Special Issue: Cardiothoracic Critical Care

Journal of INTERNATIONAL MEDICAL RESEARCH

Journal of International Medical Research
2019, Vol. 47(8) 3491–3501
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DOI: 10.1177/0300060519836511
journals.sagepub.com/home/imr

Implementation of an evidence-based practice to decrease surgical site infection after coronary artery bypass grafting

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Abstract

Objective: Surgical site infection (SSI) is a serious complication after coronary artery bypass grafting (CABG). This study was performed to evaluate evidence-based practice and structured problem-solving to reduce SSI after CABG.

Methods: An infection control strategy including supervised chlorhexidine gluconate (CHG) showers was implemented from January 2017 to March 2018 for 119 patients undergoing CABG. The controls comprised 244 patients who underwent CABG from 2014 to 2016. Risk factors for SSI were identified, and a problem-focused strategy was used to control SSI. Propensity score matching was used to study the effect of CHG showers on SSI.

Results: SSI occurred in 25 patients (10.25%) in the control group, and the significant risk factors were the postoperative blood glucose level, transfer from an outside hospital, emergency operation, redo sternotomy, a higher American Society of Anesthesiologists score, and the duration

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of surgery. After implementation of the program, the SSI rate significantly decreased to 3.36%. Patients who had undergone preoperative CHG showers had a significantly lower SSI rate (1.69%) than the matched controls (13.56%).

Conclusion: SSI after CABG can be reduced using evidence-based practice and structured problem-solving to identify risk factors. A preoperative CHG shower is associated with a lower SSI rate after CABG.

Keywords

Surgical site infection, coronary artery bypass grafting, infection control, chlorhexidine gluconate, evidence-based practice, propensity score matching

Date received: 3 January 2019; accepted: 18 February 2019

Introduction

Surgical site infection (SSI) is currently recognized as a measure of healthcare quality, and SSI surveillance is an integrated part of quality improvement programs.[1,2] Despite improvements in surgical techniques and infection control practices, SSI accounts for 31% of all in-hospital acquired infections and is considered as a major cause of increased length of hospital stay and mortality; additionally, it has a significant economic burden.[3]

SSI after coronary artery bypass grafting (CABG) is a serious complication associated with a marked increase in short- and long-term morbidity. The reported incidence of SSI can range from 1% to 10%,[4,5] and many risk factors have been identified as predictive of SSI following CABG.[4–6]

The effectiveness of preoperative chlorhexidine gluconate (CHG) showering continues to be debated. Preoperative showering is strongly recommended by the Centers for Disease Control and Prevention because it is effective in decreasing bacterial colonization;[7] however, the decline in clinical infection after the use of CHG showering is still debated, and the reduction of SSI is not consistent.[8] The National Institute of Health and Care Excellence in the UK has not strongly recommended the use of CHG showering in its guideline on prevention and treatment of SSI for this reason.[9]

In the recent years, we have noticed that SSI rate in our institution was higher than the standardized rate recommended by the National Healthcare Safety Network, which ranges from 2.6% to 8.2%, and the rate at our institution reached 9.0% in the period from January to June 2014. We designed a bundle-of-care strategy to address the increased SSI rate through adjustment of identifiable risk factors, strengthening of compliance with this strategy, and addition of supervised CHG showering routinely in all patients undergoing CABG. In the present study, we evaluated the effect of implementation of this strategy and assessed the clinical value of preoperative CHG showering on reducing SSI in patients undergoing CABG.

Materials and methods

Study population and design

This prospective, nonrandomized, historically controlled study was conducted in a single tertiary center to study SSI in both sternal and harvest site incisions in patients who underwent CABG from January 2017 to March 2018. This group was compared with patients who underwent CABG during the previous 3 years (2014–2016). Patients who had undergone concomitant procedures (either cardiac or extracardiac) and those who had undergone minimally invasive CABG were excluded from the study. Immunocompromised patients, organ transplant patients, and patients receiving corticosteroids or other immunosuppressants were also excluded. CABG was performed in all patients using the standard technique.[10,11]

Study endpoints

The primary outcome measure for our study was SSI prior to discharge or SSI requiring re-hospitalization within 30 days for superficial incisions and within 1 year for deep incisions. SSIs were classified as superficial or deep wound infections.

Criteria for diagnosis

The diagnostic criteria established by the Centers for Disease Control and Prevention were used to define superficial and deep SSI after CABG.[12] Superficial SSI occurred within 30 days of the surgery and involved only the skin and subcutaneous tissues. Patients showed purulent wound discharge and/or the organism was cultured from the wound. Superficial SSI was either primary or secondary; primary SSI occurred at the sternotomy site, and secondary SSI occurred at the graft incisional site. Stitch abscesses and diathermy burns were not considered SSIs.

Deep or organ/space SSI occurred within 30 or 90 days after the operative procedure and involved soft tissues deep to the incision (e.g., fascial and muscle layers) or mediastinal organs. Patients often showed purulent wound discharge, sternal dehiscence, and/or infection of the deep organs as evidenced by myocarditis, pericarditis, or mediastinitis. Deep SSI was classified as either primary or secondary, similar to superficial SSI.

Data collection

We used the operative database, microbiology data, and hospital admission data to identify patients who had undergone CABG and met the inclusion criteria.

Data were collected from the infection control records and medical records. The demographic data were age, sex, weight, height, and body mass index, and the associated risks factors were diabetes mellitus, end-stage renal disease, liver disease, and a history of infection or colonization by methicillin-resistant *Staphylococcus aureus* and vancomycin-resistant enterococci.

Other data analyzed in this study were referral from another facility, length of stay prior to surgery, blood glucose level within 48 hours before surgery, blood glucose level within 24 hours after surgery, emergent nature of surgery (according to the NCEPOD, found at https://www.ncepod.org.uk/classification.html), duration of surgery, perioperative American Society of Anesthesiologists (ASA) score, and history of median sternotomy. The antimicrobial agents given for perioperative prophylaxis and the time of their administration relative to the surgical incision were also recorded. Appropriate timing of prophylaxis was defined as an agent given within 2 hours before surgical incision.

Identification of pathogens

Different strains of bacteria were isolated and identified using standard methods.[13] Antibiotic sensitivity tests were performed according to the Kirby–Bauer disc diffusion technique.[14] All CABG procedures were classified as clean according to the system employed in the American College of Surgeons and Surgical Infection Soceity.[15]

Methodology and interventions

We identified the rate of SSI after CABG in 244 patients and identified the risk factors for infection. An improvement project team was formed in late 2016 to address the problem of SSI in our center. We applied strict blood glucose control preoperatively, intraoperatively, and postoperatively for both patients with and without diabetes. Our target was to maintain the glucose level at <11.1 mmol/dL and the hemoglobin A1C level at <7%. Blood glucose level monitoring continued until the patients were discharged, and follow-up for at least 6 months was scheduled for patients without diabetes. Methicillin-resistant *S. aureus* and vancomycin-resistant enterococci screening and decolonization were performed in all patients with proper selection of the type and dose of antibiotics and timely administration 2 hours before the incision; nasal decontamination and CHG showering were also performed. Infected patients were isolated in a special room and followed by repeated culture. Moreover, all patients underwent a supervised CHG shower before the intervention. Patient education regarding the importance of antiseptic measures to prevent postoperative infection was implemented, and the patients were provided written instructions to follow. For all patients, 4% CHG (HiBiScrub; Regent Medical, Manchester, UK) was used for a minimum of two showers in the evening and morning prior to surgery, and the patients was instructed not to use creams or lotions after the shower. CHG was applied to the body only during the shower, then rinsed with water. The process of showering was supervised by an infection control nurse.

To maintain the program throughout the study period and ensure consistency, staff education was implemented and pocket guidance was distributed to all surgeons. All patients were checked before surgery to ensure that they all complied with the CHG shower and that all interventions were in place. The pharmacy department contributed to the plan by changing and correcting the prophylactic antibiotic ordered by the surgeon according to the culture and sensitivity results and adjusting the correct dose.

Statistical analysis

Statistical analysis was performed using STATA 14 software (StataCorp, College Station, TX, USA). The patients were divided into two groups: Group A comprised patients who had undergone CABG before January 2017, and Group B comprised patients who had undergone CABG after January 2017. The patients' characteristics differed between those who had undergone CABG before and after implantation of the infection control strategy. To adjust for the variables affecting the occurrence of wound infection between the two groups, we used propensity score matching adjusting for the preoperative and operative variables. The propensity score was calculated using the variables presented in Figure 1 with 1:1 matching. The distribution of the propensity scores is shown in Figure 2. Univariable logistic regression analysis was used to identify the risk factors for infection in the control group.

Continuous variables are presented as mean $\pm$ standard deviation and were compared using the Wilcoxon rank-sum test. Categorical variables are presented as number and percentage and were compared using the chi-square test or Fisher's exact test when the expected frequency was <5. A p-value of <0.05 was considered statistically significant.

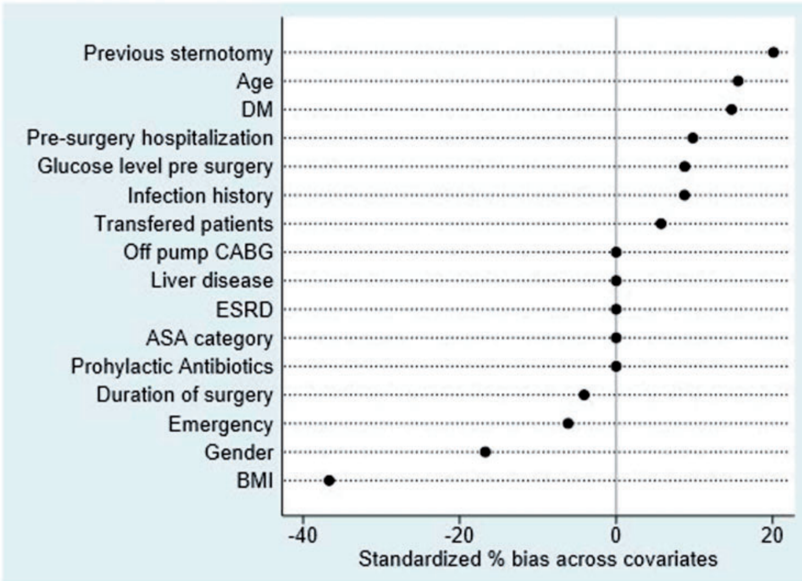

Figure 1. Variables used in preoperative propensity score matching and standardized percent of bias across covariates in the selected variables. ASA, American Society of Anesthesiologists; BMI, body mass index; CABG, coronary artery bypass grafting; DM, diabetes mellitus; ESRD, end-stage renal disease.

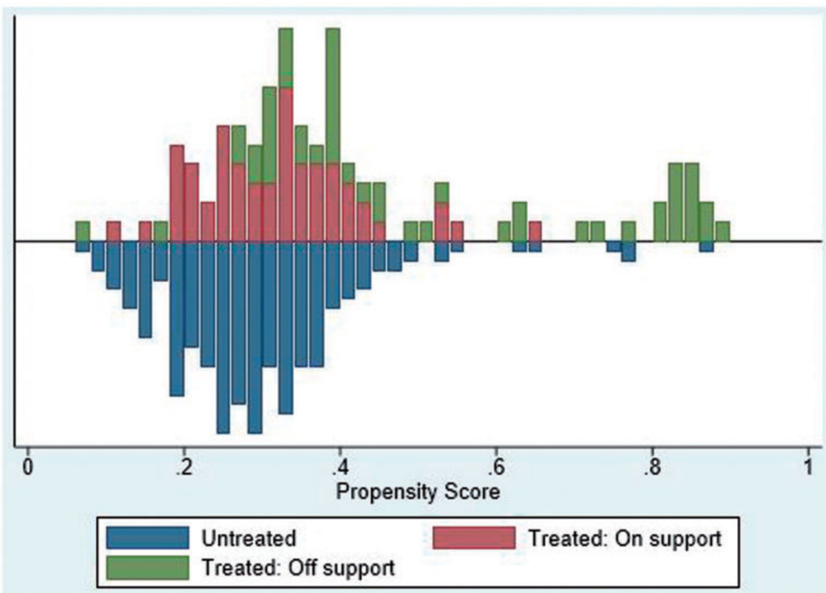

Figure 2. Mirrored histogram of distribution of propensity scores for patients who underwent chlorhexidine gluconate showers (red bars) and patients before implantation of the procedure (blue bars). The green bars represent patients who underwent chlorhexidine gluconate showers and were not matched.

Ethics

This study was approved by the Institutional Review Board of King Faisal Specialist and Research Center Jeddah (IRB number 2017-39). Informed consent for retention and use of patient data for research purposes was routinely obtained at the time of obtaining consent for the procedure.

Results

Risk factors for SSI in the control group

The patients who underwent CABG from 2014 to 2016 were the historical control group (Group A). SSI occurred in 25 of 244 patients (10.25%). Univariable logistic regression analysis was used to identify the risk factors for postoperative SSI (Table 1). Wound infection was significantly associated with the postoperative blood glucose level ($p = 0.004$), transfer from an outside hospital ($p < 0.001$), emergency operation ($p = 0.003$), redo sternotomy ($p = 0.004$), a higher ASA score ($p < 0.001$), and the duration of surgery ($p = 0.001$).

Effect of the infection control improvement program

We implemented an infection control improvement program including strict control of the blood glucose level, administration of preoperative antibiotics based on culture and sensitivity results, and administration of the antibiotics at the proper dose and time in patients who underwent CABG after January 2017 (Group B). The incidence of SSI after CABG significantly decreased to 3.36% (n = 4 of 119) ($p = 0.023$) (Figure 3).

Effect of CHG showers

To study the sole effect of CHG showering on the rate of post-CABG SSI, the

Table 1. Univariable logistic regression analysis of factors affecting postoperative wound infection in the control group.

Risk factor	OR	p	95% CI
Age	1.026578	0.206	0.99–1.07
Sex	0.4894663	0.122	0.20–1.21
BMI	1.051173	0.148	0.98–1.12
ESRD	0.645485	0.568	0.14–2.90
History of infection	1.298539	0.418	0.69–2.44
Transfer from another hospital	27.125	<0.001	4.94–148.87
Preoperative hospitalization (days)	1.009992	0.772	0.94–1.08
Preoperative glucose level (mmol/dL)	1.104939	0.072	0.99–1.23
DM	1.935937	0.244	0.64–5.88
Postoperative glucose level (mmol/dL)	1.165269	0.004	1.05–1.29
Duration of surgery (minutes)	0.9852103	0.001	0.98–0.99
Off-pump CABG	1.098963	0.931	0.13–9.17
BIMA harvest	6.26087	0.051	0.99–39.43
Redo sternotomy	29.59091	0.004	2.95–296.70
ASA score	10.59559	<0.001	2.84–39.48
Emergency operation	4.620915	0.003	1.69–12.61

ASA, American Society of Anesthesiologists; BIMA, bilateral internal mammary artery; BMI, body mass index; CABG, coronary artery bypass grafting; CI, confidence interval; DM, diabetes mellitus; ESRD, end-stage renal disease; OR, odds ratio.

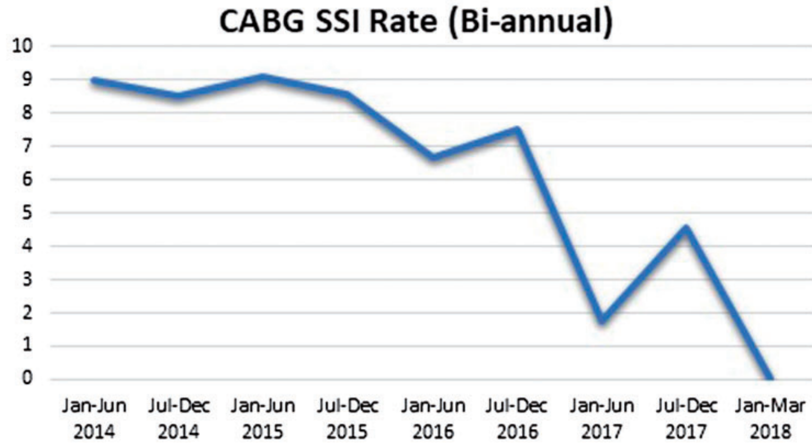

Figure 3. Biannual rate of SSI after CABG. SSI, surgical site infection; CABG, coronary artery bypass grafting.

preoperative and operative characteristics were matched between patients who underwent CHG s and the historical controls with 1:1 propensity score matching. Variables within the infection control improvement program, such as the blood glucose level and antibiotics used, were also matched. The preoperative, operative, and postoperative variables before and after matching are compared in Table 2. Patients who had undergone a preoperative CHG shower had a lower incidence of SSI ($n = 1$, 1.69%) than did the matched controls ($n = 8$, 13.56%) ($p = 0.032$). The hospital stay decreased from 9.51 ± 3.03 days in the control group to 8.22 ± 1.09 days in the CHG group ($p = 0.04$). No readmission for SSI was reported in either group.

Discussion

SSI after CABG increases morbidity and mortality; additionally, it is a major cause of an increased cost of care.[16]

Several risk factors for SSI development after CABG were recognized. However, research is still being conducted to investigate the impact of new treatments strategies[17,18] and patient- and operation-specific risk factors[19] on the incidence of SSI after CABG. We believe that risk factors for this condition vary widely among different institutions and that different risk factors were identified in previous studies because of the differences in patient populations and infection prevention practices. Therefore, every hospital should apply an evidence-based practice to identify local factors contributing to the occurrence of SSI and direct the intervention toward these factors to control the incidence of SSI.

We have observed a high incidence of SSI after CABG in our institution in the last 3 years. We therefore investigated the local risk factors that could contribute to the increased risk of this complication and directed our efforts toward these factors. Consistent with a recent multicenter study,[20] SSI in our population was related to the postoperative blood glucose level ($p = 0.004$), which emphasizes the importance of continuous blood glucose monitoring and control in both patients with and without diabetes. Several risk factors identified in our population contributed to the incidence of infection, and their clinical

Table 2. Unmatched and matched comparison between preoperative and operative characteristics of patients who underwent CABG before and after implementation of infection control.

	Group A (n = 244)	Group B (n = 119)	p	Matched Group A (n = 59)	Matched Group B (n = 59)	p
Age (years)	58.23 ± 10.54	59.71 ± 9.68	0.362	59.07 ± 9.48	60.64 ± 10.23	0.505
Male	195 (79.92)	94 (78.99)	0.837	50 (84.75)	46 (77.97)	0.344
BMI	28.69 ± 5.57	28.61 ± 5.57	0.916	30.32 ± 5.51	28.28 ± 5.49	0.055
DM	181 (74.18)	77 (64.17)	0.062	40 (67.80)	44 (74.58)	0.416
ESRD	28 (11.48)	8 (6.72)	0.155	6 (10.17)	6 (10.17)	0.99
Liver disease	8 (3.28)	2 (1.68)	0.503	2 (3.39)	2 (3.39)	0.99
Prior infection			0.874			0.99
MDR	15 (6.17)	6 (5.04)		2 (3.39)	2 (3.39)	
MRSA	13 (5.35)	6 (5.04)		5 (8.47)	5 (8.47)	
VRE	2 (0.82)	1 (0.82)		0 (0.00)	1 (1.69)	
Preoperative hospitalization (days)	6.00 ± 5.76	6.23 ± 5.30	0.341	5.93 ± 7.23	6.47 ± 5.86	0.244
Preoperative glucose level (mmol/dL)	11.04 ± 3.86	9.55 ± 3.44	<0.001	9.89 ± 3.07	10.21 ± 3.41	0.364
Emergency surgery	24 (9.84)	8 (6.72)	0.326	8 (13.56)	7 (11.86)	0.99
Off-pump CABG	9 (3.69)	4 (3.36)	0.875	3 (5.08)	3 (5.08)	0.99
ASA score			0.521			0.679
2	2 (0.83)	0 (0.00)		1 (1.69)	0 (0.00)	
3	230 (95.04)	116 (97.48)		55 (93.22)	57 (96.61)	
4	10 (4.13)	3 (2.52)		3 (5.08)	2 (3.39)	
Previous sternotomy	4 (1.65)	5 (4.20)	0.161	0 (0.00)	2 (3.39)	0.496
Surgery duration (minutes)	264.02 ± 64.67	249.34 ± 59.34	0.040	255.51 ± 57.13	252.97 ± 59.98	0.648
Postoperative glucose level (mmol/dL)	10.54 ± 3.55	10.04237 ± 3.726835	0.074	10.03 ± 3.46	11.13 ± 4.10	0.135
Antibiotic prophylaxis			<0.001			0.679
Cefazolin	237 (97.13)	107 (89.92)		56 (94.92)	55 (93.22)	
Vancomycin	3 (1.23)	12 (10.08)		2 (3.39)	4 (6.78)	
Others	4 (1.64)	0 (0.00)		1 (1.69)	0 (0.00)	
BIMA harvest	5 (2.05)	2 (1.68)	0.99	2 (3.39)	1 (1.69)	0.99
Transfer from another hospital	7 (2.87)	21 (17.65)	<0.001	1 (1.69)	2 (3.39)	0.99

Continuous variables are presented as mean ± standard deviation and categorical variables as number (percent). ASA, American Society of Anesthesiologists; BIMA, bilateral internal mammary artery; CABG, coronary artery bypass grafting; MDR, multi-drug resistant; MRSA, methicillin-resistant *Staphylococcus aureus*; BMI, body mass index; DM, diabetes mellitus; ESRD, end-stage renal disease; VRE, vancomycin-resistant enterococci.

importance is not consistent in the literature.[20,21] These factors were transfer of patients from an outside hospital, emergency operation, redo sternotomy, a higher ASA score, and the duration of surgery. This patient subset represents the high-risk group in our institution who require more attention and care to prevent SSI. Conversely, several other risk factors were identified in other series but were not significant in our study, including a higher body mass index, higher creatinine level, peripheral vascular disease, preoperative corticosteroid use, and a ventricular assist device or transplant surgery.[20,21] These findings support our concept that each institution has its own risk profile and that preventive measures should be directed toward the specific institution's own risk factors to increase efficacy and save resources. Application of an evidence-based practice directed toward our institution- and patient-specific risk factors significantly reduced the incidence of SSI after CABG from 10.25% to 3.36% ($p = 0.023$).

In addition to applying strict blood glucose control and the use of antibiotics according to culture and sensitivity results with the proper dose and timing, we implemented a strict and supervised CHG shower preoperatively. There are conflicting results about the effect of preoperative CHG showering in reducing postoperative wound infection, and the level of recommendation varies among different guidelines.[22] The 2019 National Institute of Health and Care Excellence recommendations suggest CHG washing combined with nasal decontamination with mupirocin for high-risk patients; however, the 2016 World Health Organization guideline suggests nasal decontamination with or without CHG washing.

Controversies arising from preoperative CHG showering could be attributed to the lack of specific protocols and wide variation in application methods in the literature.[23] Previous studies have shown that CHG has a cumulative effect and that repeated administration in a proper amount and concentration is required to be effective.[24] We followed a predefined protocol for preoperative CHG showering in all patients with a minimum application of two times and maximum of four times in our previously identified high-risk patients. Despite the proven efficacy of preoperative CHG showering in reducing and killing pathogenic bacteria on the skin,[23] its effect on reducing postoperative wound infection is still being debated. In the present study, we performed propensity score matching to neutralize risk factors that could contribute to SSI and implemented specific measures to reduce SSI (including the use of strict blood glucose level and antibiotic use protocols) to identify the sole effect of preoperative CHG showering in reducing SSI. We found that the use of preoperative CHG showering significantly decreased the SSI rate (1.69%) compared with the matched control (13.56%) ($p = 0.032$).

Study limitations

The major limitation of this study is that it was a single-center experience with a limited number of patients. However, we believe that every institution should identify its specific risk factors and direct their efforts toward controlling those factors to save resources. Additionally, we applied strict inclusion criteria to create a homogeneous set of patients for comparison because the number of events was low and a multivariable analysis would have been underpowered. Another limitation is the use of a historical control group; however, this is the most suitable design to study the intervention because patient randomization is unethical. Several other unmeasured factors could have affected the outcomes, such as patients' and doctors' education levels, which cannot be adjusted for in the propensity score analysis. The true incidence of SSI could be underestimated because SSIs that developed after hospital discharge were not included if they did not require readmission.

Conclusion

SSI after CABG can be reduced by using evidence-based practice and structured problem-solving to identify the risk factors specific to each institution, and proper presentation of the problem will help in identifying the potential solutions and improving quality of care. Patients' and surgeons' education could have played a role in decreasing the incidence of infection, but the magnitude of the effect is unmeasurable. Preoperative CHG showers at the recommended frequency, dose, and concentration are associated with a reduction of SSI after CABG.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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