Cross-sectional Study

Risk adjustment performance between NNIS index and NHSN model for postoperative colorectal surgical site infection: A retrospective cohort study

Tharntip Sangsuwan [*], Silom Jamulitrat, Pattharapa Watcharasin

Department of Family Medicine and Preventive Medicine, Faculty of Medicine, Prince of Songkla University, Hat Yai, Songkhla, 90110, Thailand

A B S T R A C T

Background: Risk stratifications to predict development of surgical site infections (SSI) are crucial methods before surgery. Hence, we aimed to compare the performance of risk adjustment between the former NNIS risk index and the new NHSN procedure-specific risk model for postoperative colorectal SSI.
Materials and methods: A retrospective cohort study was conducted. Data of post-colorectal SSI, indicating the use of the NNIS risk index for SSI adjustment, were retrieved from the medical records. Data were taken from patients who underwent colorectal surgery procedures between January 2005 and December 2016. Additional information regarding emergency colorectal surgery was retrieved to fulfill the requirements for calculation of the risks for SSI; via the new model. The predictive performance between the two models was compared using the means of the area under the receiver operating characteristic curve.
Results: In total 1989 patients were included. Fifteen patients were excluded; thus, the remaining number of procedures was 1974. Surgical site infections occurred in 85 (4.3%) procedures. In colectomy surgery, the means of area under the curve (AUC) yielded 0.6196 and 0.5976 for the NNIS risk index model and the new NHSN risk model, respectively; differences in the AUC were not statistically significant (p = 0.39). In rectal surgery, the means of the AUC yielded 0.516 and 0.49 for the NNIS risk index model and the new NHSN procedure-specific risk model, respectively; differences in the AUC were not statistically significant (p = 0.56).
Conclusion: The new NHSN procedure-specific risk model was not superior to the former NNIS risk index.

1. Introduction

Surgical site infection (SSI) is the third most common hospital-acquired infection, with SSI accounting for 14–16% of all such infections [1]. In surgical patients, SSI is the most common hospital-acquired infection [2,3]. Several reports have described the substantial cost of these infections, in terms of; attributable mortality [3], increased morbidity; measured as increased postoperative hospital length of stay, and increased hospital expenses [4–7]. SSI in patients undergoing colorectal resection has been specifically studied, with similar general findings [6,7]. However, there has been a wide discrepancy in the reported incidence of incisional SSI following colectomy surgery; ranging from 3 to 30% [8–15].

To predict the risk of developing SSI in patients before surgery, risk stratifications are crucial methods. The risk stratification most commonly used is the National Healthcare Safety Network (NHSN) risk index, which was formerly the National Nosocomial Infections Surveillance (NNIS) risk index; however, it has poor efficacy in predicting SSI

after several surgical procedures; including colectomy. Hence, the NHSN investigators conducted a novel NHSN procedure-specific risk model. However, this new model is only slightly better than the original one.

The purpose of this study was to compare the performance of risk adjustment between the former NNIS risk index and the new NHSN procedure-specific risk model.

2. Methods

2.1. Setting

We conducted a retrospective cohort study in Songklanagarind Hospital, which is an 860-bed tertiary care facility, serving as a medical school with residency training and as a referral center for the South of Thailand.

Table 1

Patient and procedure characteristics.

| Characteristic	n	Percentage	95% CI
Male gender	1110	56.2	54.0–58.4
DM	233	11.8	10.4–13.3
DM with complication	37	15.9	11.4–21.2
ASA scores			
I	61	3.1	2.4–4.0
II	1378	69.8	67.7–71.8
III	492	24.9	23.0–26.9
IV	43	2.2	1.6–2.9
Cancer	1743	88.3	86.8–89.7
Emergency	353	17.9	16.2–19.7
Endoscopy	249	12.6	11.3–14.4
Wound classification			
Clean	6	0.3	0.1–0.7
Clean-contamination	22	1.1	0.7–1.7
Contamination	1906	96.6	95.7–97.3
Dirty	40	2.0	1.5–2.8
Age		61.4	60.7–62.1
BMI		22.2	22.0–22.4
Preoperative hospital stay		3.2	3.1–3.3
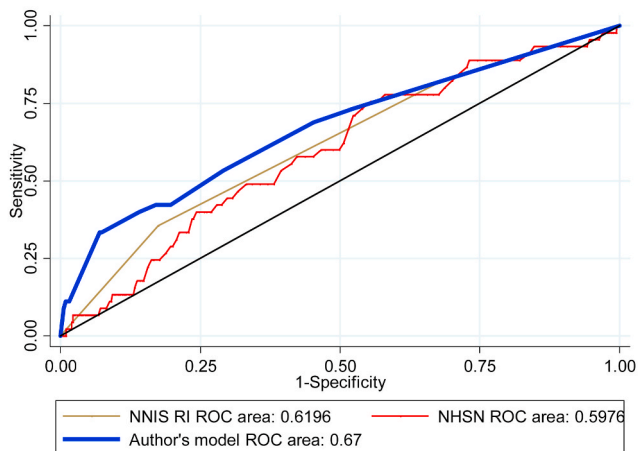
Fig. 1. Comparison of the receiver operative characteristic (ROC) curves between postoperative colectomy surgery surgical site infection predicted by NNIS risk index, NHSN procedure specific risk model and the Author's model.
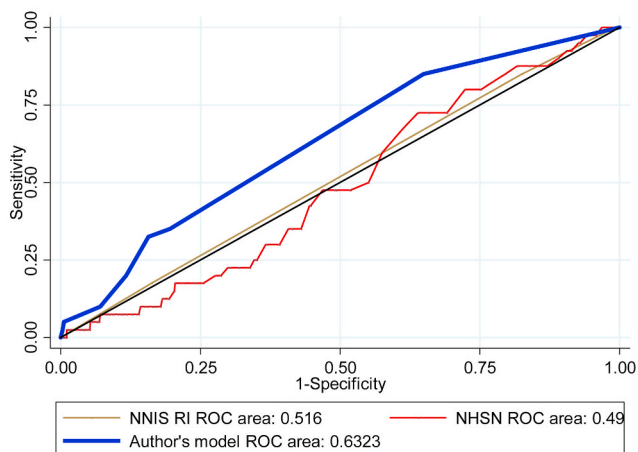

Fig. 2. Comparison of the receiver operative characteristic (ROC) curves between postoperative rectal surgery surgical site infection predicted by NNIS risk index, NHSN procedure specific risk model and the Author's model.

Table 2

Comparison of means of percentage with corresponding 95% confidence intervals (in parenthesis) for patient characteristics; between the patients with and without post-colorectal operative surgical site infections.

	SSI	No SSI	P-value
	N = 86	N = 1889	
Age (arithmetic mean)	60.7 (57.0–64.4)	61.4 (60.8–62.1)	0.7[c]
Male gender (%)	67.1 (56.0–76.9)	55.7 (53.5–58.0)	0.03[a]
Body mass index (mean)	22.0 (21.2–22.9)	22.2 (22.0–22.3)	0.76
DM (%)	17.7 (10.2–27.4)	11.5 (10.1–13.1)	0.088[a]
DM with complication (%)	26.7 (7.8–55.1)	15.1 (10.7–20.6)	0.237[a]
ASA scores			
I	1.2 (0.0–6.4)	3.2 (2.4–4.1)	0.001[a]
II	61.2 (50.0–71.6)	70.2 (68.1–72.3)	
III	29.4 (20.0–40.3)	24.7 (22.8–26.7)	
IV	8.2 (3.4–16.2)	1.9 (1.4–2.6)	
Preoperative hospital stay (geometric mean)	5.0 (0.6–5.1)	4.3 (0.1–5.8)	0.21[b]
Cancer (%)	78.8 (68.6–86.9)	88.7 (87.2–90.1)	0.005[a]
Emergency (%)	36.5 (26.3–47.6)	17.1 (15.4–18.8)	0.000[a]
Endoscopy (%)	3.5 (0.7–10.0)	13.0 (11.5–14.6)	0.01[a]
Wound classification			
Dirty	5.9 (1.9–13.2)	1.9 (1.3–2.6)	0.01[a]

*Unpaired *t*-test.

[a] Pearson 's chi-square test.

[b] Unpaired *t*-test of natural log of preoperative hospital stay.

[c] one-sided 97.5% CI.

2.2. Inclusion criteria

The target population in this study comprised of all patients who underwent colectomy in Songklanagarind Hospital between January 2005 and December 2016. Colorectal surgery was defined by the ICD-9-CM procedure codes. In addition, one patient can have more than one operation; thus, some patients have more than one record.

2.3. Exclusion criteria

The exclusion criteria included: i) patients who stayed in the hospital for less than 7 consecutive days after colorectal surgery; ii) patients who had incomplete or concealing data; and iii) patients whose surgery was longer than 929 min.

A 10-min increase in operative duration, analyzed for expected SSI, was considered as continuous data; which meant this factor had no upper limit value. For this reason the Centers of Disease Control and Prevention (CDC) suggests setting the upper limit value at 5 times the interquartile range (IQR). Hence, the upper limit of this value was 929 min.

2.4. Definitions

1. Criteria for defining SSI was defined and classified by the CDC [3].
    1.1 Superficial Incisional SSI
    1.2 Deep Incisional SSI
    1.3 Organ/Space SSI
2. ASA score

The American Society of Anesthesiologists (ASA) score was used to classify patients into six groups with different degrees of severity of
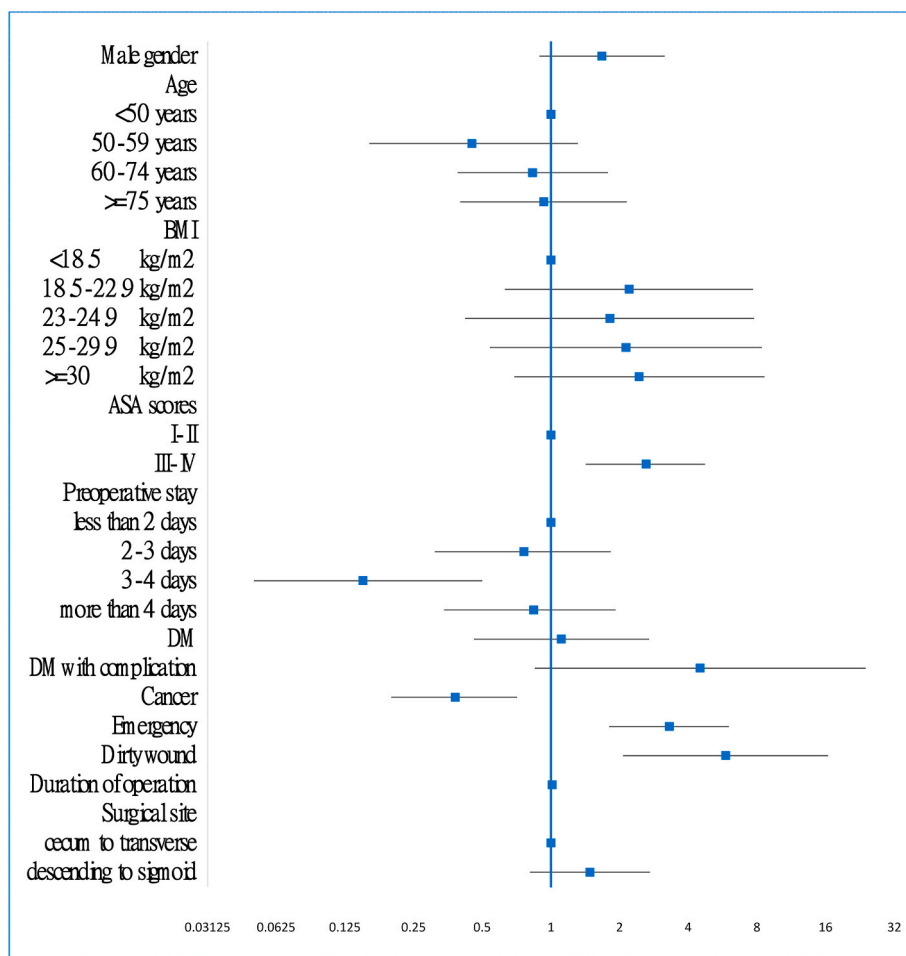
Fig. 3. Factors associated with postoperative colectomy surgical site infection (SSI) by univariate analysis.

illness during an admission [16].

2.4.1. ASA physical status classification

ASA I: A normal healthy patient.

ASA II: A patient with mild, systemic disease.

ASA III: A patient with severe, systemic disease.

ASA IV: A patient with severe, systemic disease that is a constant threat to life.

ASA V: A moribund patient who is not expected to survive without the operation.

ASA VI: A declared brain-dead patient whose organs are being removed for donor purposes.

3. Wound Classification

Surgical patient wounds were classified by the CDC. This classification was used to classify the patients into five groups with different degrees of hygienic of wound [3].

3.1 Class I or Clean

3.2 Class II or Clean-Contaminated

3.3 Class II or Contaminated

3.4 Class III or Contaminated

3.5 Class IV or Dirty-Infected

2.5. Data collection

The data in our study were recorded in the medical records of the Hospital Information System by experienced doctors and nurses. The data; including, age, gender, diabetic mellitus, admission date, discharge date, cancer, operation, presence of SSI complications, duration of operation, emergency, and endoscopy of the patients were retrieved from the Infection Control Unit of Songklanagarind Hospital.

2.6. Statistical analysis

In summary: statistics, continuous data were described in terms of arithmetic mean geometric mean and a 95% confidence interval (CI). Categorized data were summarized by percentage and a corresponding 95% CI; calculated by exact binomial statistics.

The ROC curve was used to compare the predictive performance of the risk adjustment between the former NNIS risk index and the new NHSN procedure-specific risk model for post-colorectal surgical site infection. Chi-square tests of association were used to evaluate differences in proportion for each of the categorical factors. The associations between each of the risk factors and SSI are shown in odds ratio, and evaluated by the stepwise logistic regression technique. Statistical analyses were performed using statistical software STATA, version 13 (**StataCorp**). **A p-value of <0.05 was considered to be statistically significant.**

Ethical approval

The study protocol was approved by the Ethics Committees of the Faculty of Medicine, Prince of Songkla University (EC: 60-006-09-1).

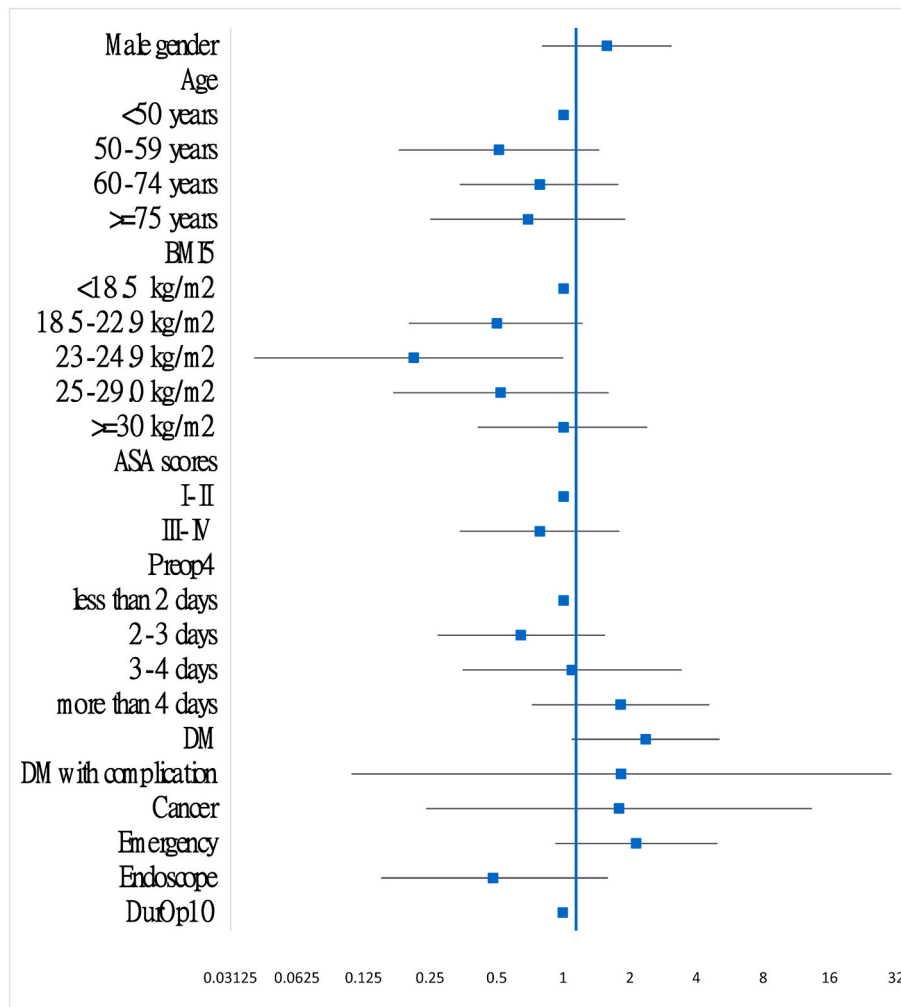**The registration process and the issuance of unique**

Fig. 4. Factors associated with postoperative rectal surgery surgical site infection (SSI) by univariate analysis.

identification number (UIN) for this study is **researchregistryT697.** **The Hyperlink is** https://www.researchregistry.com/browse-the-regis try#home/?view_2_search=Sangsuwan&view_2_page=1**.**

This work has been reported in line with the STROCSS criteria [17]: "Mathew G and Agha R, for the STROCSS Group. STROCSS 2021: Strengthening the Reporting of cohort, cross-sectional and case-control studies in Surgery. International Journal of Surgery 2021; 96:106165.

3. Results

In this retrospective cohort study, initially 1989 procedures of 1989 patients were included. However, using the inclusion criteria, one patient was excluded, due to no hospital number (HN), three patients were excluded due to the wrong HN procedure, and 11 patients were excluded from the study because their operations were not colorectal surgery. Finally, this study analyzed the data of 1974 procedures.

Surgical site infection after colorectal surgery occurred in 85 (4.3%) of all procedures. The demographic characteristics of patients who underwent colorectal surgery procedures are summarized in Table 1. Most patients had contamination wounds (96.56%), cancer (88.30%), and ASA class II (69.81%).

3.1. Model comparisons

3.1.1. Colon
Predictive performances of the two models were analyzed by the

ROC curve method (Fig. 1). The AUC results yielded 0.6196 and 0.5976 for the former NNIS risk index model and the new NHSN procedure-specific risk model, respectively, for postoperative colorectal surgical site infection.

The differences in the AUC were not statistically significant (p = 0.39). A significant P level was calculated using the formula of Delong et al.

3.1.2. Rectal
Predictive performances of the two models were analyzed by the ROC curve method (Fig. 2). The AUC results yielded 0.516 and 0.49 for the former NNIS risk index model and the new NHSN procedure-specific risk model, respectively, for postoperative colorectal surgical site infection.

The differences in the AUC were not statistically significant (p = 0.56). A significant P level was calculated using the formula of Delong et al.

3.2. Risk factors associated with SSI after colorectal procedure

To identify risk factors associated with SSI after the procedure, the patients were divided into two groups by the occurrence of SSI after the procedure (Table 2).

According to the classification of risk factors, some variables in this study did not reach statistical significance; these being: age, BMI, DM, DM with complications, and preoperative hospital stay. Other variables
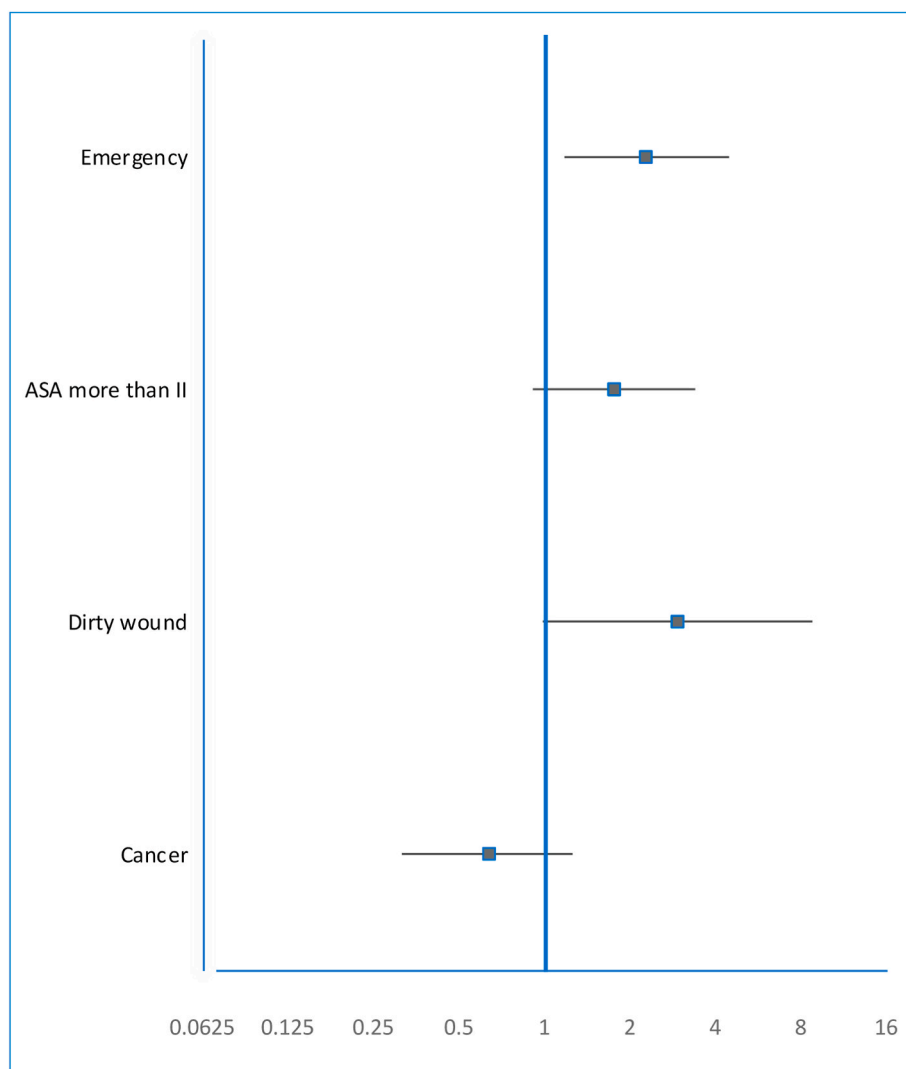
Fig. 5. Multivariate logistic regression for the factors associated with the development of colectomy surgical site infection (SSI).

with significant differences were: male gender, cancer, emergency, endoscopy, dirty wound classification, and ASA scores.

3.3. Univariate analysis

3.3.1. Colon
The list of significant variables associated with colon surgical site infection were separated into two groups: protective and aggravating factors. Cancer was the only protective factor. The aggravating factors were emergency and an ASA score of more than II. The results of the univariate analysis are shown in Fig. 3.

3.3.2. Rectum
From a list of significant variables associated with rectal surgical site infection, DM was the only aggravating factor. The results of univariate analysis are shown in Fig. 4.

3.4. Multivariate analysis

After using stepwise logistic regression with a backward elimination approach, four potential independent variables were identified in colon surgery and three potential independent variables were identified in rectal surgery (Figs. 5 and 6).

In colon surgery, ASA Classification (Class I-II or III-IV), emergency

(Yes or No) and wound contamination (clean-contaminated, contaminated or dirty wound) were the aggravating factors, while cancer (Yes or No) was the only protective factor to predict SSI as a risk factor. In rectum surgery, DM (Yes or No), emergency (Yes or No), and gender (male or female) were the aggravating determinants to predict the rise of SSI risk.

4. Discussion

The rate of SSI after colorectal cancer surgery was in the range of 5–30% [1], which is higher when compared with other general procedures. The risk model is based on the NNIS risk index; which is simple in design, but with poor predictive performance for many procedures. New procedure-specific predictive models, collected from the NHSN data, significantly improved the predictive performance for most procedures; such as the colorectal procedure [2].

This study represents the data of 1974 surgical procedures, which included 950 colon procedures and 1024 rectal procedures, to predict the risk of SSI risk for comparison between the NNIS risk index model and the new procedure-specific predictive model. Our study showed that the risks of SSI after colorectal surgery depended on factors related to the patient, the operations and the surgeon's compliance with basic principles; such as, antibiotic prophylaxis, skin preparation, and good surgical techniques [1]. According to our results, the new
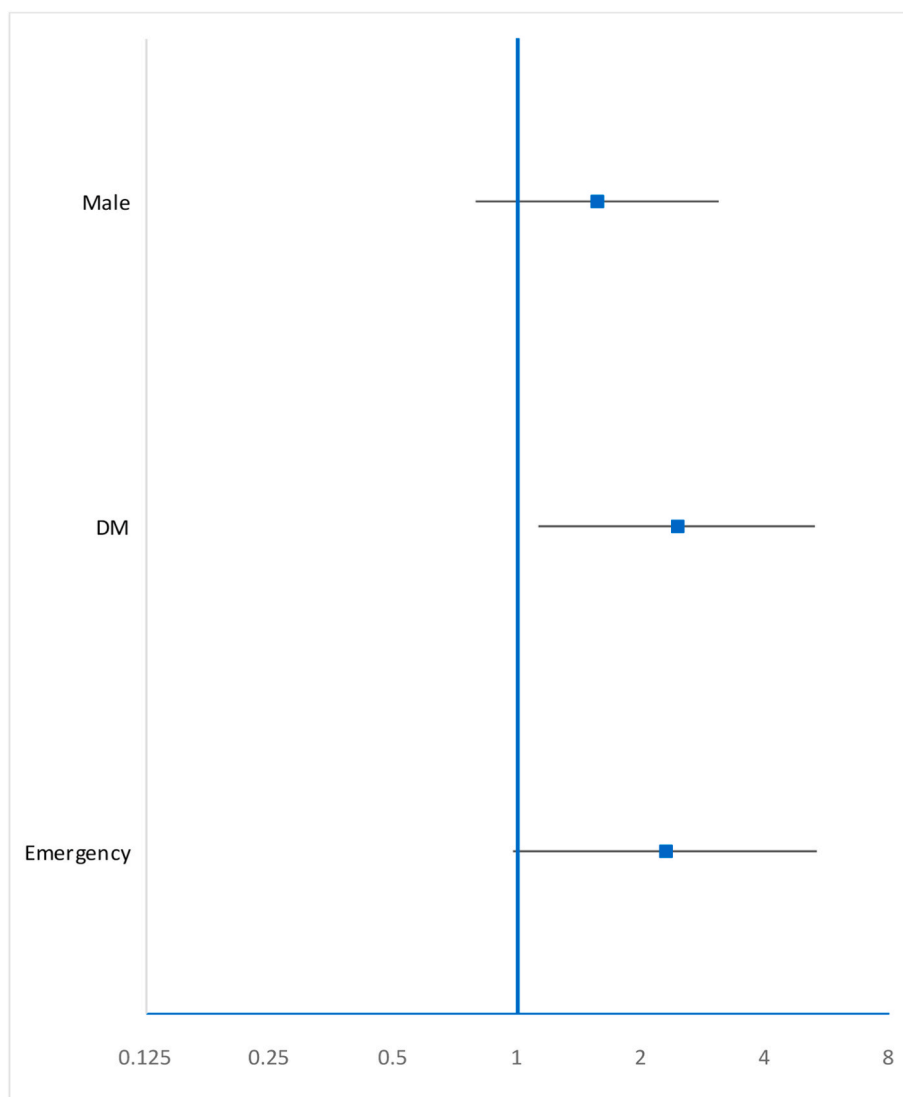
Fig. 6. Multivariate logistic regression for the factors associated with the development of rectal surgery surgical site infection (SSI).

procedure-specific predictive model was not superior to the NNIS risk index model for the prediction of SSI risks. Since the data were accumulated only at our center, and the amount of data was less than other trials, we suggest using the NNIS risk index models in our center.

There are several limitations within this study. Our data were retrieved from medical records as secondary information. Additionally, completeness of the data depended on the individual healthcare providers in charge. We did not have post-discharge information; such as surgical site infection. The period of study was long, so the medications, technologies, and practice guidelines may have possibly changed over time. Furthermore, some variations; such as, new technologies for diagnosis or treatment, and trends of antibiotic prescriptions possibly also had an influence. The number of patients who had developed surgical site infections was also limited in this study; therefore, the samples could only be crudely grouped. However, the primary aim of this project was to compare the surgical site infection predicting models not to identify the risk factors. Other possible risk factors, which could be confounders in the study; such as, tumor type, treatment, patient's immune status and patient's nutritional status were not collected.

For our next project, we should add the variable emergency and cancer factors to the new model that will improve the performance in colorectal surgery, because it incurs less cost and has great reliability. The models that are already included emergencies; such as, appendectomy, caesarian section and gastrectomy.

Ethical approval

The study protocol was approved by the Ethics Committees of the Faculty of Medicine, Prince of Songkla University (EC: 60-006-09-1). Because of the observational nature of the study, written informed consent was not required.

Sources of funding

This work did not receive any funding.

Author contributions

Tharntip Sangsuwan, MD: Study design, data collection, writing the paper.
Silom Jamulitrat, MD: Data analysis.
Pattharapa Watcharasin, MD: Data collection, writing the paper.

Registration of research studies

Research Registry Unique: researchregistry7697.

Registration Date: March 02, 2022.

Public and Scientific Title of Research: Risk adjustment performance between NNIS index and NHSN model for postoperative colorectal surgical site infection: a Retrospective cohort Study.

Primary Investigator: Tharntip Sangsuwan.

Guarantor

Assistant Professor Tharntip Sangsuwan.

Consent

Because of the observational nature of the study, written informed consent was not required.

Provenance and peer review

Not commissioned: externally peer-reviewed.

Declaration of competing interest

All authors of this article have certified that there were no financial, nor non-financial conflicts of interest.

Acknowledgements

We would like to thank Mr. Gleen Shingledecker, from the International Affairs Department, who assisted in the editing of the English language for this manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amsu.2022.103715.

References

[1] E.T. Smyth, A.M. Emmerson, Surgical site infection surveillance, J. Hosp. Infect. 45 (2000) 173–184.

[2] C.A. Weiss 3rd, C.L. Statz, R.A. Dahms, M.J. Remucal, D.L. Dunn, G.J. Beilman, Six years of surgical wound infection surveillance at a tertiary care center: review of the microbiologic and epidemiological aspects of 20,007 wounds, Arch. Surg. 134 (1999) 1041–1048.

[3] A.J. Mangram, T.C. Horan, M.L. Pearson, L.C. Silver, W.R. Jarvis, Guideline for prevention of surgical site infection, Hospital infection control practices advisory committee, Infect. Control Hosp. Epidemiol. 20 (1999) 250–278, 1999.

[4] W.J. Martone, R.L. Nichols, Recognition, prevention, surveillance, and management of surgical site infections: introduction to the problem and symposium overview, Clin. Infect. Dis. 33 (Suppl 2) (2001) S67–S68.

[5] R.P. Gaynes, D.H. Culver, T.C. Horan, J.R. Edwards, C. Richards, J.S. Tolson, Surgical site infection (SSI) rates in the United States, 1992–1998: the National Nosocomial Infections Surveillance System basic SSI risk index, Clin. Infect. Dis. 33 (Suppl 2) (2001) S69–S77.

[6] P. Astagneau, C. Rioux, F. Golliot, G. Brucker, Morbidity and mortality associated with surgical site infections: results from the 1997–1999 INCISO surveillance, J. Hosp. Infect. 48 (2001) 267–274.

[7] K.B. Kirkland, J.P. Briggs, S.L. Trivette, W.E. Wikinson, D.J. Sexton, The impact of surgical-site infections in the 1990s: attributable mortality, excess length of hospitalization, and extra costs, Infect. Control Hosp. Epidemiol. 20 (1999) 725–730.

[8] H.H. Stone, C.A. Hooper, L.D. Kolb, C.E. Geheber, E.J. Dawkins, Antibiotic prophylaxis in gastric, biliary and colonic surgery, Ann. Surg. 184 (1976) 443–452.

[9] G.F. Coppa, K. Eng, T.H. Gouge, J.H. Ranson, S.A. Localio, Parenteral and oral antibiotics in elective colon and rectal surgery. A prospective, randomized trial, Am. J. Surg. 145 (1983) 62–65.

[10] J.S. Clarke, R.E. Condon, J.G. Bartlett, S.L. Gorbach, R.L. Nichols, S. Ochi, Preoperative oral antibiotics reduce septic complications of colon operations: results of prospective, randomized, double-blind clinical study, Ann. Surg. 186 (1977) 251–259.

[11] D.G. Jagelman, T.C. Fabian, R.L. Nichols, H.H. Stone, S.E. Wilson, S.R. Zellner, Single-dose cefotetan versus multiple-dose cefoxitin as prophylaxis in colorectal surgery, Am. J. Surg. 155 (1988) 71–76.

[12] A.B. Kaiser, J.L. Herrington, J.K. Jacobs, J.L. Mulherin, A.C. Roach, J.L. Sawyer, Cefoxitin versus erythromycin, neomycin, and cefazolin in colorectal operations. Importance of the duration of the surgical procedure, Ann. Surg. 198 (1983) 525–530.

[13] J. Goldring, W. McNaught, A. Scott, G. Gillespie, Prophylactic oral antimicrobial agents in elective colonic surgery. A controlled trial, Lancet 2 (7943) (1975) 997–1000.

[14] D.J. Schoetz Jr., P.L. Roberts, J.J. Murray, J.A. Coller, M.C. Veidenheimer, Addition of parenteral cefoxitin to regimen of oral antibiotics for elective colorectal operations. A randomized prospective study, Ann. Surg. 212 (1990) 209–212.

[15] R. Tang, H.H. Chen, Y.L. Wang, C.R. Changchien, J.S. Chen, K.C. Hsu, et al., Risk factors for surgical site infection after elective resection of the colon and rectum: a single-center prospective study of 2,809 consecutive patients, Ann. Surg. 234 (2001) 181–189.

[16] M. Daabiss, American Society of Anaesthesiologists physical status classification, Indian J. Anaesth. 55 (2011) 111–115.

[17] G. Mathew, R. Agha, for the STROCSS Group, STROCSS 2021: Strengthening the Reporting of cohort, cross-sectional and case-control studies in Surgery, Int. J. Surg. 96 (2021), 106165.