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Locke, T., Parsons, H., Briffa, N. et al. (3 more authors) (2022) A bundle of infection control measures reduces post-operative sternal wound infection due to Staphylococcus aureus but not Gram-negative bacteria : a retrospective analysis of 6,903 patient episodes. Journal of Hospital Infection, 126. pp. 21-28. ISSN 0195-6701

https://doi.org/10.1016/j.jhin.2022.03.006

A bundle of infection control measures reduces post-operative sternal wound infection due to *Staphylococcus aureus* but not Gram-negative bacteria: a retrospective analysis of 6,903 patient episodes

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Declarations of interest: none. **Funding:** none.

SUMMARY

Background

Prevention of cardiac surgical site infection has largely focused on reducing infection due to *Staphylococcus aureus* although other bacteria also play an important role in this complication.

Aim

We assess the impact of an evolving infection control program on the incidence of sternal wound infection (SWI) and the changing incidence of non-staphylococcal infections.

Methods

We conducted a retrospective cohort study of all patients who underwent primary sternotomy at a single UK centre between September 2010 and May 2018. Data were collated from two-years prior to the stepwise introduction of a broad-ranging infection control program, including *S. aureus* decolonisation.

Findings

6,903 primary sternotomies were performed of which 2.6% (n=178) were complicated by SWI. Gram-negative bacteria (GNB) and *S. aureus* were most commonly identified as causative pathogens (45.5% and 30.3% respectively). Following program introduction there was a reduction in the rate of SWI from 3.9 to 1.8 cases/100 patients/month. This was mainly due to a sustained reduction in *S. aureus* infected cases with no discernible impact on GNB. Multivariable logistic regression analysis identified coronary artery bypass grafting, procedural urgency and procedures performed in the 3rd quarter as independent risk factors for post-operative infection.

Conclusion

A multifaceted infection control program was successful at reducing the rate of SWI primarily due to a reduction in *S. aureus* infections. GNB also play an important role in SWI and traditional preventative measures fail to address these. Future intervention and impact assessments should consider Gram negative infection when measuring effectiveness.

Keywords: Cardiac surgical procedures, surgical wound infection, Gram-negative bacterial infections, *Staphylococcus aureus*, infection control.

INTRODUCTION

Sternal wound infection (SWI) continues to be a serious complication of cardiac surgery and is associated with a complicated and prolonged postoperative recovery and high mortality. Reported rates of postoperative SWI vary by centre with recent reports ranging from 0.79% to 4.1% [1-3]. Prevention of surgical site infection (SSI) often involves a bundled approach including skin/hair preparation, topical antiseptic agents, perioperative prophylactic antibiotics, maintenance of perioperative homeostasis and postoperative wound care [4]. The majority of these interventions focus on the operative site specifically and try to reduce infection principally by targeting common skin commensals such as *Staphylococcus aureus.* However, gram-negative bacteria (GNB) also play an important role in SWI and are frequently associated with more complex infections requiring additional surgical management and prolonged courses of broad-spectrum antibiotics [5].

As there is an increasing focus on antimicrobial stewardship with rising global rates of antimicrobial resistance, there is an urgent need to develop preventative strategies to address non-staphylococcal causes of SSI to limit antimicrobial requirement and exposure in these vulnerable populations. The primary objective of this work was to assess the impact of an infection control program on the incidence of SWI and describe the changing microbiological profile associated with these interventions. Secondary objectives included characterising the infected and non-infected cohorts in more detail with the aim of identifying further modifiable risk factors.

METHODS

Setting and patients

This retrospective cohort study was performed at Sheffield Teaching Hospitals (STH), a tertiary cardiothoracic referral centre in the UK. All patients who had undergone primary median sternotomy between 1st September 2010 and 1st June 2018 were eligible for inclusion and were identified by review of registry data. Exclusion criteria included sternotomy not performed by the local cardiothoracic team and surgery performed outside of the operating theatres. Each case was only included once regardless of the number of further operative procedures required and the SWI had to occur as a complication of the primary procedure. Further data including microbiology results and clinical observations were extracted from electronic databases. The study was approved as a Service Evaluation without need for NHS Research Ethics Committee review by the Clinical Effectiveness Unit at STH, who provide oversight on research and data governance in our institution.

Case definitions

A modified version of the U.S. Centres for Disease Control and Prevention SSI criteria was used to define SWI with the time limit extended to 180 days in order to capture delayed infections [6]. All cases required documentation of a clinical diagnosis of SSI. Superficial SWI was confined to the skin or subcutaneous tissue of the incision site with an organism isolated from a superficial wound swab and/or blood culture. Deep SWI cases involved the deeper tissues with an organism isolated from a bone, tissue or pus sample and/or blood culture. If deep samples were culture negative then cases were still included if the surgeon reported compatible intraoperative findings.

Sample collection and microbiology procedures

Samples for microbiological analysis were obtained at the clinician’s discretion either within the hospital or the community following discharge. Sampling and subsequent microbiological analysis was performed in accordance with national standards [7-10]. Organism identification was based on morphological appearance, phenotypic tests and MALDI-TOF analysis (MALDI Biotyper, Bruker, Germany). The causative pathogen was the isolate(s) cultured from the earliest relevant clinical sample and any other isolates obtained in the following seven days (later isolates were felt to be more reflective of evolving flora associated with antibiotic exposure). Cases were labelled mixed if more than one pathogen was isolated.

Outcome measures and endpoints

The date of infection was recorded as the date of the first significant culture result or first clinical documentation of SWI if culture negative. Procedure-related outcome measures included death and hospital readmission (only to the operating hospital) within 12 months of the initial procedure. Infection outcome measures were determined by the last available clinical assessment within a six-month period from the date of infection and included cured (full resolution), improved (symptoms improved but unresolved infection), ongoing (no improvement), unknown and death. Patients who were lost to follow up were still included in the overall analysis.

Statistical analysis

Risk factors associated with SWI were identified using univariate testing (Pearson's chi-squared, Fisher's exact or Mann-Whitney U tests) prior to selection for inclusion in regression analysis. Following this, multivariable logistic regression (with 95% confidence intervals) was used to assess which features were associated with SWI. An initial model was formed using the patient and operative factors, with step-wise removal of non-significant ($p \geq 0.05$) variables. Analysis was subsequently repeated with the inclusion of infection control measure time periods. All analyses were performed using R version 4.0.3 and RStudio version 1.3 [11-12].

RESULTS

Patient and operation characteristics

During the 7 years and 8 months period reviewed, a total of 6,903 primary sternotomies were performed. Median patient age was 68 years (range 16 to 91 years) and most were male (4,953/6,903, 71.8%). The median length of stay was 10 days (interquartile range (IQR) 11) and most patients survived to discharge (6,723/6,903, 97.4%). Multiple different surgical procedures were performed, frequently in combination, including coronary artery bypass grafting (CABG) (4,111/6,903, 59.6%), procedures involving cardiac valves (3,308/6,903, 47.9%), or the aorta (419/6,903, 6.1%), and miscellaneous other procedures (853/6,903, 12.4%; Table I). The most common procedures were CABG only (3,175/6,903, 46.0%), valve procedures only (1,830/6,903, 26.5%) and combined CABG and valve procedures (651/6,903, 9.4%). Overall, 68.9% (4,759/6,903) were elective procedures with the remaining classified as urgent (required surgery before discharge after an acute hospital admission, 1,989/6,903, 28.8%), emergency (operation required before the beginning of the next working day, 145/6,903, 2.1%) or salvage (requiring cardiopulmonary resuscitation en route to the operating theatre or prior to induction of anaesthesia, 10/6,903, 0.1%).

Sternal wound infection

Sternal wound infection complicated 2.6% (178/6,903) of procedures performed. The majority (167/178, 93.8%) of infections were diagnosed within the first 90 postoperative days. For patients with SWI, the length of hospital admission and number of further surgical procedures during the first hospital episode was greater compared to those who remained uninfected (Table I). Of the SWI identified, 50% (89/178) were classified as deep (Table II). Superficial infections were diagnosed earlier and less frequently required further surgical procedures during the initial admission compared to deep infections.

SWI caused by a single attributable Gram-negative (GN) pathogen was the most common finding (61/178, 34.3%), followed by infection caused by *S. aureus* alone (46/178, 25.8%) or mixed infection (28/178, 15.7%; Table II). GN pathogens were isolated either alone or in combination in 45.5% (81/178) of cases with *S. aureus* isolated in 30.3% of cases (54/178). Specific GN organisms included *Klebsiella* spp. (n=28), *E. coli* (n=19), *Enterobacter* spp. (n=18), *Pseudomonas* spp. (n=18), *Proteus* spp. (n=14) and miscellaneous others (n=23). Where tested, antibiotic resistance was detected at the following rates: co-amoxiclav 42.9% (39/91), cefuroxime 20.0% (20/100), gentamicin 1.7% (2/118) and ciprofloxacin 0.8% (1/118). An AmpC

beta-lactamase was detected in 22.0% (26/118) of GN isolates. Just over a fifth of patients had concurrent bacteraemia (38/178, 21.3%) and it was more commonly identified in patients with deep SWI.

Patient outcomes

Half of the patients with a confirmed SWI were readmitted to our centre at least once, compared to 19.2% in the non-SWI group (Table I). Data on the specific cause for readmission was not available. Readmission was more common amongst those with deep SWI compared to superficial SWI (Table II). All-cause mortality was higher in those with SWI compared to uninfected patients, including death during the first hospitalisation episode and the following 12 months.

Infection outcome data was available for 97.8% (174/178) of cases of SWI and was assessed a median of 55.5 days from the date of infection (IQR 67.3). The majority were classified as either “cured” or “improved” (78.7%, 140/178). Outcomes were worse for the deep SWI group with fewer cases considered cured and higher rates of ongoing symptoms than those diagnosed with superficial SWI (Table II).

Factors predisposing to SWI

To assess the contribution of the infection control interventions, we first aimed to identify preoperative factors which might increase the risk of SWI. No significant differences were found in the age, sex or preoperative EuroSCORE of patients who did or did not develop post-operative SWI (Table I). Procedures classified as urgent and those involving CABG (either alone or in combination) were significantly associated with risk of subsequent SWI.

Multivariable logistic regression analysis demonstrated that procedures performed urgently (adjusted odds ratio (aOR) 1.59, 95%CI 1.16-2.16), those involving CABG (aOR 2.98, 95%CI 2.03-4.50), and those performed in the 3rd quarter of each calendar year (July to September, aOR 1.65, 95%CI 1.08-2.55) were independently associated with an increased pre-operative risk of SWI. Male sex was associated with a decreased risk (aOR 0.69, 95%CI 0.50-0.97).

Effect of infection control interventions to reduce SWI

A total of 1834 procedures were performed during the two-year and one month Pre-Intervention observation period (1/9/10 to 30/9/12). Following this, a series of interventions were introduced in a bid to reduce the incidence of SWI and have been grouped into three phases.

Phase One (1/10/12 to 1/1/13, n=192), included theatre etiquette guidance, theatre deep clean, change in perioperative antibiotic prophylaxis (co-amoxiclav to gentamicin with flucloxacillin or gentamicin with vancomycin if penicillin allergy or MRSA colonised), wound care education and defined minimum surgical training grades for sternotomy wound closure. Phase Two (2/1/13 to 7/3/16, n=2,836) included a preoperative *S. aureus* screening programme (nasal, axillary and groin swabs) with decolonisation of those found to be carriers for five days prior to the procedure (continued postoperatively if urgency required). In Phase Three (8/3/16 to 1/6/18, n=2,041) there was a switch to a universal *S. aureus* decolonisation program regardless of carriage status.

During the pre-intervention period 3.9% (71/1,834) of procedures were complicated by SWI (mean rate of 3.9 infections/100 patients/month). Following intervention, the overall rate of SWI fell to 2.1, 1.8 and 2.5 infections/100 patients/month, in Phases 1, 2, and 3, respectively (Figure 1). Introduction of control measures appeared to principally impact the rate of *S. aureus* infection rather than infections caused by GNB.

A further multivariable logistic regression was performed that also included the three phases of intervention. This demonstrated the impact of Phase 2 and, to a lesser extent, Phase 3 interventions on overall rates, principally through a significant reduction in the risk of post-operative *S. aureus* infection (**Table III**). Interestingly, while CABG remained a risk factor for infection with both *S. aureus* and GNB, procedures performed urgently, female sex and season remained risks for infection caused by GNB only.

DISCUSSION

SWI is a devastating consequence of cardiothoracic sternotomy and has high health and economic costs to both the individual and the broader healthcare system. Post-operative mortality is much higher in those with SWI and this risk appears to persist for many years [13-14]. Many also require further surgical procedures and suffer medical complications that can contribute to chronic organ failure [13-14]. Healthcare costs have been estimated to be nearly three times as high compared to those without SWI [15]. Cardiac surgery remains a relatively common procedure with over 32,000 cases performed in the UK in 2017 and over 200,000 in the USA in 2016 [16-17]. This review demonstrates a reduction in the incidence of SWI over a period of nearly six years of intervention with the greatest impact achieved through early simple measures targeting human factors and prior to a *S. aureus* decolonisation program. However none of these measures had any discernible impact on the incidence of GN SWI.

At our institution the baseline rate of SWI in the two years prior to any specific intervention was 3.9%, with deep infection accounting for half of these cases. The rate following CABG (either alone or with another procedure) was 5.0% and 2.0% following non-CABG cardiac surgery. For comparison, surveillance data from England shows a pooled national SWI rate of 3.0% following CABG and 1.3% following other cardiac surgical procedures (2014 to 2019) [5]. At an international level the rate of SWI varies more widely, with recent reports ranging from 0.79% to 4.1% [1, 3, 13, 18]. GNB and *S. aureus* were the most commonly isolated organisms in our dataset and similar microbiological profiles are reported elsewhere [3, 5, 13]. Outcomes were worse in the SWI group (particularly those with deep infection) with higher rates of mortality, readmission, further surgical procedures and persistence of symptoms.

We identified three independent risk factors for developing SWI following sternotomy: CABG, procedures classed as urgent and those performed during the third quarter of each year. Cardiac surgery involving CABG has frequently been reported as a risk factor for subsequent SWI [3, 18]. Specifically, procedures that involve bilateral internal thoracic artery harvesting appear to be riskier although we did not have access to this level of operative detail [2]. Urgent cases will have undergone the same preoperative preparation as elective cases including decolonisation if during the appropriate phase. However, by definition they were likely more acutely unwell compared to those undergoing elective procedures. They also spent longer in hospital prior to surgery (median 11 vs 2 days) and this additional preoperative healthcare

exposure may have increased the risk of nosocomial infection and the likelihood of preoperative antibiotic exposure with subsequent disruption of normal colonising flora. This theory is supported by the higher rates of GN SWI seen in urgent cases (53.8% vs. 39.2%) with comparable rates of *S. aureus* infection (26.9% vs. 33.0%) when compared to elective cases. Finally, seasonality of infection risk is well described for both surgical site and bloodstream infection with a trend towards higher rates during warmer months [19, 20, 21]. Proposed mechanisms include the influence of ambient temperature on environmental bacterial levels which may in turn affect human bacterial colonisation [19, 22, 23]. Concern has been raised about the influence of junior, less experienced medical staff who tend to rotate to new posts in the summer months although there is little data to support this association [19]. Human factors may also contribute, for example increased frequency of door opening during cardiac surgery was found to be associated with subsequent SSI although it is not clear whether room temperature influenced this behaviour [24]. In our cohort the observed seasonal risk appears to be specifically associated with GN SWI and female sex. We cannot explain this finding but this association has been previously reported [25].

We introduced a phased bundle of infection control measures that led to a significant and sustained reduction in the overall rate of SWI. Time series analysis suggests that the earlier phases of intervention had the greatest impact. These interventions were primarily focussed on addressing human factors such as theatre etiquette and postoperative wound care. However, a change in antibiotic prophylaxis, standards regarding sternal wound closure and the early stages of the *S. aureus* decolonisation program also occurred at this time point. The specific technique chosen for sternal wound closure can influence surgical site healing and therefore likely plays a role in SWI risk [26]. However, the quality of comparative studies in this field is considered to be low and infection isn't always included as an outcome measure [26]. In the absence of any formal guidelines the final choice should be based upon the surgeon's skillset, equipment availability and the patient's risk factors [26]. Current evidence suggests that preoperative *S. aureus* decolonisation may reduce SSI although there are few randomised controlled trials evaluating this intervention [27-30]. Poor patient compliance with topical therapies, particularly in the community setting, may reduce the efficacy and a preoperative 'screen and treat' approach also has added administrative challenges [29]. This was one of the main drivers of our shift to a 'universal' decolonisation program, particularly as many of our patients are referred from out of region. In addition, this approach may actually be cheaper than 'screen and treat' for the same level of benefit [31]. In contrast, the potential role of interventions aimed at addressing human factors has received much less attention [24, 32].

This study has several limitations. Firstly, due to the phased nature of the interventions and retrospective analysis, it is not possible to determine whether the greatest impact came from a single intervention or was a cumulative effect. We are also mindful of the influence of the Hawthorne effect, specifically that staff awareness of a new infection prevention program and an increased level of attention on infection rates may have introduced bias that favoured the earlier phases of intervention. Reassuringly we didn't observe a later rebound in the rate of infection suggesting that adherence to the interventions and infection control awareness in general was maintained.

Secondly, the methodology may have underestimated the true incidence of SWI as cases would have been missed if sampling didn't take place and/or microbiological analysis or management occurred at a different hospital. However, given the typical practice in the region we suspect most cases of SWI would have been referred back to our centre for assessment at an early stage.

Thirdly, we were not able to quantify the coverage of the nasal decolonisation program as we did not have access to dispensary data and there is no system to monitor patient compliance. We hope that a shift to universal decolonisation in phase 3 would have helped here by simplifying the process for all parties. Furthermore, the sustained decline in *S. aureus* cases alone may point towards good compliance with this intervention.

Finally, we had limited access to detail on the specific surgical techniques and methods of sternal wound closure employed, both of which can influence the risk of SWI. The longitudinal nature of the study over a number of years will have meant it captured an evolving roster of surgeons and shifts in standard surgical practice. Given the diverse range of cardiac surgical procedures performed via median sternotomy it would also be an oversimplification to consider this group to have an equal pre-operative infection risk. However, we hope that our strict definition of infection and rigorous search strategy will have provided an accurate assessment of the post-operative infection risk in this tertiary cardiac surgery unit.

The reduction in the overall rate of SWI during the time period studied was largely due to a decline in *S. aureus* infections specifically. There was no discernible impact on the rate of SWI

due to GNB during the whole observation period. This is perhaps to be expected given that *S. aureus* SWI is likely related to pre-existing skin colonisation whereas GN infection typically occurs as a consequence of perioperative infection at a distal site [33]. Our interventions, as per most general SSI prevention guidelines, were predominantly focussed on the pre-/intra-operative phase and the surgical site itself and therefore had little impact on GN infection. This is of particular importance as GNB are more commonly isolated in SWI compared to other types of SSI [5]. Furthermore, GN SWI seems to follow a more severe and complex course with higher mortality rates, longer periods of postoperative hospitalisation and the need for long courses of broad-spectrum antibiotics [25, 34]. Yet in spite of this there has been very little evaluation of this specific group in the literature [25, 34]. Future preventative measures must redress this imbalance by broadening their focus to incorporate all stages of the patient's journey, including the early postoperative period. This is in part recognised by the Enhanced Recovery After Surgery (ERAS) initiative and recent publication of cardiac surgery specific guidelines is encouraging [35]. However, many of our interventions and established local practice already align with these recommendations and therefore our experience would suggest that additional interventions are also required to reduce the risk of GN SWI specifically. This would align with other international drives to reduce GN blood stream infections and may include timely removal of indwelling prosthetic devices (e.g. urinary catheters and intravascular access) and measures to reduce the risk of hospital acquired pneumonia.

CONCLUSIONS

Our study demonstrates the serious consequences of SWI for the individual and points to the additional demand this complication places on healthcare systems. A phased bundle of interventions resulted in a significant decrease in the rate of *S. aureus* SWI, however there was no discernible impact on SWI caused by GNB. GN SWI tend to be more complex and often require long courses of broad-spectrum antibiotics. We identified significant risk factors for the development of GN post-operative SWI including operations performed in late summer and female sex. Assessment of specific interventions to address the risk of GN infection is required to have any further success in improving infection outcomes following cardiac surgery.

Acknowledgments: We thank Mike Bradburn (Clinical Trials Research Unit, University of Sheffield) for comments on the manuscript and Trevor Winstanley (Department of Medical Microbiology, Sheffield Teaching Hospitals NHS Foundation Trust) for assistance with the initial database searches.

Conflict of interest: none.

Funding statement: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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TABLES

	Sternal wound infection	Non sternal wound infection	p-value
Total, % (n)	2.6 (178)	97.4 (6725)	-
Age, years, median (IQR)	69.0 (60-76)	68.0 (60-75)	0.74
Male, % (n)	69.1 (123)	71.8 (4830)	0.48
EuroSCORE, median (IQR)	4.6 (2.5-8.9)	4.2 (2.1-8.1)	0.09
Operation type, % (n)			
Isolated CABG	64.0 (114)	45.5 (3062)	<0.001
Isolated valve procedure	11.8 (21)	26.9 (1809)	<0.001
Isolated other procedure	0.6 (1)	3.2 (212)	0.05
Isolated aortic procedure	1.1 (2)	1.4 (97)	1.0
CABG and valve	10.1 (18)	9.4 (633)	0.85
Other combinations	12.4 (22)	13.6 (912)	0.73
Operative urgency, % (n)			
Elective	54.5 (97)	69.3 (4662)	<0.001
Urgent	43.8 (78)	28.4 (1911)	<0.001
Emergency	1.7 (3)	2.1 (142)	1.0
Salvage	0 (0)	0.1 (10)	1.0
Return to theatre during primary admission, % (n)	28.1 (50)	4.5 (300)	<0.001
Length of stay, median (IQR)	22.0 (30.8)	10.0 (10)	<0.001
Alive at discharge, % (n)	93.3 (166)	97.5 (6557)	0.001
Readmission within 12 months of the primary sternotomy, % (n)	50.0 (89)	19.2 (1293)	<0.001
Death within 12 months of the primary sternotomy, % (n)	11.8 (21)	5.0 (337)	<0.001
One year survival rate, %	88.2	95.0	<0.001

Table I – Baseline, operative and post-operative characteristics for all patients, subdivided into SWI and no SWI.
IQR, interquartile range; EuroSCORE, European system for cardiac operative risk evaluation; CABG, coronary artery bypass grafting; SWI, sternal wound infection.

	Superficial SWI	Deep SWI	P-value
Total, % (n)	50.0 (89)	50.0 (89)	-
Time to diagnosis, days, median (IQR)	15 (24)	24 (30)	0.001
Infections occurring at 90-180 days post-operatively, % (n)	1.1 (1)	11.2 (10)	0.13
Microbiology, % (n)			
***S. aureus* alone**	31.5 (28)	19.1 (17)	0.12
MRSA	0 (0)	1.1 (1)	-
GNB alone	42.7 (38)	25.8 (23)	0.03
Mixed	16.9 (15)	14.6 (13)	0.84
Other	9.0 (8)	13.5 (12)	0.48
Culture negative	0 (0)	27.0 (24)	<0.001
Total including *S. aureus*	38.2 (34)	22.5 (20)	0.03
Total including GNB	56.2 (50)	34.8 (31)	0.007
Bacteraemia, % (n)	12.4 (11)	30.3 (27)	0.007
Infection related outcomes (within 6 months of diagnosis), % (n)			
Cured	57.3 (51)	34.8 (31)	0.004
Improved	29.2 (26)	36.0 (32)	0.42
Ongoing	5.6 (5)	18.0 (16)	0.02
Died	4.5 (4)	10.1 (9)	0.25
Unknown	3.4 (3)	1.1 (1)	0.62
Return to theatre during primary admission, % (n)	9.0 (8)	47.2 (42)	< 0.001
Alive at discharge, % (n)	94.4 (84)	92.1 (82)	0.77
Death within 12 months of the primary sternotomy, % (n)	11.2 (10)	12.4 (11)	1.0
Readmission within 12 months of the primary sternotomy, % (n)	41.6 (37)	58.4 (52)	0.04

Table II – Infection related characteristics and outcomes for all cases of SWI, subdivided into superficial and deep SWI.

IQR, interquartile range; MRSA, methicillin resistant *Staphylococcus aureus*; GNB, Gram-negative bacteria.

	All SWI aOR (95% CI)	**p - value**	***S. aureus*** aOR (95% CI)	**p - value**	**GNB** aOR (95% CI)	**p - value**
Male sex	**0.69 (0.50-0.97)**	0.03	0.95 (0.54-1.76)	0.86	**0.48 (0.32-0.73)**	<0.001
CABG	**2.9 (2.0-4.5)**	<0.001	**2.17 (1.19-4.20)**	0.02	**3.04 (1.82-5.35)**	<0.001
Operative urgency						
Elective	1		1		1	
Urgent	**1.7 (1.3-2.3)**	0.001	1.38 (0.79-2.35)	0.25	**2.31 (1.53-3.50)**	<0.001
Emergency	1.3 (0.3-3.5)	0.67	1.12 (0.06-5.35)	0.91	0.83 (0.05-3.88)	0.85
Salvage	NA	0.98	NA	0.98	NA	0.98
Seasonality						
Jan-Mar	1		1		1	
Apr-Jun	1.3 (0.82-2.0)	0.28	0.95 (0.45-1.99)	0.89	1.54 (0.84-2.91)	0.17
Jul-Sep	**1.6 (1.0-2.4)**	0.04	1.43 (0.74-2.83)	0.29	**2.02 (1.13-3.74)**	0.02
Oct-Dec	1.1 (0.7-1.9)	0.59	0.69 (0.30-1.53)	0.37	1.40 (0.74-2.69)	0.30
Intervention						
Pre-intervention	1		1		1	
Phase 1	0.48 (0.14-1.2)	0.18	0.31 (0.02-1.68)	0.27	0.54 (0.08-1.94)	0.41
Phase 2	**0.44 (0.30-0.63)**	<0.001	**0.11 (0.05-0.24)**	<0.001	0.70 (0.43-1.16)	0.17
Phase 3	**0.65 (0.44-0.93)**	0.02	**0.35 (0.18-0.62)**	0.001	0.94 (0.57-1.58)	0.83

Table III – Multivariable logistic regression analysis of predictors for post-operative sternal wound infection for all cases of SWI and subdivided into those with infection due to *S. aureus* and GNB. Figures in bold font are those with a significant impact on infection.
Hosmer-Lemeshow Test: p = 0.341; c-statistic: p = 0.688
aOR, adjusted odds ratio; CI, confidence interval; CABG, coronary artery bypass grafting

FIGURES

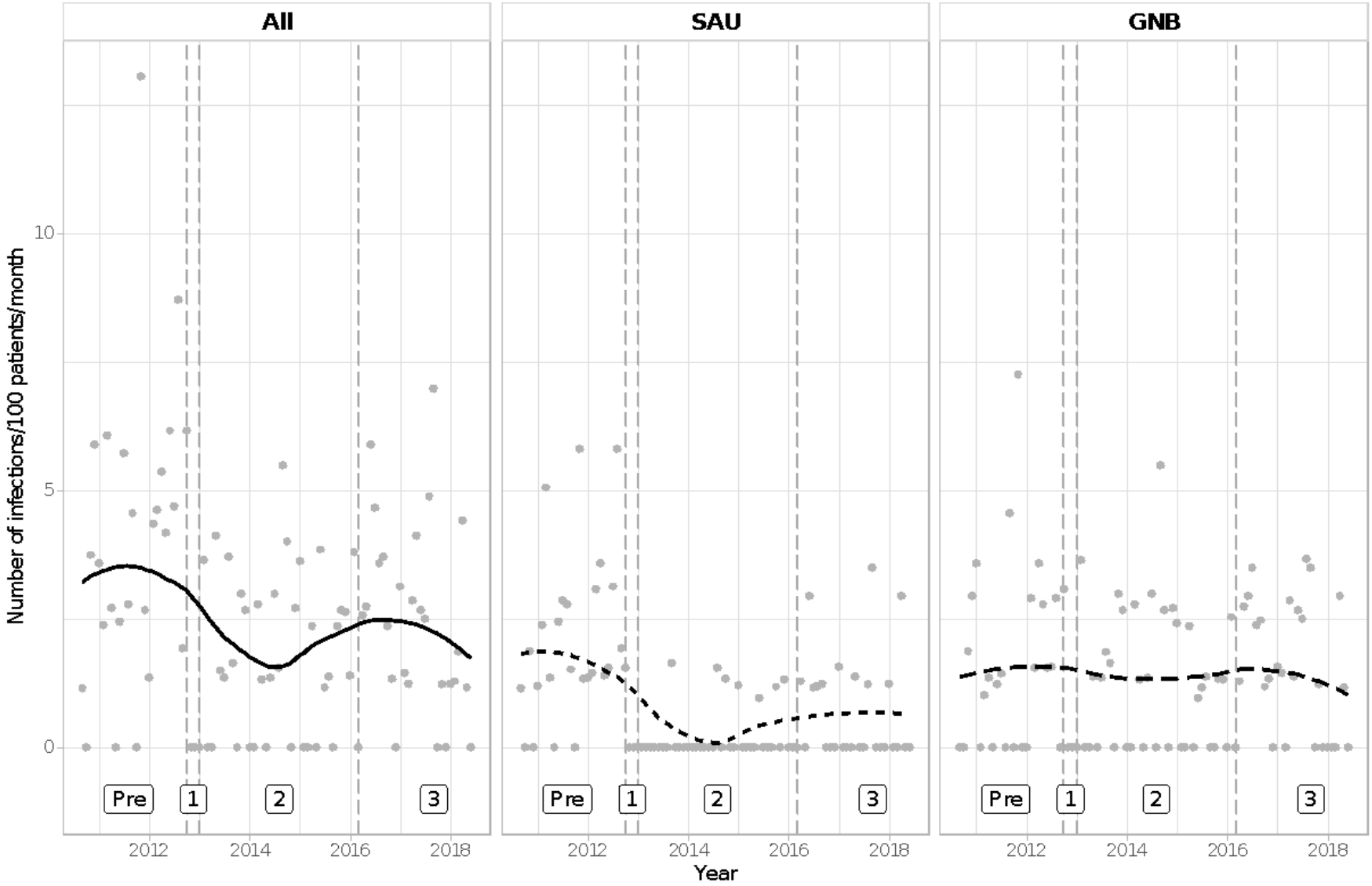

Figure 1 – Rate of sternal wound infection in relation to a phased infection control program, shown as all infections and those caused by *S. aureus* (SAU) and GNB alone.