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EMPIRICAL RESEARCH QUANTITATIVE

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Impact of a quality improvement intervention on the incidence of surgical site infection in patients undergoing colorectal surgery: Pre-test–post-test design

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Abstract

Aims and Objectives: The aim of this study was to measure the impact of a complex quality improvement intervention on the incidence of SSI in patients undergoing elective colorectal surgery.

Background: Surgical site infections are a major postoperative complication for patients undergoing colorectal surgery. Prevention of SSIs necessitates a complex intervention requiring many elements to be in place to ensure the successful implementation of prevention measures.

Design: This study was a non-equivalent pre-test post-test design where consecutive patients undergoing colorectal surgery were surveyed for surgical site infections for 30 days postoperatively and is reported using the SQUIRE 2.0.

Methods: A baseline cohort of patients was retrospectively reviewed in a single centre to ascertain the surgical site infection incidence rate in the first 6 months of 2018 (T0) and prospectively at two 6-month time periods in 2019 (T1, T2) following the introduction of a complex intervention. There were 311 patients included across three time periods.

Results: There was a notable decrease in surgical site infection incidence rates from baseline over the course of the study. Univariate analysis identified Body Mass Index, a wound contamination classification of dirty or contaminated, duration of surgery >75th percentile and a National Healthcare Safety Network risk index score of 3 as factors that significantly increase the probability of developing a surgical site infection. Multivariate analysis identified duration of surgery and body mass index increased the probability of an SSI. The results of the logistical regression model found that there was a significant reduction in the probability of an SSI between T0 and T2.

Conclusions: The implementation of a complex intervention led to a reduction in the incidence of surgical site infections and improved implementation of evidence-based practices as part of a care bundle in relation to the prevention of surgical site infections in patients undergoing elective colorectal surgery.

Relevance to Clinical Practice: A multicomponent multidisciplinary complex intervention as part of a quality improvement project can successfully reduce the incidence rates of surgical site infections in patients who require elective colorectal surgery. Normalisation Process Theory provides guidance and support in implementing complex interventions for the prevention of surgical site infection.

Patient or Public Contribution: Patients provided post-discharge information on their wound healing as part of the surveillance component of the intervention. Five patients reviewed and provided feedback on a patient information booklet which was developed from this quality improvement intervention. A multidisciplinary steering group guided all stages of the project.

KEYWORDS
evidence-based, infection Control, multidisciplinary care team, quality improvement, surgical Wound Infection

1 | INTRODUCTION

It is widely recognised that the development of healthcare-associated infection (HCAI) is one of the most common avoidable, adverse events experienced by hospitalised patients (World Health Organization, 2018). Surgical Site infection (SSI) remains one of the most common health-care-associated infections (European Centre for Disease Prevention and Control, 2019; World Health Organization, 2018). They represent a substantial burden to patients and healthcare systems contributing to increased patient morbidity and mortality, increased post-operative hospital stay, the possibility of treatment in intensive care units, readmissions and additional surgical procedures (Anderson et al., 2014; Ban et al., 2017; European Centre for Disease Prevention and Control, 2017; Magill et al., 2014; Mujagic et al., 2018; World Health Organization, 2018).

A SSI is defined as a wound infection that occurs within 30 days in the area where the surgery took place. Diagnostic criteria for a SSI are outlined by the European Centre for Disease Prevention and Control (ECDC) guidance (European Centre for Disease Prevention and Control, 2017). SSIs are frequent major postoperative events among patients undergoing elective colorectal surgery with incidences ranging from 15% to 30% (Tanner et al., 2015). Incidences of SSIs are higher in colorectal surgery than other specialities which is attributable to contamination from the bowel flora, pre-existing conditions and extended surgical time (Ali et al., 2014; Azoury et al., 2015; Keita et al., 2014; Manilich et al., 2013; Murray et al., 2016; Panos et al., 2021; Paulson et al., 2017). Postoperative SSIs from colorectal surgery are difficult to treat and, therefore, it is essential that such infections are prevented; this requires clinicians to put in place processes to both prevent and monitor the rates of SSIs (Tsai & Caterson, 2014).

International guidance recommends that healthcare staff in hospitals engage in surveillance to reduce SSI incidence rates (European Centre for Disease Prevention and Control, 2017; Health Protection Surveillance Centre, 2021). Surveillance aims to lower the incidence of SSI and is one aspect of an overall systems approach within hospital settings which endeavours to engage in sustainable preventative quality improvement initiatives for surgical patients. Quality improvement initiatives to reduce SSI rates are complex and require a number of organisational-led elements and resources to be in place to bring about sustainable change (Allegranzi et al., 2016; Troughton et al., 2019; World Health Organization, 2018).

The aim of this study was to assess the impact of a complex quality improvement intervention on the incidence of surgical site infection in patients undergoing elective colorectal surgery in an institution where SSI surveillance was not previously routinely undertaken. This paper describes the elements of the intervention and a comparison of SSI rates before and after implementation of the complex intervention.

What does this paper contribute to the wider global clinical community?

- Demonstrates the impact of a multicomponent multidisciplinary complex intervention on surgical site infection incidence rates.
- Provides recommendations on the implementation of complex interventions to reduce surgical site infection incidence rates.
- Highlights the benefits of using Normalisation Process Theory in guiding clinical teams in implementing surgical site infection prevention strategies in a complex surgical environment.

2 | METHODS

2.1 | Setting and design

This study used a pretest-posttest non-equivalent groups design and was undertaken in a large university teaching hospital which is also a regional cancer centre. This study is reported according to the Standards for QUality Improvement Reporting Excellence (SQUIRE 2.0) (File S1; Ogrinc et al., 2015). A non-probability consecutive sample of patients aged 16 years and older undergoing elective colorectal surgery, for either cancer, uncomplicated diverticulitis or inflammatory bowel disease (ulcerative colitis and Crohn's disease), were included in the study. The pre-intervention period was from January 2018 to June 2018 where 95 colorectal surgery cases were studied retrospectively at baseline - Time 0 (T0). This T0 data was instrumental in understanding the potential of the problem. It served as a check on the effectiveness of the quality improvement process and provided a comparator for the intervention phase of the study. The post-intervention surveillance was performed prospectively on two patient cohorts with 117 enrolled at Time 1 (T1) (January 2019 to June 2019) and 99 enrolled at Time 2 (T2) (July 2019 to December 2019). Surgical procedures performed included: abdominoperineal resection, Hartman's procedure, right hemicolectomy, anterior resection, trans-anal endoscopic microsurgery and colostomy reversal.

2.2 | Intervention

In 2018, a multidisciplinary implementation team was convened to assess the needs and requirements for the successful implementation of a SSI quality improvement intervention. A study was initiated which followed a locally designed process named after the steps followed: **I**nitiation, **S**urveillance, **S**haring, **I**mprovements and **P**lan for future (**ISSIP**) (Figure 1). ISSIP was guided by Normalisation Process theory (NPT) where all key constructs (coherence, cognitive participation, collective action, and reflexive monitoring) provided understanding and structure to this complex intervention (Murray et al., 2010). The elements of the complex intervention are presented in Figure 2; these included: convening of an implementation team, initiation of SSI surveillance (SSIS), development of a care bundle, production and use of a patient information booklet, patient and staff education and the appointment of a facilitator.

In line with the Plan, Do, Study Act (PDSA) cycles, a number of evidence-based practices were introduced sequentially in T1 and T2 (Figure 2). After reviewing published international guidelines and literature, the consensus was reached by all members of the implementation team on a number of key additional interventions that would be incorporated into the care pathway for patients in the service undergoing colorectal surgery. Prior to the intervention the care provided was not standardised and would have been practitioner-dependent and many elements were not part of routine clinical care. An element of the care bundle was to ensure that wound barrier skin protection was used as part of routine management. These additional elements of best practice were collated into a care bundle to standardise the care provided. The care bundle included a series of interventions in the preoperative, intraoperative and postoperative phases of surgery. This care bundle was presented to practitioners as a checklist, aide-mémoire during the patient's perioperative journey (File S2). By having the checklist, the health care practitioners were prompted to both complete the relevant items as appropriate to the stage of the perioperative journey and address abnormal assessment findings. For instance, if iron deficiency was detected preoperatively, patients were administered intravenous iron replacement prior to surgery; and if the malnutrition universal screening tool scored low, a dietetic referral and review were undertaken. Additional elements were added at T2 including an educational booklet for patients and the expansion of the care bundle checklist to include preOp™ drinks (nutritional supplement), Preoperative showering with skin cleanser, and preoperative antibiotics. The care bundles administered at T1 and T2 are outlined separately in File S2.

A newly developed booklet explaining all aspects of their expected perioperative journey was given to the patients at a preoperative hospital visit up to 2 weeks before surgery. The comprehensive booklet was developed in collaboration with patients, surgeons, anesthesiologists, dietitians, physiotherapists, occupational therapists, theatre personnel, ward staff and nurse specialists in colorectal, wound care and stoma therapy. The post-discharge questionnaire was incorporated into the booklet which contributed to the compliance with returning the questionnaire on SSI. The booklet was awarded the plain English stamp award for reading age of 11 years for readability and comprehension (HSE, 2017) which followed the recommendation that the education of patients in preventative measures should be delivered at a reading level that is comprehensible to ensure patients participation in their health journey (Tartari et al., 2017).

Patients, where clinically indicated, were given a prescription to be taken or utilised on the day before surgery with antimicrobial skin disinfectant body wash, carbohydrate drinks, oral antibiotics, and mechanical bowel preparation. Other elements of the intervention included change of instruments for closure of the wounds, patient warming throughout the perioperative period to maintain normothermia, blood glucose monitoring in the post-operative period and patient education on SSI (Figure 2).

2.3 | Measures

The project commenced with the development of the SSIS system to determine the rate of, and factors which, contributed to the development of SSI. This involved the design of a paper-based surveillance form to capture key data elements throughout the patient journey including intraoperative and postoperative variables, risk factor variables and surgical site infection within 30 days. Data acquisition and integration were facilitated by a locally designed Microsoft Access© data management system. Standardised format and definitions were employed in compliance with the European Centre for

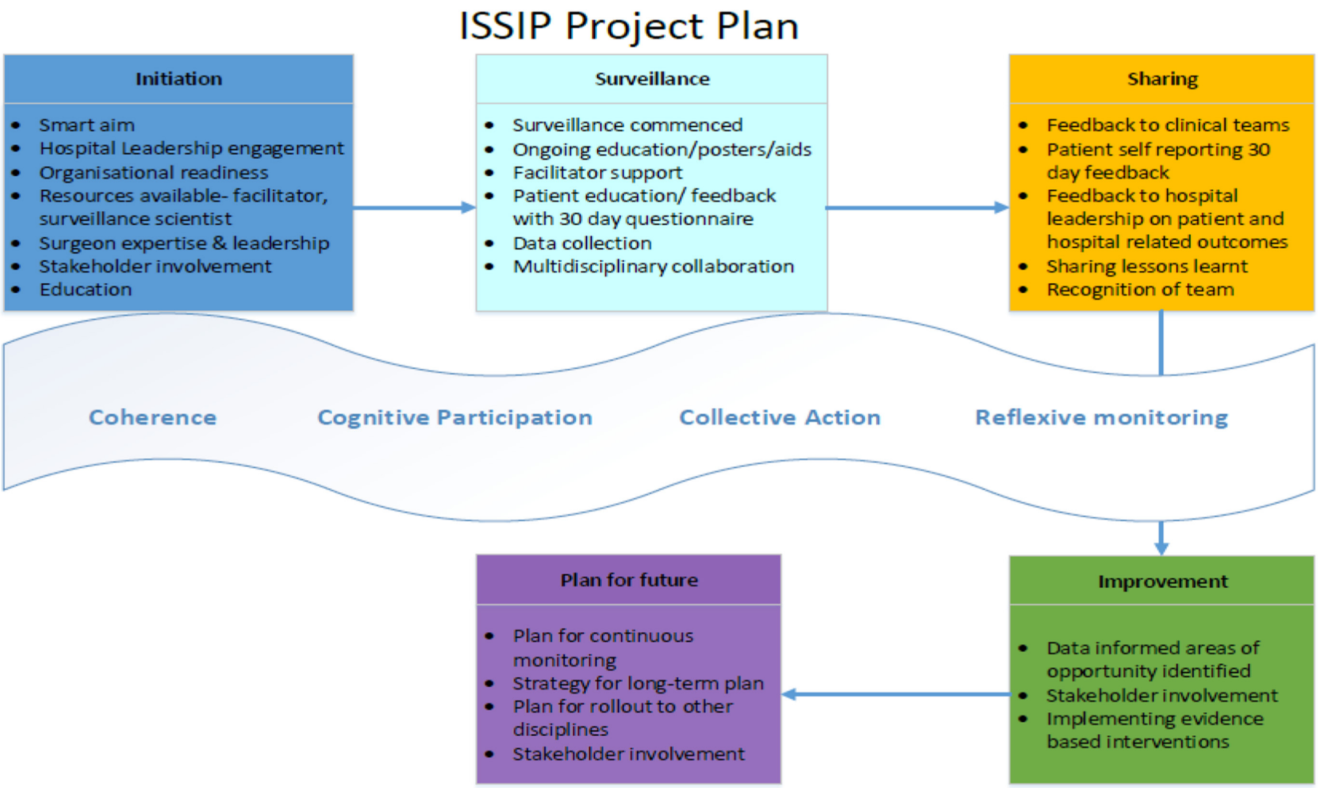

FIGURE 1 Initiation, Surveillance, Sharing, Improvements and Plan for future (ISSIP) Project plan. [Colour figure can be viewed at wileyonlinelibrary.com]

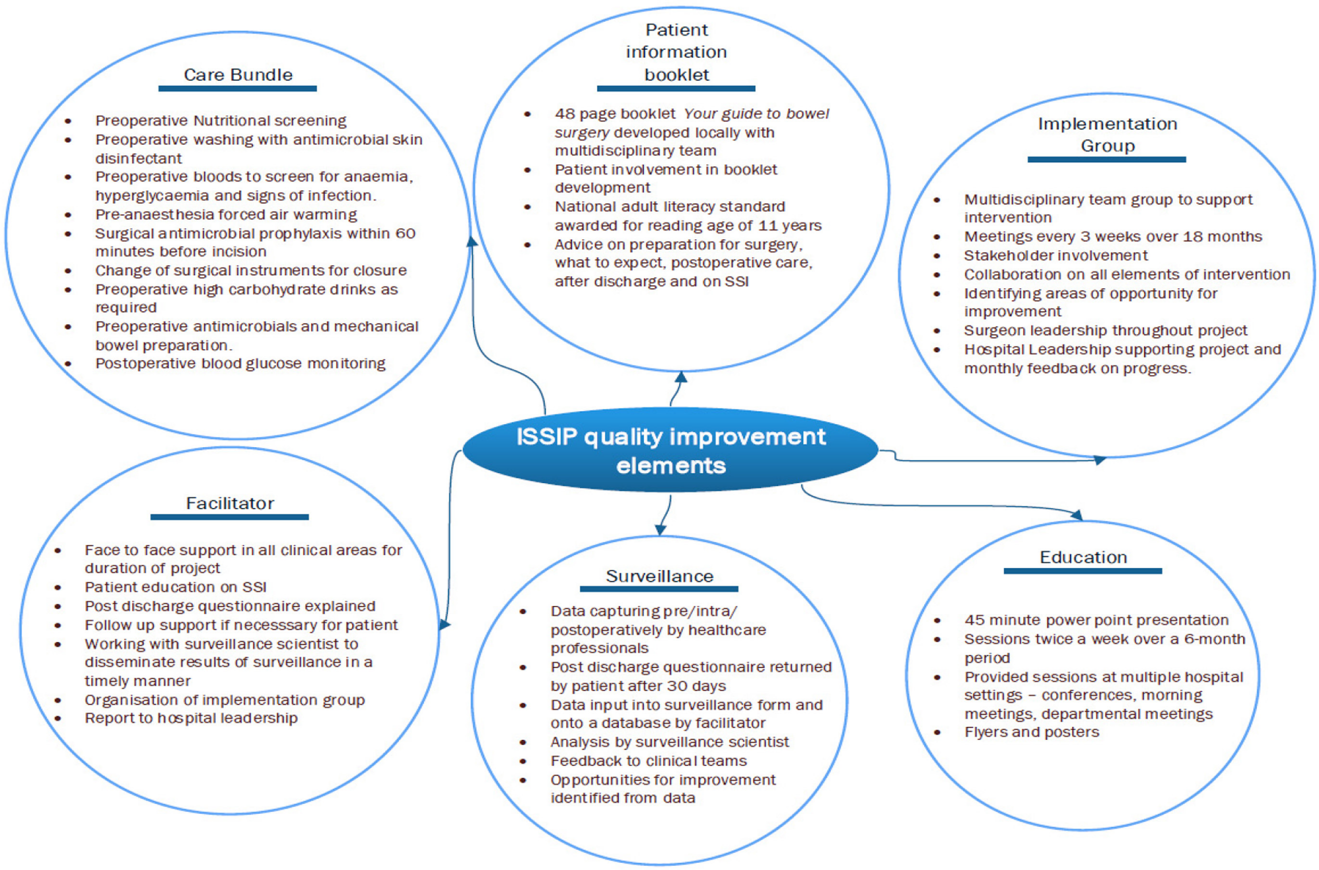

FIGURE 2 Initiation, Surveillance, Sharing, Improvements and Plan for future (ISSIP) quality improvement elements. [Colour figure can be viewed at wileyonlinelibrary.com]

Disease Prevention (ECDC) SSI surveillance guidelines. T0 cohort data were collected through a retrospective chart review, laboratory results and the hospital's patient management system. T1 and T2 cohort data were collected by members of the multidisciplinary team at various time points throughout the patient's surgical journey and through a post-discharge questionnaire. All SSI diagnosis data were validated by the clinical team.

2.4 | Ethical considerations

Ethical approval was obtained from the Clinical Research Ethics Committee of the hospital in which the study was undertaken. Approval was granted to review retrospective medical records of colorectal surgery patients over a 6-month period in 2018 and prospectively in 2019 (T0). Written consent was obtained from all patients in the prospectively collected data (T1 and T2).

2.5 | Intraoperative and postoperative data

Data collected through the SSIS system included: patient demographics, infection characteristics, administration of antibiotic prophylaxis and perioperative temperature. Data was also collected on length of stay, patient outcome at hospital discharge and readmissions within 30 days post-discharge. Further information was gathered on clinical practice variables and process indicators which included monitoring of temperature and blood glucose measurement in the perioperative period, the correct timing of surgical antibiotic prophylaxis, details of hair removal practices, use of surveillance form for collection of data, and recording of wound contamination classification. Improving the awareness of the importance of these practices captured as process indicators was part of the intervention.

Studies have shown that hypothermia in the intraoperative period increases the risk of SSI and recommend targeted interventions to maintain body temperature at 36°C or above through monitoring and implementing improvement measures (Burger & Fitzpatrick, 2009; Torossian, 2008; Walters et al., 2020). Body temperature was measured at 3-time points: preoperatively; after the patient was anaesthetised and; following surgery on arrival to the recovery room. Two aspects of temperature monitoring were examined at each time point; first, was the temperature monitored (yes/no) and second was the temperature > 36°C (yes/no). Temperature on admission was recorded using a tympanic thermometer, an oropharyngeal thermometer was used in theatre with a forehead thermometer measuring the patient's temperature in the recovery area.

Blood glucose measurement was also undertaken as this is recommended in surgical patients due to perioperative hyperglycaemia being shown to increase the incidence of SSI with early treatment averting this outcome (Kwon et al., 2013). Data pertaining to the practice of monitoring of blood glucose levels within 4 h in the postoperative period (yes/no) was collected.

Data was collected on the timing of administration of surgical prophylactic antibiotics as it is recommended to administer prophylactic antibiotics up to 60 min prior to surgical incision (Bratzler et al., 2013; European Centre for Disease Prevention and Control, 2017; Health Service Executive, 2021). Data were collected on correct timing of administration of prophylactic antibiotic within 60 min prior to incision (yes/no) and administration of a second antibiotic dose if operative time was greater than 4 h (yes/no).

Finally, information was gathered on the practice of recording hair removal practices and the type of hair removal practices used as it is recommended that, if hair is to be removed from the operation site, it is removed by clippers only (Allegranzi et al., 2016).

In summary, the primary outcome was the presence or absence of SSI infection, and secondary outcomes related to the completion of certain evidence-based SSI prevention practices captured as process indicators and length of stay.

2.6 | Risk factors for development of SSI data

The US National Healthcare Safety Network (NHSN) Risk Index adopted by the ECDC was used to assign patients to one of four risk categories (European Centre for Disease Prevention and Control, 2017). This system assigns surgical patients into risk categories based on the presence of three major risk factors: the American Society of Anaesthesiologists (ASA) physical status classification, the duration of surgery and the wound contamination classification (Berard & Gandon, 1964; Edwards et al., 2009; European Centre for Disease Prevention and Control, 2017; Saklad, 1941). Each risk factor was given a score of 1 if present; the patient's SSI risk index is the sum of these scores. In this study, a score of 1 was assigned for surgery duration at the 75th percentile where the length of surgery was >180 min for colon surgery and > 240 min for rectal surgery. Risk for wound contamination classification was assigned a score of 1 if the classification was contaminated or dirty, however, these data were not collected at T0, therefore, it was not possible to compute an overall NHSN risk index for the patient cohort. Finally, an ASA score of 3 or greater was also assigned a risk score of 1.

2.7 | Surgical site infection data

Standardised ECDC criteria were complied with in the determination of SSI (European Centre for Disease Prevention and Control, 2017). All patients where SSI was suspected were reviewed by the clinical team as well as being validated by laboratory findings and clinical presentation which included radiological findings or the necessity for a further surgical procedure in the affected area. Post-discharge surveillance was completed by patients in the T1 and T2 cohorts who consented to complete and return a post-discharge questionnaire by post 30 days from the date of surgery. A facilitator met with each patient to explain and administer the post discharge questionnaire. The post-discharge questionnaires collected information from the perspective of the patient on the presence of SSI, and treatment and diagnosis since discharge from the hospital; this self-reported information was further validated by laboratory findings and a clinician.

2.8 | Statistical analysis

Data was initially inputted into Microsoft Access© software datasheet and then transferred to IBM SPSS Statistics for Windows, version 28 for analysis (IBM, 2021). Differences between the patient groups at the three time periods were analysed using one-way ANOVA, Kruskall-Wallis one-way ANOVA and Chi-squared test of independence where appropriate for continuous, ordinal and categorical variables. Histograms and normal Q-Q plots for continuous variables were inspected for normality. Missing data and data not collected were excluded from statistical tests but are included in the tables to show changes in surveillance over time. Fishers-Freeman–Halton exact test of independence was used when a contingency table was greater than two-by-two and when expected cell counts were below five. Multiple group (pairwise) comparisons were made when the overall statistical significance level was less than .05 and the Bonferroni adjustment to the significance level was utilised. The percentage of SSI was calculated by dividing the number of cases with validated infection (numerator) by the number of colorectal surgeries performed (denominator) and multiplying by 100 to compute the rate; in addition, the 95% Klopper Pearson's confidence interval was presented. Univariate logistic regression analysis was undertaken to determine which patient characteristics and patient risk factors could predict an SSI and to compute odds ratios. The level of significance was set at $p \leq .05$. Multivariate logistical regression was used to investigate the relationships between SSI and the elements of the NHSN risk index. The Box-Tidwell test was used to check the assumption of linearity between the Log-odds and a continuous independent predictor prior to applying logistic regression.

3 | RESULTS

3.1 | Patient characteristics

Three hundred and eleven cases met the inclusion criteria. The demographic data across the three time points were comparable on the majority of variables with the exception of body mass index (BMI) (Table 1).

There was a higher proportion of males than females at each time point at approximately 60% of the overall sample. The age profile of the patients was similar across all three time points ranging from 17–88 years with the most prevalent age group between 55–79 years. Of the sample studied, 29.6% (88/297) of patients had a BMI of 30 or greater. Of the 311 operations, the most frequently performed surgery across all three time points was surgery of the colon (61.1%, n = 190/311); laparoscopy was the predominant surgical approach (74.6%, n = 232; Table 2).

Of the ASA classifications, ASA II was the most prevalent with a distribution similar across all three times with a moderate increase of ASA III scores noted from 19% in T0 to 27.4% and 28.3% in T1 and T2, respectively; however, the overall change in the distribution of scores was not statistically significant (p = .093). There was a slight increase over the time points in the median body mass index of the cohort of patients: T0 (median 26, IQR [23.1–29.0]), T1 (median 27, IQR [23.9–31.0]) and T2 (median 27 IQR [25.0–31.0]; p = .043).

As preoperative mechanical bowel preparation and antibiotic prescribing were not routinely used prior to the intervention, this data was not collected at T0. For the use of preoperative mechanical bowel preparation, between T1 (21.4%) and T2 (38.4%) there was a statistically significant increase observed in the practice of using bowel preparations (p = .006) as well as an increase in the prescribing of oral prophylactic antibiotics the day before admission 23.9% vs 35.4% (p = .066).

3.2 | Surgical site infection rate

Surgical site infection rate changed over time (p = .016). In T0, a SSI rate of 25.3% (n = 24/95) was reported with a reduction in SSI rates seen in T1 to 15.4% (n = 18/117) with a further reduction in T2 to 10.1% (n = 10/99). Superficial incisional site infection was the most prominent type of infection in both T0 and T2, whereas in T1 deep incisional (n = 7) and organ space infections (n = 7) were equally prominent recorded SSIs (Table 3). There was a reduction in the readmission of patients with SSI within 30 days at T2; however, this was identified as not being statistically significant. The monthly trend of surgical SSI diagnosis over the three time periods is included in File S3.

Over T1 and T2, 95% (n = 206/216) of patients had post-initial discharge data pertaining to SSI rates in total. This was comprised of: 59.7% (n = 129) data returned in the post-discharge questionnaire by mail, 27% (n = 59) had a follow-up phone call, and 8.3% (n = 18) were inpatients at the 30-day follow-up. The remaining 5.5% (n = 10) were uncontactable. Of those who were lost to follow-up, there were four (3.4%) at T1 and six (6%) at T2 that was uncontactable.

Length of stay also reduced following the implementation of the complex intervention from a median stay of 10 days at T0 to 7 days at T1 and 8 days at T2 (p = .014).

3.3 | Intraoperative and postoperative process indicators

Temperatures were measured at 3-time points and statistical significance was noted in the recording and monitoring of temperatures over three time points (Table 2) with the practice of monitoring and recording of temperature increasing post the introduction of the intervention. Following the administration of anaesthesia to patients, there were 35.3% (n = 34) missing recordings of temperature at T0

TABLE 1 Preoperative patient characteristics over three time points.

Variable	Time 0 (*n* = 95)	Time 1 (*n* = 117)	Time 2 (*n* = 99)	*p*-value†
Gender % (*n*)				
Male	70.5 (67)	58.1 (68)	54.5 (54)	.057[1]
Female	29.5 (28)	41.9 (49)	45.5 (45)	
Age (years)				
Median (IQR)	62.0 (53.70)	61 (51.69)	65 (51.71)	.572[2]
Age categories % (*n*)				
16–34	6.3 (6)	5.1 (6)	5 (5)	
35–44	7.4 (7)	10.3 (12)	7.1 (7)	
45–54	12.6 (12)	15.4 (18)	16.2 (16)	
55–64	32.6 (31)	29.9 (35)	20.2 (20)	
65–79	36.9 (35)	32.5 (38)	46.5 (46)	
80–90	4.2 (4)	6.8 (8)	5 (5)	
ASA score				
I	8.4 (8)	6.0 (7)	3 (3)	.093[2]
II	70.5 (67)	65.8 (77)	65.7 (65)	
III	18.9 (18)	27.3 (32)	28.3 (28)	
IV	1.1 (1)	.9 (1)	3 (3)	
Missing	1.1 (1)			
BMI kg/m^2				
Median (IQR)	26 (23.1, 29)	27 (23.9, 31)	27 (25, 31)	.043[2]
≤30	79.5 (70)	64.6 (73)	68.8 (66)	
>30	20.5 (18)	35.4 (40)	31.3 (30)	.065[1]
Missing	7.4 (7)	3.4 (4)	3.0 (3)	
MBP % (*n*)				
Yes	Not collected	21.4 (25)	38.4 (38)	.006[1]
No	Not collected	78.6 (92)	61.6 (61)	
Data not collected	(*n* = 95)	(*n* = 0)	(*n* = 0)	
Oral SAP taken day before surgery				
Yes taken	(*n* = 0)	23.9 (28)	35.4 (35)	.066[1]
Not prescribed	100.0 (95)	76.1 (89)	64.6 (64)	

Abbreviations: MBP, Mechanical bowel preparation day before surgery; SAP, Surgical Antibiotic Prophylaxis - oral antibiotics taken day before surgery.

†Missing cases or data not collected excluded from tests.

[1]Pearsons Chi–Square.

[2]Kruskal-Wallis Test.

which reduced to 3% (*n* = 3) missing recordings in T2, ($p < .001$). There was also an improvement in post-induction body temperatures where at T0, only 26.2% were over 36.0°C (mean = 35.5 [SD = .649]) increasing to 62.5% in T2 (mean [SD]: 36.1 [.634], $p < .001$). Furthermore, pairwise comparisons showed a statistically significant difference between two time periods with an increase in degrees Celsius from T0 to T1 (mean difference = .392, 95% CI = .156, .629, $p < .001$) and between T0 and T2 (mean difference = .536, 95% CI = .293, .780, $p < .001$). For the recorded body temperature in the postoperative period on arrival in the recovery room, there was a statistically significant change across the three groups for the recording of the data however there was no significant change identified in body temperature. This study found no statistically significant association between lower body temperature and SSI. Temperature measurements were recorded by different devices at different body locations and therefore were not comparable across the three perioperative time points, but were comparable across the time periods T0, T1 and T2 (see Table 2).

Data relating to the removal of hair practices around the site of surgery preoperatively was not collected in T0 due to the fact that in the chart review, where hair removal was noted, the method of hair removal was not documented. There was a statistically significant difference noted between T1 and T2, following the introduction of the intervention, in collection of data on hair removal practices

Journal of Clinical Nursing – WILEY

TABLE 2 Intraoperative and postoperative variables.

Variable	Time 0 (*n* = 95)	Time 1 (*n* = 117)	Time 2 (*n* = 99)	*p*-value[†]
Site of surgery % (*n*)				
Colon	54.7 (52)	65 (76)	62.6 (62)	.294[1]
Rectal	45.3 (43)	35 (41)	37.4 (37)	
Surgical approach				
Laparoscopic	75.8 (72)	77.8 (91)	69.7 (69)	.377[1]
Open	24.2 (23)	22.6 (26)	30.3 (30)	
Duration of surgery				
Median [IQR]	192 [93, 272]	174 [108, 246]	189 [98, 275]	.909[3]
Length of stay post-surgery				
Median [IQR]	10 [6, 14[a]]	7 [5, 10.5[b]]	8 [6, 14[ab]]	.014[3]
Wound Contamination Classification % (*n*)				
Clean–contaminated	Not collected	70.1 (82)	80.8 (80)	<.018[1]
Contaminated	Not collected	25.6 (30)	11.1 (11)	
Dirty	Not collected	4.3 (5)	8.1 (8)	
Temperature preoperatively % (*n*)				
≥36°C	87.4 (76)	88.7 (102)	84.7 (83)	.683[1]
<36°C	12.6 (11)	11.3 (13)	15.3 (15)	
Mean (SD)	36.46 (.46)	36.30 (.42)	36.35 (.40)	.077[2]
Range	(35.5, 38.4)	(35.2, 38.5)	(35.5, 37.5)	
Data not collected[†]	8.4 (8)	1.7 (2)	1 (1)	.013[4]
Hair removal method % (*n*)				
Disposable clippers	Not collected	33.9 (38)	39.4 (37)	.209[4]
Disposable razor	Not collected	5.1 (6)	1 (1)	
No hair removal required	77.9 (74)	60.7 (68)	59.6 (56)	
Hair removal undertaken (method unknown)	(*n* = 21)	(*n* = 0)	(*n* = 0)	<.001[4]
Temperature after induction of anaesthesia % (*n*)				
≥36°C	26.2 (16[a])	50.4 (57[b])	63.2 (60[b])	<.001[1]
<36°C	73.8 (45)	49.6 (56)	36.8 (35)	
Mean (SD)	35.54[a] (.65)	35.93[b] (.59)	36.08[b] (.63)	<.001[2]
Range	(33.8, 37.0)	(34.2, 37.3)	(34.1, 39.1)	
Data not collected[†]	35.8 (34)	3.4 (4)	3 (3)	<.000[1]
Postoperative temperature on arrival in recovery % (*n*)				
≥36°C	77.6 (66)	83.6 (92)	80.6 (79)	.571[1]
<36°C	22.4 (19)	16.4 (18)	19.4 (19)	
Mean (SD)	36.24 (.39)	36.26 (.45)	36.22 (.54)	.847[2]
Range	(35.0, 37.3)	(35.0, 37.5)	(33.3, 37.7)	
Data not collected[†]	10.5 (10)	6 (7)	0 (0)	.005[1]
Hair removal method % (*n*)				
Disposable clippers	Not collected	33.9 (38)	39.4 (37)	.209[4]
Disposable razor	Not collected	5.1 (6)	1 (1)	
No hair removal required	77.9 (74)	60.7 (68)	59.6 (56)	
Hair removal undertaken (method unknown)	(*n* = 21)	(*n* = 0)	(*n* = 0)	<.001[4]
Missing[†]	(*n* = 0)	(*n* = 5)	(*n* = 5)	
Blood glucose within 4 h postoperatively recorded				

(Continues)

TABLE 2 (Continued)

Variable	Time 0 (*n* = 95)	Time 1 (*n* = 117)	Time 2 (*n* = 99)	*p*-value[†]
Yes	25.3 (24[a])	89.7 (105[b])	88.9 (88[b])	**<.001**[1]
No	74.7 (71)	10.3 (12)	11.1 (11)	
Timing of SAP (minutes) % (*n*)				
0 to 60 min before incision	92.6 (88)	92.0 (105)	90.7 (88)	.903[4]
61 to 79 min before incision	2.1 (2)	1 (1)	1 (1)	
−1 to 35 min after incision	5.3 (5)	7.0 (8)	8.2 (8)	
Missing data[†]	(*n* = 0)	(*n* = 3)	(*n* = 2)	
2ND dose SAP where operative time ≥4 h % (*n*)				
Yes	8.8 (3[a])	50 (17[b])	88.6 (31[c])	<.001[1]
No	91.2 (31)	50 (17)	11.4 (4)	

Note: Each subscript letter (abc) denotes a subset of time period of study categories whose column proportions or mean values or mean rank values do not differ significantly from each other at the .05 level. Each subscript with the same letter denote that they do not differ significantly from each other. Significant values have been adjusted by the Bonferroni correction for multiple tests.

Abbreviation: SAP, Surgical Antibiotic Prophylaxis.

[†]Missing cases and data not collected excluded from tests.

[1]Pearson Chi-Square.

[2]Anova.

[3]Kruskal-Wallis Test.

[4]Fisher–Freeman–Halton exact test of independence.

TABLE 3 Surgical site infection outcome variables.

	Time 0 (*n* = 95)	Time 1 (*n* = 117)	Time 2 (*n* = 99)	*p*-value
Infection				
SSI rate % (*n*)	25.3 (24[a])	15.4 (18[a])	10.1 (10[b])	.016[1]
[95% CI]	[16.9, 35.2]	[9.4, 23.2]	[5.0, 17.8]	
Odds Ratio	Ref.	.538	.332	
[95% CI]	–	[.27, 1.06]	[.150, .740]	
Classification of SSI				
Superficial incisional % (*n*)	48.5 (11)	22.2 (4)	50.0 (5)	.358[2]
Deep incisional % (*n*)	20.8 (5)	38.9 (7)	10.0 (1)	
Organ/Space % (*n*)	33.3 (8)	38.9 (7)	40.0 (4)	
Readmission of cases with an SSI within 30 days				
Yes % (*n*)	20.8 (5)	38.9 (7)	10.0 (1)	.253[2]
No % (*n*)	79.2 (19)	61.1 (11)	90.0 (9)	

Note: Each subscript letter (ab) denotes a subset of time period of study categories whose column proportions do not differ significantly from each other at the .05 level. these post hoc tests only occur when tests had a significant association with time. Each subscript with the same letter denote that they do not differ significantly from each other. Significant values have been adjusted by the Bonferroni correction for multiple tests.

[1]Pearson Chi-Square.

[2]Fisher–Freeman–Halton exact test of independence.

and with an increase in the practice of recording of methods used ($p \leq .001$).

Data were not collected at T0 for wound contamination classification; however, recording was initiated, and data was collected for all patients at T1 and T2. A change in percentage for recording of wound contamination classification between Time 1 and Time 2 ($p < .018$) was observed.

Monitoring of blood glucose levels within 4 h in the postoperative period was present in 25.3% ($n = 24$) in T0 which increased to 90% in both T1 89.7% ($n = 105$) and T2 88.9% ($n = 88$) ($p \leq .001$). Pairwise comparisons show improvement in glucose monitoring between T0 and T1 with no difference noted between T1 and T2. Duration of surgery in minutes was noted to be similar across all three time points.

Over 90% of patients at pre-intervention and post-intervention received the correct timing of administration of prophylactic antibiotic within 60 min prior to incision. However, the frequency of administration of a second antibiotic dose, which is recommended if operative time is greater than 4 h, improved over the three time periods increasing from 8.3%($n = 3/34$) in T0 to 88.6%($n = 31/35$) in T2 ($p \leq .001$). Pairwise comparisons in receiving a second dose antibiotics where indicated show statistically significant differences across all three time points.

3.4 | Risk factors for the development of SSI

Data pertaining to patients who develop SSI over the three time points were combined, i.e. 52/311. Where variables were not collected at T0, the logistical regression results are based on T1 and T2 data only, where the number of patients with SSI was 28/216. Univariate logistic regression analysis was used to determine the relationship between SSI and other independent variables relating to patient and perioperative factors (Table 4). The univariate analysis identified three factors that were significantly associated with developing an SSI: BMI, duration of surgery greater than the 75th percentile; wound contamination classification of contaminated or dirty. A cumulative NHSN risk index was also found to be significant (Table 4). Surgical approach was not found to be statistically significant with an incidence rate of SSI in laparoscopic procedures of 11.4% ($n = 9$) and in open procedures a rate of 18.5% ($n = 43$; $p = .146$).

Further analysis was undertaken using multivariate logistical regression. The model included significant variables identified in Table 4 (BMI and duration of surgery in minutes) which were recorded at the three time periods, plus the time-period factor, i.e. being a patient in either T0, T1 or T2. After adjusting for two significant risk factors of BMI and duration of surgery that were recorded at the three time periods, there was a significant reduction in the probability of an SSI between T0 and T2; the odds of an SSI at T2 were .297 times the odds of an SSI at T0 ($p = .005$). The results of the logistical regression model (Table 5) showed that an increase in the duration of surgery ($p = .003$) and BMI ($p = .016$) increased the probability of an SSI and found that the time period factor also had an effect on the reduction of SSI rates in the same model ($p = .019$).

4 | DISCUSSION

In this study, it was identified that, following the introduction of a complex intervention including initiation of surgical site surveillance, there was an observed reduction in SSI rates in patients undergoing colorectal surgery. The baseline SSI rate (prior to the introduction of the intervention) of 25.3% was comparable to a US study (26%) (Paulson et al., 2017) and a Spanish study (24%) (Pedroso-Fernandez et al., 2016) of patients who had undergone colorectal surgery. The reduction in SSI rates following the implementation of the complex intervention to 10.1% in T2 was similar to other studies that introduced care bundles and included surveillance as part of their intervention (Bert et al., 2017; Tanner et al., 2015). This adds to the growing knowledge that identifies that multiple components of an intervention is the most effective approach in reducing infection rates (Lin et al., 2020; Maturo et al., 2017; Staubitz, 2019). There was an increase in the diagnosis of deep incisional infections in T1 (38.9% at T1 vs. 20.8% at T0) which may be due to the improvement in knowledge by clinical staff on the correct classification of SSIs.

From the univariate analysis, independent risk factors identified for SSI were higher BMI, extended duration of surgery, wound contamination classification of contaminated or dirty and NHSN risk score of 3, all of which have also been identified in previous studies (Gurunathan et al., 2017; Ho et al., 2011; Lei et al., 2020; Panos et al., 2021).

ISSIP was a locally designed complex intervention with multiple components including convening of a multidisciplinary implementation group, initiation of SSI surveillance (SSIS), development of a care bundle, production and use of a patient information booklet, patient and staff education and the appointment of a facilitator; all of which were critical in reducing SSI rates and improving practice. The constructs of the NPT allowed for an understanding of and guidance in implementing a complex intervention in a complex environment (Murray et al., 2010). Commencing ISSIP required cognitive participation where all members of the multidisciplinary team were aware of their key role in SSI prevention, in the ISSIP complex intervention and in their role in sustaining the intervention. The collective action of the multidisciplinary team in reviewing evidence-based recommendations, decision making on the elements of the care bundle brought further coherence allowing for interactional planning and collective ownership. SSI surveillance incorporates by definition the need for feedback and makes information available on SSI incidences to all those who are involved in the patient's care which is the construct of reflexive monitoring. This allows the multidisciplinary team to appraise as a group or individually on whether the evidence-based interventions were effective and adjust accordingly. ISSIP also utilised key personnel to implement the quality improvement intervention; these included a surveillance scientist and a surgeon champion who were central in facilitating the implementation of the complex intervention. Roles such as these, are recommended in an expert guidance document from the Society for Healthcare Epidemiology in America (SHEA) (Anderson et al., 2014) and have been identified as being effective in the provision of leadership, team motivation and strengthening collaboration (Sartelli et al., 2018).

The process of surveillance was introduced to perioperative staff and supported in all surgical areas by a facilitator. International recommendations advocate for the role of a facilitator who have the key skills required to provide expertise, education, support, analysis, and feedback to the wider multidisciplinary team as well as patient involvement in feedback on the development of an SSI post-discharge (Anderson et al., 2014; Gillespie et al., 2015; Lin et al., 2020; Miech et al., 2018). The role of facilitator is also recommended for ongoing education for

TABLE 4 Univariate analysis of the presence/absence of surgical site infection (SSI) by patient characteristics over all time periods.

Patient characteristic	Surgical site infection %(*n*)	Odds ratio	95% confidence interval	*p*-value
Age[a] (years) (*n* = 311)		.991	[.971, 1.011]	.366
BMI[a] kg/m^2 (*n* = 297)		1.071	[1.012, 1.133]	.018
Gender (*n* = 311)				
Male (*n* = 189)	19.0 (36)	1.56	[.82, 2.95]	.171
Female (*n* = 122)	13.1 (16)	Ref		
Site of surgery (*n* = 311)				
Rectum (*n* = 121)	14.7 (28)	1.43	[.80, 2.61]	.242
Colon (*n* = 190)	19.8 (24)	Ref		
Surgical approach (*n* = 311)				
Open (*n* = 79)	11.4 (9)	.565	[.26, 1.22]	.146
Laparoscopic (*n* = 232)	18.5 (43)	Ref		
MBP preadmission (*n* = 216**)**				
Yes (*n* = 63)	12.7 (8)	.97	[.84, 2.33]	.941
No (*n* = 153)	13.1 (20)	Ref		
Preadmission oral antibiotics (*n* = 216)				
Yes (*n* = 63)	15.9 (10)	1.42	[.614, 3.26]	.416
No (*n* = 153)	11.8 (18)	Ref		
ASA classification (*n* = 310)				
ASA III, IV, V (*n* = 83)	16.9 (14)	1.01	[.52, 1.98]	.979
ASA I, II (*n* = 227)	16.7 (38)	Ref		
Preoperative temperature[a] (*n* = 300)	1.20	[.45, 3.13]	.717	
Temperature after induction[a] (*n* = 270)	1.23	[.65, 2.34]	.524	
Temperature in recovery[a] (*n* = 294)	1.97	[.84, 4.60]	.118	
Wound Contamination Classification (*n* = 216)				
Contaminated/Dirty (*n* = 54)	22.2 (12)	2.61	[1.14, 5.94]	**.023**
Clean/Clean-Contaminated (*n* = 162)	9.9 (16)	Ref		
Duration of Surgery (*n* = 311)				
Risk >75th percentile (*n* = 136)	24.3 (33)	2.63	[1.42, 4.88]	.002
No Risk ≤75th percentile (*n* = 175)	10.9 (19)	Ref		
NHSN[b] risk index score (*n* = 216)				
3 (*n* = 11)	45.5 (5)	8.33	[1.95, 36.65]	.004
2 (*n* = 37)	13.5 (5)	1.56	[.44, 5.52]	.488
1 (*n* = 102)	11.8 (12)	1.33	[.48, 3.75]	.585
0 (*n* = 66)	9.1 (6)			

Abbreviations: ASA, American Association of Anaesthesiologists; MBP, Mechanical Bowel Preparation.

[a]The assumption of linearity between the Log-odds and a continuous independent predictor was met. The Box-Tidwell test was used to check this assumption.

[b]NHSN- National Healthcare Safety Network risk index comprises of 3 risks: American Association of Anaesthesiologists (3, 4 or 5), wound contamination classification (contaminated or dirty) and duration of procedure risk of greater than the 75th percentile.

TABLE 5 Multivariate logistic regression for SSI over the 3 time periods ($n = 297$).

Variables	Odds ratio	95% CI	*p* value
Body mass index	1.077	1.014, 1.143	.016
Duration of surgery			
Risk - duration>75th percentile	2.715	1.408, 5.236	.003
No risk - duration<75th percentile	Ref.		
Time periods			.019
Time period T1	.551	.263, 1.151	.113
Time period T2	.297	.127, .696	.005
Time period T0	Ref.		

Note: After adjusting for two significant risk factors identified in Table 4, that were recorded at the three time periods, there was significant reduction in the probability of an SSI between T0 and T2; the odds of an SSI at T2 was .297 times the odds of an SSI at T0 ($p = .005$). Nagelkerke R Square = .130; Hosmer and Lemeshow goodness of fit test: $p = .403$.

healthcare workers to support continuous quality improvement (Lin et al., 2020; Staubitz, 2019). Adapting an internationally recognised guidance, as in this study, ensured the collection of standardised surveillance data which is imperative for benchmarking and to relate to other similar model hospitals (European Centre for Disease Prevention and Control, 2017). Audit and feedback to multidisciplinary team members facilitated collective identification of areas for improvement and in planning for intervention measures as well as changing practice. Audit and feedback as part of a multicomponent intervention are seen as effective in improving practice (Ivers et al., 2012). The NPT construct of reflexive monitoring occurred through audit where areas that required further attention were identified and brought to the attention of the implementation group to action.

Care bundles improve adherence to evidence-based guidelines and have been found in this and other studies to reduce SSI rates (Keenan et al., 2014; Lin et al., 2020; Tanner et al., 2015). It is recognised that a bundled approach to care allows for all disciplines to collaborate and form cohesiveness in all aspects of the patient's care (Keenan et al., 2014). This was similar to the findings in a study by Resar et al. on ventilator-associated pneumonia which led to the development of a care bundle and to help ensure that all patients are in receipt of the same standard of care which results in decreasing infection rates (Resar et al., 2005). As a consequence of the elements of the intervention in this study, there was an improvement in the monitoring of temperature and blood glucose levels and in the timely delivery of surgical antibiotic prophylaxis; each of which is recommended as best practice in the prevention of SSIs (Crosland, 2016; Kiran et al., 2013; World Health Organization, 2018).

The concept of developing the patient information booklet, a key element in this study, commenced with the aim of educating the patient on surgical site infection and surveillance; however, was further developed to provide information on all aspects of the patient's perioperative journey. Booklets have been found to be very beneficial to patients by improving their understanding of their healthcare needs, their knowledge of the surgery, their compliance with preparation for surgery and in providing guidance in the postoperative period (Ergen et al., 2016; Eschalier et al., 2017; McGregor et al., 2007).

4.1 | Limitations

This study included a relatively small sample in a single tertiary referral centre where there were no national surveillance guidelines in comparison to international studies with large datasets where surveillance is already established; this may impact on the external validity of the study. More certainty and understanding of the relationships between risk factors and patient outcomes could be obtained from data using a larger study across a number of hospitals. Baseline SSI rates were based only on chart review and laboratory findings with no patient involvement and it may be possible that the incidence rate could be higher than reported. Another limitation was the case mix of the cohort was not directly measured which may have impacted the results reported in the study.

The presence/absence of an SSI in this study was measured differently at T0 compared to T1 and T2 where the intervention included a patient-completed post-discharge questionnaire and the intervention led to increased awareness of SSI diagnosis classifications and SSI generally. Therefore, SSI rates at T0 are potentially underestimated. Authors acknowledge that there may have been a downward trend in SSI rates over the 2 years (T1 and T2) without the intervention or an extra step down could be due to the intervention interruption, but this cannot be viewed due to the non-collection of data for July to December 2018. In T0, there was no post-discharge surveillance undertaken; therefore, the potential for higher SSI rates is a possibility within that time period. Similarly, there were 10 patients in total over T1 and T2 where 30-day surveillance could not be undertaken as the patients did not return questionnaires and were uncontactable by phone. Due to the size of the sample, all patients who were undergoing elective colorectal surgery were invited to participate which led to a non-randomised inclusion. Key limitations to logistical regression on the effects of the intervention are the absence of data over a six-month period between T0 and T1 and due to reduced surgical activity in some months of T2 due to holiday periods. Future research should include a larger cohort of patients over a continuous time period to allow for variations. The holiday trends of surgeons and closure of theatres in the hospital setting should be considered in the design of studies with SSI prevention interventions.

5 | CONCLUSION

Our study has demonstrated an overall improvement in SSI incidence rates over time following the introduction of the complex quality improvement intervention and adjusts for duration of surgery and BMI in the model. Wound contamination classification could not be included since this was unknown at T0. There was a significant reduction in the probability of an SSI between T0 and T2. However, the authors also acknowledge that this was a real-world intervention in one centre with a relatively small sample size.

The complexity of addressing SSI rates requires a multicomponent intervention which includes: a surveillance system in conjunction with organisational supports, champions, leadership, facilitator resource and collaboration from the multidisciplinary team. These elements were identified as being critical for the successful reduction of the incidence of SSI in patients following colorectal surgery. This study demonstrates that a multidisciplinary team focus on all aspects of the surgical patient's journey, using an evidenced-based approach and a willingness to deal with issues raised can have a significant and positive impact on patient outcomes. This study may provide guidance to other institutions looking to improve the outcomes of elective colorectal surgery patients. Surveillance, through a national network, would also allow for benchmarking against other countries, hospitals and departments.

5.1 | RELEVANCE TO CLINICAL PRACTICE

A multicomponent multidisciplinary complex intervention can successfully reduce SSI incidence rates in patients who require elective colorectal surgery. Critical to the success of a multicomponent intervention for the prevention of SSIs is the role of a facilitator in providing education and support, undertaking audit, giving feedback to the multidisciplinary teams and driving change. The expert skills of a facilitator are necessary in sustaining the impact of the interventions and in embedding surveillance into practice to safeguard patients undergoing elective colorectal surgery. Implementing interventions in complex environments for the prevention of surgical site infection can be difficult, however, the use of the Normalisation Process Theory provides guidance and support in implementing such a complex intervention. The key constructs of Normalisation Process Theory facilitate a greater understanding of the individual and collective roles which support collaboration and engagement by multidisciplinary staff in delivering the common objective of reducing incidences of SSI.

AUTHOR CONTRIBUTIONS

SH conceived of the presented idea. SH developed the study. CH and SH developed the surveillance model and performed the computations. JH and JD verified the analytical methods and supervised the findings of this work. EA, CH and SH led the complex intervention in the clinical setting. All authors provided critical feedback and helped shape the research, analysis and manuscript.

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CONFLICT OF INTEREST STATEMENT

There are no conflicts of interest to disclose.

DATA AVAILABILITY STATEMENT

Data available on request from the authors.

ETHICS STATEMENT

Ethical approval was obtained from Clinical Research Ethics Committee of Cork Teaching Hospitals - ECM 4 (ww) 12/02/19.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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