while providing patient care (e.g., having to wash their hands twice, once inside the patient room after care delivery and again outside in the auditor's view, to make sure that the HH event is observed and not documented as a missed HH opportunity).

This technology can also benefit the health care system in general. The most important benefit is the ability to measure HH compliance around the clock; this can free up human resources for other quality improvement initiatives, improve auditor turnover, and provide a more accurate and transparent compliance rate to the public. A major advantage of the EMS is its relative invisibility. This should increase the comfort of the staff and not affect workflow or temporarily change the normal behaviour of HCP, which should help measure true compliance, provided this method is proved to be valid. Furthermore, it can sometimes take two to three

days for ordinary soap and alcohol dispensers to be refilled, depending on the location of the dispenser. With an EMS, staff could be notified to refill dispensers immediately.

3.3.3 Potential challenges of EMS

The interviewees also expressed several concerns regarding the use of EMS:

- Lack of confidence in the measuring methods of expected number of HH opportunities (algorithm or room entry and exit).
- Criticism from units regarding the EMS compliance number, which is usually drastically lower than in DO audits.
- In the initial phase of implementation, the need to adapt the algorithm to suit the unique patient acuity and workload of each unit.
- The impact of non-unit staff and visitors on the accuracy of compliance measurement.
- The EMS's inability to provide immediate feedback during a non-compliance event and in-the-moment quality assessment of HH technique to drive educational initiatives.
- The additional workload and cost for EMS, as DO continues to be a requirement from national and provincial quality assurance agencies.
- Individual badge EMS might also be a challenge due to high maintenance, privacy issues in the workplace, and the extra cost and challenges to distribute badges to out-of-unit hospital personnel.
- Contractual challenges with regard to data ownership and services included in the subscription fees.

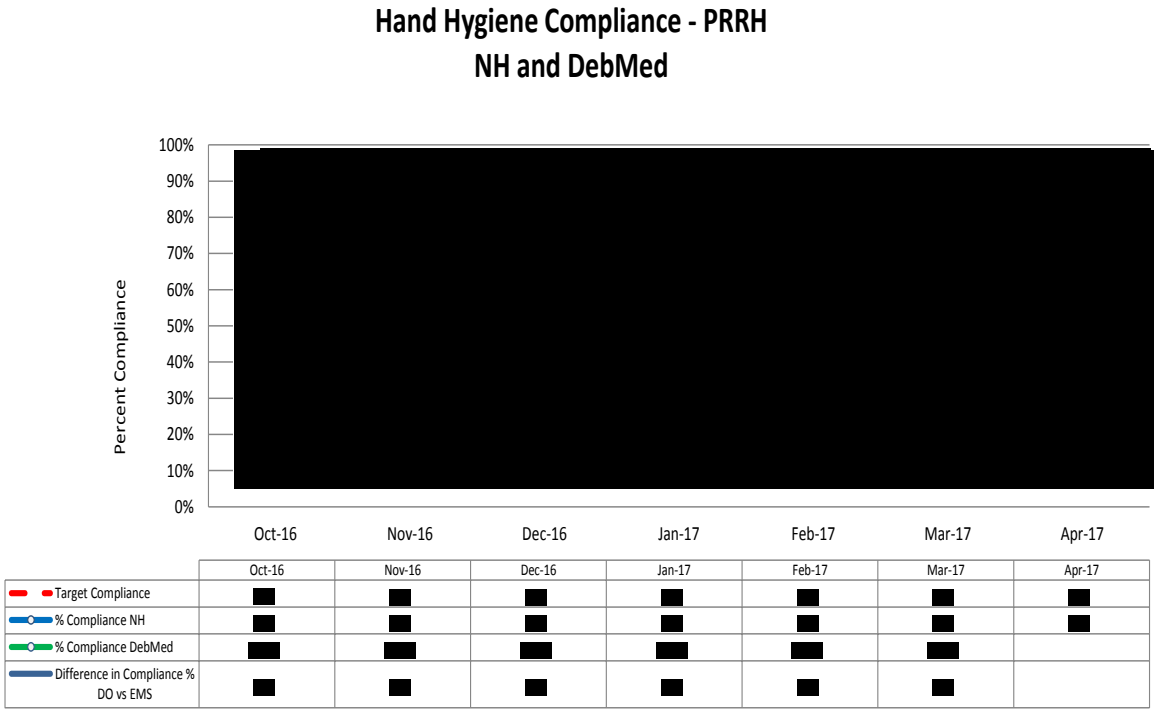
3.3.4 Clinical experience with the EMS in BC and perspectives on adopting the technology

The only BC health authority currently piloting an EMS is Northern Health, who are testing the validity and feasibility of the DebMed EMS in monitoring compliance. The DebMed system was chosen because all the existing soap and alcohol dispensers in Northern Health medical facilities are manufactured by DebMed, making it easier and more economical to implement their sensors. The heath authority continued to monitor compliance by DO audits as usual, and no feedback about the EMS data was provided to the HCP.

In a preliminary analysis of the data (Figure 4), the EMS reports show substantially lower compliance rates when compared with those measured by DO (49). On average, the compliance rate was 28 percentage points lower than the DO reported (ranging from 11 to 41 percentage points), which was attributed to biases of the DO method (Hawthorne effect, observer bias). Interestingly, Northern Health also noticed periods of over-compliance (i.e., greater than 100%) in some units during periods of outbreak, where HCP washed their hands more frequently than expected.

EMS would not completely replace DO audits for HH. DO audits are still necessary to provide qualitative data not captured by the EMS, such as missed moments of HH (specifically which moments are missed most often), which HCP groups show the lowest or highest compliance, HH technique, and validation of the EMS reports.

Figure 4. Preliminary results comparing compliance rates reported by DebMed EMS and DO in Northern Health Authority, BC, pilot trial.



Note: Northern Health preliminary results. % compliance must be redacted from the report. Differences between the two methods can be disclosed. (49)

Northern Health is in its final year of EMS implementation, which proved to be smooth in terms of setup and refilling of soap and alcohol dispensers. If the EMS is confirmed to be capturing reliable and valid data, Northern Health anticipates extending the contract and reducing the frequency and quantity of DO audits.

The interviewees across all health authorities unanimously noted the need for evidence of the validity of the EMS as a condition for expansion of its implementation. If reliability, accuracy, and effects on compliance and HCAI are proven, they would not object to adopt this technology. Otherwise, the high cost of EMS could be transferred to support other infection prevention activities (e.g., to provide support for educational activities after missed HHOs). The

interviewees attribute the shift in culture and HH practices mainly to auditors providing immediate education during audits and campaigns targeting specific HCP groups or units with low compliance.

3.3.5 Patient experiences and burden of illness reported by HCP

The interviewees mentioned that patients feel embarrassed, disappointed, frustrated, isolated, and afraid on hearing that they have acquired an infection. Patients are often confused about how they truly acquired the infection, how it will impact their recovery or health status, and especially how the infection is transmitted and what precautions they must take with visiting family members or others in their vicinity. The conversation is never framed as assigning blame or labelled as an HAI; rather, they are told that the infection is due to an outbreak on the unit or via contact with contaminated surroundings. Patients commonly blame the cleaning staff for their cleaning techniques or the frequency of witnessed cleaning activities, and do not usually associate the transmission infections with the HCP providing their care.

A patient's mood is certainly affected by isolation and precaution measures put in place in response to the infection. Interaction with health care personnel, family, and friends decreases, and staff interactions are transformed by the constant use of gloves and gowns. In residential care units, infected patients are often prohibited from joining group activities, which sometimes leads to depression that can persist even after recovery from infection.

Other factors add to the burden of the acquired infection, such as increase of hospital stay, a longer recovery period away from work, increased risk for complications that can lead to more severe outcomes including death, a severe impact on quality of life, and inability to

perform usual daily activities, even after recovery. History of *C. diff.* infection or MRSA may also increase the length of stay for future hospitalizations. Despite the overwhelming negative impact of HAI on patients, many were unexpectedly positive and appreciative of being assigned to a private room.

HCP were asked whether patients' experiences are at all affected by the current HH auditing system or the possibility of an EMS implementation. They unanimously agreed that patients are not actually aware of when HH audits are being conducted. In fact, the auditors are careful to avoid entering areas where patient care is being provided or otherwise invading the patient's privacy. Also, the auditors are careful to speak privately to HCP during educational moments about missed HH opportunities. An EMS would not actually change the patient's experience in any way, except to potentially reduce the risk for HCAI with increased HH compliance.

3.3.6 Access to technology

There are two main manufacturers for EMS for group monitoring: DebMed and Gojo. Each uses a different method to detect and calculate the number of HHO. Every soap and alcohol dispenser currently in the province is provided by DebMed. Gojo EMS can be adapted to DebMed dispensers, but most stakeholders believe it may be smoother and less complicated to implement the DebMed EMS. However, Gojo provides a bigger portfolio of other products to the province, which may affect negotiation and contracts. Implementing the DebMed EMS would not require replacing the current soap and alcohol dispensers, and the subscription would include all necessary hardware, sensors, dispensers, routers, and cell services for sensor communication (independent of the hospital data network).

Gojo EMS comprises activity counters, dispenser actuation counters, data receivers, a server, and a digital monitor. (50) The activity counters are installed at every doorway into a patient room; they detect the infrared signature of a warm body passing through the doorway and generate an entry or exit opportunity. The difference between human body temperature and the ambient room atmosphere must be large enough for the infrared sensor to detect. High room temperature, such as on a hot summer afternoon, might interfere with the sensor's ability to detect entry and exit. The dispenser counter is housed inside the dispenser and is not visible from the outside. The dispenser transmits information to a wireless data receiver installed in the facility. The data is time-stamped and stored in the cloud, on a server accessible by secure login.

With both DebMed and Gojo EMS, stakeholders are concerned about the lack of cell reception or available Wi-Fi in certain areas in hospitals and medical facilities, which they believe could limit data transmission from the sensors. Ultimately, implementation of EMS will depend on budget constraints.

3.3.7 Cost for patients

The primary costs for the patient with HCAI are time away from work, expenses for supplies for at-home treatment of HCAI and their specific consequences (e.g., antibiotics, ostomy supplies), and the cost of managing ongoing health status and physical ability if the HCAI limits activities of daily living (mobility, meal preparation, special diets, ostomy supplies). Costs depend on the type and site of HCAI, severity of the case, and whether the patient has extended health care insurance benefits.

3.3.8 Sector cost

No sector shift is anticipated.

3.3.9 The cost of EMS and other associated costs

DebMed group monitoring system costs $[redacted] per bed per year, typically with a three-year contract. Subscription includes hardware, sensors, dispensers, routers, cell services for sensor communication (independent from the hospital data network), batteries, installation, and staff training. This price may be subject to change according to the negotiated length of the contract.

Gojo Smartlink AMS group monitoring system costs $[redacted] per bed per year, typically with a three-year contract. Subscription includes hardware, sensors, dispensers, repeaters, gateways, activity counters, installation, and staff training. This cost may be subject to change according to the negotiated length of the contract and bulk purchasing. Sensors include a battery life guarantee, but the activity counter monitor has a three-year battery whose replacement is not included in the annual fee. Another option for this EMS is a one-time capital investment for the purchase of the hardware of $[redacted] per bed, and an annual software licence fee of $[redacted] per bed per year.

Table 8 includes BC Clinical and Support Services Society (BCCSSS) data from 2014 to February 2016 (51) showing the historical expenses for HH products in BC. The province currently spends over $2.1 million per year on HH supplies. These expenses vary by health authority bed and inpatient capacity, staff capacity, and compliance rate levels.

Table 8. Expenses for hand hygiene products in BC by health authority.

	2014	2015	2016
FHA	876,372	741,162	679,032
IHA	328,968	410,434	483,791
NHA	24,464	143,069	184,020
PHSA	98,479	99,722	101,160
VCHA	485,267	485,741	430,126
VIHA	298,239	323,964	315,955
Total	2,111,789	2,204,093	2,194,083

Note: FHA = Fraser Health Authority; HA: health authority; IHA = Interior Health Authority; NHA = Northern Health Authority; PHSA = Provincial Health Services Authority; VCHA = Vancouver Coastal Health Authority; VIHA = Vancouver Island Health Authority.

3.3.9.1 Cost of implementation

Other than the cost of devices, the only anticipated cost of implementation would be the time required to train team leaders how to use the EMS program and generate reports, and time for administrative/IT personnel to enter nurse–patient census data into the program so the DebMed system can calculate the HHO.

3.3.9.2 Environmental impact and costs

There seems to be no major perceived environmental impact in the implementation of EMS systems with sensors incorporated into soap and alcohol dispensers. There were some concerns about systems with sensors in individual badges, primarily related to the cost of replacing and disposing of badges and batteries.

DebMed EMS sensors include a five-year battery, and replacement is included in the annual fee. The Gojo sensors include a battery life guarantee, but the activity counter monitor has a three-year battery that is not included in the annual fee.

Another consideration for implementation of any EMS is soap and alcohol product usage. As compliance is expected to increase, so is soap and alcohol utilization, although this is unlikely to be significant when compared with the cost of antibiotics used to treat HCAI.

3.3.10 Risk for successful implementation (financial, human resource, stakeholders, other)

The primary concern remains lack of confidence in the validity and reliability of the EMS methods of measuring and defining HH opportunities and events, and the diversity of dynamic situations and factors that may influence the count of these events. For example, the number of procedures or moments of care varies by patient needs and health status. Situations such as dropping instruments on the ground or picking up a pen can affect the event count, as can the number of HH stations on the unit. Human factors and behaviours, like excessive HH or a preference for a particular HH station due to the type of soap available, the ability to control the water temperature, etc., can also affect the variability in the data.

The complexity of the environment and random occurrences of various events are so subject to change that hospital leaders are hesitant to accept that a calculated algorithm can count the true number of opportunities; they see the need for validation studies at the unit level during the implementation process. For EMS with sensors that measure room exit and entry, there is also a need to adjust for multiple-occupancy rooms.

Hospital leaders consider the risk for EMS implementation to be moderate, though it may not even be feasible in all units due the lack of funding or logistical issues (e.g., lack of cell reception). It would not be financially feasible to add the cost of implementing an EMS to the already high cost of conducting DO audits for reporting purposes unless EMS measurements could be reported instead of or complementary to DO audit measurements. The provincial HH reporting mandate would need to change to include EMS as an accepted tool to measure HH compliance.

Other important considerations are the staff's level of acceptance of EMS and whether the system is built around individual or group monitoring. An individualized monitoring system would be controversial in terms of both staff privacy and the ability to pinpoint blame to individuals, and hospital leaders envisioned a difficult transition and integration into the work environment and culture with this kind of system. In almost all conducted interviews with multiple stakeholders in varying roles, there was recurrent mention of the idea of "Big Brother" watching.

Despite the scientific evidence, it was also made clear in the stakeholder interviews that there is some disbelief among doctors, nurses, and other HCP about whether the spread of infections is in fact related to HH practices. They seem to attribute infections more to environmental sanitation, frequency of cleaning activities, and the spread of infection by the housekeeping staff or food service personnel. This presents a fundamental discrepancy in ideology that cannot be resolved with any new HH technology; therefore, there is perhaps a need to focus on changing HCW perceptions and beliefs via education around the importance of HH practices and compliance.

Stakeholders also fear that implementing an EMS may lead to a lack of DO audits, which can lead to HCP using evasive manoeuvres to increase the compliance rates, such as dispensing soap or alcohol products into a paper towel to avoid getting the products on their hands (due to personal dislike or a wish to avoid frequent product usage).

Chapter 4 Patient Experience

Summary

Patients are quite aware of the hand hygiene practices during their admissions, observe inconsistencies among health care practitioners' behaviour, yet very few patients interfere in their practice of care, for fear of straining their relationship with the team and suffering the consequences on their care provision. Despite this, they still place great trust in the judgement of their health care team. Patients still hold misconceptions and beliefs about the transmission of HCAI and place great importance to the cleanliness of the environment.

The impact of HCAI in their lives is substantial and enduring with great social and mental impact (fear, anxiety, depression, social isolation) that last long after the treatment of the infection per se.

4.1 Objective

To gain an understanding of the outcomes important to patients in order to guide the evaluation of the clinical literature and health policy.

4.2 Patient experience from literature

A rapid review of qualitative studies was conducted by CADTH on behalf of the HTR Office from the BC Ministry of Health to aid in meeting the overall objectives of this HTA. (52)

4.2.1 Methods

The CADTH rapid response review described patients' perspectives of and experiences with health care practitioners' HH practices, and their experiences with HCAI. (52) The research questions guiding this review were:

- What are the perspectives and experiences of people receiving health care at acute and long-term care facilities or their caregivers regarding health care practitioner HH practices and monitoring systems?

- What are the experiences of people who have acquired a health care-associated infection in an acute or long-term care facility, and the impact of that infection on their health care, their lives, and their caregivers?

4.2.2 Results

CADTH found 815 citations in a preliminary literature search. Of these studies, 773 were excluded based on first-level screening of titles and abstracts. Upon full-text review, an additional 23 articles were excluded, with 19 articles meeting the inclusion criteria established by the above declared research questions. Of these, 11 studies were relevant for patient's perspectives on HH, and 15 were relevant for patients' experiences of HCAI.

This review provided rich qualitative data on patient experiences. Interestingly, the results from the CADTH review is in full agreement with the information obtained from interviews with key stakeholders reported above, suggesting that saturation of content on this topic has been achieved specifically related to patient views on HH methods and HCAI. The summary findings from the CADTH review are discussed in the next two sections. (52)

4.2.3 What are the perspectives and experiences of people receiving health care at acute and long-term care facilities regarding health care practitioner hand hygiene practices and monitoring systems?

Patients are quite aware of the important role of HH practices in infection prevention and control, despite not always holding accurate beliefs and knowledge about appropriate HH guidelines. For example, they "overwhelmingly saw the use of gloves as an appropriate method of ensuring hand hygiene, whereas wearing gloves was not held to be the appropriate standard in that clinical setting." (p. 8) It was found that "awareness through visual observance…and visual confirmation of hand hygiene was important to patients." (p. 8)

Patients have longstanding confidence in the HCP. As one patient put it, “they are the experts so they know best” (p. 9); however, they noticed inconsistencies in HH practices by different HCP, which confused the patients about techniques and regulations. When witnessing such discrepancies or missed HHO, “a tension arises where patients articulate a keen awareness of . . . practitioners’ adherence to hand hygiene practices but are reluctant to ask them to wash their hands.” (p. 13) One patient noted, “you’d better not ask [the doctors]. You do not want to be troublemakers. You never know, they may feel controlled or something and then . . . things may even get worse.” (p. 9) Evidence shows that patients generally do not engage or communicate with their HCP about whether they have sufficiently cleaned their hands before providing care for fear of repercussions or changes in care delivery. They do not wish to upset the power dynamic between HCP and patients by inquiring about HH compliance.

To combat this power imbalance, “some patients’ experiences lead them to alternative strategies to meet their desire for practitioners’ adherence” (p. 13), such as coming up with creative ways to go around the problem, including amplifying their own HH compliance, removing their dressing if they believed that there had been an incidence of missed HH before the dressing was applied, or using humour to express concerns. “The evidence suggests patients are indeed key stakeholders, involved and observant of hand hygiene practices, even if they are reluctant to speak up” (p. 13), and that “the actions of patients can be viewed as expressions of agency, with patients perceiving themselves as having a role in hand hygiene and IPC.” (p. 10)

In accordance with the key stakeholder interviews, some patients “viewed the most important cause of infection not as lack of HH and infection prevention control, but as overall

cleanliness of the hospital environment. These patients perceived hospitals as dirty, either because of the lack of cleaning or inappropriate staffing levels, both of which they attributed to higher-level budget constraints." (p. 10)

4.2.4 What are the experiences of people who have acquired a health care-associated infection in an acute or long-term care facility, and the impact of that infection on their health care, their lives, and their caregivers?

There is consensus "that the impact of HCAI on patients is substantial and enduring." (p. 14) Patients often struggle with news of their acquired HCAI, with the main area of concern being limited social interactions; "most pronounced is the impact of HCAI on patients' sense of self—the feeling of being stigmatized leads many to feel unclean, dirty, ashamed, and guilty" (p. 14) as well as "struggling with boredom, hopelessness, and depression." (p. 11) Patients are also concerned about their ability to receive care for their original health condition, due to the additional HCAI complications in management of care.

Another factor adding to the burden of HCAI to the patient experience is the confusion about the general knowledge of the different types of HCAI due to "poor communication around their infection." (p 11) For example, not making distinctions between "colonized" versus "infected," not making known the different modes of transmission and changes in care delivery in response to the infection, or patients not being advised about their health condition but overhearing the staff talking about their case. (p. 11)

"Fear and anxiety lingered after discharge with patients in the community who remained colonized with a HCAI. These participants worried about telling others due to the fear of gossip or the potential impact it would have on their children. Thus, patients continued to

alter their behaviour and social interactions post discharge." (p. 12) It is clear that the overall impact of acquiring a HCAI is not only substantial during the recovery period, but has a ripple effect in the lived experiences of patients post recovery.

4.3 Conclusions

Patients are quite aware of the HH practices during their admissions, and observe the inconsistencies in HH practices by the HCPs, although they still place great trust in the health care team with regards to their appropriate judgment. There is tension to engage in reminding HCP about observed missed HH opportunities and fear of disturbing the relationship dynamic with the health care team. However, they still find some creative actions to communicating dissatisfaction with the HH practices. Patients still hold misconceptions and beliefs about the transmission of HCAI and place great importance to the cleanliness of the environment. The impact of HCAI in their lives is substantial and enduring with great social and mental impact (fear, anxiety, depression, social isolation) that last long after the treatment of the infection per se. Monitoring technologies may reduce patient's felt need to directly observe their health care providers HH practices, and if lead to a decrease in HCAI can reduce the important emotional and social burden carried by patients who acquired those infections.

Chapter 5 Assessment of Evidence

Summary

The available evidence about EMS is limited (four conference proceedings and two published studies). All studies were interrupted time series and did not apply the appropriate trend analysis to the design.

DebMed EMS has validation studies against DO and video surveillance using the WHO 5 Moments and Canada 4 Moments to measure hand hygiene opportunities. Gojo EMS has one validation study for two moments (room entry and exit) performed in single occupancy room. No studies are available for Gojo comparing with Canada 4 Moments or adjusting for multiple-bed rooms.

Five studies using DebMed reported a wide range in the positive impact on hand hygiene compliance (5% to 20% absolute improvement in compliance rates). One study using Gojo examined the effect on compliance with or without additional interventions (EMS in both arms). The study did not use appropriate trend analysis, but visually, compliance improved in both groups.

Overall multiple co-interventions were reported in three studies, so the effect size on compliance improvement cannot be solely attributed to periodic feedback with the EMS data. Before-and-after MRSA infection rates were reported in four studies using DebMed systems; in all of them, as compliance increased, infections rates decreased. However, only one study performed a correlation analysis and reported a confirmation of a negative correlation (r=−0.373.) between MRSA infection rate and HH compliance. No cost-effectiveness studies of the EMS were found.

5.1 Objectives

To assess the clinical effectiveness of EMS and periodic feedback to health care workers on HH compliance in acute care and residential care settings.

5.2 Methods

5.2.1 Inclusion criteria

Table 9 defines the population, inclusion criteria, and outcomes of interest.

Table 9. Inclusion criteria.

Population	Intervention	Comparator	Outcomes
All health care workers in acute care and residential care settings	Adding group electronic hand hygiene monitor with group feedback to direct observation	Direct observation alone	Clinical outcomes Hand hygiene compliance Hospital-associated infection rate Mortality (HCAI related or overall, if available) Patient satisfaction
			Economic outcomes Cost of measuring, monitoring, or reporting compliance Costs with HCAI resource use (hospital readmissions, LOS) Cost of implementation (devices, procedure, subscriptions, fees) Utility measures ICERs, WTP, CEAC

Note: CEAC = cost-effectiveness acceptability curve; HCAI = health care-associated infection; ICER = incremental cost-effectiveness ratio; LOS = length of stay; WTP = willingness-to-pay.

5.2.2 Exclusion criteria

- Non–English-language publications
- Letters and commentaries
- Individual monitoring systems
- Studies published before 2000

5.2.3 Literature search overview

Initial scoping searches were done in March 2017 using Medline (Ovid) to assess the volume and type of literature relating to the objectives. The scoping search also informed the development of the final search strategies (Appendix B). The search strategies were developed by an information specialist, with input from the reviewers. The strategies were designed to capture generic terms for EMS and HH. We searched relevant citations from 2000 to 2017. Published articles were identified in Medline and Embase via Ovid. Search results were

imported into Endnote and Microsoft Excel for screening. The search is considered up to date as of March 13, 2017.

Articles relevant to HH compliance and electronic monitoring were identified during screening. Articles retrieved for full-text reading were separated by the type of publication (i.e., systematic reviews, randomized trials, and nonrandomized comparative studies). Economic studies were also sorted out for detailed reading at this point in the process. Search filters for the various study designs were incorporated into the searches to increase the sensitivity of the searches. (53, 54)

5.2.4 Study selection and data extraction

One reviewer screened titles and abstracts and then full texts following a specified protocol. A second reviewer confirmed the relevance of included studies. The study flow was summarized using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) diagram (Figure 5).

A reviewer extracted all the data for clinical outcomes, while another reviewer extracted all the data from economic analyses. Data were cross-checked for errors by the two reviewers. Any discrepancy was resolved by discussion.

5.2.5 Quality assessment

For the purposes of this project, we followed the 2011 report on the hierarchy of evidence from the Centre for Evidence-based Medicine at University of Oxford. (55) We first searched for any systematic review of randomized controlled trials (level 1). If the amount of evidence was deemed insufficient at this level, we searched for large-scale randomized trials (level 2). If the amount of evidence was again deemed insufficient at this level, we searched for

nonrandomized studies (level 3). Lower levels of evidence were considered hypothesis-generating and deemed insufficient for policy decision making.

We critically appraised the included studies using a modified checklist from Cochrane Effective Practice and Organization of Care group. (56)

5.2.6 Data synthesis

Cochrane Review Manager Software, RevMan 5.3.5, was used to synthesize data for clinical outcomes when appropriate. Dichotomous outcomes were analyzed by using risk ratio or odds ratio.

5.2.7 Subgroup analysis

No subgroup analysis was planned for clinical effectiveness.

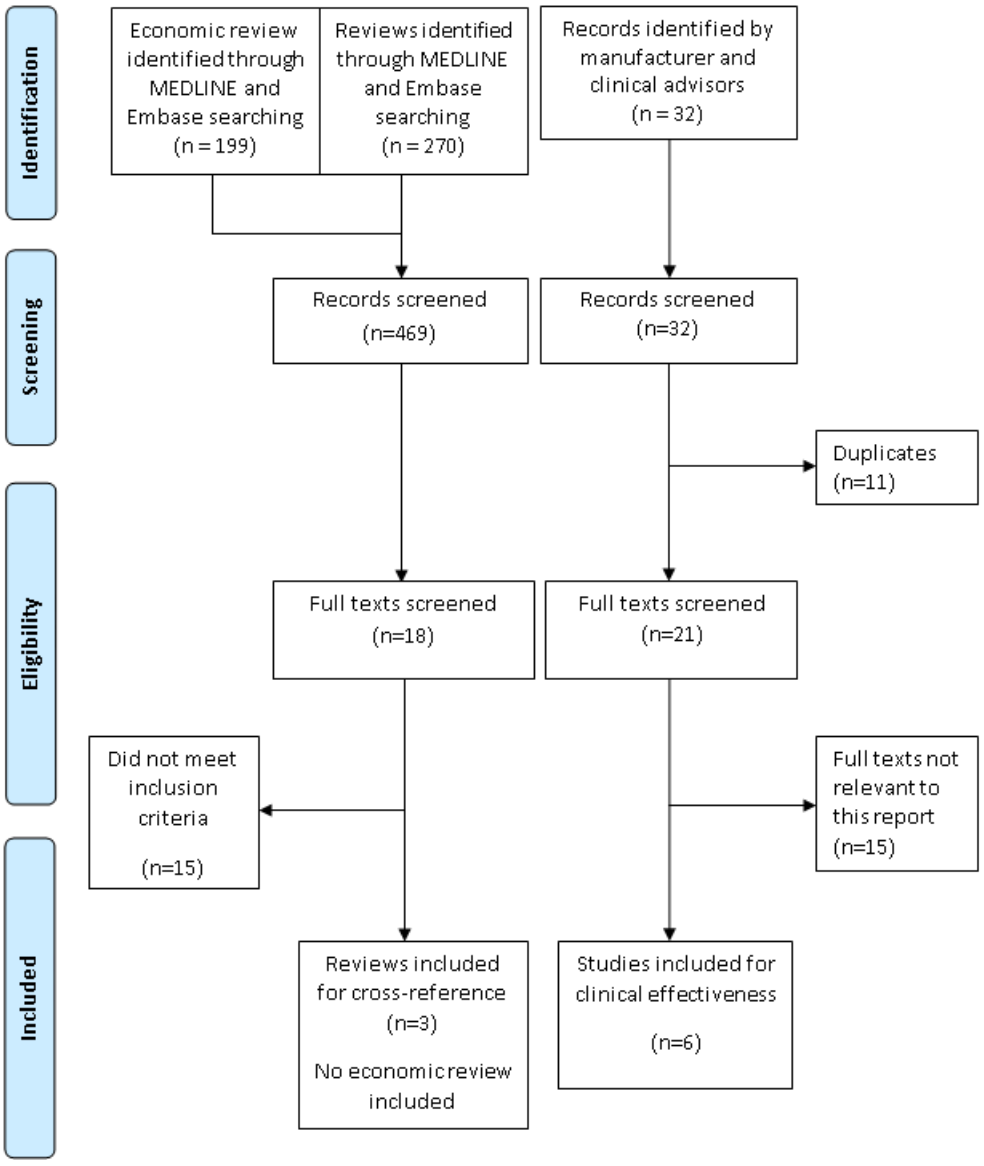
5.3 Search results

We screened 270 systematic reviews and 199 economic studies from Medline and Embase as well as 32 articles suggested by the manufacturers and clinical advisers. Since the proper method for critical appraisal of systematic reviews of nonrandomized studies is still under debate, the systematic reviews of nonrandomized studies found in our search were used for cross-reference only but not included in the clinical effectiveness analysis, as none of them examined solely the EMS specified in this report. The most updated search in the systematic reviews was performed in December 2013. (45, 57, 58) After cross-referencing, no study was found to be eligible for inclusion.

Thirty-two citations suggested by DebMed, Gojo and clinical advisers were screened and six studies were included in this HTA (three conference posters, one conference presentation, and two publications).

After considering the reviews and included studies and consulting with experts in the field, we did not perform further screening into primary studies from Medline and Embase, as it was unlikely that they would include additional relevant studies. No eligible economic review was identified in our search.

Figure 5. PRISMA diagram of study selection.



5.4 Validation of devices

Individualized EMS was not under consideration for this HTA and was not included. Only electronic group monitoring systems that have been validated to ensure the accuracy of measurements, preferably using WHO 5 Moments or Canada 4 moments, with ability to provide group feedback were included in this HTA. We identified two EMS capable of group monitoring (Gojo Smartlink AMS and DebMed group monitoring system) and retrieved their validation studies.

5.4.1 DebMed group monitoring system

The DebMed system was validated in three publications. (47, 59, 60) The algorithm was developed during the initial study using data from DO following WHO 5 Moments. (47) Moving forward, the accuracy of the algorithm was assessed using video surveillance. (59, 60) The compliance calculated from the algorithm was found to correlate to the compliance found via the video surveillance ($r=0.976$, $p=0.004$). The average compliance measured by the three different monitoring methods: DO, video surveillance, and DebMed was 95%, 69.54%, and 67.54%, respectively. This study also found that the wash-in (room entry) and wash-out (room exit) method accounted for 36% fewer HH opportunities when compared with the WHO 5 Moments to determine the total number of HH opportunities.

The DebMed algorithm is designed to estimate the expected number of HH opportunities based on several factors, including the individualized information for each unit's patient census and patient-to-nurse ratio. The number of HH opportunities it generates can vary from unit to unit. Before implementation, the number of opportunities generated by algorithm should be tested for accuracy by comparing with DO in each specified unit. In

addition, the dispenser counters cannot distinguish between staff and visitors, so usage from visitors or any individuals other than unit staff may affect the compliance accuracy of the DebMed system. DebMed mentioned that, in their study, usage by visitors only made up 1.5% of total events in a common acute care setting in North America. (61)

A study examining the difference between using the Canada 4 Moments to the WHO 5 Moments to calculate the number of HH opportunities found that Canada 4 Moments generated 30.6% more opportunities. (62) The authors suggested that the additional opportunities were the result of HH requirement before and after contact with the patient environment. DebMed stated that, based on this study, their algorithm was adjusted for the Canadian standard; this was confirmed by the Ontario site that participated in this study and implementation.

5.4.2 Gojo Smartlink AMS

The Gojo Smartlink AMS was validated in Limper 2017. (50) This study aimed to assess the sensitivity and positive predictive value of Gojo AMS when compared with DO using the wash-in wash-out method. The overall sensitivity was 92.7% and positive predictive value (PPV) was 84.4%. The sensitivity and PPV varied significantly across units. Sensitivity was higher on inpatient floors, but PPV was higher in intensive care units.

The validation study was conducted in a private room setting. Most hospital rooms in BC contain more than one patient bed. The manufacturer has been asked whether the Gojo AMS can accommodate a multiple-bed setting in one room; despite the manufacturer's statement that it can be done, no study using the Gojo AMS adjusted for multiple-bed rooms is available.

The wash-in wash-out method only captures the first two of the Canada 4 Moments. In one study, it was suggested that HH compliance was similar when comparing the WHO 5 Moments with the wash-in wash-out method. (63) However, this is still debatable since another study found that the wash-in wash-out method captured 36% fewer opportunities. (59, 60) Furthermore, no studies were found comparing the wash-in wash-out method with the Canada 4 Moments. How much the opportunities generated by wash-in wash-out method needs to be adjusted is unknown. Since Gojo AMS was validated only according to the wash-in wash-out method in a single bed patient room setting, it does not seem to be comparable to the current DO or to the DebMed EMS system unless the method to adjust for multiple beds and the Canada 4 Moments can be clarified.

5.5 Clinical effectiveness

Six studies were included in the clinical effectiveness analysis. They differed in methodology, co-interventions, length of study, baseline HH compliance, types and sizes of participating units, and reported outcomes. It is not appropriate to perform a meta-analysis of their data, but their results were summarized. One significant difference between the studies was the additional interventions introduced after feedback from the EMS data began (Table 10), which may have influenced the results for compliance changes and HCAI rates. Additional information about the included studies can be found in 7.5Appendix D.

Table 10. Additional interventions in included studies.

Study	Device	Additional interventions	Duration of intervention (Duration of baseline measurement)	Effect on hand hygiene compliance			Change in health care-associated infection rate (per 10,000 patient days)		
				Before	After	Absolute Change	Before	After	Absolute Change
Bouk 2016 (64)	DebMed	Staff training and education, leadership engagement, hand hygiene champion, increase accessibility to dispenser	21 months (2 months)	57%	79%	22%	3.94	1.98	1.96
Conway 2013 (65, 66)	DebMed	No additional intervention	9 months (6 months)	NR	NR	4.9%	NR		
Crnich 2016 (67)	DebMed	No additional intervention	ICU: 7 month Non-ICU: 3 months (baseline period not reported)	ICU: 58%	68%	10%	See section 5.5.2.1		
				Non-ICU: 32%	45%	13%			
Kelly 2016 (61, 68, 69)	DebMed	Increased accessibility to dispenser, unit champion, leadership engagement	30 months (3 months)	54.9%	68.8%	13.9%	3.81	2.67	1.14
Moore 2016 (70)	Gojo AMS	Staff education, leadership engagement, physician engagement, unit leadership engagement	2012-2015 (Baseline period not reported)	See section 5.5.2.2			NR		
So 2016 (38)	DebMed	Some hand hygiene programs were in place before and during the study period, but no new intervention was added during the study	6 months (3 months)	[redacted]%	[redacted]%	[redacted]%	[redacted]	[redacted]	[redacted]

Note: AMS = activity monitoring system; ICU = Intensive Care Unit; NR = not reported.

5.5.1 Description of excluded studies

Fifteen studies suggested by the manufacturer and the clinical experts were excluded, and the reasons are listed in Appendix E.

5.5.2 Description of included studies

5.5.2.1 Studies that used DebMed group monitoring system

Bouk 2016 examined the effect of implementing EMS on HH compliance and MRSA infection rates in Riverside Medical Center in Kankakee, Illinois. (64) Weekly or monthly EMS reports were emailed to unit managers and the unit conducts weekly staff meetings to discuss the result of the report. In addition to EMS, they immediately used other interventions such as leadership engagement and the reward for HH champion program. It was an interrupted time series measuring HH compliance and MRSA infection rates before and after the implementation of all interventions. This study reported that HH compliance increased from 57% to 79% from December 2013 to September 2015. In the same period, MRSA infection rates decreased from 3.94 to 1.98 per 10,000 patient days. This effect was likely the result of multiple HH interventions rather than EMS alone.

Conway 2013 was an interrupted time series that examined the effect of implementing EMS on HH compliance in a 140-bed community hospital in Northampton, MA. (65, 66) Monthly reports were emailed to unit managers, and an infection prevention specialist met with unit managers periodically to encourage them to discuss the reports with unit staff. No other co-intervention was used. From January to July 2012, they measured the baseline compliance in various units in the hospital without disclosing this data to the units (no feedback). From October 2012 to March 2013, they provided a monthly compliance report to each unit and

compared the HH compliance in this period with that in the baseline period. The overall HH compliance increased by 4.9% between the baseline period and the intervention period. Change of absolute compliance ranged from 9.2% in critical care units to −3.2% in the emergency room. The publication did not explain why ER compliance decreased, and did not provide enough data to analyze the trend; therefore, an interpretation of this data can be misleading. Crnich 2016 was an interrupted time series that examined the effect of implementing an EMS and engaging the staff with periodic feedback on HH compliance and HAI rates in two hospital units in Madison, WI. (67) The method of staff engagement was not reported, and no other co-intervention was reported by the authors. The authors separated ICU and non-ICU data. From January to July 2014, in a 7-bed ICU unit that received feedback from the EMS, HH compliance increased from 58% at baseline to 68%. From October to December 2015, staff in a 21-bed non-ICU unit received feedback from the EMS, resulting in a HH compliance increase from 32% at baseline to 45%. The infection rate decreased from 4.7 per 1,000 patient days in the ICU and 1.7 per 1,000 patient days in non-ICU to no infections in the same period. However, the infection rate was based on a very small sample size (3 cases in ICU, 2 cases in non-ICU).

Kelly 2016 was an interrupted time series that examined the effect of implementing EMS as a part of HH improvement program on HH compliance and MRSA infection rates in a 746-bed hospital in Greenville, SC. (61, 68, 69) Unit managers received monthly or quarterly reports and were encouraged to discuss the report with staff. Leadership engagement, unit champion campaigns, relocating dispensers, and signs and posters were also used as a co-intervention. From July 2012 to March 2015, HH compliance increased from 54.9% to 68.8%,

while the MRSA infection rate decreased from 0.381 per 1,000 patient days to 0.267 per 1,000 patient days. Kelly 2016 was the only study that reported a correlation between HH compliance and MRSA infection rate (r=−0.373). This was a weak correlation suggesting that when HH compliance went up, MRSA infection rate went down. This effect on MRSA infection rate might be a result of other infection prevention programs in the hospital. The author stated that no additional initiative was introduced during this period, but this does not rule out the possibility that other existing infection prevention program in the hospital might have influenced the MRSA infection rate.

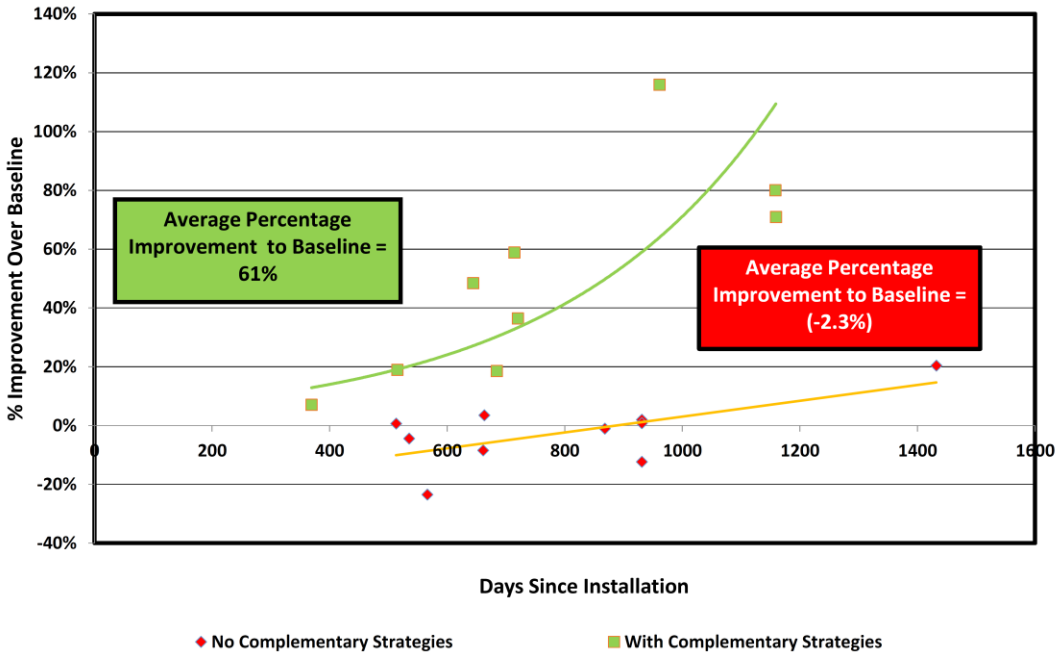
So 2016 examined the impact of EMS and feedback on HH compliance and MRSA infection rates in six units in a 428-bed hospital in Toronto. (38) Other HH programs were also in place in the background before and after the activation of EMS, but no new HH intervention was added during the study period. This interrupted time series study is ongoing; interim data was presented on a poster. HH compliance increased from [redacted]% at baseline quarter (July-August 2015) to [redacted]% in March 2016. The MRSA infection rates decreased from more than [redacted] per 1,000 patient days to [redacted] per 1,000 patient days. The MRSA information was extracted from a graph; an exact number was not obtained.

5.5.2.2 Study that used Gojo Smartlink AMS

Moore 2016 was an interrupted time series that examined the effects of having complementary engagement programs with EMS feedback on HH compliance in 18 U.S. and U.K. hospitals from 2012 to 2015. (70) Nine hospitals used additional HH interventions with EMS feedback, while the other nine continued with existing programs with EMS feedback. This study therefore investigates the effect of additional interventions, not the effect of EMS versus

no EMS. They used the wash-in and wash-out method to monitor HH compliance. After the implementation of EMS, most hospitals presented an increase in compliance rates, however, the hospitals with co-interventions had a greater improvement trend (green line) than the hospitals that continued with existing program without additional interventions (orange line). The reported 61% and -2.3% in the graph (Figure 6) were relative changes from baseline. A trend analysis should be used to compare the two groups of hospitals. However, the results were aggregated and reported as group means, which can be misleading in an interrupted time series. The absolute values for baseline compliance were not reported.

Figure 6. Result of hand hygiene compliance from Moore 2016. (70)



5.5.3 Quality assessment

Five of the six included studies used the DebMed group monitoring system and one used the Gojo AMS. Four included studies were conference posters or presentations. (38, 64,

67, 70) The other two included one brief report and one full publication. Critical appraisal was difficult because conference proceedings did not provide much information regarding methods. The critical appraisal result can be found in Appendix C.

All of the included studies were interrupted time series. The advantage of interrupted time series is that a trend analysis could be performed using the unit's baseline as its own comparator. When the baseline HH compliance and infection rates varied greatly between units and hospitals, using the units as their own control minimized the potential confounding factor of having different baselines. However, all the included studies reported these interrupted time series as before-and-after comparisons. None of the studies analyzed the trend of HH compliance over time.

In some of the included studies, only selected units were included. Administrative or implementation difficulties might be the reason that only a few units within the hospital were selected. However, it raised concern for selection bias, in that the selected unit might not be a realistic representation for all other units within the hospital.

None of the included studies were blinded. One study reported the baseline measurement to be blinded, but the intervention period was not. It is possible that the HCP in the study unit modified their behaviour knowing the monitor was in place, and discontinued that behaviour once the study was finalized. For this reason, there is a high risk of performance bias.

HH compliance is likely to be different during outbreak periods as compared with baseline stretches. Two of the included studies, Crnich 2016 and So 2016, ran for only a few months, which may not be sufficient to capture the differences in seasonal effects that could change behaviour.

Other co-interventions were allowed in some studies, so the observed changes in HH compliance may not be solely attributable to the implementation of EMS.

The outcome reporting was often so brief that sample size and variation were not reported in many of the studies. The results from statistical analysis were reported briefly without any details on the methods, so there is a high risk for reporting bias.

5.5.4 Limitations

The quality of evidence for the effect of EMS on HH compliance is rather low. Only four conference proceedings and two published studies were included. Five of the included studies used the DebMed system, and only one used the Gojo AMS. Moreover, the Gojo AMS has adopted the wash-in and wash-out method to monitor HH compliance, which is different from the current monitoring standards in BC hospitals.

It was not possible to meta-analyze the HH compliance data from the included studies, because of differences in methodology and baseline characteristics. The absolute value of change in HH compliance ranged from 5% to 20%. For the purpose of the economic evaluation, the data from So 2016 was selected to be the best option due to the fact that it is a Canadian study with no additional co-interventions introduced during the study period. The baseline measurements were also blinded and the MRSA infection rates were reported during the entire study period. However, this is an ongoing study and final analysis has not yet been performed; the overall effect on HH compliance and MRSA infection rates might change upon conclusion and finalization of the study.

The funding sources of the included studies were not disclosed, except for Conway 2013, which has been funded by DebMed.(65) This could potentially increase the risk of reporting bias.

5.5.5 Summary of clinical effectiveness

- The amount of evidence on EMS is very limited (four conference proceedings and two published studies). All the included studies were interrupted time series but with different methodologies, which does not allow appropriate meta-analysis of the data.
- Whether the opportunities generated by wash-in wash-out method is comparable to the Canada 4 Moments or WHO 5 Moments is still debatable. It is not clear that systems using the wash-in wash-out method to estimate HH opportunities can be used along with DO using Canada 4 Moments. Since Gojo AMS was validated only according to the wash-in wash-out method in a single bed patient room setting, until the method to adjust for multiple beds and Canada 4 Moments is clarified, it was not appropriate to compared Gojo AMS with the visual audits and DebMed EMS as equivalents.
- Five of the included studies using DebMed reported a positive impact on HH compliance ranging from 5% to 20% absolute improvement in compliance, which suggests a high degree of uncertainty in the data.
- One study using Gojo examined the effect on compliance with or without additional interventions. However, the study did not use appropriate trend analysis. In the group not using additional intervention, the aggregated relative compliance was −2.3% over baseline while the trend was going up. This was potentially misleading, as the aggregated result showed decreased compliance while the trend was clearly going up.
- In three studies, multiple co-interventions were reported, so the effect size on compliance improvement may not be solely attributable to periodic feedback with the EMS data.

- Before-and-after MRSA infection rates were reported in four studies using DebMed systems. One study reported zero MRSA infections after EMS feedback. This dramatic result is likely due to the small sample size. All three other studies reported a decrease in MRSA infection rates. The effect size ranged from 1.2 per 10,000 patient days to 1.96 per 10,000 patient days. Only one study reported a negative correlation between HH compliance and MRSA infection rate ($r=-0.373$), which means that the higher the HH compliance, the lower the MRSA infection rate.
- No published studies conducted in BC have been found. HH compliance would likely depend on specific circumstances within each individual hospital setting, such as level of care, HH culture, and the baseline infection rates. Therefore, the effects reported in these studies may not be replicated in BC settings.

The economic model required additional information not provided by the included studies. The list of parameters and the citations that provided the data can be found in Table 11 to Table 14.

Table 11. Additional parameters.

Parameter	Values				Reference
Direct observation bias	Risk ratio [redacted]				So 2016 (38)
Self-reporting bias	Risk ratio 0.71 (95%CI 0.67-0.75)				Dhar 2010 (44)
MRSA infection rate ratio between acute care and residential care		Total cases	2007 estimated rate (per 1K patient days)	2015 estimated rate (per 1K patient days)	Evans 2017(3)
	ICU	1,811	1.133	0.147	
	Non-ICU	4,516	0.452	0.09	
	Long-term care	3,607	0.221	0.112	

Note: ICU = intensive care unit; MRSA = methicillin-resistant *Staphylococcus aureus.*

Table 12. Number of MRSA infections and colonizations in the CNISP network from 1995 to 2009. (71)

Surveillance year	MRSA Infections	MRSA Colonizations	Numerator	Denominator	
				(patient-admissions)	(patient days)
1995	106	83	189	374,027	2,907,905
1996	192	247	440	405,791	3,801,608
1997	293	358	653	418,465	3,625,997
1998	418	616	1,050	407,297	2,990,598
1999	513	1,381	1,953	510,095	4,078,163
2000	736	1,781	2,553	507,910	3,862,873
2001	696	1,602	2,328	614,421	4,967,214
2002	845	1,849	2,729	583,658	4,732,172
2003	1,064	2,390	3,465	671,240	5,611,833
2004	1,369	2,642	4,019	677,829	5,227,447
2005	2,067	3,427	5,636	764,341	6,493,286
2006	2,011	3,850	5,867	770,118	5,963,506
2007	1,952	4,335	6,287	768,294	5,695,520
2008	2,001	4,364	6,273	678,610	5,441,458
2009	2,036	4,610	6,646	701,477	5,374,036

Note: CNISP = Canadian nosocomial infection surveillance program; MRSA = methicillin-resistant *Staphylococcus aureus.*

Table 13. Aggregate number of MRSA infection and colonization and incidence rate per 10,000 patient days by region. (7)

Western			Central		Eastern		Overall	
	Cases	Rate (%)	Cases	Rate (%)	Cases	Rate (%)	Cases	Rate (%)
2008	2,043	9.80	3,590	13.59	713	9.96	6,346	11.66
2009	2,080	10.49	3,941	15.02	528	7.58	6,549	12.35
2010	2,120	9.14	4,611	16.60	628	8.23	7,359	12.56
2011	2,525	10.10	4,315	14.48	685	7.86	7,525	11.85
2012	2,426	9.47	4,220	14.13	560	7.41	7,206	11.43
2013	1,485	8.03	2,753	13.68	427	6.48	4,665	10.32

Note: MRSA = methicillin-resistant *Staphylococcus aureus*
Note: 2013 data is preliminary. Data included are from January 1 to September 30, 2013. For all years, only sites that submitted both numerator and denominator data are included in the rate calculations.

Table 14. Number of MRSA infections and incidence rate per 10,000 patient days by region. (7)

Western			Central		Eastern		Overall	
	Cases	Rate %	Cases	Rate %	Cases	Rate %	Cases	Rate %
2008	1,064	5.10	657	2.49	261	3.65	1,982	3.64
2009	962	4.85	851	3.23	219	2.90	2,032	3.78
2010	898	3.87	846	3.05	247	3.24	1,991	3.40
2011	891	3.56	720	2.26	246	2.82	1,857	2.83
2012	844	3.30	704	2.36	240	2.87	1,788	2.80
2013	479	2.59	528	2.62	172	2.61	1,179	2.61

Note: MRSA = methicillin-resistant *Staphylococcus aureus*
Note: 2013 data is preliminary. Data included are from January 1 to September 30, 2013. For all years, only sites that submitted both numerator and denominator data are included in the rate calculations.

5.6 Literature review of cost-effectiveness data

No cost-effectiveness studies of the EMS compared with DO was found.

Chapter 6 Economic Analysis for BC

Summary

The best available evidence suggests that the addition of EMS to the current audit process for monitoring hand hygiene compliance in BC will increase costs compared with the current audit process alone. The costs avoided with MRSA treatment and reduced DO are unlikely to outweigh the total cost of implementing EMS to monitor HH at current prices if implemented across acute care and residential care settings.

The cost estimates were most sensitive to the effect of improving compliance, the price of the EMS, the cost of MRSA cases (infections and colonizations), and especially the effect of improved compliance in reducing infections, which have not yet been rigorously studied in the medical literature.

The scenarios where EMS potentially looks more efficient entail a dramatic price reduction ($[redacted] per bed per year), or a considerably higher cost of treating MRSA cases than the costs published in the literature.

There is a considerable degree of uncertainty in the model, in large part because the effectiveness estimates were generated from observational studies. Simultaneous adoption and empirical evaluation of the technology in realistic settings with appropriate study designs and statistical analysis are highly recommended and can help explore the benefits of the technology and reduce the uncertainty.

6.1 Objectives

To evaluate the cost-consequence of incorporating EMS with aggregate feedback into the HH compliance measurement and reporting process in BC compared with the current standard audit process (DO only).

6.2 Methods

We created a decision-analytic model for HH compliance and MRSA infections to estimate the costs and health outcomes associated with changes in compliance attributed to the use of EMS in acute and residential care units over a 10-year period in BC.

6.2.1 Target population and subgroups

We stratified the BC population into acute care facilities and residential care facilities by the six different health authorities: Fraser Health, Interior Health, Northern Health, Provincial Health Services, Vancouver Coastal–Providence Health, and Vancouver Island Health. The analysis was performed separately within each subgroup. To generate results for the entire province, weighted-averages were applied to subgroup-specific results, with the weights being their specific bed capacity in 2016.

6.2.2 Setting and location

The public health care system in BC, in total and divided across health authorities, covering all acute and residential care patients within the province. The period from which the empirical data for this analysis were available was 2012/2013 to 2015/2016. The projections were made for the same population for the years 2018 to 2027.

6.2.3 Study perspective

We chose a publicly funded health system perspective. Out-of-pocket expenses and productivity loss were not included.

6.2.4 Comparators

We examined EMS alongside DO audits as compared with DO audits only; the latter is the current standard for HH compliance measurement in BC.

6.2.5 Time horizon

We used a 10-year period in the base-case analysis. Three-year and five-year periods were investigated in the sensitivity analyses.

6.2.6 Discount rate

A 1.5% discount rate was applied to both costs and outcomes (including compliance). Alternative values were explored in the sensitivity analyses. (72)

6.2.7 Currency, price date, and conversion

All costs were inflated to 2016 Canadian dollars using the annual health and personal care Consumer Price Index for BC. (73)

6.2.8 Choice of health outcomes

The main outcome of interest was the number of MRSA cases avoided, since this is the goal of improving HH practices. The secondary outcome was change in HH compliance, since change in compliance due to the health technologies under study is considered the main mediator affecting the rate of infection. Measures of general health such as quality-adjusted life years are not chosen as the effectiveness metric, so this evaluation is a cost-consequence analysis and not strictly a cost-effectiveness analysis.

6.2.9 Model structure

After evaluating the available evidence and consulting with infection control experts and epidemiologists, we created a simulation model based on forecasted curves to accommodate the relevant outcomes for patients and the health system with regard to HH. These outcomes were HH compliance adjusted for the known biases affecting compliance measurement (Hawthorne effect, observer bias, etc.), MRSA infection rates, and costs. Each point of extrapolation in the forecasted curves represents a three-month cycle, in accordance with the provincial HH compliance reports.

6.2.10 Study parameter, sources, and assumptions

Input parameters for the model came from the literature review (reported in Chapter 5), and analysis of administrative data from multiple databases within the Ministry of Health and health authorities (PICNet compliance and infection rates reports, Hospital, Diagnostics, and Workforce Branch database, and other health authority-specific databases and reports).

6.2.10.1 The effectiveness of technologies

6.2.10.1.1 Effect of HH measurement methods on compliance

The observed HH compliance rates and the effect of the intervention in changing HH compliance rates are key parameters in determining the costs and health outcomes in the model. It is known that the observed compliance rates are biased (Hawthorne effect, observer bias) (40-42, 44); correcting this bias is key to producing valid economic evaluation results.

To predict future compliance rates under the status quo scenario of HH practices in BC, we obtained quarterly compliance rates for 18 three-month periods from 2012 to 2016 in each of the six health authorities and used a mixed-effects logistic regression to model compliance rate as a log-linear function of time. We included a random intercept and a random linear time trend in the model for each health authority. We explored more complicated functions of time, including quadratic and cubic forms, but found them unstable for predicting future rates. We used this model to obtain forecasts for quarterly compliance rates in each health authority up to 2027 and corresponding 95% prediction intervals. This analysis was performed using R version 3.3.1. (74) The compliance curves showing the historical data from each health authority and their forecasted trajectory are shown in Appendix F.

The Hawthorne effect and other biases present in contemporary reports based on DO audits are a well-known phenomenon to HH specialists (41, 42). These biases are expected to be even greater in self-reported units (performed by front-line staff auditing their unit peers) than in units where auditing is performed by dedicated auditors (infection control practitioners, co-op students, or other types of dedicated auditors). We have made assumptions for two different effect sizes for biases present in DO audits, as derived from data retrieved from two independent studies. For non-self-audited units, we used the estimated compliance under DO as well as EMS in the data from Mount Sinai Hospital, Toronto (unpublished data, confidential communication with the author) (75) during a one-year period in which compliance was measured by both DO and DebMed EMS. Because the health care team did not have access to the EMS data, the difference in compliance rate represented the extent of observation bias. The absolute difference in compliance rates reported by EMS in this period was [redacted]% lower than rates reported by DO, resulting in a relative ratio (RR) of [redacted] that could be applied to nominal compliance value to correct for observation bias (Table 11).

For self-audited units, the same bias effect observed in Mount Sinai Hospital was applied and further inflated to account for observer bias (Table 11), as reported in Dhar 2010. (44) Because different health authorities apply different audit modes, the amount of bias is specific to each health authority (Table 3). We applied the above-mentioned bias effects proportionately to each health authority according to their different audit modes (Table 15).

Table 15. Bias effect by health authority by facility type expressed in risk ratio of compliance.

	IHA	FHA	VCHA	PHSA	VIHA	NHA
ACF	0.3216	0.2926	0.3207	0.3216	0.2990	0.3161
RCF	0.3216	0.2894	0.2977	0.0000	0.2894	0.3151

Note: ACF = acute care facilities; FHA = Health Authority; IHA = Interior Health Authority; NHA = Northern Health Authority; PHSA = Provincial Health Services Authority; RCF = residential care facilities; VCHA = Vancouver Coastal Health Authority; VIHA = Vancouver Island Health Authority.

For each health authority, we forecasted compliance curves under status quo were then adjusted for biases for each quarter. These biases-adjusted curves represent background compliance, which corresponds to the real compliance rates if HH was being monitored invisibly and continuously without EMS implementation.

Reported changes in compliance after the introduction of EMS varied substantially across studies (Table 10).We reviewed the literature and sought a conservative estimate due to the quality of evidence available. The effect of EMS on compliance rates in the reference case was modelled through an odds ratio (OR) from published data by So 2016 (38), since this is the only study performed in a Canadian setting (Table 16) using the DebMed EMS. We assumed a gamma distribution for OR with an arbitrary coefficient of variance of 0.25 to model uncertainty around its point estimate. The geometric mean of the pooled odds ratio including all studies was applied in a sensitivity analysis.

Table 16. Odds ratio of compliance after the introduction of EMS for compliance report (calculated).

		Gamma distribution parameters	
Study name	OR	Alpha	Beta
Bouk (64)	2.8379	16	0.1774
Crnich ICU(67)	1.5388	16	0.0962
Crnich non-ICU(67)	1.7386	16	0.1087
**** So (38)**	[redacted]	[redacted]	[redacted]
Kelly (69)	1.8115	16	0.1132
Geometric mean of the pooled OR	1.7888	16	0.1118

Note: ICU = intensive care unit; OR = odds ratio.
** = study used in the base case

To simulate the effect of the use of EMS on compliance rates in the intervention arm, we applied this OR of compliance to the bias-adjusted compliance curves over time.

6.2.10.1.2 Effect of compliance on MRSA

HCAI are known to be multifactorial (HH, antibiotics usage, and environmental disinfection). It is difficult to correlate HH compliance data with the HCAI infection rates because a number of elements affect infection rates, including the time lag between compliance measurements and diagnosis of infections and the multidirectional effect of compliance–infection (e.g., low compliance can drive infection rates up, whereas outbreaks can in fact increase compliance). It is also challenging to find the attributable effect size of one specific intervention in increasing compliance, because there is usually a bundle of quality improvement actions in place to improve compliance, tailored to the clinical context and targeting the general public. However, some experimental data are available to make some extrapolations to link HH compliance changes and the subsequent effect on infection rates (Table 17).

Table 17. Compliance and MRSA rates from before-after-studies using EMS.

Study name	Compliance before	Compliance after	Baseline MRSA rate baseline (per 10K patient days)	End of study MRSA rate baseline (per 10K patient days)
Bouk (64)	57%	79%	3.94	1.98
So (38)	[redacted]	[redacted]	[redacted]	[redacted]
Kelly (69)	54.9%	68.8%	3.81	2.67
Pittet (1)	47.60%	66.20%	2.16	0.93

Note: MRSA = methicillin-resistant *Staphylococcus aureus.*

Compliance data and MRSA infection rates obtained from four time series studies were treated as before-and-after experiments (incorporation of EMS (38, 61, 64, 69) or HH promotion program (1)). The relationship was investigated using a log-linear regression model whose parameters were estimated using Bayesian inference, implemented in OpenBUGS. (76). The linear predictor included an intercept and slope for the effect of compliance on infection rates:

$$Log(MRSA\ rate_t) = \beta 0_{HA} + \beta 1 \times Compliance_t$$

BC reports quarterly HH compliance rates and MRSA cases rates (infection and colonizations aggregated) in acute care facilities by health authorities. HH compliance rates have also been reported for residential care facilities in the same fashion, but data on MRSA in those facilities have not been published. Therefore, the intercept for MRSA cases ($\beta 0_{HA}$) was taken from the provincial data as follows: based on the PICNet quarterly reports, we calculated the average annual compliance and average annual MRSA rates in acute care facilities per health authority for the last five years. Since BC has not reported the MRSA cases rates in residential care facilities, we used the ratio between MRSA infections in residential care and acute care (Table 18), calculated from published data by Evans 2017. (3) We applied this ratio

to the historical average of MRSA cases rates in acute care facilities in BC to find the average MRSA cases rate in residential care facilities.

Table 18. MRSA infections in acute care and residential care facilities. (3)

	Total cases	Estimated rate October 2007	Calculated patient days per 1,000	Weight
Acute care intensive care unit	1,811	1.133	1,598	0.1379
Acute care non-intensive care unit	4,516	0.452	9,991	0.8621
Total HAIs Long-term care	3,607	0.221		

Calculated weighted ratio of MRSA infections	
Acute care	0.55
Long-term care	0.22
Ratio RCF/ACF	0.4048

Note: ACF = acute care facilities; HAI = hospital-acquired infection; MRSA = methicillin-resistant Staphylococcus aureus; RCF = residential care facilities.

The slope ($\beta 1$) is estimated from the model. Since there were only four studies, we limited the number of parameters in our model by using a fixed, rather than a random, intercept (thereby assuming the relationship between compliance and infection rate is the same across all health authorities). We also used an informative prior of Normal (0,1) for this parameter.

The mean of the posterior distribution for the slope ($\beta 1$) of the regression model of compliance on MRSA rates, and corresponding 95% credible intervals, were obtained (Table 19) and were approximated by a lognormal distribution in the probabilistic model. The expected MRSA rates for both comparator and intervention were forecasted using the model described above and plugging the individual health authority intercept for MRSA infections in to their

forecasted compliance curves (with and without the EMS intervention) and the calculated slope of changes in MRSA depending on compliance.

Table 19. LN ($\beta 1$) – slope for the Bayesian regression model of compliance on MRSA infection rates.

LN(mean)	sd	95% CI lb	95% CI ub	Distribution
−0.0802	0.7354	−1.79	1.117	Lognormal

Note: CI lb = confidence interval lower bound; CI ub = confidence interval upper bound; LN = lognormal; MRSA = methicillin-resistant *Staphylococcus aureus;* sd = standard deviation.

These predicted MRSA rates per patient day were then applied to the forecasted inpatient days in acute care facilities and residential care facilities to estimate the number of MRSA cases within each health authority. Since Provincial surveillance for MRSA only captures incident cases, the model only refers to 'incident' MRSA cases forecasted or avoided,

The number of inpatient days in acute care facilities was estimated based on historical data from PICNet (Table 7), calculating the average growth rate per health authority, and applying this rate into the following years. However, inpatient days per health authority was capped at 115% bed capacity, assuming there will not be additional beds in the future and 15% is the maximum patient turnover they can accommodate (Table 20).

Table 20. Estimated inpatient days in acute care facilities per health authority based on historical data and growth rate.

	IHA	FHA	VCHA	PHSA	VIHA	NHA	Total
2018/2019	504,066	1,194,189	704,115	72,228	648,338	199,496	3,322,432
2019/2020	507,141	1,194,189	713,625	69,409	655,230	202,216	3,341,809
2020/2021	510,234	1,194,189	723,264	66,699	655,230	204,972	3,354,588
2021/2022	513,346	1,194,189	733,034	64,095	655,230	207,767	3,367,660
2022/2023	516,477	1,194,189	742,935	61,593	655,230	210,599	3,381,023
2023/2024	519,627	1,194,189	752,970	59,189	655,230	213,470	3,394,675
2024/2025	522,796	1,194,189	763,140	56,878	655,230	216,381	3,408,614
2025/2026	525,985	1,194,189	773,448	54,658	655,230	219,331	3,422,840
2026/2027	529,193	1,194,189	777,797	52,524	655,230	222,321	3,431,254

Note: FHA = Fraser Health Authority; IHA = Interior Health Authority; NHA = Northern Health Authority; PHSA = Provincial Health Services Authority; VCHA = Vancouver Coastal Health Authority; VIHA = Vancouver Island Health Authority.

No such history of inpatient days in residential care facilities is available. Therefore, we assumed residential care facilities (Table 6) will be operating in full capacity constantly. No over-capacity was assumed in this setting; the calculated inpatient days per year in residential care facilities are displayed in Table 21.

Table 21. Estimated inpatient days per year in residential care facilities per health authority based on number of beds at full capacity.

	IHA	FHA	VCHA	PHSA	VIHA	NHA	Total
N. beds	2,520	1,505	2,557	0	1,793	1,080	9,455
100% inpatient capacity	919,800	549,325	933,305	0	654,445	394,200	3,451,075

Note: FHA = Fraser Health Authority; IHA = Interior Health Authority; NHA = Northern Health Authority; PHSA = Provincial Health Services Authority; VCHA = Vancouver Coastal Health Authority; VIHA = Vancouver Island Health Authority.

6.2.10.1.3 Costs

The cost of EMS was provided by the manufacturer (DebMed). We used this value as the input parameter for the technology cost, as DebMed is the only validated EMS in Canada. The price schedule for the DebMed EMS is $[redacted] per bed per year and includes hardware, software,

training, maintenance, and batteries. The cost of implementing the EMS across the province was applied to the specific health authority's bed capacity in acute care facilities and residential care facilities.

The costs incurred to perform DO were elicited through a costing exercise with the individual health authorities, and we calculated their average cost per observation performed (Table 5**Error! Reference source not found.**, Table 22 and Appendix A) as reported in the last four quarters of PICNet data (Q4 2015/2016 to Q3 2016/2017).

For the status quo arm, to calculate the annual cost of performing DO, we applied the specific health authority average costs per observation over their annual volume of observation (Table 23). For the intervention arm, we assumed a two-year phase-in for the EMS implementation, during which the annual volume of DOs would remain the same as under the status quo. This period was assumed to allow for validation purposes, methods, and policy transition. After the second year, the number of DOs was assumed to decrease to the minimum requirement adapted from WHO recommendations:

- For acute care facilities with more than 25 beds, 200 observations per quarter per site.
- For acute care facilities with less than 25 beds, 300 observations a year.
- For residential care facilities with more than 25 beds, 300 observations per year.
- For residential care facilities with less than 25 beds, 200 observations a year.

Table 22. Average cost per direct observation in acute and residential care facilities by health authority.

		IHA	FHA	VCHA	PHSA	VIHA	NHA	VCH	PHC	cv	Distribution
Acute Care	Mean	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	sd	[redacted]	[redacted]		[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
	alpha	[redacted]	[redacted]		[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
	beta	[redacted]	[redacted]		[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
Residential Care	Mean	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	
	sd	[redacted]	[redacted]			[redacted]	[redacted]	[redacted]	[redacted]		
	alpha	[redacted]	[redacted]			[redacted]	[redacted]	[redacted]	[redacted]		
	beta	[redacted]	[redacted]			[redacted]	[redacted]	[redacted]	[redacted]		

Note: cv = coefficient of variation; FHA = Fraser Health Authority; IHA = Interior Health Authority; NHA = Northern Health Authority; PHC = Providence Health Care; PHSA = Provincial Health Services Authority; sd = standard deviation; VCH= Vancouver Coastal Health authority (excluding PHC); VCHA = Vancouver Coastal Health Authority (including PHC); VIHA = Vancouver Island Health Authority.
Note: VCHA average cost per observation was a weighted average of the VCH and PHC costs, with the weights being calculated based on the volume of observations performed by PHC contributing into the VCHA public compliance rates (16.42% in acute care and 25.88% in residential care).
Note: IHA could not perform the costing exercise. We therefore assume the IHA acute care facilities costs per observation was the average between VCH and VIHA cost per observation, and IHA residential care facilities costs per observation was the average costs between VCH and Northern Health cost per observation, because they are the most similar health authorities in mode of audit.
Note: PHC was the only health authority whose costing exercise can based on collected data. We therefore calculated the coefficient of variance found in PHC's data and used it to calculate the other health authorities' standard deviation for the probabilistic model.

Table 23. Annual volume of direct observations in acute and residential care facilities.

	IHA	FHA	VCHA	PHSA	VIHA	NHA
Under the status quo						
*ACF	31,577	104,103	27,067	4,600	22,036	16,400
*RCF	9,920	16,562	9,890	0	6,294	6,408
After EMS phase-in period						
ACF	11,100	9,900	7,300	1,600	7,900	8,400
RCF	9,920	6,300	5,700	0	5,800	6,408

Note: ACF = acute care facilities; FHA = Fraser Health Authority; IHA = Interior Health Authority; NHA = Northern Health Authority; PHSA = Provincial Health Services Authority; RCF = residential care facilities; VCHA = Vancouver Coastal Health Authority; VIHA = Vancouver Island Health Authority.
* Reported in the last four quarters of PICNet data (Q4 2015/2016 to Q3 2016/2017)

These rules were applied to all health authorities except for residential care facilities in Interior Health Authority and Northern Health Authority. We kept these two health authorities' current volumes of DO, as is not realistic to expect an increase in performing DO (compared to status quo) in addition to the EMS implementation.

A costing exercise was also carried out with PICNet management to estimate the resources employed in producing the quarterly and annual reports. It was estimated that approximately $[redacted] in personnel time is invested in producing those reports (Table 24).

Table 24. PICNet costs of maintaining the direct observation public reports.

Activities in the DO reporting process	Total hours	Cost
Data entry, preparation, and cleaning	41	[redacted]
Data collection, validation, cleaning, analysis, drafting report, responses to comments and report reviews	195	[redacted]
Reviewing report, drafting, communications with PHSA and MOH, posting	51.5	[redacted]
Report review and discussion	11.5	[redacted]
Total costs		[redacted]

Note: DO = direct observation; MOH = Ministry of Health; PHSA = Provincial Health Services Authority.

This cost was applied annually in the model. During the phase-in of EMS implementation, there may be an increase in time dedicated to the compliance reports to clarify auditing methods, sample size, data collection, consolidation, analysis, and reporting with each individual health authority, but this is hard to predict. To provide some adjustment for this period, a 15% increase in PICNet costs was assumed during the phase-in period, returning to the current costs in the third year. An arbitrary 0.25 coefficient of variation was applied to this cost to incorporate uncertainty in the probabilistic model. PICNet costs were proportionally attributed to acute and residential care facilities according to their weights. Based on the volume of DO performed across the province in the last year, acute care facilities

corresponded to 80.7% of the reported observations. Residential care facilities corresponded to 19.3% of the reported observations.

To estimate the costs of HH products per health authority (Table 25), their total expenses for those products were divided by their total acute care facilities and residential care facilities inpatient days (weighted between acute care and residential care days). Dividing this value by the observed compliance during the same period would result in the estimated total costs under 100% compliance scenario. Multiplying this quantity with a forecasted compliance in the future enables the prediction of total costs at predicted levels of compliance in the future.

Table 25. Cost with hand hygiene supplies by health authority.

Year reference 2016	IHA	FHA	VCHA	PHSA	VIHA	NHA
ACF inpatient days	494,954	1,127,448	676,337	81,393	598,271	191,554
RCF inpatient days	919,800	549,325	933,305	0	654,445	394,200
ACF average compliance (2015/2016) – adjusted for biases (%)	0.2505	0.2558	0.2527	0.2919	0.3631	0.2414
RCF average compliance (2015/2016) – adjusted for biases (%)	0.2498	0.2460	0.2546	0	0.2591	0.2584
Cost with hand hygiene products ($)	483,791	679,032	430,126	101,160	315,955	184,020
Cost per inpatient day ($)	0.34	0.40	0.27	1.24	0.25	0.31
Cost of HH supplies per inpatient day assuming 100% compliance ($)	1.37	1.60	1.05	4.26	0.82	1.24

Note: ACF = acute care facilities; FHA = Fraser Health Authority; IHA = Interior Health Authority; NHA = Northern Health Authority; PHSA = Provincial Health Services Authority; RCF = residential care facilities; VCHA = Vancouver Coastal Health Authority; VIHA = Vancouver Island Health Authority.

In terms of the attributable costs of MRSA infections, there is not much data available in the literature for a Canadian context (Table 26) (13, 77, 78). Kim et al. (77) (infections = 20; colonizations = 79) is the only study with primary data that enables investigating uncertainty

around the costs parameter (standard deviation and coefficient of variance) and the cost differences between managing infection cases ($17,361) and colonization cases ($1,648). Goethebeur et al. (13) gathered most Canadian publications on MRSA costs and performed a costing exercise aggregating their different pieces of information (from primary data, from other cost exercises, from modelling-based studies) and provides a slightly different estimation of the cost of MRSA infections and colonizations ($13,794 and $1,701, respectively). A poster conference presented while this economic evaluation was being performed was brought to our attention by experts; it suggests a much higher cost of MRSA infections ($39,227).

The authors gave us access to some more unpublished data and the methods applied. The Alberta cost study was a matched study, used case-mix group methodology, and included direct and indirect health care costs, costs for physicians, rehabilitation, drugs, and supplies. However, this study has not been peer-reviewed and published, so we chose the values from Kim et al. (77) as our reference case, and sensitivity analysis was performed with the Alberta cost data.

Based on the above data, the management of colonizations is estimated to be 9 to 12 percent of the costs of infections in the published literature, but 38 to 49 percent of the costs of infections in the unpublished study from Alberta (Table 26). In BC, the MRSA rates reported to PICNet, following the current case definition, aggregate both infection and colonization cases. To adjust for this, Canadian proportions of infections and colonization were applied to the estimated number of cases for BC. These proportions were calculated from data from PHAC 1995 to 2007 and CNISP 2007 to 2013 and estimated for future years using a log-linear regression (Table 27).

Table 26. MRSA costs of treating infections and colonizations from literature (and estimated cost ratio).

Mean Adjusted for CAD$2016	Mean	min	max	cv	sd	alpha	beta		Health Inflation correction factor	Source/reference year/assumption
Infections										
17,361	14,360			0.32	4,610	9.704	1,480		1.209	Kim 2001 /CAD 2001/ infections n=20(77)
13,794	12,216	6,878	17,553		3,921	9.704	1,259		1.129	Goethebeur 2006/ CAD 2005/multiple sources of data e.g. primary data, models, etc.(13)
39,227	38,228				12,271	9.704	3,939		1.023	Waldner 2017 Poster/CAD 2014/ applied Kim's 2001 cv and ratio infection/colonization costs(78, 79)
48,596	47,500				15,248	9.704	4,895		1.023	Waldner 2017 Presentation - Health Acquired - unpublished data (confidential)/ CAD 2014(78, 79)
31,550	31,550				10,128	9.704	3,251		1.023	Waldner 2017 Presentation – Community Acquired - unpublished data (confidential)/ CAD 2014(78, 79)
Colonizations										
1,648	1,363			0.25	341	16	85		1.209	Kim 2001 /CAD 2001/ colonizations n=79(77)
1,701	1,506	1,506	1,506		377	16	94		1.129	Goethebeur 2006 - 2006/ CAD 2005/multiple sources of data e.g. primary data, models, etc.(13)
4,133	4,027				1,007	16	252		1.023	Waldner 2017 Poster/CAD 2014/ applied Kim's 2001 cv and ratio infection/colonization costs (78, 79)
3,182	3,101				775	16	194	Gamma distribution	1.023	Waldner 2017 Poster/CAD 2014/ applied Kim's 2001 cv and Goethebeur's ratio infection/colonization costs (78, 79)
24,132	23,588				5,897	16	1,474		1.023	Waldner 2017 Presentation - Health Acquired - unpublished data (confidential)/ CAD 2014(78, 79)
12,437	12,157				3,039	16	760		1.023	Waldner 2017 Presentation – Community Acquired - unpublished data (confidential)/ CAD 2014 (78, 79)
Ratio Colonization/Infection costs										
0.095	times the cost of infection									Kim 2001(77)
0.123										Goethebeur 2006 (13)

Note: max = maximum; min = minimum; cv = coefficient of variation; sd = standard deviation; CAD = Canadian Agency for Drugs and Technologies in Health (CADTH); CAD$ = Canadian dollars

Table 27. Proportion of infection and colonization cases among the reported MRSA rates.

Year	% Infection	% Colonization
2018	18.7%	81.3%
2019	18.3%	81.7%
2020	18.0%	82.0%
2021	17.6%	82.4%
2022	17.3%	82.7%
2023	16.9%	83.1%
2024	16.6%	83.4%
2025	16.3%	83.8%
2026	15.9%	84.1%
2027	15.6%	84.4%
2028	15.3%	84.7%

Note: MRSA = methicillin-resistant *Staphylococcus aureus.*

6.2.11 Currency, price date, and conversion

All costs were inflated to 2016 Canadian dollars using the annual health and personal care Consumer Price Index for BC. (73)

6.2.12 Analytic methods

For the base-case analysis, we calculated a single set of outcomes within each health authority for compliance, infections, and cost with or without the use of EMS, by weighted-averaging the outcomes within for each facility type (acute care and residential care). We then aggregated by weighted-averaging health authority-level results to generate BC results with weights representing the size of each health authority measured by their bed capacity in 2015/2016. Base-case results were calculated from a probabilistic analysis using a Monte Carlo simulation with 10,000 iterations. The same set of generated results was used to evaluate the degree of uncertainty. Results are reported as summary tables with the average estimates, in the cost-effectiveness plane and the cost-effectiveness acceptability curve. Probability distributions were assigned to each uncertain model parameter, as follows:

- Gamma distributions were used for relative ratios modelling biases around compliance rates (Hawthorne effect, observer bias, etc.), risk ratio of change in compliance with the use of EMS for feedback, cost of infections and colonizations, cost of DOs (from health authorities and PICNet), and cost of HH supplies per inpatient day. We used an arbitrary coefficient of variation of 0.25 for the cost of DOs and HH supplies as uncertainty could not be estimated from the original data.
- We used lognormal distribution for the forecasted compliance curves, the slope of the effect of changes in compliance on MRSA rates, and the forecasted infection and colonization among all reported MRSA cases.

The price of devices was assumed to be known, because price is subject to negotiation. We did not assume any uncertainty around the proportion of mode of audits within each health authority, bed capacity (or calculated inpatient capacity), or ratio of MRSA rates in acute and residential care.

We conducted several scenario analyses to evaluate the effect of changes in key assumptions on the results. We evaluated variations in the odds ratio of changes in compliance with the implementation of EMS, variations in the slope of the effect of changes in compliance on MRSA rate, in the cost of infections and colonization, alternative discounting values (0% and 3%), and alternative price of the new technology.

6.3 Results

6.3.1 Total costs and outcomes – population level

Based on the trends within individual health authorities in reported compliances rates from the past 4.5 years, we forecast that, under the current audit system, those rates are

expected to increase to between 78% and 99.8% in both acute care facilities and residential care facilities, except in Vancouver Island Health, where compliance rates stabilize around 79% in acute care facilities and have a downward trend in residential care facilities (but not lowering below 70%) (Appendix F and Appendix G). When those compliance curves were adjusted for biases in the observation method according to each health authority mode of audit, the background compliance rates seem to range from 23% to 32% in acute care facilities, and 20% to 30% in residential care facilities (Appendix H).

Using DO to measure HH compliance (status quo), in acute care facilities, the average compliance in BC (discounting and adjusting for bias) is 26.6% over a 10-year period, with a total of 20,017 expected MRSA cases. From the estimated total costs of 105.6 million, $86.6 million (82% of total cost) would be spent on treating infections and colonizations, $7.3 million (6.9%) on HH audits, and $11.6 million (11%) on purchasing supplies for HH (soap/alcohol) (Table 28).

In residential care facilities (status quo), the average compliance in BC (discounting and adjusting for bias) over 10-year period is 26.7%, with a total of 7,891 expected cases of MRSA. From the estimated total costs of $47.4 million, $34.1 million (72% of total costs) would be spent on treating infections and colonization, $2.5 million (5.3%) on HH audits, and $10.7 million (22.7%) on purchasing supplies for HH (Table 28).

With the addition of EMS to the auditing process, in acute care facilities, the discounted average compliance in BC are expected to increase to 31.9% (Table 28) if no other quality improvement intervention is put in place. MRSA cases are expected to decrease to 19,427 during the forecasted period. Of the total cost of $134.4 million, BC is expected to spend $84.1 million (62%) to treat infections and colonization. Cost with DO is expected to decrease to $2.8

million (2.1%). HH supplies expenses are expected to increase with the increase in compliance to $13.9 million (10.4%). The EMS alone is expected to cost $33.5 million, accounting for 25% of total costs (Table 28).

In residential care facilities (with EMS) the discounted average compliance in BC are expected to increase to 32% (Table 28) if no other quality improvement intervention is put in place. MRSA cases are expected to decrease to 7,653 during the forecasted period. Of the total cost of $85.4million, BC is expected to spend $33.1 million (38%) to treat infections and colonization. Cost with DO is expected to decrease to $1.7 million (2%). HH supplies expenses are expected to increase with the increase in compliance to $12.9 million (15%). The EMS alone is expected to cost $37.6 million, accounting for 44% of total costs (Table 28).

Table 28 Cost of treatment of MRSA cases, cost of the direct observation audits, cost of EMS, cost with hand hygiene supplies, number of MRSA cases (colonization and infections) and average hand hygiene compliance over a 10-year time horizon for the entire inpatient population (discounted).

	Costs					Outcomes	
	MRSA treatment	DO auditing	EMS	HH supplies	Total	MRSA cases*	Discounted average compliance
Acute Care Facilities							
DO	86,666,904	7,316,424	0	11,634,698	105,618,025	20,017	0.266
DO + EMS	84,111,073	2,807,729	33,563,168	13,981,325	134,463,295	19,427	0.319
Residential Care Facilities							
DO	34,175,684	2,517,243	0	10,746,818	47,439,745	7,891	0.267
DO + EMS	33,148,690	1,735,105	37,635,170	12,920,287	85,439,253	7,653	0.320

Note: *Incident Cases

6.3.2 Incremental costs and outcomes – population level

Over a 10-year time horizon, the implementation of EMS has an incremental cost compared with the status quo per MRSA case avoided. Assuming that EMS implementation will reduce volumes of DO and no additional quality improvement intervention is implemented, the average compliance (discounting and adjusting for bias) is expected to increase by 5% for both acute care and residential care facilities. This results in 590 MRSA cases avoided in acute care facilities, and 237 cases avoided in residential care facilities (

Table 29).

The use of EMS, the improved compliance, and the consequent prevention of MRSA cases will reduce the resources necessary to conduct the DO audits by $4.5 million, increase HH supplies expenses by $2.3 million, and avoid $2.5 million in MRSA treatment expenses in acute care facilities. In residential care facilities, it is expected that DO expenses will decrease by $782,137, HH supplies expenses will increase by $2.1 million, and $1.0 million in MRSA treatment will be avoided (

Table 29).

An overall incremental cost-effectiveness ratio (ICER) of $48,852 per incident MRSA case avoided was found in the acute care, base-case analysis. Similarly, an ICER of $160,258 was found in the base-case analysis of residential care. Here it is assumed that resources are being reallocated efficiently, and that no other co-interventions are introduced. Costs avoided with MRSA treatment, and reduced DO, are less than total cost of implementing EMS at current prices; BC would spend an additional $33.6 million in monitors for acute care, and $37.6 million in monitors for residential care (

Table 29).

Table 29. Cost-effectiveness of the implementation of EMS in the auditing process in BC over a 10-year time horizon.

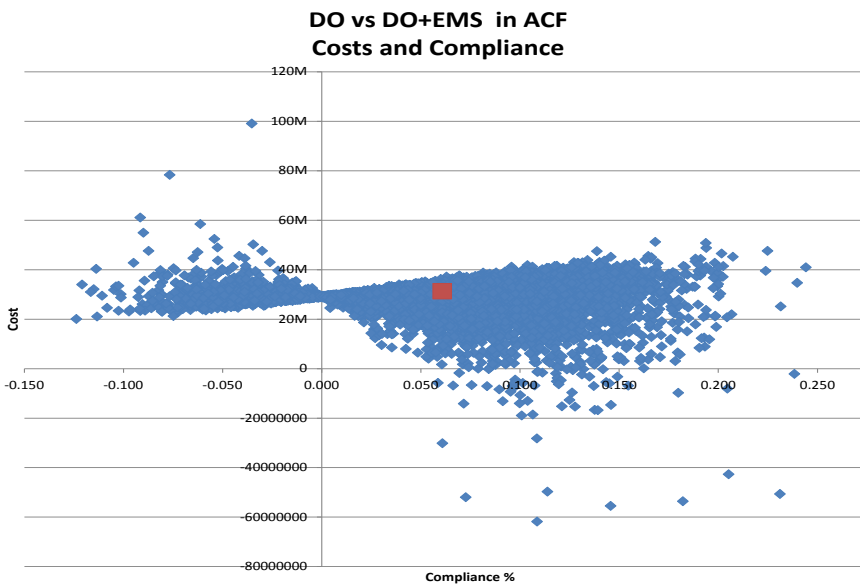
	DO vs. DO +EMS	
	ACF	RCF
Incremental costs	28,845,269	37,999,508
Incremental change in compliance	0.053	0.053
MRSA cases avoided*	590	237
MRSA costs avoided	2,555,831	1,026,994
DO costs avoided (available for reallocation)	4,508,695	782,137
EMS costs	33,563,168	37,635,170
Incremental HH supplies costs	2,346,627	2,173,469
ICER per MRSA case avoided	48,852	160,258
ICER per % compliance increase	549,118,311	722,448,233

Note: *Incident Cases

The model showed a high degree of uncertainty (Figure 7 and Figure 8). The cloud in the cost-effectiveness plane spread over three quadrants, with a great number of points into the northeast and southeast quadrant, showing that the EMS can improve outcomes but potentially at an incremental cost. It may be cost-effective depending on the willingness-to-pay (WTP) threshold defined by the decision makers. The cost-effectiveness acceptability curve

(CEAC) quantifies the uncertainty by demonstrating the probability of cost-effectiveness of EMS at a given WTP. Over a 10-year period, EMS is not more likely to be considered cost-effective than the current observation method unless the BC WTP threshold per MRSA case avoided is beyond $190,000 (Figure 9 and Figure 10). This seems implausible, however, outcomes from decision models typically have asymmetric distributions, and if the distribution of the incremental net benefit is asymmetric, the alternative with the maximum probability of having the maximum benefit may not have the maximum expected benefit. (80)

Figure 7. Cost-effectiveness plane of probabilistic analysis over a 10-year time horizon for acute care facilities.



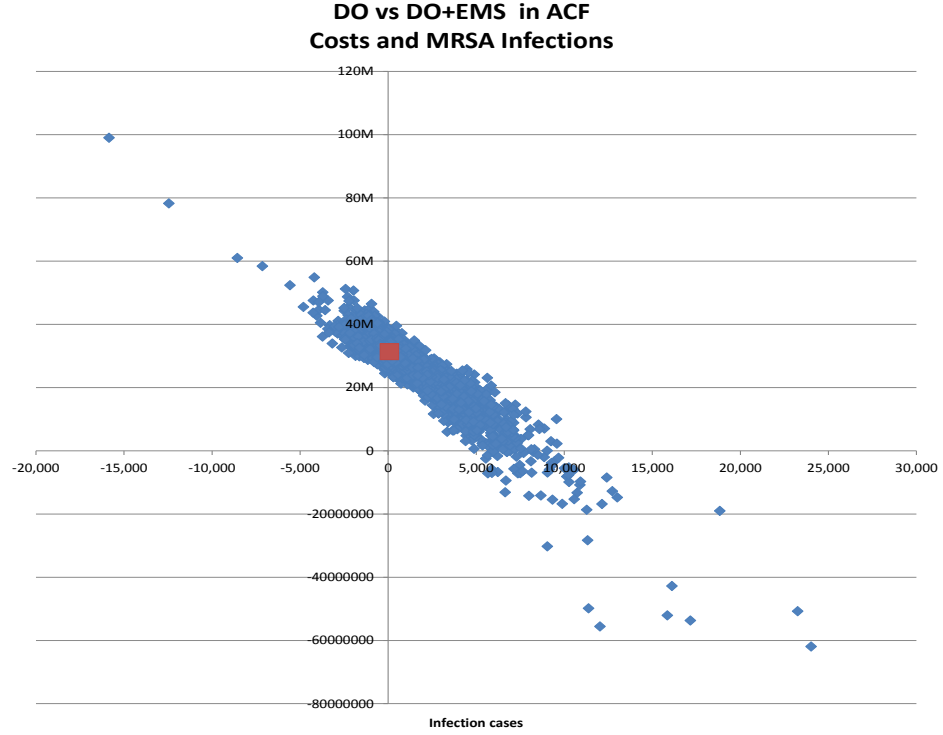
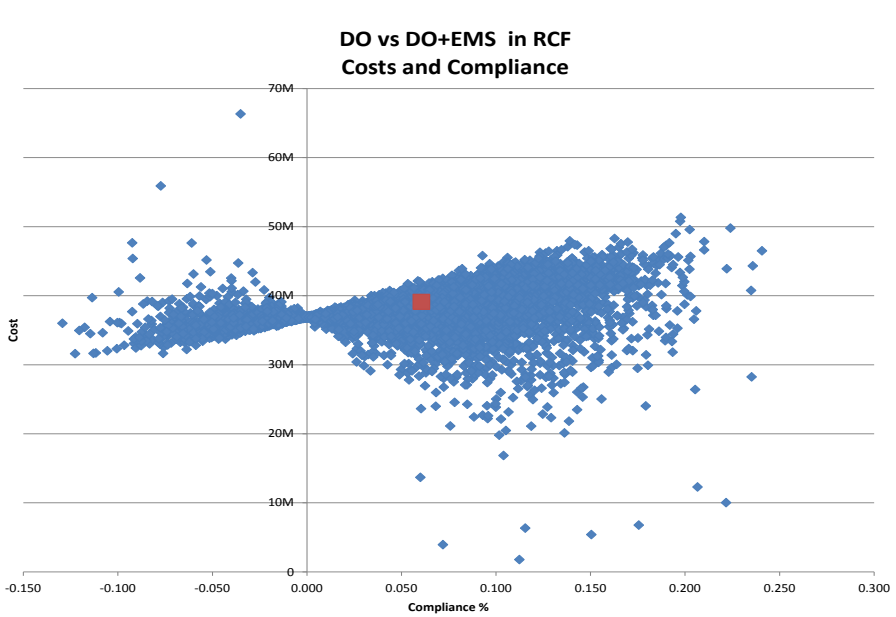


Figure 8. Cost-effectiveness plane of probabilistic analysis over a 10-year time horizon for residential care facilities.



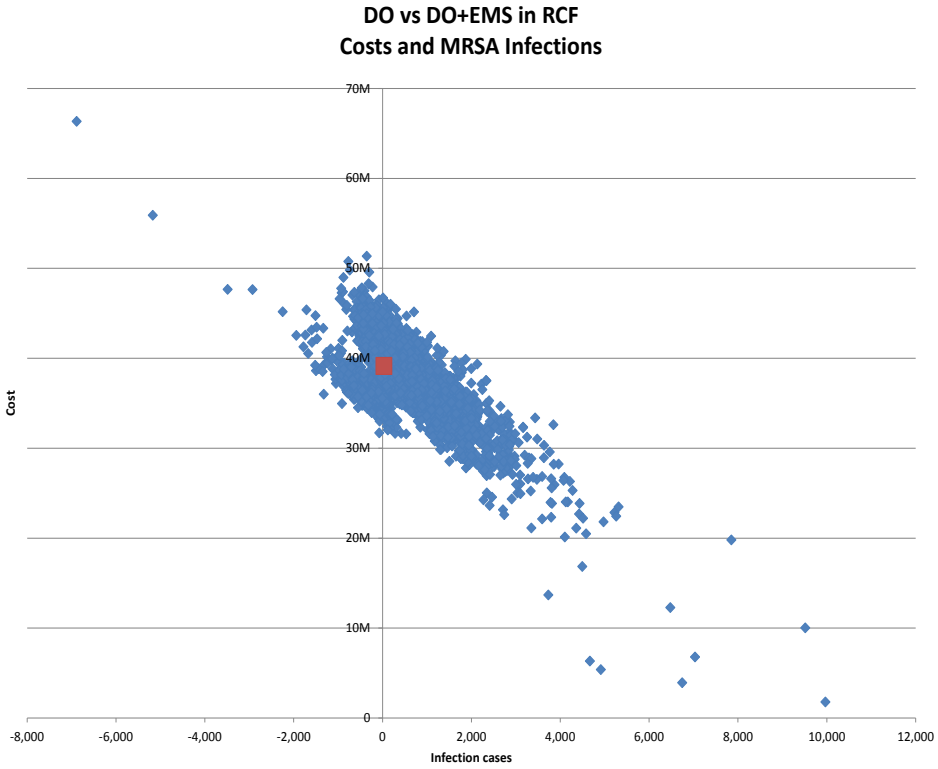
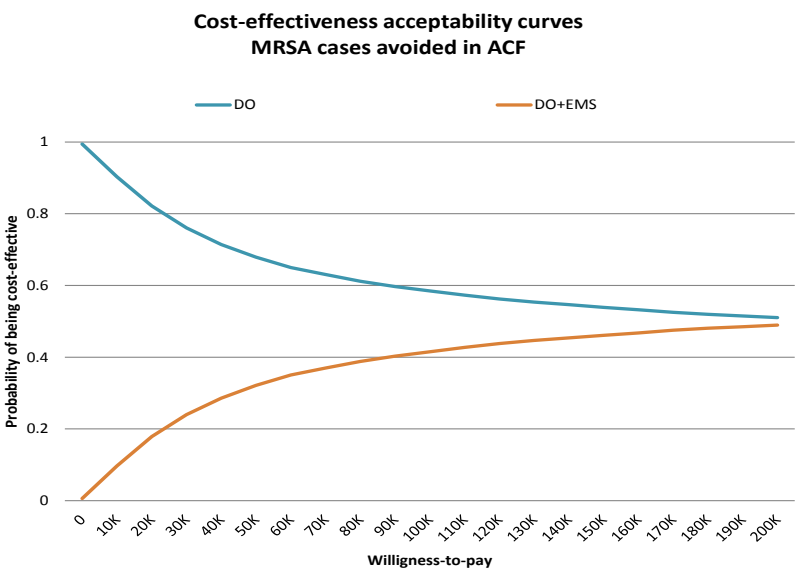


Figure 9. Cost-effectiveness acceptability curve at different thresholds of willingness-to-pay for acute care facilities.



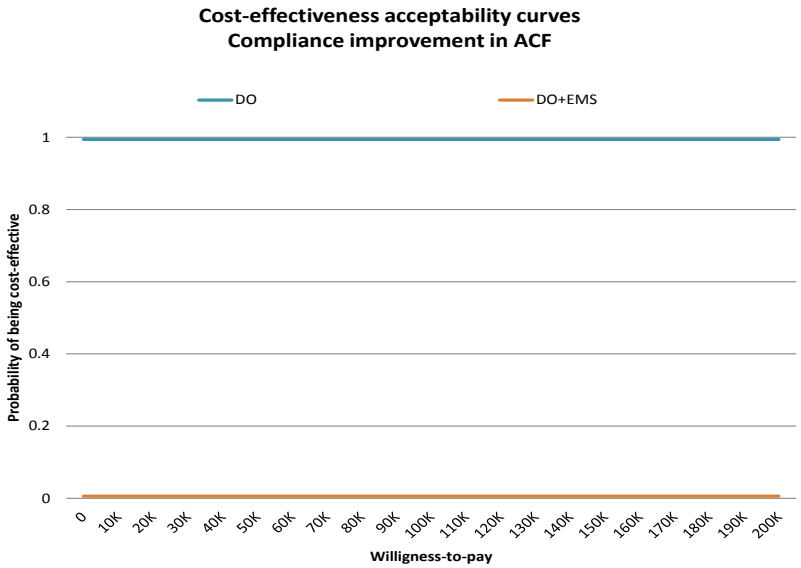
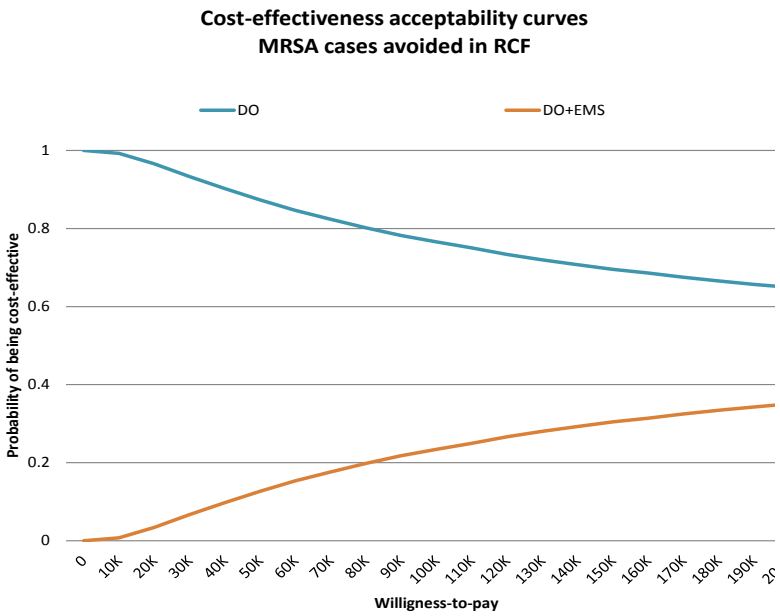
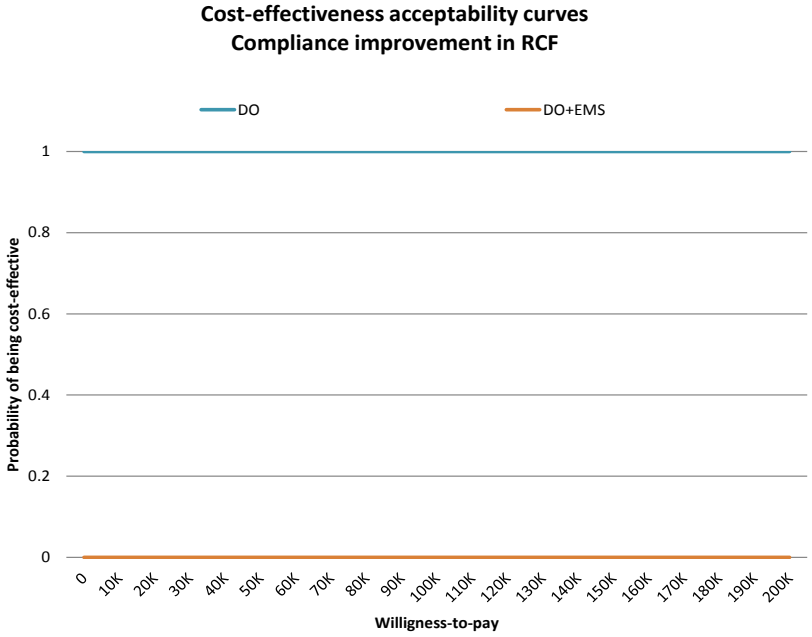


Figure 10. Cost-effectiveness acceptability curve at different thresholds of willingness-to-pay for residential care facilities.





6.3.3 Characterizing uncertainty

Several probabilistic sensitivity analyses (Table 30 and Table 31) were conducted, and results are consistent with the base case. Most sensitivity analyses followed the same pattern with a high degree of uncertainty remaining, mainly around how change in compliance affects infection rates.

A probabilistic analysis using the costs for MRSA infection and colonization from an unpublished study from Alberta (that demonstrates MRSA infections treatment costs are two to three times higher than in the published literature) resulted in an ICER of $22,950 per MRSA case avoided in acute care facilities, and $130,539,000 per MRSA case avoided in residential care facilities. Lowering the price of technology alone does not dramatically change the results. The average ICERs seem to improve, but the degree of uncertainty is such that the probability of those ICERs occurring remains low, even if the technology costs below $[redacted] per bed per year (Figure 11a). EMS was the dominant choice for acute care when all the following conditions were met: 1) cost of infection used is from Alberta; and 2) the price of EMS is $[redacted] per bed per year (compared to the current $[redacted] per bed per year). When these conditions are met, in a conservative scenario EMS has the potential to avoid $2.1 million in acute care facilities when compared to the status quo. In this scenario EMS has a moderate chance (50-60%) of being cost-effective in acute care, in a range of WTPs for MRSA avoided as the outcomes (Figure 11b), but not in residential care.

It is important to note that the use of EMS in the included studies was usually accompanied by other quality improvement co-interventions, and so the improvement in compliance rates cannot be solely attributed to the EMS technology. Therefore, we adjusted this latter scenario to not solely attribute the observed improvement in compliance to the EMS alone, but in between the calculated odds ratio from the study and odds ratio equal to 1 (no effect), still using the highest costs of MRSA infections from Alberta, and EMS costing $[redacted] per bed per year.

Table 30. Probabilistic sensitivity analysis (fully probabilistic analysis changing some parameters sources).

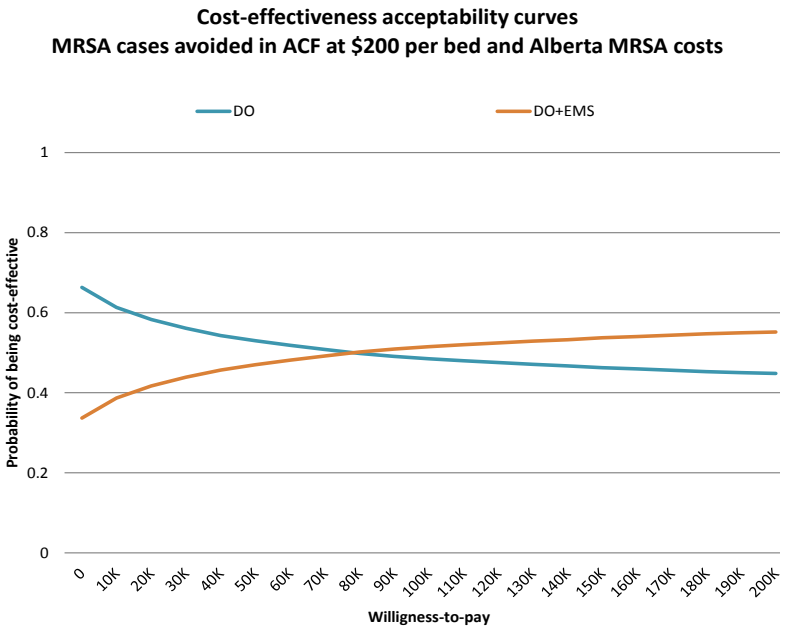
ACUTE CARE	ICER per % increase in compliance	ICER per MRSA	Incremental costs	Incremental compliance	MRSA cases avoided
Base case	549,118,311	48,852	28,845,269	0.053	590
EMS $[redacted] per bed per year (all other parameters as in the base case)	379,627,932	32,135	20,307,308	0.053	632
EMS $[redacted] per bed per year (all other parameters as in the base case)	224,153,881	19,661	11,984,972	0.053	610
EMS $[redacted] per bed per year (all other parameters as in the base case)	65,195,189	5,497	3,504,803	0.054	638
0% discount (all other parameters as in the base case)	534,909,244	43,745	28,544,374	0.053	653
3% discount (all other parameters as in the base case)	536,701,233	50,299	28,989,943	0.054	576
Pooled OR of change in compliance from 4 studies	240,429,804	20,933	28,376,449	0.118	1356
Cost of MRSA – Alberta study – Health acquired only	263,448,570	22,950	14,019,788	0.053	611
Cost of MRSA – Alberta study – Health acquired only +EMS $[redacted] per bed per year	dominant	dominant	-11,096,773	0.053	608
Cost of MRSA - Alberta study - Health acquired only +EMS $[redacted] per bed per year	dominant	dominant	-3,337,619	0.053	638
Cost of MRSA - Alberta study - Health acquired only + EMS $[redacted] per bed per year	104,452,814	8,929	5,518,401	0.053	618
Cost of MRSA - Alberta study - Health acquired only +EMS $[redacted] per bed per year +OR Effect of EMS in compliance - capped to midpoint between reference value and 1 (no effect)	dominant	dominant	-2,105,447	0.019	241
Base case + OR slope of the effect of compliance in infections – without priors	437,673,067	11,868	23,007,778	0.053	1939
Base Case +RR of Biases for adjustment of compliance curves – midpoint between reference value and 1 (no bias effect)	543,888,158	46,878	28,733,336	0.053	613
Cost of MRSA - Alberta study - Health acquired only - costs inflated by 20% to estimate some downstream costs of the incident case	199,401,331	17,466	10,699,707	0.054	613
MRSA cases rates in RCF lowered by 80%, AND proportion of infections among all cases in RCF set to 60% and in ACF to 30%	515,496,054	46,216	27,638,018	0.054	598

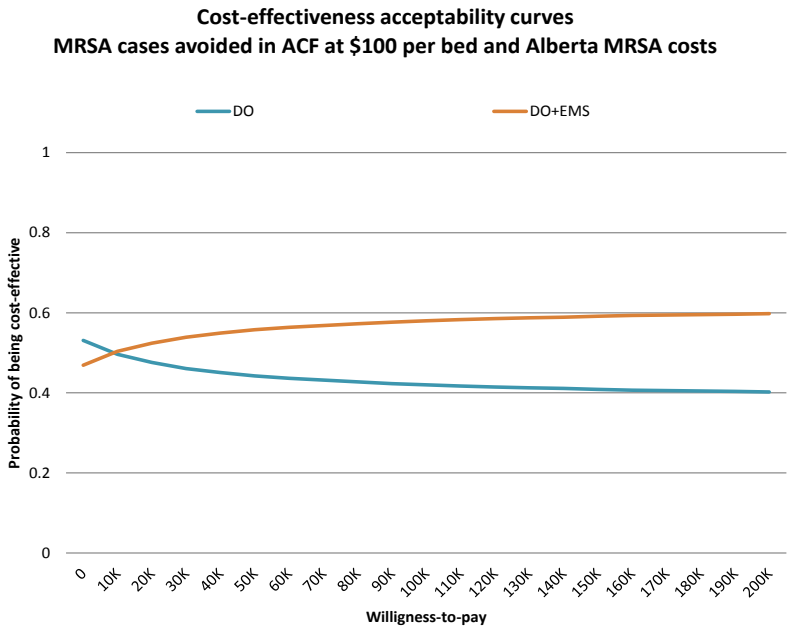
Table 31. Probabilistic sensitivity analysis (fully probabilistic analysis changing some parameters sources).

RESIDENTIAL CARE	ICER per % increase in compliance	ICER per MRSA	Incremental costs	Incremental compliance	MRSA cases avoided
Base case	722,448,233	160,258	37,999,508	0.053	237
EMS $[redacted] per bed per year (all other parameters as in the base case)	533,335,870	112,403	28,546,870	0.054	254
EMS $[redacted] per bed per year (all other parameters as in the base case)	358,289,658	78,221	19,157,707	0.053	245
EMS $[redacted] per bed per year (all other parameters as in the base case)	180,927,374	37,930	9,721,902	0.054	256
0% discount (all other parameters as in the base case)	715,485,236	145,735	38,187,400	0.053	262
3% discount (all other parameters as in the base case)	699,662,858	163,353	37,814,041	0.054	231
Pooled OR of change in compliance from 4 studies	333,051,630	72,116	39,312,209	0.118	545
Cost of MRSA – Alberta study – Health acquired only	602,132,109	130,539	32,053,126	0.053	246
Cost of MRSA – Alberta study – Health acquired only +EMS $[redacted] per bed per year	72,584,942	15,743	3,843,534	0.053	244
Cost of MRSA - Alberta study - Health acquired only +EMS $[redacted] per bed per year	245,621,620	50,705	12,997,114	0.053	256
Cost of MRSA - Alberta study - Health acquired only +EMS $[redacted] per bed per year	426,969,687	90,867	22,576,032	0.053	248
Cost of MRSA - Alberta study - Health acquired only +EMS $[redacted] per bed per year + OR Effect of EMS in compliance - capped to midpoint between reference value and 1 (no effect)	185,745,637	36,896	5,558,246	0.030	151
Base case + OR slope of the effect of compliance in infections – without priors	675,638,338	44,269	35,543,469	0.053	803
Base Case +RR of Biases for adjustment of compliance curves – midpoint between reference value and 1 (no bias effect)	718,161,902	153,996	37,950,309	0.053	246
Cost of MRSA - Alberta study - Health acquired only - costs inflated by 20% to estimate some downstream costs of the incident case	572,175,601	124,635	30,708,905	0.054	246
MRSA cases rates in RCF lowered by 80%, AND proportion of infections among all cases in RCF set to 60% and in ACF to 30%	718,220,603	800,926	38,528,240	0.054	48

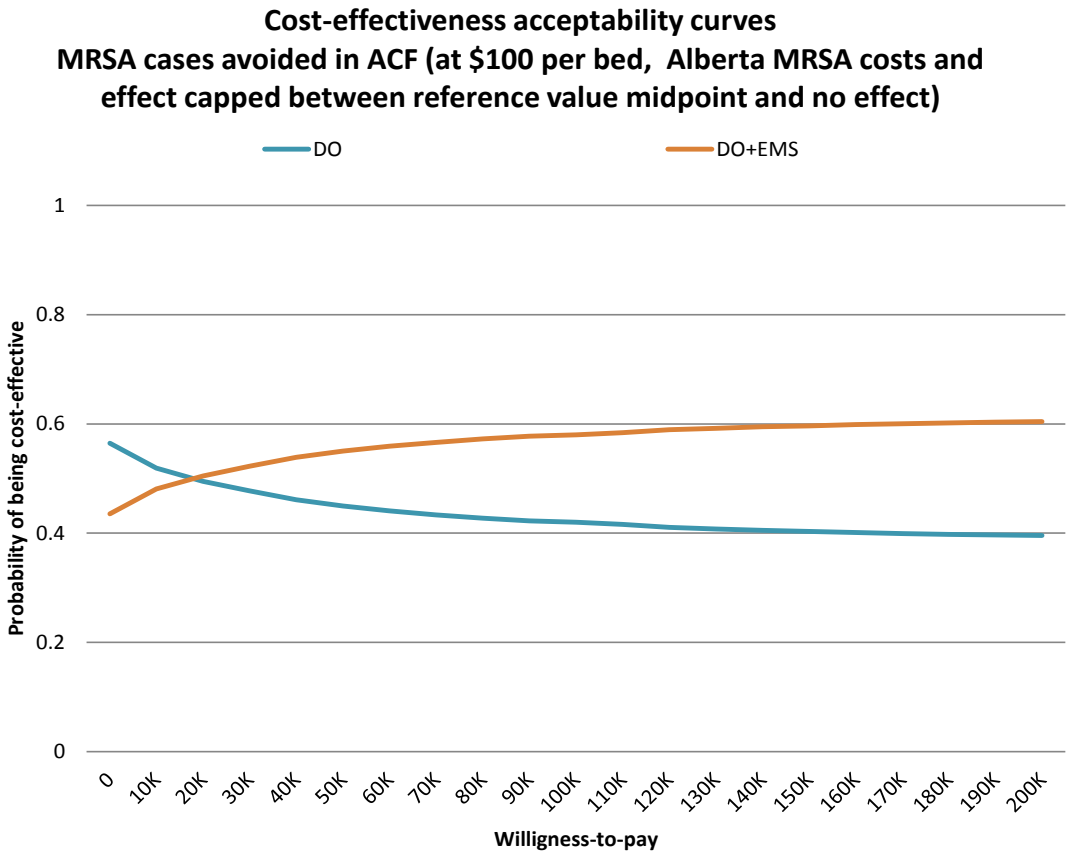
Figure 11. Cost-effectiveness acceptability curves of lowering the price of technology in a scenario with higher costs for MRSA management

11a) Assuming the entire effect in improving compliance found in the published studies attributed to EMS (best case scenario for the technology)





11b) Assuming a partial effect in improving compliance found in the published studies attributed to EMS (conservative scenario for the technology)



6.4 Discussion

Incorporating the best available evidence into a statistical and decision-analytic simulation model showed that the addition of EMS to the current audit process to monitor HH compliance in BC will likely come with incremental costs compared to the current audit process alone at a wide range of WTP values per MRSA case avoided. At this point, the potential costs avoided by the EMS concentrate more in costs for the audit process itself than in costs for MRSA cases. However, at the current price, the estimated cost avoidance cannot offset the EMS costs.

This cost-consequence analysis included only incident MRSA cases because of the lack of quality evidence of the effect of the improvement in compliance on other types of infections from EMS studies (or in general). Thus, it should be acknowledged that this limitation likely underestimates the burden and cost of HCAIs to the healthcare system. It also seems plausible that improved compliance to HH will improve other infection rates beyond MRSA; however, due to the complexity of studying other types of infections and the need for a greater amount of data, it was not feasible to study all HCAIs (e.g., blood infections or surgical site infections that can be caused by a vast number of microorganisms that each have their own specific treatment protocol and costs analysis). The model also does not incorporate the effect of additional interventions the health authorities might choose to implement to improve compliance after accessing the data on compliance rates measured by the EMS. Continuous compliance rates measured by EMS clearly show drastically lower health care team compliance to HH. If feedback about real compliance from monitoring compliance using the EMS does not affect HCP behaviour to improve HH, infection control teams would naturally implement other

strategies to address the issue (education programs, target audits, awareness campaigns, etc.). It is difficult to predict and measure the effect of future interventions that might arise, because health authorities might tailor them according to their teams' capacity and behaviour and other polices in place.

This economic analysis has some other limitations because there are no randomized controlled trials comparing EMS to DO alone and controlling for other quality improvement co-interventions. The effectiveness estimates came from observational studies with risk of biases (selection bias, performance bias, detection bias). Therefore, readers must interpret the results with caution. Our overall recommendation is that if the decision is to adopt EMS, the technology must be adopted in a step-wise fashion with a concomitant real-world assessment of changes in compliance rates (OR 1.33, gamma ~ 16, 0.0832) and testing whether the degree of improvement in MRSA cases follows the same magnitude from the regression models (log Beta: -0.08 (slope of the regression line).

Also, despite our best efforts to include the relevant costs associated with MRSA cases, there are no high-quality studies available costing those infections and colonizations. Costs are very context-specific and depend on factors such as reimbursement system, coverage, and local economy. The Alberta cost study was a matched study, used case-mix group methodology, and included direct and indirect health care costs, cost for physicians, rehabilitation, drugs, and supplies. This study showed a much higher health system cost for MRSA cases and can offer a more conservative approach to cost-effectiveness analysis. However, this study has not been peer-reviewed and we did not feel comfortable using it as the main source of evidence on costs in the model.

Finally, it is important to note one limitation of the provincial data on MRSA rates itself, which is the applied case definition. Currently, healthcare-associated cases are defined by the time frame of the patient encounter with the health care facility, and include the encounter prior to current hospitalization (so-called healthcare associated, community-onset). Given the wide spread and increasing MRSA rates in the community, it is difficult to distinguish whether the case was acquired during a previous encounter or from exposure in the community, albeit their classification as health care associated. Therefore, it is challenging to examine the trends of MRSA and evaluate the effectiveness of interventions. The model assumed all the reported cases as hospital acquired.

Chapter 7 Budget Impact

Summary

Under status quo, BC will spend approximately $1 million per year to perform DOs in both acute and residential care facilities. At current prices the implementation of EMS in acute and residential care facilities would raise the overall cost of monitoring hand hygiene to $8.3 million per year in the initial two years and $7.4 million in subsequent years.

According to the available published evidence, the additional cost of monitoring hand hygiene by EMS at current prices is not offset by costs avoided from a reduction in MRSA cases and DO audits, in both acute and residential care facilities.

If the included MRSA costs in the sensitivity analysis are proven accurate, and a significant price reduction is negotiated, EMS has a moderate probability (50-60%) to potentially avoid costs in acute care settings (− $18.5 million) but would still incur incremental costs in residential care ($11.9 million) over 10 years.

Perhaps a monitored implementation in high risks areas should be targeted to elicit the remaining uncertainties and optimize resources at first (i.e., Settings with above average MRSA rates, or where the acquisition of MRSA infections tends to lead to higher treatment costs).

7.1 Objectives

To evaluate the budget impact of a policy change in BC to incorporate the use of EMS in addition to DO audits to monitor and report HH compliance in acute and residential care facilities in BC.

7.2 Methods

Two scenarios were created to evaluate the budget impact in BC:

1. The status quo scenario, representing the current audit process of using DO alone to monitor and report HH compliance.
2. A scenario that assumes EMS would be available in every acute and residential care unit in addition to an audit process using DO in reduced volumes.

In all scenarios, it was assumed that all health care costs, including cost of the devices, were paid by the public health care system.

The probabilistic statistical model used in the economic evaluation was also used for budget impact analysis to simulate the population impact over 10 years (2018 to 2027). Yearly costs of the devices and system subscription were included and assumed to be incurred under the health authorities' budgets. The overall budget impact on the province is presented separately by acute care and residential care facilities. It was not possible to separate costs for the MSP and health authority budgets because all available data sources presented aggregated costs.

Number of MRSA cases, annual compliance rates and costs were not discounted, and inflation was not applied following the International Society for Pharmacoeconomics and Outcomes Research (ISPOR) guidelines for budget impact (81). Costs were expressed in 2016 Canadian dollars. No changes in price units during the period were assumed (meaning that any nominal change in price in the future would equate to the inflation rate).

Compliance rates, total numbers of MRSA cases, total cost, cost of MRSA treatment and cost of HH supplies, monitors, and DO audits were the outcomes of interest.

7.3 Results

Appendix H shows the forecasted compliances curves for individual health authorities with and without any adjustment for biases, and the expected compliances rates with the incorporation of EMS. We decided not to aggregate the undiscounted compliance rates. They are more informative for decision-making since the health authorities have different bias effects proportional to their own mode of audit.

7.3.1 Status quo

For the status quo scenario in BC for acute care facilities (DO audits alone), the health care cost to treat MRSA cases (infections and colonizations) was estimated to be $92.9 million over 10 years. This scenario predicted approximately 2,073 MRSA cases per year (Table 32 and Table 33), adding up to 21,166 over 10 years. The yearly costs with DO alone are estimated at approximately $781,800, accumulating to $7.8 million over 10 years. The total costs of HH (audit, supplies) and management of MRSA cases are estimated to be around $11.6 million per year, adding to $113.2 million over 10 years. Estimates for individual years are shown in Appendix H and Appendix J.

In residential care facilities, under the status quo, the health care cost to treat MRSA cases was estimated to be $36.6 million over 10 years. This scenario predicted approximately 846 MRSA cases per year (Table 32 and Table 33), adding up to 8,399 over 10 years. The yearly costs with DO alone are estimated at approximately $269,100, accumulating to $2.7 million over 10 years. The total costs of HH (audit, supplies) and management of MRSA cases are estimated to be around $5.3 million per year, adding to $50.8 million over 10 years. Estimates for individual years are shown in Appendix H and Appendix J.

7.3.2 EMS for hand hygiene audit

Incorporating EMS to audit HH (without any other intervention to improve compliance) is expected to improve compliance levels and decrease MRSA cases in BC by approximately 643 cases in acute care facilities and 257 cases in residential care facilities over 10 years.

At the current prices, for acute care facilities, the additional costs for EMS are estimated at $33.7 million ($3.4 million per year). After EMS implementation, costs of HH supplies are expected to increase by $2.5 million (> $238,900 per year as compliance gradually increases). DO costs avoided by the use of EMS are estimated at $4.9 million ($611,900 per year after the phase-in period). Treatment costs for MRSA are expected to decrease by approximately $2.1 million ($211,000 per year). The incremental budget impact expected in the first two years of the implementation of EMS is $3.4 million, dropping to $2.8 million per year with reductions in the number of DO audits. Total costs will increase by $29.2 million (Table 32). Estimates for individual years are shown in Appendix H and Appendix J.

In residential care facilities, at the current prices, the additional costs for EMS are estimated at $37.8 million ($3.8 million per year). Costs associated with HH supplies are expected to increase by $2.3 million (> 229,400 per year as compliance gradually increases). DO costs avoided by the use of EMS are estimated at $850,500 (106,400 per year after the phase-in period). Treatment costs for MRSA are expected to decrease by approximately $840,700 ($86,800 per year). The incremental budget impact expected in the first two years following implementation of EMS is $3.9 million, dropping to $3.8 million as reduction in the number of DO audits occurs. The total increase in costs associated with EMS implementation in residential care facilities is $38.5 million (Table 33). Estimates for individual years are shown in Appendix H and Appendix J.

Table 32. Total costs and annual budget impact for BC for management of MRSA cases, direct observation audits and implementation of EMS in acute care facilities in year 1-4, 9 and cumulative over 10 years (base case undiscounted)

Acute Care	Outputs	2018	2019	2020	2021	2027	Total 2018-2027
Status Quo Direct Observation	MRSA cases	2,073	2,097	2,103	2,107	2,147	21,166
	Cost of DO	781.8 K	781.8 K	781.8 K	781.8 K	781.8 K	7.8 M
	Cost HH supplies	1.2 M	1.2 M	1.2 M	1.2 M	1.3 M	12.5 M
	Cost of MRSA treatment	9.6 M	9.6 M	9.5 M	9.4 M	8.9 M	92.9 M
	Total costs (audit, HH supplies, MRSA treatment)	11.6 M	11.6 M	11.5 M	11.4 M	11.0 M	113.2 M
EMS + Reduced Direct Observation	MRSA cases	2,010	2,033	2,039	2,044	2,081	20,523
	MRSA cases avoided	-63	-64	-64	-64	-66	- 643
	Cost of DO	783.2 K	783.2 K	169.9 K	169.9 K	169.9 K	2.9 M
	Costs of EMS	3.4 M	3.4 M	3.4 M	3.4 M	3.4 M	33.7 M
	Costs of auditing (DO + EMS)	4.2 M	4.2 M	3.5 M	3.5 M	3.5 M	36.7 M
	Cost HH supplies	1.4 M	1.4 M	1.5 M	1.5 M	1.6 M	15.0 M
	Cost of MRSA treatment	9.4 M	9.4 M	9.3 M	9.2 M	8.7 M	90.8 M
	Total costs (audit, HH supplies, MRSA treatment)	15.0 M	15.0 M	14.3 M	14.2 M	13.8 M	142.4 M
	Direct observation cost avoided	1.5 K	1.5 K	-611.9 K	-611.9 K	-611.9 K	-4.9 M
	Cost of MRSA treatment avoided	-211.0 K	-215.3 K	-216.6 K	-217.0 K	-211.5 K	-2.1 M
	Audit process incremental cost	3.4 M	3.4 M	2.8 M	2.8 M	2.8 M	28.8 M
	HH supplies incremental cost	238.9 K	244.2 K	248.0 K	248.7 K	256.9 K	2.5 M
	Overall incremental costs	3.4 M	3.4 M	2.8 M	2.8 M	2.8 M	29.2 M

Note: DO = direct observation; EMS = electronic monitoring system; HH = hand hygiene; MRSA = methicillin-resistant *Staphylococcus aureus*.

Table 33. Total costs and annual budget impact for BC for management of MRSA cases, direct observation audits and implementation of EMS in residential care facilities in year 1-4, 9 and cumulative over 10 years (base case undiscounted).

Residential Care	Outputs	2018	2019	2020	2021	2027	Total 2018-2027
Status Quo Direct Observation Alone	MRSA cases	846	843	842	840	837	8,399
	Cost of DO	269.1 K	269.1 K	269.1 K	269.1 K	269.1 K	2.7 M
	Cost HH supplies	1.1 M	1.1 M	1.1 M	1.1 M	1.2 M	11.5 M
	Cost of MRSA treatment	3.9 M	3.8 M	3.8 M	3.7 M	3.4 M	36.6 M
	Total costs (audit, HH supplies, MRSA treatment)	5.3 M	5.2 M	5.2 M	5.1 M	4.9 M	50.8 M
EMS + Reduced Direct Observation	MRSA cases	821	818	816	815	811	8,142
	MRSA cases avoided	-26	-25	-26	-26	-26	-257
	Cost of DO	269.2 K	269.2 K	162.7 K	162.7 K	162.7 K	1.8 M
	Costs of EMS	3.8 M	3.8 M	3.8 M	3.8 M	3.8 M	37.8 M
	Costs of auditing (DO + EMS)	4.1 M	4.1 M	3.9 M	3.9 M	3.9 M	39.7 M
	Cost HH supplies	1.3 M	1.3 M	1.4 M	1.4 M	1.4 M	13.8 M
	Cost of MRSA treatment	3.8 M	3.8 M	3.7 M	3.6 M	3.4 M	35.8 M
	Total costs (audit, HH supplies, MRSA treatment)	9.2 M	9.2 M	9.0 M	9.0 M	8.7 M	89.3 M
	Direct observation cost avoided	144	144	-106.4 K	-106.4 K	-106.4 K	-850.5 K
	Cost of MRSA treatment avoided	-86.8 K	-85.5 K	-87.1 K	-86.6 K	-80.5 K	-840.7 K
	Audit process incremental cost	3.8 M	3.8 M	3.7 M	3.7 M	3.7 M	37.0 M
	HH supplies incremental cost	229.4 K	231.4 K	233.8 K	233.7 K	235.9 K	2.3 M
	Overall incremental costs	3.9 M	3.9 M	3.8 M	3.8 M	3.8 M	38.5 M

Note: DO = direct observation; EMS = electronic monitoring system; HH = hand hygiene; MRSA = methicillin-resistant *Staphylococcus aureus*.

7.4 Sensitivity analysis

The scenario from the cost-effectiveness analysis in which EMS had a higher added value to the health system was assumed as the new reference case. This scenario assumed BC has a higher cost to treat MRSA cases than the published literature (used unpublished Alberta costs for health care-acquired MRSA), a dramatic decrease in EMS price (to $[redacted] per bed per year), and attributed all the effect in improving compliance found in studies to the use of EMS. Increasing compliance was attributed to more transparency of reported compliance rates (no investments in other co-interventions beyond feedback with EMS data).

In acute care facilities, under the status quo (DO only) over 10 years, the health care cost to treat MRSA cases was estimated to be $611.4 million, predicting 21,541 MRSA cases in this scenario (infections and colonizations). The cost of DO auditing is estimated at $7.8 million ($781,600 per year). The total costs of HH (audit, supplies) and management of MRSA cases are estimated at $631.7 million ($62.7 million per year) (Table 34).

The additional costs of incorporating EMS into HH auditing in this scenario were estimated at $843,200 per year. Over 10 years, BC would spend $8.4 million for EMS. The DO costs expected to be avoided (or reallocated to other quality improvement programs) are estimated at $4.9 million ($611,700 a year after the phase-in period). The treatment costs expected to be avoided due to reduced MRSA cases are approximately $24.7 million ($2.5 million a year). Expenses for HH products are expected to increase with the increase in compliance by $2.6 million.

The yearly budget impact BC can expect in the first two years of the EMS implementation (while DOs are not yet reduced) is a cost avoidance of around $1.4 million. The

total budget impact over 10 years would avoid approximately $18,5 million in costs. Estimates for individual years are shown in (Appendix K and Appendix L).

In residential care facilities, under the status quo (DO only) over 10 years, the health care cost to treat MRSA cases was estimated to be $241 million, predicting 8,489 cases in this scenario. The cost of DO auditing is estimated at $2.7 million ($269,000 per year). The total costs of HH (audit, supplies) and management of MRSA cases are estimated at $255.2 million ($26 million per year) (Table 35).

The additional costs of incorporating EMS into HH auditing in this scenario were estimated at $945,500 per year. Over 10 years, BC would spend $9.5 million for EMS. The DO costs expected to be avoided (or reallocated to other quality improvement programs) are estimated at $106,200 a year after the phase-in period, summing to $849,300 over 10 years. The treatment costs expected to be avoided due to reduced MRSA cases are approximately $10.1 million. Expenses for HH products are expected to increase with the increase in compliance by $2.4 million over 10 years.

The yearly incremental budget impact BC can expect in the first two years of the EMS implementation (while DOs are not yet reduced) is around $148,000 and dropping to 62,500 to 91,500 after the phase in period. The total budget impact over 10 years would increase by approximately $929,300 in costs. Estimates for individual years are shown in (Appendix K and Appendix L).

Table 34. Total costs and annual budget impact for BC for management of MRSA cases, direct observation audits and implementation of EMS in acute care facilities in year 1-4,9 and cumulative over 10 years (sensitivity analysis undiscounted)

Acute Care							
	Outputs	**2018**	**2019**	**2020**	**2021**	**2027**	**Total 2018-2027**
Status Quo Direct Observation	MRSA cases	2,110	2,134	2,140	2,145	2,184	21,541
	Cost of DO	781.6 K	781.6 K	781.6 K	781.6 K	781.6 K	7.8 M
	Cost HH supplies	1.2 M	1.2 M	1.2 M	1.2 M	1.3 M	12.4 M
	Cost of MRSA treatment	60.7 M	61.2 M	61.2 M	61.2 M	61.2 M	611.4 M
	Total costs (audit, HH supplies, MRSA treatment)	62.7 M	63.2 M	63.2 M	63.2 M	63.3 M	631.7 M
EMS + Reduced Direct Observation	MRSA cases	2,026	2,049	2,055	2,060	2,098	20,682
	MRSA cases avoided	-84	-85	-85	-85	-87	-858
	Cost of DO	783.5 K	783.5 K	170.0 K	170.0 K	170.0 K	2.9 M
	Costs of EMS	843.2 K	843.2 K	843.2 K	843.2 K	843.2 K	8.4 M
	Costs of auditing (DO + EMS)	1.6 M	1.6 M	1.0 M	1.0 M	1.0 M	11.4 M
	Cost HH supplies	1.4 M	1.4 M	1.5 M	1.5 M	1.6 M	15.0 M
	Cost of MRSA treatment	58.3 M	58.7 M	58.7 M	58.7 M	58.7 M	586.8 M
	Total costs (audit, HH supplies, MRSA treatment)	61.3 M	61.8 M	61.2 M	61.2 M	61.3 M	613.1 M
	Direct observation cost avoided	1.8 K	1.8 K	-611.7 K	-611.7 K	-611.7 K	-4.9 M
	Cost of MRSA treatment avoided	-2.5 M	-2.5 M	-2.5 M	-2.5 M	-2.5 M	-24.7 M
	Audit process incremental cost	845.0 K	845.0 K	231.5 K	231.5 K	231.5 K	3.5 M
	HH supplies incremental cost	248.6 K	253.8 K	254.7 K	257.5 K	265.5 K	2.6 M
	Overall incremental costs	-1.4 M	-1.4 M	-2.0 M	-2.0 M	-2.0 M	-18.5 M

Note: DO = direct observation; EMS = electronic monitoring system; HH = hand hygiene; MRSA = methicillin-resistant *Staphylococcus aureus*.

Table 35. Total costs and annual budget impact for BC for management of MRSA cases, direct observation audits and implementation of EMS in residential care facilities in year 1–4,9 and cumulative over 10 years (sensitivity analysis undiscounted).

Residential Care	Outputs	2018	2019	2020	2021	2027	Total 2018–2027
Status Quo Direct Observation Alone	MRSA cases	856	853	851	849	846	8,489
	Cost of DO	269.0 K	269.0 K	269.0 K	269.0 K	269.0 K	2.7 M
	Cost HH supplies	1.1 M	1.1 M	1.1 M	1.1 M	1.2 M	11.5 M
	Cost of MRSA treatment	24.6 M	24.5 M	24.3 M	24.2 M	23.7 M	241.0 M
	Total costs (audit, HH supplies, MRSA treatment)	26.0 M	25.8 M	25.7 M	25.6 M	25.1 M	255.2 M
EMS + Reduced Direct Observation	MRSA cases	820	818	816	814	811	8,139
	MRSA cases avoided	-35	-35	-35	-35	-35	-351
	Cost of DO	269.3 K	269.3 K	162.8 K	162.8 K	162.8 K	1.8 M
	Costs of EMS	945.5 K	945.5 K	945.5 K	945.5 K	945.5 K	9.5 M
	Costs of auditing (DO + EMS)	1.2 M	1.2 M	1.1 M	1.1 M	1.1 M	11.3 M
	Cost HH supplies	1.3 M	1.3 M	1.4 M	1.4 M	1.4 M	13.9 M
	Cost of MRSA treatment	23.6 M	23.5 M	23.3 M	23.2 M	22.7 M	230.9 M
	Total costs (audit, HH supplies, MRSA treatment)	26.1 M	26.0 M	25.8 M	25.7 M	25.2 M	256.1 M
	Direct observation cost avoided	300	300	-106.2 K	-106.2 K	-106.2 K	-849.3 K
	Cost of MRSA treatment avoided	-1.0 M	-1.0 M	-1.0 M	-1.0 M	-989.7 K	-10.1 M
	Audit process incremental cost	945.8 K	945.8 K	839.3 K	839.3 K	839.3 K	8.6 M
	HH supplies incremental cost	234.5 K	235.5 K	239.1 K	239.6 K	242.0 K	2.4 M
	Overall incremental costs	148.0 K	169.2 K	62.5 K	65.8 K	91.5 K	929.3 K

Note: DO = direct observation; EMS = electronic monitoring system; HH = hand hygiene; MRSA = methicillin-resistant *Staphylococcus aureus*.

7.5 Discussion

The budget impact analysis considered a dynamic patient population in BC over the next 10 years and incorporated uncertainty using a probabilistic model.

Under the status quo, BC will incur approximately $1 million dollars per year in resources to perform DOs in both acute and residential care facilities. At the current prices, the implementation of EMS would raise the cost of monitoring hand hygiene to $8.3 million per year in the initial two years and $7.4 million in subsequent years.

Clearly at the current prices (and published costs estimates of MRSA treatment), the costs avoided with MRSA treatment and reduced DO are unlikely to outweigh the total cost of implementing EMS to monitor HH, unless the technology proves to drive compliance rates to higher levels and, most importantly, better compliance is proven to affect rates of MRSA (or other infections) more dramatically.

However, even if BC costs for treating MRSA cases are more comparable to the unpublished estimates from Alberta (which were 2.8 times higher for infections and 14 times higher for colonization) than the values used in this analysis, and a significant price reduction for the EMS licence is negotiated, implementing the technology for HH monitoring would become cost−saving in acute care facilities, but there would still be incremental costs for residential care facilities. The costs avoided in acute care facilities (−$18.5 million over 10 years) could potentially outweigh the incremental cost for residential care facilities ($929,300 over 10 years). However, there is so much parameter uncertainty remaining in the model that the probability of reaching these results are between 50- 60% (Figure 11 b).

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Appendix A Resource Use and Cost of Performing Direct Observation for Hand Hygiene Compliance

OVERALL Yearly Costs of Measuring and Reporting Hand Hygiene Compliance by direct observation in BC

Costs	IHA	FHA	VCH	PHC#	PHSA	VIHA	NHA
Auditors	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Administrative personnel	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Management personnel	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Software	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Training	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Travel expenses	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Community of practice/recertification program/campaigns	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Reporting supplies	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Total costs	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Average cost per observation performed	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Total number of observations **	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Management time (yearly hours)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Administrative time (yearly hours)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Auditors time (yearly hours)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Note: FHA = Fraser Health Authority; IHA = Interior Health Authority; NHA = Northern Health Authority; PHSA = Provincial Health Services Authority; VCHA = Vancouver Coastal Health Authority; VIHA = Vancouver Island Health Authority.

Note: NA - not available. Health authority did not provide data, expert opinion, or validation of assumptions.

Note: This cost exercise was based on expert opinion of the estimate number of observations performed per hour, type of professionals employed in the process and other resources. We then calculated auditors' time and applied the health authorities' salary schedule to estimate costs except for Providence Health Care that have some observational data.

Providence costing exercise mostly based on an internal observation study measuring resource utilization (auditor hrs, # of observations, admin and management time, travel expenses)

**Last 4 quarters reported in PICNet data, Q4 2015/2016 to Q3 2016/2017, except PHSA for which we included observations performed at other sites not included in the PICNet report

	Yearly costs of measuring and reporting hand hygiene compliance by direct observation in BC: Acute care portion						
Costs	**IHA**	**FHA**	**VCHA**	**PHC#**	**PHSA**	**VIHA**	**NHA**
Auditors	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Administrative personnel	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Management personnel	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Software	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Training	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Travel expenses	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Community of practice/recertification program/campaigns	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Reporting supplies	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Total costs	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Average cost per Observation performed	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Total number of observations **	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Management time (yearly hours)	[redacted]		[redacted]				
Administrative time (yearly hours)	[redacted]		[redacted]				
Auditors time (yearly hours)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Observations per hour (average)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Note: FHA = Fraser Health Authority; IHA = Interior Health Authority; NHA = Northern Health Authority; PHSA = Provincial Health Services Authority; VCHA = Vancouver Coastal Health Authority; VIHA = Vancouver Island Health Authority.

Note: NA - not available. Health authority did not provide data, expert opinion, or validation of assumptions.

Note: This cost exercise was based on expert opinion of the estimate number of observations performed per hour, type of professionals employed in the process and other resources. We then calculated auditors' time and applied the health authorities' salary schedule to estimate costs except for Providence Health Care that have some observational data.

Providence costing exercise mostly based on an internal observation study measuring resource utilization (auditor hours, number of observations, admin and management time, travel expenses)

**Last 4 quarters reported in PICNet data, Q4 2015/2016 to Q3 2016/2017, except PHSA for which we included observations performed at other sites not included in the PICNet report

Yearly Costs of Measuring and Reporting hand hygiene Compliance by direct observation in BC: Residential Care Portion

Costs	IHA	FHA	VCHA	PHC#	PHSA	VIHA	NHA
Auditors	[redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]
Administrative personnel	[redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]
Management personnel	[redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]
Software	[redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]
Training	[redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]
Travel expenses	[redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]
Community of practice/recertification program/campaigns	[redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]
Reporting supplies	[redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]
Total costs		[redacted]	[redacted]	[redacted]		[redacted]	[redacted]
Average cost per Observation performed	[redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]
Total number of observations **	[redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]
Management time (yearly hours)	[redacted]						
Administrative time (yearly hours)	[redacted]						
Auditors time (yearly hours)	[redacted]	[redacted]		[redacted]		[redacted]	[redacted]
Observations per hour (average)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Note: FHA = Fraser Health Authority; IHA = Interior Health Authority; NHA = Northern Health Authority; PHSA = Provincial Health Services Authority; VCHA = Vancouver Coastal Health Authority; VIHA = Vancouver Island Health Authority.

Note: NA - not available. Health authority did not provide data, expert opinion, or validation of assumptions.

Note: This cost exercise was based on expert opinion of the estimate number of observations performed per hour, type of professionals employed in the process and other resources. We then calculated auditors' time and applied the health authorities' salary schedule to estimate costs except for Providence Health Care that have some observational data.

Providence costing exercise mostly based on an internal observation study measuring resource utilization (auditor hours, number of observations, admin and management time, travel expenses)

**Last 4 quarters reported in PICNet data, Q4 2015/2016 to Q3 2016/2017, except PHSA for which we included observations performed at other sites not included in the PICNet report

Appendix B Search Strategies

B.1 Medline

Database: Ovid MEDLINE(R) Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Ovid MEDLINE(R) Daily and Ovid MEDLINE(R) <1946 to Present>

Search Strategy:

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1 Hand Hygiene/ (679)
2 Hand Disinfection/ (4954)
3 Hand Sanitizers/ (71)
4 Hand/ and hygiene/ (177)
5 (hand? adj3 wash$).mp. (3360)
6 (hand? adj3 hygiene).mp. (3389)
7 (hand? adj3 disinfect$).mp. (5421)
8 (hand? adj4 sanitiz$).mp. (340)
9 (hand? adj3 clean$).mp. (613)
10 or/1-9 [Hand Hygiene] (9697)

11 Technology/ (8304)
12 Reminder Systems/ (2891)
13 Ultrasonography/ (162248)
14 telemetry/ or remote sensing technology/ (10703)
15 automatic Data Processing/ (12591)
16 automated.mp. (112267)
17 Electronics/ (8471)
18 ((automat$ or electronic$) adj4 (monitor$ or system? or technology or device?)).mp. (48356)
19 monitor$ system?.kf. (269)
20 automation/ or automation, laboratory/ or robotics/ (33960)
21 automatic.mp. (69927)
22 sensor$.mp. (313893)
23 Computer Systems/ (12326)
24 Wireless Technology/ (2307)
25 Electronics, Medical/ (6343)
26 Software/ (91267)
27 Artificial Intelligence/ (20981)
28 "Electrical Equipment and Supplies"/ (1019)
29 ((automat$ or electr$ or comput$) adj4 (monitor$ or system? or technology or device?)).mp. (164337)
30 (monitor$ adj4 (system? or technology or device?)).mp. (28448)
31 or/11-30 [Technology] (915973)

32 10 and 31 [Search #1] (263)

33 Infection Control/ (21072)
34 Infectious Disease Transmission, Professional-to-Patient/ (1633)
35 Infectious Disease Transmission, Patient-to-Professional/ (3644)
36 Cross Infection/ (50947)
37 Pneumonia, Ventilator-Associated/ (2600)
38 Iatrogenic Disease/ (14844)
39 nosocomial.mp. (26013)
40 ((hospital or health care or health care) adj3 infection?).mp. (14809)
41 Iatrogenic$.mp. (33765)
42 Methicillin-Resistant Staphylococcus aureus/ (10399)
43 exp Drug Resistance, Bacterial/ (72421)
44 exp Drug Resistance, Microbial/ (141744)
45 Disease Transmission, Infectious/ (7406)
46 MRSA.mp. (18569)
47 Clostridium difficile/ (7183)
48 clostridium infections/ or enterocolitis, pseudomembranous/ (12942)
49 or/33-48 (275110)

50 31 and 49 (4974)

51 mt.fs. [Methods] (3160409)
52 st.fs. [Standards] (621707)
53 pc.fs. [Prevention & Control] (1148968)
54 compliance/ (3842)
55 compliance.mp. (139351)
56 feedback/ (27771)
57 feedback.mp. (124083)
58 aggregate.mp. (37804)
59 reminder?.mp. (10974)
60 Guideline Adherence/ (26171)
61 Professional Practice/ (16032)
62 exp population surveillance/ (58716)
63 surveillance.mp. (178782)
64 alarm?.mp. (10760)
65 alert?.mp. (24577)
66 or/51-65 (4871196)

67 and/31,49,66 [Search #2] (2627)

68 32 or 67 [Both searches combined] (2767)
Reviews
69 limit 68 to systematic reviews (67)

70 limit 68 to "review articles" (325)

71 meta-analysis/ (75191)
72 meta-analysis as topic/ (15475)
73 technology assessment, biomedical/ or technology, high-cost/ (9954)
74 ((systematic* adj3 (review* or overview*)) or (methodologic* adj3 (review* or overview*))).ti,ab,kf,kw. (111387)
75 ((integrative adj3 (review* or overview*)) or (collaborative adj3 (review* or overview*)) or (pool* adj3 analy*)).ti,ab,kf,kw. (17730)
76 (data synthes* or data extraction* or data abstraction*).ti,ab,kf,kw. (18592)
77 (mantel haenszel or peto or der simonian or dersimonian or fixed effect* or latin square*).ti,ab,kf,kw. (19513)
78 (met analy* or metanaly* or technology assessment* or HTA or HTAs or technology overview* or technology appraisal*).ti,ab,kf,kw. (6907)
79 (meta regression* or metaregression*).ti,ab,kf,kw. (5062)
80 (meta-analy* or metaanaly* or systematic review* or biomedical technology assessment* or bio-medical technology assessment*).mp. (191856)
81 (medline or cochrane or pubmed or medlars or embase or cinahl).ti,ab,hw. (143051)
82 (cochrane or (health adj2 technology assessment) or evidence report).jw. (17052)
83 (comparative adj3 (efficacy or effectiveness)).ti,ab,kf,kw. (9829)
84 (outcomes research or relative effectiveness).ti,ab,kf,kw. (7215)
85 ((indirect or indirect treatment or mixed-treatment) adj comparison*).ti,ab,kf,kw. (1506)
86 or/71-85 [CADITH SR Filter] (315611)

87 68 and 86 (72)

88 Meta-Analysis as Topic/ (15475)
89 meta analy$.tw. (107660)
90 metaanaly$.tw. (1728)
91 Meta-Analysis/ (75191)
92 (systematic adj (review$1 or overview$1)).tw. (98715)
93 exp Review Literature as Topic/ (9208)
94 or/88-93 (197068)
95 cochrane.ab. (51105)
96 embase.ab. (53169)
97 (psychlit or psyclit).ab. (902)
98 (psychinfo or psycinfo).ab. (16570)
99 (cinahl or cinhal).ab. (17476)
100 science citation index.ab. (2562)
101 bids.ab. (426)
102 cancerlit.ab. (626)

103 or/95-102 (85884)
104 reference list$.ab. (13773)
105 bibliograph$.ab. (14581)
106 hand-search$.ab. (5381)
107 relevant journals.ab. (973)
108 manual search$.ab. (3360)
109 or/104-108 (34079)
110 selection criteria.ab. (25197)
111 data extraction.ab. (14205)
112 110 or 111 (37428)
113 Review/ (2234667)
114 112 and 113 (24779)
115 comment/ or editorial/ or letter/ (1552745)
116 animal/ not (animal/ and human/) (4294719)
117 or/115-116 (5787492)
118 94 or 103 or 109 or 114 (236817)
119 118 not 117 [SIGN SR Filter] (224116)

120 68 and 119 (45)

121 or/69-70,87,120 [Reviews] (366)

122 limit 121 to English language (320)
123 limit 122 to yr="2000 -2008" (95)
124 limit 122 to yr="2009 -Current" (169)

RCTs
125 68 not 121 [References minus reviews] (2401)

126 Randomized Controlled Trial.pt. (449152)
127 Pragmatic Clinical Trial.pt. (527)
128 randomized controlled trials as topic/ or intention to treat analysis/ or pragmatic clinical trials as topic/ (111937)
129 Randomized Controlled Trial/ (449152)
130 Randomization/ (89960)
131 Random Allocation/ (89960)
132 Double-Blind Method/ (143466)
133 Double-Blind Studies/ (143466)
134 Single-Blind Method/ (23818)
135 Single-Blind Studies/ (23818)
136 Placebos/ (34211)
137 (random* or sham or placebo*).ti,ab,hw,kf,kw. (1240184)
138 ((singl* or doubl*) adj (blind* or dumm* or mask*)).ti,ab,hw,kf,kw. (210029)
139 ((tripl* or trebl*) adj (blind* or dumm* or mask*)).ti,ab,hw,kf,kw. (650)

140 or/126-139 (1263917) [CADTH RCT Filter]
141 125 and 140 (126)

142 Randomized Controlled Trials as Topic/ (110058)
143 randomized controlled trial/ (449152)
144 Random Allocation/ (89960)
145 Double Blind Method/ (143466)
146 Single Blind Method/ (23818)
147 clinical trial/ (508418)
148 clinical trial, phase i.pt. (18019)
149 clinical trial, phase ii.pt. (29046)
150 clinical trial, phase iii.pt. (13170)
151 clinical trial, phase iv.pt. (1410)
152 controlled clinical trial.pt. (91962)
153 randomized controlled trial.pt. (449152)
154 multicenter study.pt. (219676)
155 clinical trial.pt. (508418)
156 exp Clinical Trials as topic/ (304974)
157 or/142-156 (1194098)
158 (clinical adj trial$).tw. (288793)
159 ((singl$ or doubl$ or treb$ or tripl$) adj (blind$3 or mask$3)).tw. (153243)
160 PLACEBOS/ (34211)
161 placebo$.tw. (190200)
162 randomly allocated.tw. (22552)
163 (allocated adj2 random$).tw. (25486)
164 or/158-163 (528433)
165 157 or 164 (1399783)
166 letter/ (955591)
167 historical article/ (339415)
168 case report.tw. (252351)
169 or/166-168 (1533760)
170 165 not 169 [SIGN RCT Filter] (1367261)

171 125 and 170 (180)
172 limit 125 to "therapy (best balance of sensitivity and specificity)" (59)

173 or/141,171-172 [RCTs] (244)

174 limit 173 to English language (227)
175 limit 174 to yr="2000 -Current" (198)

Observational Studies
176 125 not 173 [Search minus Reviews & RCTs] (2157)

177 Epidemiologic studies/ (7375)
178 exp case control studies/ (836789)
179 exp cohort studies/ (1626999)
180 Case control.tw. (100095)
181 (cohort adj (study or studies)).tw. (133884)
182 Cohort analy$.tw. (5474)
183 (Follow up adj (study or studies)).tw. (43278)
184 (observational adj (study or studies)).tw. (70624)
185 Longitudinal.tw. (186458)
186 Retrospective.tw. (382342)
187 Cross sectional.tw. (246247)
188 Cross-sectional studies/ (235775)
189 or/177-188 [SIGN OS Filter] (2381194)

190 176 and 189 (436)

191 ((non-randomi#ed or nonrandomi#ed) adj4 trial?).mp. (5312)
192 (quasi experimental adj3 stud$).mp. (4338)
193 (quasi randomi#ed adj3 stud$).mp. (409)
194 Interrupted Time Series Analysis/ (247)
195 Interrupted Time Series.mp. (1782)
196 Controlled Before-After Studies/ (222)
197 Before-After Studies.mp. (462)
198 (controlled adj3 before-after).mp. (499)
199 ((controlled adj3 before) and after).mp. (1521)
200 or/191-199 [Observational] (12713)

201 176 and 200 (10)
202 limit 176 to comparative study (303)
203 limit 176 to observational study (15)
204 or/190,201-203 [Observational studies] (685)

205 limit 204 to English language (605)
206 limit 205 to yr="2000 -Current" (522)
207 176 not 204 [Search results minus Rev, RCTs, Obs] (1472)

208 Economics/ (26836)
209 exp "Costs and Cost Analysis"/ (205716)
210 Economics, Nursing/ (3976)
211 Economics, Medical/ (8950)
212 Economics, Pharmaceutical/ (2689)
213 exp Economics, Hospital/ (22095)
214 Economics, Dental/ (1890)
215 exp "Fees and Charges"/ (28648)

216 exp Budgets/ (13029)
217 budget*.ti,ab,kf. (23897)
218 (economic* or cost or costs or costly or costing or price or prices or pricing or pharmacoeconomic* or pharmaco-economic* or expenditure or expenditures or expense or expenses or financial or finance or finances or financed).ti,kf. (186381)
219 (economic* or cost or costs or costly or costing or price or prices or pricing or pharmacoeconomic* or pharmaco-economic* or expenditure or expenditures or expense or expenses or financial or finance or finances or financed).ab. /freq=2 (221582)
220 (cost* adj2 (effective* or utilit* or benefit* or minimi* or analy* or outcome or outcomes)).ab,kf. (123504)
221 (value adj2 (money or monetary)).ti,ab,kf. (1804)
222 exp models, economic/ (12353)
223 economic model*.ab,kf. (2498)
224 markov chains/ (11795)
225 markov.ti,ab,kf. (17056)
226 monte carlo method/ (23671)
227 monte carlo.ti,ab,kf. (39497)
228 exp Decision Theory/ (10720)
229 (decision* adj2 (tree* or analy* or model*)).ti,ab,kf. (17407)
230 or/208-229 [CADITH Econ Filter] (598235)

231 207 and 230 (90)

232 Economics/ (26836)
233 "costs and cost analysis"/ (45073)
234 Cost allocation/ (1973)
235 Cost-benefit analysis/ (69228)
236 Cost control/ (21039)
237 Cost savings/ (10170)
238 Cost of illness/ (21814)
239 Cost sharing/ (2200)
240 "deductibles and coinsurance"/ (1582)
241 Medical savings accounts/ (512)
242 Health care costs/ (32757)
243 Direct service costs/ (1120)
244 Drug costs/ (13942)
245 Employer health costs/ (1080)
246 Hospital costs/ (9274)
247 Health expenditures/ (16072)
248 Capital expenditures/ (1970)
249 Value of life/ (5553)
250 exp economics, hospital/ (22095)
251 exp economics, medical/ (13998)
252 Economics, nursing/ (3976)

253 Economics, pharmaceutical/ (2689)
254 exp "fees and charges"/ (28648)
255 exp budgets/ (13029)
256 (low adj cost).mp. (37719)
257 (high adj cost).mp. (10736)
258 (health?care adj cost$).mp. (7348)
259 (fiscal or funding or financial or finance).tw. (115935)
260 (cost adj estimate$).mp. (1820)
261 (cost adj variable).mp. (39)
262 (unit adj cost$).mp. (2017)
263 (economic$ or pharmacoeconomic$ or price$ or pricing).tw. (229613)
264 or/232-263 [SIGN Economic Filter] (589531)

265 207 and 264 (76)

266 limit 207 to "economics (best balance of sensitivity and specificity)" (135)
267 limit 207 to "costs (best balance of sensitivity and specificity)" (78)
268 or/231,265-267 [Economic Studies] (165)

269 limit 268 to English language (146)
270 limit 269 to yr="2000 -Current" (121)

271 207 not 268 [Remaining references] (1307)

B.2 Embase

Database: Embase <1974 to 2017 March 10>
Search Strategy:
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1 sanitizer dispensing door handle/ (1)
2 hand sanitizer dispenser/ (1)
3 electronically assisted hand hygiene monitoring system/ (2)
4 hand washing/ (11601)
5 Hand/ and hygiene/ (265)
6 (hand? adj3 wash$).mp. (13035)
7 (hand? adj3 hygiene).mp. (5222)
8 (hand? adj3 disinfect$).mp. (1138)
9 (hand? adj3 clean$).mp. (875)
10 (hand? adj4 saniti#$).mp. (652)
11 hand sanitizer dispenser/ (1)
12 sanitizer dispensing door handle/ (1)
13 hand sanitizer/ (324)
14 or/4-13 [Hand Hygiene] (15624)

15 technology/ or medical technology/ (238983)
16 information system/ (40303)
17 Reminder Systems/ (2010)
18 information processing/ (247123)
19 automated.mp. (140201)
20 ((automat$ or electronic$) adj4 (monitor$ or system? or technology or device?)).mp. (62325)
21 electronics/ (27157)
22 automation/ (53448)
23 automatic.mp. (74778)
24 sensor$.mp. (398817)
25 wireless communication/ (3529)
26 medical electronics/ (89)
27 electronics/ (27157)
28 computer program/ (221093)
29 ((automat$ or electr$ or comput$) adj4 (monitor$ or system? or technology or device?)).mp. (194993)
30 (monitor$ adj4 (system? or technology or device?)).mp. (39440)
31 feedback system/ (97003)
32 voice/ (24557)
33 wireless communication/ (3529)
34 sensor/ (58231)
35 electronic sensor/ (1856)
36 health program/ (99119)

37 *health program/ (19067)
38 personal monitoring/ (980)
39 electric hand/ (58)
40 or/15-39 [Technology] (1621057)

41 14 and 40 [Search #1] (1813)

42 limit 41 to (conference abstract or conference paper or conference proceeding or conference review or conference abstract status) (603)
43 41 not 42 (1210)

Reviews
44 limit 43 to "reviews (best balance of sensitivity and specificity)" (187)

45 meta analysis/ (160313)
46 "systematic review"/ (157183)
47 "meta analysis (topic)"/ (38802)
48 "systematic review (topic)"/ (27981)
49 biomedical technology assessment/ (11867)
50 ((systematic$ adj3 (review$ or overview$)) or (methodologic$ adj3 (review$ or overview$))).ti,ab,kw. (139252)
51 ((quantitative adj3 (review$ or overview$ or synthes$)) or (research adj3 (integrati$ or overview$))).ti,ab,kw. (9052)
52 ((integrative adj3 (review$ or overview$)) or (collaborative adj3 (review$ or overview$)) or (pool$ adj3 analy$)).ti,ab,kw. (24655)
53 (data synthes$ or data extraction$ or data abstraction$).ti,ab,kw. (22646)
54 (handsearch$ or hand search$).ti,ab,kw. (8454)
55 (mantel haenszel or peto or der simonian or dersimonian or fixed effect$ or latin square$).ti,ab,kw. (24284)
56 (met analy$ or metanaly$ or technology assessment$ or HTA or HTAs or technology overview$ or technology appraisal$).ti,ab,kw. (10413)
57 (meta regression$ or metaregression$).ti,ab,kw. (6488)
58 (meta-analy$ or metaanaly$ or systematic review$ or biomedical technology assessment$ or bio-medical technology assessment$).mp,hw. (320423)
59 (medline or cochrane or pubmed or medlars or embase or cinahl).ti,ab,hw. (188361)
60 (cochrane or (health adj2 technology assessment) or evidence report).jw. (19666)
61 (comparative adj3 (efficacy or effectiveness)).ti,ab,kw. (14182)
62 (outcomes research or relative effectiveness).ti,ab,kw. (10601)
63 ((indirect or indirect treatment or mixed-treatment) adj comparison$).ti,ab,kw. (2796)
64 or/45-63 [Filter CADTH SRs E] (469043)

65 43 and 64 (80)

66 meta analysis/ (160313)
67 ((meta adj analy$) or metaanalys$).tw. (142728)
68 (systematic adj (review$1 or overview$1)).tw. (121589)
69 or/66-68 (250431)
70 cancerlit.ab. (697)
71 cochrane.ab. (64832)
72 embase.ab. (66498)
73 (psychlit or psyclit).ab. (976)
74 (psychinfo or psycinfo).ab. (15436)
75 (cinahl or cinhal).ab. (19464)
76 science citation index.ab. (2889)
77 bids.ab. (537)
78 or/70-77 (103510)
79 reference lists.ab. (14331)
80 bibliograph$.ab. (18258)
81 hand-search$.ab. (6283)
82 manual search$.ab. (3916)
83 relevant journals.ab. (1124)
84 or/79-83 (39536)
85 data extraction.ab. (17214)
86 selection criteria.ab. (27466)
87 85 or 86 (43021)
88 review.pt. (2255346)
89 87 and 88 (20324)
90 letter.pt. (980178)
91 editorial.pt. (535816)
92 animal/ (1749377)
93 human/ (18472963)
94 92 not (92 and 93) (1329794)
95 or/90-91,94 (2830160)
96 69 or 78 or 84 or 89 (296723)
97 96 not 95 [SIGN SR Filter E] (288143)

98 43 and 97 (43)

99 or/44,65,98 [Hand Hygiene & Technology & Reviews] (209)

100 limit 99 to English language (201)
101 limit 100 to yr="2009 -Current" (133)
102 limit 100 to yr="2000 - 2008" (61)

RCTs
103 43 not 99 [Search minus reviews] (1001)

104 limit 103 to "therapy (best balance of sensitivity and specificity)" (85)

105 randomized controlled trial/ (483760)
106 "randomized controlled trial (topic)"/ (134015)
107 randomization/ (85143)
108 double blind procedure/ (141820)
109 single blind procedure/ (30134)
110 placebo/ (334102)
111 (random* or sham or placebo*).ti,ab,hw,kw. (1634591)
112 ((singl* or doubl*) adj (blind* or dumm* or mask*)).ti,ab,hw,kw. (257533)
113 ((tripl* or trebl*) adj (blind* or dumm* or mask*)).ti,ab,hw,kw. (835)
114 or/105-113 [CADTH RCT Filter Embase] (1664952)
115 103 and 114 (95)

116 Clinical trial/ (1046674)
117 Randomized controlled trial/ (483760)
118 Randomization/ (85143)
119 Single blind procedure/ (30134)
120 Double blind procedure/ (141820)
121 Crossover procedure/ (55555)
122 Placebo/ (334102)
123 Randomi?ed controlled trial$.tw. (156534)
124 Rct.tw. (23559)
125 Random allocation.tw. (1673)
126 Randomly allocated.tw. (27424)
127 Allocated randomly.tw. (2237)
128 (allocated adj2 random).tw. (861)
129 Single blind$.tw. (19325)
130 Double blind$.tw. (178509)
131 ((treble or triple) adj blind$).tw. (700)
132 Placebo$.tw. (254674)
133 Prospective study/ (403560)
134 or/116-133 (1861292)
135 Case study/ (96475)
136 Case report.tw. (335451)
137 Abstract report/ or letter/ (1022833)
138 or/135-137 (1445267)
139 134 not 138 [SIGN RCT Filter E] (1808152)

140 103 and 139 (119)

141 or/104,115,140 (150)

142 limit 141 to English language (146)
143 limit 142 to yr="2000 -Current" (141)

Observational Studies
144 103 not 141 [Search minus Reviews & RCTs] (851)

145 Clinical study/ (281425)
146 case control study/ (126620)
147 Family study/ (35468)
148 Longitudinal study/ (109775)
149 Retrospective study/ (541363)
150 Prospective study/ (403560)
151 Randomized controlled trials/ (134015)
152 150 not 151 (398449)
153 Cohort analysis/ (319296)
154 (Cohort adj (study or studies)).mp. (193745)
155 (Case control adj (study or studies)).tw. (104028)
156 (follow up adj (study or studies)).tw. (54685)
157 (observational adj (study or studies)).tw. (106695)
158 (epidemiologic$ adj (study or studies)).tw. (90930)
159 (cross sectional adj (study or studies)).tw. (137823)
160 or/145-149,152-159 [SIGN Obs Filter Embase] (1945465)

161 144 and 160 (81)

162 ((non-randomi#ed or nonrandomi#ed) adj4 trial?).mp. (6610)
163 (quasi experimental adj3 stud$).mp. (6707)
164 (quasi randomi#ed adj3 stud$).mp. (443)
165 Interrupted Time Series.mp. (2054)
166 Before-After Studies.mp. (278)
167 (controlled adj3 before-after).mp. (337)
168 ((controlled adj3 before) and after).mp. (1576)
169 epidemiology/ (284627)
170 or/162-169 [Observational studies] (300859)

171 144 and 170 (31)

172 or/161,171 (107)

173 limit 172 to English language (104)
174 limit 173 to yr="2000 -Current" (102)

Economic
175 144 not 172 [Search minus reviews, RCTs Obs] (744)

176 limit 175 to "economics (best balance of sensitivity and specificity)" (44)

177 Economics/ (226375)
178 Cost/ (57847)
179 exp Health Economics/ (751286)
180 Budget/ (29250)
181 budget$.ti,ab,kw. (30762)
182 (economic$ or cost or costs or costly or costing or price or prices or pricing or pharmacoeconomic$ or pharmaco-economic$ or expenditure or expenditures or expense or expenses or financial or finance or finances or financed).ti,kw. (225611)
183 (economic$ or cost or costs or costly or costing or price or prices or pricing or pharmacoeconomic$ or pharmaco-economic$ or expenditure or expenditures or expense or expenses or financial or finance or finances or financed).ab. /freq=2 (300575)
184 (cost$ adj2 (effective$ or utilit$ or benefit$ or minimi$ or analy$ or outcome or outcomes)).ab,kw. (171113)
185 (value adj2 (money or monetary)).ti,ab,kw. (2498)
186 Statistical Model/ (161606)
187 economic model$.ab,kw. (3496)
188 Probability/ (79319)
189 markov.ti,ab,kw. (21743)
190 monte carlo method/ (31197)
191 monte carlo.ti,ab,kw. (37038)
192 Decision Theory/ (2716)
193 Decision Tree/ (9466)
194 (decision$ adj2 (tree$ or analy$ or model$)).ti,ab,kw. (24234)
195 or/177-194 [CADTH Econ Filter Embase] (1381821)

196 175 and 195 (76)

197 Socioeconomics/ (126519)
198 Cost benefit analysis/ (76882)
199 Cost effectiveness analysis/ (130848)
200 Cost of illness/ (17136)
201 Cost control/ (63296)
202 Economic aspect/ (116479)
203 financial management/ (112790)
204 Health care cost/ (164907)
205 Health care financing/ (12891)
206 Health economics/ (37592)
207 Hospital cost/ (18566)
208 (fiscal or financial or finance or funding).tw. (140698)
209 Cost minimization analysis/ (3149)
210 (cost adj estimate$).mp. (2634)

211 (cost adj variable$).mp. (192)
212 (unit adj cost$).mp. (3397)
213 or/197-212 [SIGN Econ Filter Embase] (807195)

214 175 and 213 (70)

215 or/176,196,214 (110)

216 limit 215 to English language (105)
217 limit 216 to yr="2000 -Current" (102)

218 175 not 215 [Remaining references] (634)

Appendix C Critical Appraisal Checklist and Result

Appraisal	Bouk 2016	Conway 2013	Crnich 2016	Kelly 2016	Moore 2016	So 2016
Was there a clear research question, and was it important and sensible?	Y	Y	Y	Y	Y	Y
Is the design most appropriate to test this question? (Could a randomized or non-randomized controlled design have been used?)	Y	Y	Y	Y	Y	Y
Was the intervention independent of other change over time?	N	N	N	N	N	N
Were there sufficient data point to enable reliable statistical inferences?	Y	Y	N	Y	Y	U
Was a formal statistical test for trend correctly undertake?	N	N	N	Y	N	N
Was the primary outcome measure valid?	Y	Y	Y	Y	Y	Y
Was the primary outcome measure reliable?	Y	Y	N	Y	N	Y
Was the intervention unlikely to affect data collection?	N	N	N	N	N	N
Were outcomes measured by blinded observers or were they objectively verified?	N	N	N	N	N	N
Does the data-set cover all or most of the episode of care covered in the study?	Y	N	N	Y	Y	Y
Was the follow-up continued for long enough for the primary outcome measure to show an impact and for sustainability to be demonstrated?	Y	N	N	Y	Y	Y

Appendix D Characteristics of Included Studies

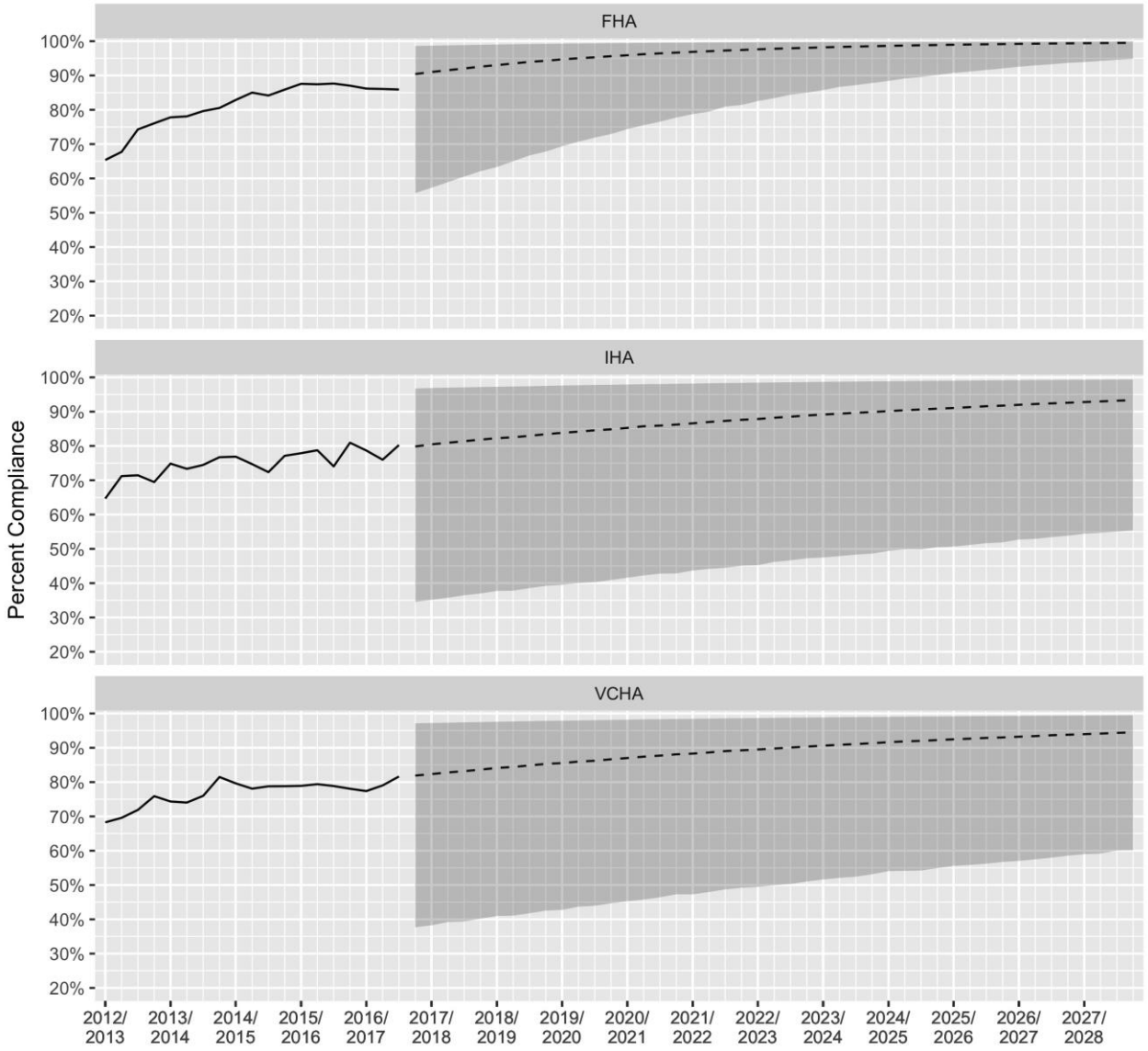
Study	Unit settings	Duration	Feedback method	Baseline hand hygiene compliance
Bouk 2016 (64)	336-bed academic hospital in Kankakee, IL	Dec 2013 to Sept 2015 (21 months)	Weekly & monthly reports emailed to unit managers. Staff meet weekly to discuss the report	57%
Conway 2013 (65, 66)	Seven units (acute care, ICU, ER) in a 140-bed community hospital in Northampton, MA	Jan 2012 to Mar 2013 (14 months)	Monthly reports emailed to unit manager. Infection prevention manager held periodic conversation with unit managers about the reports encouraging them to share data with staff	63.5%-69.5%
Crnich 2016 (67)	7-bed ICU and 21-bed non-ICU in Madison, WI	Jan to Jul 2014 (7 months) in ICU Oct to Dec 2015 (3 months) in non-ICU	Did not report	58% in ICU 32% in non-ICU
Kelly 2016 (61, 68, 69)	23 units in a 746-bed academic hospital in Greenville, SC	Jul 2012 to Mar 2015 (33 months)	Unit managers were encouraged to discuss the monthly or quarterly report with unit staff	54.9%
Moore 2016 (70)	18 U.S. and U.K. hospitals (comparing hospitals that utilized EMS with additional interventions to those without)	2012 to 2015	Not reported	Not reported
So 2016 (38)	6 units in a 428-bed academic hospital in Toronto	Jul 2015 to Mar 2016 (8 months)	Daily, weekly or monthly reports were downloaded from online interface	[redacted]%

Appendix E Characteristics of Excluded Studies

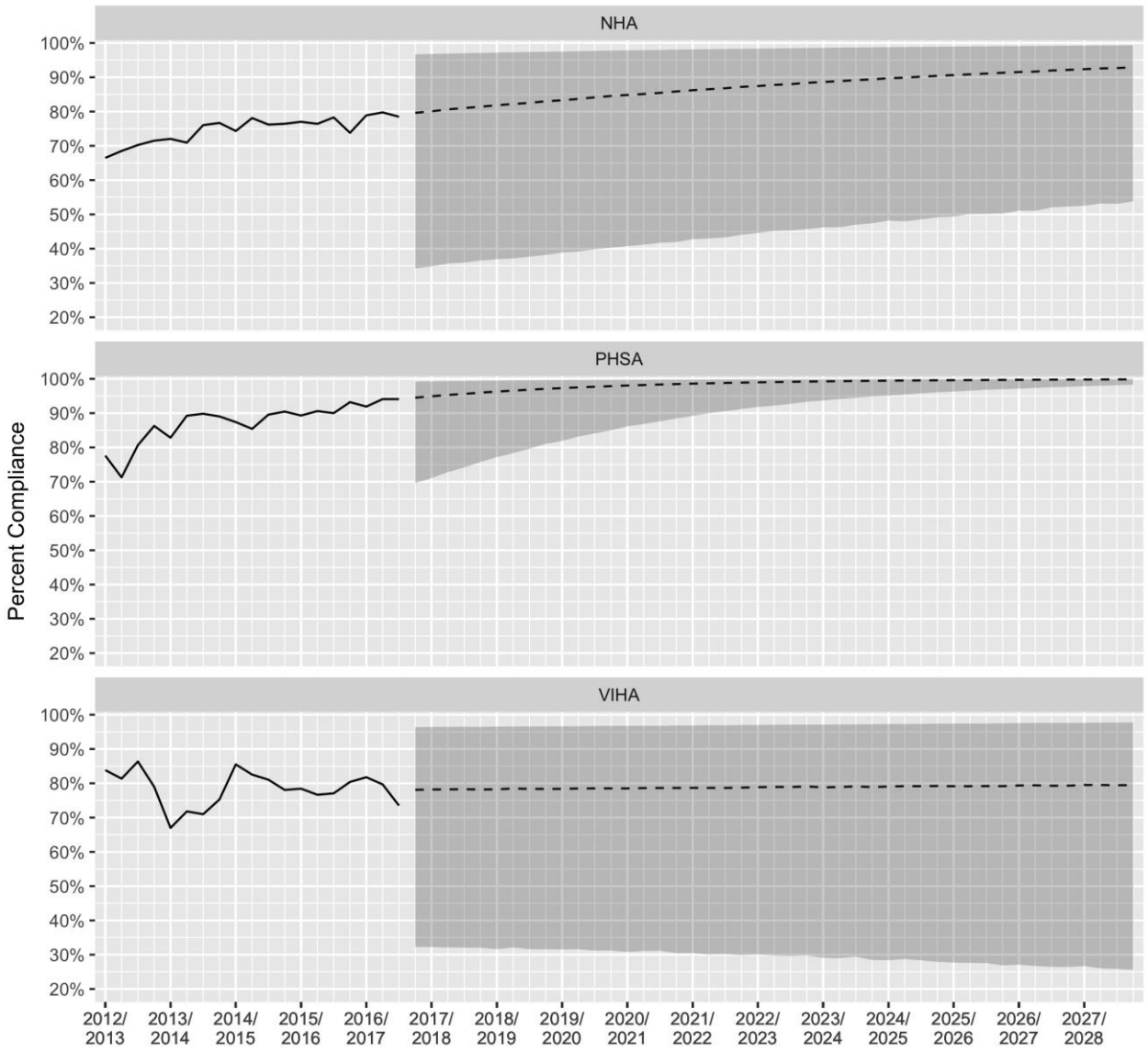
Study	Reason for exclusion
Azim 2016 (82)	Not comparing hand hygiene before and after
Alper 2016 (62)	Comparing WHO 5 vs Canada 4 Moments
Armellino 2012 (83)	Examined effect of video auditing
Armellino 2013 (84)	Examined effect of video auditing
Bialachowski 2016 (85)	Study compare direct observation and EMS at baseline, no feedback
Diller 2014 (60)	Validation study
Diller 2013(59)	Validation study
Limper 2017 (50)	Validation study for Gojo AMS
Marra 2008(86)	Measured dispenser usage, no hand hygiene compliance %
Robinson 2014 (87)	Specific population (stem cell transplant population)
Roberts 2010(88)	Did not include hand hygiene data
Srigley 2014(42)	Quantifying hawthorn effect
Steed 2011 (47)	Validation study
Sunkesula 2015 (63)	Study showed that wash-in wash-out is comparable to WHO 5, however, hospital seems to have only private rooms
Zoutman 2003(89)	Opinion paper

Note: This list only included studies suggested by vendors and our clinical experts. Validation studies were not included for clinical effectiveness assessment. But validation studies were mentioned in the validation of device section.

Appendix F Historical and Forecasted Compliance Rates in Acute Care Facilities per Health Authority

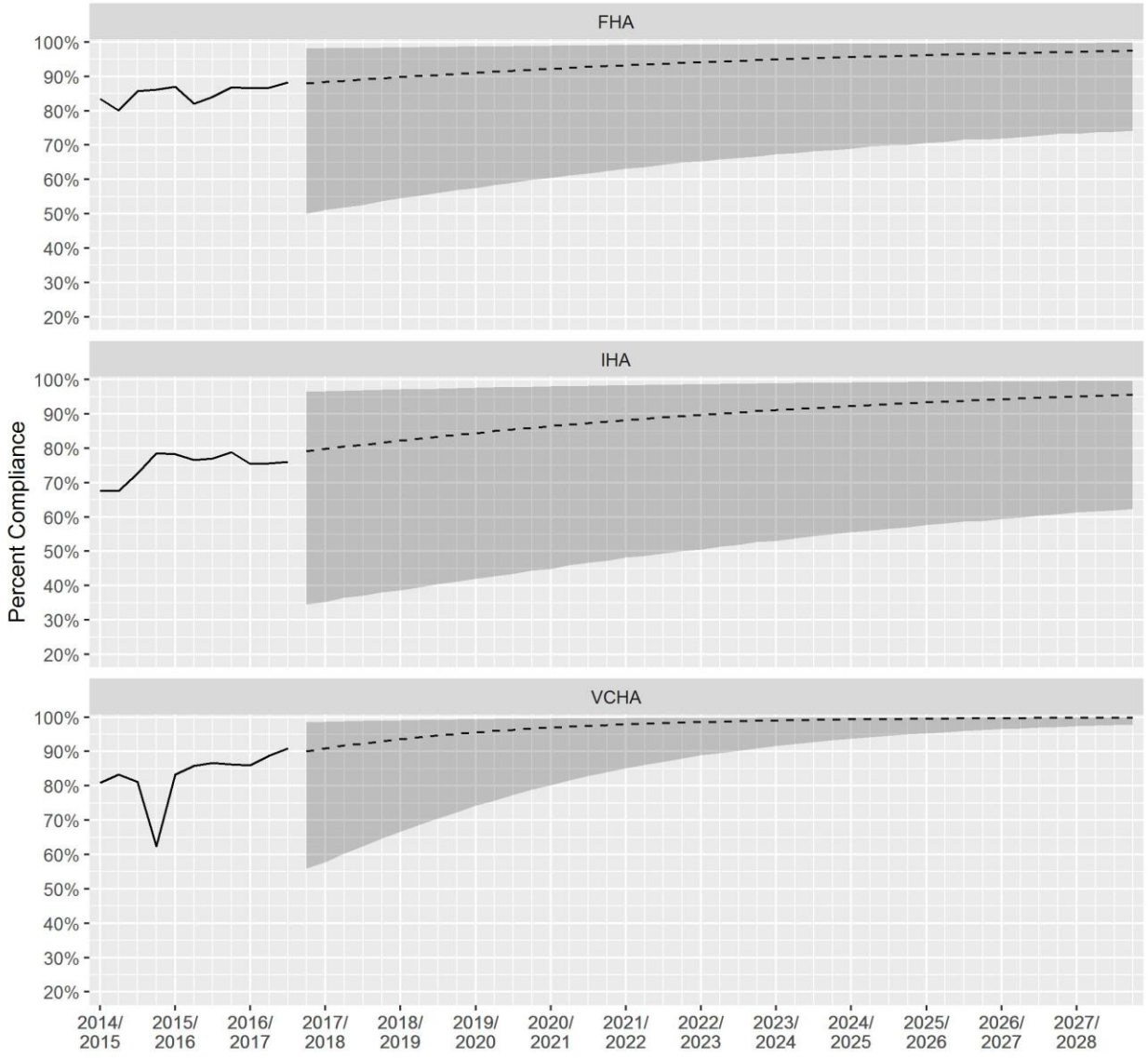


Note: The solid black line from 2012/2013 to 2016/2017 is based on compliance rates reported to PICNet (measured by direct observation). The dotted lines and surrounding grey areas are the forecasted compliance and confidence intervals using a mixed-effects logistic regression

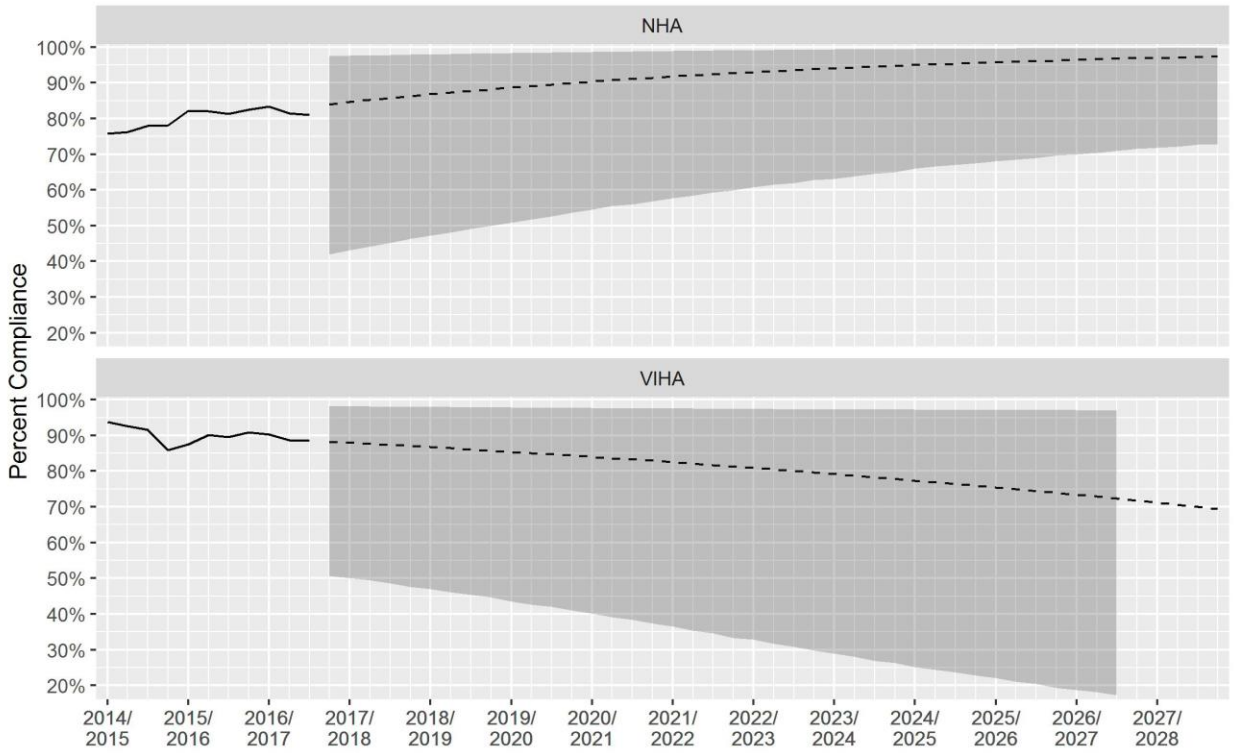


Note: The solid black line from 2012/2013 to 2016/2017 is based on compliance rates reported to PICNet (measured by direct observation). The dotted lines and surrounding grey areas are the forecasted compliance and confidence intervals using a mixed-effects logistic regression

Appendix G Historical and Forecasted Compliance Rates in Residential Care Facilities per Health Authority



Note: The solid black line from 2012/2013 to 2016/2017 is based on compliance rates reported to PICNet (measured by direct observation). The dotted lines and surrounding grey areas are the forecasted compliance and confidence intervals using a mixed-effects logistic regression



Note: The solid black line from 2012/2013 to 2016/2017 is based on compliance rates reported to PICNet (measured by direct observation). The dotted lines and surrounding grey areas are the forecasted compliance and confidence intervals using a mixed-effects logistic regression

Appendix H Compliance Forecast for Acute and Residential Care (unadjusted, adjusted for biases, and after the implementation of EMS in BC) (without any effect of additional co-interventions).

Acute Care

	Direct Observation Alone - non-adjusted compliance curves (forecasted)						Direct Observation Alone - Biases-adjusted compliance						EMS + Direct Observation reduced volume					
	IHA	FHA	VCHA	PHSA	VIHA	NHA	IHA	FHA	VCHA	PHSA	VIHA	NHA	IHA	FHA	VCHA	PHSA	VIHA	NHA
2018	82.8%	93.7%	84.7%	96.7%	78.3%	82.4%	26.6%	27.4%	27.2%	31.1%	23.4%	26.0%	32.6%	33.5%	33.2%	37.5%	28.9%	31.9%
2019	84.3%	95.2%	86.2%	97.6%	78.4%	83.9%	27.1%	27.8%	27.6%	31.4%	23.5%	26.5%	33.1%	33.9%	33.7%	37.9%	29.0%	32.5%
2020	85.8%	96.3%	87.5%	98.3%	78.6%	85.4%	27.6%	28.2%	28.1%	31.6%	23.5%	27.0%	33.7%	34.3%	34.2%	38.1%	29.0%	33.0%
2021	87.1%	97.2%	88.8%	98.8%	78.7%	86.7%	28.0%	28.4%	28.5%	31.8%	23.5%	27.4%	34.1%	34.6%	34.7%	38.3%	29.1%	33.4%
2022	88.4%	97.9%	89.9%	99.1%	78.9%	87.9%	28.4%	28.6%	28.8%	31.9%	23.6%	27.8%	34.6%	34.8%	35.1%	38.4%	29.1%	33.9%
2023	89.5%	98.4%	91.0%	99.4%	78.9%	89.0%	28.8%	28.8%	29.2%	31.9%	23.6%	28.1%	35.0%	35.0%	35.4%	38.5%	29.2%	34.3%
2024	90.5%	98.8%	91.9%	99.5%	79.1%	90.0%	29.1%	28.9%	29.5%	32.0%	23.7%	28.5%	35.3%	35.1%	35.8%	38.5%	29.2%	34.6%
2025	91.5%	99.1%	92.8%	99.7%	79.2%	91.0%	29.4%	29.0%	29.8%	32.0%	23.7%	28.8%	35.7%	35.2%	36.1%	38.6%	29.2%	35.0%
2026	92.3%	99.3%	93.5%	99.8%	79.3%	91.8%	29.7%	29.1%	30.0%	32.1%	23.7%	29.0%	36.0%	35.3%	36.3%	38.6%	29.3%	35.3%
2027	93.1%	99.5%	94.2%	99.8%	79.5%	92.6%	29.9%	29.1%	30.2%	32.1%	23.8%	29.3%	36.3%	35.3%	36.6%	38.6%	29.3%	35.5%

Residential Care

	Direct Observation Alone - non-adjusted compliance curves (forecasted)						Direct Observation Alone - Biases-adjusted compliance						EMS + Direct Observation reduced volume					
	IHA	FHA	VCHA	PHSA	VIHA	NHA	IHA	FHA	VCHA	PHSA	VIHA	NHA	IHA	FHA	VCHA	PHSA	VIHA	NHA
2018	83.1%	90.3%	94.4%	0.0%	86.3%	87.5%	26.7%	26.1%	28.1%	0.0%	25.0%	27.6%	32.7%	32.0%	34.2%	0.0%	30.7%	33.6%
2019	85.2%	91.5%	96.1%	0.0%	84.9%	89.3%	27.4%	26.5%	28.6%	0.0%	24.6%	28.1%	33.5%	32.4%	34.8%	0.0%	30.2%	34.3%
2020	87.1%	92.6%	97.3%	0.0%	83.5%	90.9%	28.0%	26.8%	29.0%	0.0%	24.2%	28.6%	34.1%	32.8%	35.2%	0.0%	29.8%	34.8%
2021	88.8%	93.6%	98.2%	0.0%	81.9%	92.2%	28.5%	27.1%	29.2%	0.0%	23.7%	29.1%	34.7%	33.1%	35.5%	0.0%	29.3%	35.3%
2022	90.3%	94.4%	98.7%	0.0%	80.3%	93.4%	29.0%	27.3%	29.4%	0.0%	23.2%	29.4%	35.3%	33.4%	35.7%	0.0%	28.7%	35.7%
2023	91.6%	95.2%	99.1%	0.0%	78.5%	94.4%	29.4%	27.5%	29.5%	0.0%	22.7%	29.7%	35.7%	33.6%	35.8%	0.0%	28.1%	36.0%
2024	92.7%	95.8%	99.4%	0.0%	76.7%	95.3%	29.8%	27.7%	29.6%	0.0%	22.2%	30.0%	36.1%	33.8%	35.9%	0.0%	27.5%	36.4%
2025	93.7%	96.4%	99.6%	0.0%	74.7%	96.0%	30.1%	27.9%	29.7%	0.0%	21.6%	30.2%	36.5%	34.0%	36.0%	0.0%	26.9%	36.6%
2026	94.6%	96.9%	99.7%	0.0%	72.6%	96.6%	30.4%	28.0%	29.7%	0.0%	21.0%	30.4%	36.8%	34.2%	36.0%	0.0%	26.1%	36.8%
2027	95.4%	97.3%	99.8%	0.0%	70.3%	97.1%	30.7%	28.2%	29.7%	0.0%	20.3%	30.6%	37.1%	34.3%	36.0%	0.0%	25.4%	37.0%

Appendix I Budget Impact for Acute Care Units in BC

Acute Care												
	Outputs	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**Total 2018-2027**
Status Quo Direct Observation	MRSA cases	2,073	2,097	2,103	2,107	2,114	2,120	2,127	2,135	2,143	2,147	21,166
	Cost of DO	781.8K	781.8K	781.8K	781.8K	781.8K	781.8K	781.8K	781.8K	781.8K	781.8K	7.8M
	Costs of EMS	-	-	-	-	-	-	-	-	-	-	-
	Costs of auditing (DO + EMS)	781.8K	781.8K	781.8K	781.8K	781.8K	781.8K	781.8K	781.8K	781.8K	781.8K	7.8M
	Cost HH supplies	1.2M	1.2M	1.2M	1.2M	1.2M	1.3M	1.3M	1.3M	1.3M	1.3M	12.5M
	Cost of MRSA treatment	9.6M	9.6M	9.5M	9.4M	9.3M	9.2M	9.2M	9.1M	9.0M	8.9M	92.9M
	Total costs (audit, HH supplies, MRSA treatment)	11.6M	11.6M	11.5M	11.4M	11.4M	11.3M	11.2M	11.1M	11.1M	11.0M	113.2M
EMS + Reduced Direct Observation	MRSA cases	2,010	2,033	2,039	2,044	2,049	2,055	2,063	2,070	2,078	2,081	20,523
	MRSA cases avoided	-63	-64	-64	-64	-64	-65	-64	-65	-65	-66	-643
	Cost of DO	783.2K	783.2K	169.9K	169.9K	169.9K	169.9K	169.9K	169.9K	169.9K	169.9K	2.9M
	Costs of EMS	3.4M	3.4M	3.4M	3.4M	3.4M	3.4M	3.4M	3.4M	3.4M	3.4M	33.7M
	Costs of auditing (DO + EMS)	4.2M	4.2M	3.5M	3.5M	3.5M	3.5M	3.5M	3.5M	3.5M	3.5M	36.7M
	Cost HH supplies	1.4M	1.4M	1.5M	1.5M	1.5M	1.5M	1.5M	1.5M	1.5M	1.6M	15.0M
	Cost of MRSA treatment	9.4M	9.4M	9.3M	9.2M	9.1M	9.0M	8.9M	8.9M	8.8M	8.7M	90.8M
	Total costs (audit, HH supplies, MRSA treatment)	15.0M	15.0M	14.3M	14.2M	14.2M	14.1M	14.0M	13.9M	13.9M	13.8M	142.4M
	Direct observation cost avoided	1.5K	1.5K	-611.9K	-611.9K	-611.9K	-611.9K	-611.9K	-611.9K	-611.9K	-611.9K	-4.9M
	Cost of MRSA treatment avoided	-211.0K	-215.3K	-216.6K	-217.0K	-215.9K	-214.8K	-212.8K	-215.1K	-210.1K	-211.5K	-2.1M
	Audit process incremental cost	3.4M	3.4M	2.8M	2.8M	2.8M	2.8M	2.8M	2.8M	2.8M	2.8M	28.8M
	HH supplies incremental cost	238.9K	244.2K	248.0K	248.7K	250.8K	252.6K	252.6K	255.2K	255.6K	256.9K	2.5M
	Overall incremental costs	3.4M	3.4M	2.8M	2.8M	2.8M	2.8M	2.8M	2.8M	2.8M	2.8M	29.2M

Note: DO = direct observation; EMS = electronic monitoring system; HH = hand hygiene; MRSA = methicillin-resistant *Staphylococcus aureus*.

Appendix J Budget Impact for Residential Care Units in BC

Residential Care												
	Outputs	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**Total 2018-2027**
Status Quo Direct Observation	MRSA cases	846	843	842	840	839	839	838	837	837	837	8,399
	Cost of DO	269.1K	269.1K	269.1K	269.1K	269.1K	269.1K	269.1K	269.1K	269.1K	269.1K	2.7M
	Costs of EMS	-	-	-	-	-	-	-	-	-	-	-
	Costs of auditing (DO + EMS)	269.1K	269.1K	269.1K	269.1K	269.1K	269.1K	269.1K	269.1K	269.1K	269.1K	2.7M
	Cost HH supplies	1.1M	1.1M	1.1M	1.1M	1.2M	1.2M	1.2M	1.2M	1.2M	1.2M	11.5M
	Cost of MRSA treatment	3.9M	3.8M	3.8M	3.7M	3.7M	3.6M	3.6M	3.5M	3.5M	3.4M	36.6M
	Total costs (audit, HH supplies, MRSA treatment)	5.3M	5.2M	5.2M	5.1M	5.1M	5.1M	5.0M	5.0M	4.9M	4.9M	50.8M
EMS + Reduced Direct Observation	MRSA cases	821	818	816	815	814	813	812	812	811	811	8,142
	MRSA cases avoided	-26	-25	-26	-26	-26	-26	-26	-26	-26	-26	-257
	Cost of DO	269.2K	269.2K	162.7K	162.7K	162.7K	162.7K	162.7K	162.7K	162.7K	162.7K	1.8M
	Costs of EMS	3.8M	3.8M	3.8M	3.8M	3.8M	3.8M	3.8M	3.8M	3.8M	3.8M	37.8M
	Costs of auditing (DO + EMS)	4.1M	4.1M	3.9M	3.9M	3.9M	3.9M	3.9M	3.9M	3.9M	3.9M	39.7M
	Cost HH supplies	1.3M	1.3M	1.4M	1.4M	1.4M	1.4M	1.4M	1.4M	1.4M	1.4M	13.8M
	Cost of MRSA treatment	3.8M	3.8M	3.7M	3.6M	3.6M	3.5M	3.5M	3.5M	3.4M	3.4M	35.8M
	Total costs (audit, HH supplies, MRSA treatment)	9.2M	9.2M	9.0M	9.0M	8.9M	8.9M	8.8M	8.8M	8.8M	8.7M	89.3M
	Direct observation cost avoided	144	144	-106.4K	-106.4K	-106.4K	-106.4K	-106.4K	-106.4K	-106.4K	-106.4K	-850.5K
	Cost of MRSA treatment avoided	-86.8K	-85.5K	-87.1K	-86.6K	-85.6K	-83.1K	-82.5K	-82.3K	-80.6K	-80.5K	-840.7K
	Audit process incremental cost	3.8M	3.8M	3.7M	3.7M	3.7M	3.7M	3.7M	3.7M	3.7M	3.7M	37.0M
	HH supplies incremental cost	229.4K	231.4K	233.8K	233.7K	235.2K	235.2K	235.5K	235.9K	236.5K	235.9K	2.3M
	Overall incremental costs	3.9M	3.9M	3.8M	3.8M	3.8M	3.8M	3.8M	3.8M	3.8M	3.8M	38.5M

Note: DO = direct observation; EMS = electronic monitoring system; HH = hand hygiene; MRSA = methicillin-resistant *Staphylococcus aureus*.

Appendix K Budget Impact for Acute Care Units in BC – Sensitivity Analysis

Acute Care												
	Outputs	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**Total 2018-2027**
Status Quo Direct Observation	MRSA cases	2,110	2,134	2,140	2,145	2,151	2,158	2,165	2,172	2,180	2,184	21,541
	Cost of DO	781.6K	781.6K	781.6K	781.6K	781.6K	781.6K	781.6K	781.6K	781.6K	781.6K	7.8M
	Costs of EMS	-	-	-	-	-	-	-	-	-	-	-
	Costs of auditing (DO + EMS)	781.6K	781.6K	781.6K	781.6K	781.6K	781.6K	781.6K	781.6K	781.6K	781.6K	7.8M
	Cost HH supplies	1.2M	1.2M	1.2M	1.2M	1.2M	1.3M	1.3M	1.3M	1.3M	1.3M	12.4M
	Cost of MRSA treatment	60.7M	61.2M	61.2M	61.2M	61.1M	61.1M	61.2M	61.2M	61.3M	61.2M	611.4M
	Total costs (audit, HH supplies, MRSA treatment)	62.7M	63.2M	63.2M	63.2M	63.2M	63.2M	63.2M	63.3M	63.3M	63.3M	631.7M
EMS + Reduced Direct Observation	MRSA cases	2,026	2,049	2,055	2,060	2,065	2,072	2,079	2,086	2,094	2,098	20,682
	MRSA cases avoided	-84	-85	-85	-85	-86	-86	-86	-87	-87	-87	-858
	Cost of DO	783.5K	783.5K	170.0K	170.0K	170.0K	170.0K	170.0K	170.0K	170.0K	170.0K	2.9M
	Costs of EMS	843.2K	843.2K	843.2K	843.2K	843.2K	843.2K	843.2K	843.2K	843.2K	843.2K	8.4M
	Costs of auditing (DO + EMS)	1.6M	1.6M	1.0M	1.0M	1.0M	1.0M	1.0M	1.0M	1.0M	1.0M	11.4M
	Cost HH supplies	1.4M	1.4M	1.5M	1.5M	1.5M	1.5M	1.5M	1.5M	1.6M	1.6M	15.0M
	Cost of MRSA treatment	58.3M	58.7M	58.7M	58.7M	58.7M	58.7M	58.7M	58.7M	58.8M	58.7M	586.8M
	Total costs (audit, HH supplies, MRSA treatment)	61.3M	61.8M	61.2M	61.2M	61.2M	61.2M	61.2M	61.3M	61.4M	61.3M	613.1M
	Direct observation cost avoided	1.8K	1.8K	-611.7K	-611.7K	-611.7K	-611.7K	-611.7K	-611.7K	-611.7K	-611.7K	-4.9M
	Cost of MRSA treatment avoided	-2.5M	-2.5M	-2.5M	-2.5M	-2.5M	-2.5M	-2.5M	-2.5M	-2.5M	-2.5M	-24.7M
	Audit process incremental cost	845.0K	845.0K	231.5K	231.5K	231.5K	231.5K	231.5K	231.5K	231.5K	231.5K	3.5M
	HH supplies incremental cost	248.6K	253.8K	254.7K	257.5K	259.8K	260.4K	261.6K	263.7K	264.8K	265.5K	2.6M
	Overall incremental costs	-1.4M	-1.4M	-2.0M	-2.0M	-2.0M	-2.0M	-2.0M	-2.0M	-2.0M	-2.0M	-18.5M

Note: DO = direct observation; EMS = electronic monitoring system; HH = hand hygiene; MRSA = methicillin-resistant *Staphylococcus aureus*.

Appendix L Budget Impact for Residential Care Units in BC – Sensitivity Analysis

Residential Care												
	Outputs	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**Total 2018-2027**
Status Quo Direct Observation	MRSA cases	856	853	851	849	848	847	847	846	846	846	8,489
	Cost of DO	269.0K	269.0K	269.0K	269.0K	269.0K	269.0K	269.0K	269.0K	269.0K	269.0K	2.7M
	Costs of EMS	-	-	-	-	-	-	-	-	-	-	-
	Costs of auditing (DO + EMS)	269.0K	269.0K	269.0K	269.0K	269.0K	269.0K	269.0K	269.0K	269.0K	269.0K	2.7M
	Cost HH supplies	1.1M	1.1M	1.1M	1.1M	1.2M	1.2M	1.2M	1.2M	1.2M	1.2M	11.5M
	Cost of MRSA treatment	24.6M	24.5M	24.3M	24.2M	24.1M	24.0M	23.9M	23.8M	23.8M	23.7M	241.0M
	Total costs (audit, HH supplies, MRSA treatment)	26.0M	25.8M	25.7M	25.6M	25.5M	25.4M	25.4M	25.3M	25.2M	25.1M	255.2M
EMS + Reduced Direct Observation	MRSA cases	820	818	816	814	813	812	812	811	811	811	8,139
	MRSA cases avoided	-35	-35	-35	-35	-35	-35	-35	-35	-35	-35	-351
	Cost of DO	269.3K	269.3K	162.8K	162.8K	162.8K	162.8K	162.8K	162.8K	162.8K	162.8K	1.8M
	Costs of EMS	945.5K	945.5K	945.5K	945.5K	945.5K	945.5K	945.5K	945.5K	945.5K	945.5K	9.5M
	Costs of auditing (DO + EMS)	1.2M	1.2M	1.1M	1.1M	1.1M	1.1M	1.1M	1.1M	1.1M	1.1M	11.3M
	Cost HH supplies	1.3M	1.3M	1.4M	1.4M	1.4M	1.4M	1.4M	1.4M	1.4M	1.4M	13.9M
	Cost of MRSA treatment	23.6M	23.5M	23.3M	23.2M	23.1M	23.0M	22.9M	22.8M	22.8M	22.7M	230.9M
	Total costs (audit, HH supplies, MRSA treatment)	26.1M	26.0M	25.8M	25.7M	25.6M	25.5M	25.4M	25.4M	25.3M	25.2M	256.1M
	Direct observation cost avoided	300	300	-106.2K	-106.2K	-106.2K	-106.2K	-106.2K	-106.2K	-106.2K	-106.2K	-849.3K
	Cost of MRSA treatment avoided	-1.0M	-1.0M	-1.0M	-1.0M	-1.0M	-1.0M	-1.0M	-995.7K	-990.9K	-989.7K	-10.1M
	Audit process incremental cost	945.8K	945.8K	839.3K	839.3K	839.3K	839.3K	839.3K	839.3K	839.3K	839.3K	8.6M
	HH supplies incremental cost	234.5K	235.5K	239.1K	239.6K	240.7K	241.4K	241.4K	241.8K	241.8K	242.0K	2.4M
	Overall incremental costs	148.0K	169.2K	62.5K	65.8K	68.6K	69.4K	78.6K	85.4K	90.2K	91.5K	929.3K

Note: DO = direct observation; EMS = electronic monitoring system; HH = hand hygiene; MRSA = methicillin-resistant *Staphylococcus aureus*.