Predictive value of bacterial analysis of laparotomy wounds

Ann. Ital. Chir., 2014 85: 292-297
pii: S0003469X1402185X

Mario Minutolo*, Giovanna Blandino*, Manuel Arena**, Alessio Licciardello**, Biagio Di Stefano**, Raffaele Lanteri**, Stefano Puleo**, Antonio Licata**, Vincenzo Minutolo**

Hospital University of Catania, Catania, Italy
**Department of Microbiological Sciences*
***Department of Surgical Sciences, Organ Transplants and Advanced Technologies*

READ-ONLY COPY
PRINTING PROHIBITED

Predictive value of bacterial analysis of laparotomy wounds

BACKGROUND: *Despite improvements in antibiotic prophylaxis, surgical site infections represent the most common postoperative complication with important clinical consequences for patients.*
AIM: *The hypothesis that a bacterial analysis of the surgical wound in the operating room could predict the likelihood of developing a clinical infection, and might allow a tailored and preemptive approach, aimed to reduce the consequences of an infection, seems appealing. We would like to present a prospective study on the predictive value of the bacterial analysis of laparotomy wounds.*
MATERIAL OF STUDY: *Seventy eight prospective patients undergoing surgery were included in the study. To evaluate the risk factors associated with increased rate of wound infection, we performed a bacterial analysis of the wound.*
RESULTS*: 48 patients out of 78 (61%) had positive cultures. 23 patients out of 32 patients (72%) who didn't receive antibiotic prophylaxis were positive to the wound culture whereas 25 patients out of 46 patients (54%) grew positive cultures in the group of patients that received antibiotic prophylaxis. None of the 30 patients with negative cultures developed clinical infection. Only 6 patients out of 48 patients who had positive cultures (12.5%) developed wound infection. Clinical infection occurred in 5 patients who had gram-negative contamination of the wound. No clinical infection occurred in patients who had gram-positive contamination.*
CONCLUSION: *Wound cultures and their positivity are predictive tools to identify the patients that are at risk to develop wound infection. The positive predictive value of the bacterial analysis of the wound was 12.5%.*

KEY WORDS: Abdominal surgery, Bacterial analysis, Wound infection

Introduction

Nowadays, despite improvements in antibiotic prophylaxis, surgical site infections represent the most common postoperative complication with important clinical consequences for patients. In 2006, it is estimated that more than 30 millions of surgical interventions were performed in USA and according to the National Nosocomial Infections Surveillance (NNIS), infections occurred in 2.6% of the cases [1,2].

Infections of the wound after surgical interventions have a negative impact on the recovery leading to both further surgical intervention and, in rare cases, to the demise of the patient [1].

Surgical Infections increase medical costs by prolonging the hospital stay, by increasing antibiotic usage and causing implementation of measures such as surgical therapy, home care therapy and nursing assistance. The economical burden of all of these factors is further worsened by the psychological effects on the patients' well being who suffer from prolongation of the pain and are unable to return to work in a timely fashion [3].

Pervenuto in Redazione Maggio 2013. Accettato per la pubblicazione Ottobre 2013.
Correspondence to: Professor Vincenzo Minutolo, Via Stazzone 178, 95124 Catania, Italy (e-mail: minutolov@hotmail.com)

TABLE I - *Main characteristics of the patients of the study who had positive cultures*

Pat.	Sex	Age	Intervention	Antibiotic prophylaxis	Class	Time of intervention (min)	Species	Infection
1	M	72	Nephrectomy	ciprofloxacin	II	125	S. epidermidis	
2	M	69	Hernioplasty	piperacillin/tazobactam	I	40	S. epidermidis	
3	M	66	Hernioplasty	No	I	55	S. epidermidis	
4	M	54	Laparoscopic cholecystectomy	piperacillin/tazobactam	II	60	S. aureus	
5	M	62	Hernioplasty	No	I	30	S. epidermidis	
6	F	72	Anterior resection of rectum	imipenem+metronidazole	III	200	S. epidermidis	
7	M	19	Liver suture	piperacillin/tazobactam	II	110	S. epidermidis	
8	M	36	Laparoscopic cholecystectomy	piperacillin/tazobactam	II	45	S. epidermidis	
9	M	65	Hernioplasty	No	I	35	S. epidermidis	
10	M	48	Hernioplasty	No	I	60	S. epidermidis	
11	M	75	Hernioplasty	No	I	45	S. epidermidis	
12	M	50	Laparoscopic cholecystectomy	piperacillin/tazobactam	II	55	S. epidermidis	
13	M	47	Right hemicolectomy	imipenem+metronidazole	III	130	S. hominis	
14	M	65	Right hemicolectomy	imipenem+metronidazole	III	140	B. fragilis	B. fragilis
15	F	58	Splenectomy	No	II	110	B.fragilis	B. fragilis
16	M	86	Right hemicolectomy	imipenem + metronidazole	III	120	S. epidermidis	
17	F	35	Hernioplasty	No	I	35	S. epidermidis	
18	M	56	laparoscopic cholecystectomy	piperacillin/tazobactam	II	60	S. epidermidis	
19	F	75	Hernioplasty	No	I	40	S. epidermidis	
20	F	75	Left hemicolectomy	imipenem + metronidazole	III	180	S. epidermidis	
21	M	66	Hernioplasty	No	I	35	S. epidermidis	
22	M	62	Left hemicolectomy	imipenem + metronidazole	III	170	S. epidermidis	
23	M	75	Hernioplasty	No	I	40	S. xilosus	
24	M	71	Hernioplasty	No	I	50	S. epidermidis	
25	F	47	Ulcoraffia	No	II	130	E. coli	E. coli
26	F	31	Laparoscopic cholecystectomy	piperacillin/tazobactam	II	45	S. epidermidis	
27	M	34	Appendectomy	Ceftazidime	II	55	E. coli	
28	F	49	Hernioplasty (ileal resection)	No	III	75	E. cloacae	E.cloacae
29	M	57	Hernioplasty	No	I	50	E. aerogenes	
30	M	81	Left hemicolectomy	imipenem+metronidazole	III	190	S. epidermidis	
31	M	65	Laparoscopic cholecystectomy	piperacillin/tazobactam	II	50	S. marcescens	
32	M	67	Laparoscopic cholecystectomy	piperacillin/tazobactam	II	45	S. epidermidis	
33	M	61	Hernioplasty	No	I	30	E. coli	
34	M	77	Hernioplasty	No	I	40	S. hominis	
35	F	32	Hernioplasty	piperacillin/tazobactam	I	30	S. simulans	
36	M	37	Hernioplasty	No	I	45	E. coli	
37	M	69	Hernioplasty	piperacillin/tazobactam	I	40	S. epidermidis	
38	F	81	Right hemicolectomy	No	III	120	E. coli	E. coli
39	M	62	Left hemicolectomy	imipenem + metronidazole	III	170	S. epidermidis	
40	M	55	Hernioplasty	No	I	50	S. epidermidis	
41	M	66	Hernioplasty	No	I	50	S. epidermidis	
42	M	34	Hernioplasty	No	I	35	S. aureus	
43	M	57	Laparoscopic cholecystectomy	piperacillin/tazobactam	II	45	S.saprophyticus	
44	M	63	Total gastrectomy	imipenem	III	240	E. coli	
45	F	65	Laparoscopic cholecystectomy	imipenem	II	70	S. epidermidis	
46	M	66	Laparoscopic cholecystectomy	piperacillin/tazobactam	II	40	E. coli	
47	M	69	Hernioplasty	No	I	30	S. epidermidis	
48	M	58	Total gastrectomy	No	III	190	C. albicans	C. albicans

READ ONLY COPY PRINTING PROHIBITED

Prevention of surgical infections then seems to be an essential step in the management of the patients and a tailored antibiotic prophylaxis might be a useful adjunct to prevent infections. Furthermore, this intervention might lessen the psychological consequences on the patients and reduce the economical impact on medical resources.

The hypothesis that a bacterial analysis of the surgical wound in the operating room could predict the likelihood of developing a clinical infection, and might allow a tailored and preemptive approach, aimed to reduce the consequences of an infection, seems appealing [4,5].

We would like to present a prospective study on the predictive value of the bacterial analysis of laparotomy wounds and the relationship with clinical risk factors and type of antibiotic prophylaxis.

Materials and Methods

From January 2008 to December 2008 seventy-eight prospective patients undergoing surgery at the Department of Surgery of Guzzardi Hospital in Vittoria, Italy, were included in the study (Table I). We obtained informed consent from the patients after having received the approval from the Ethical Committee of the University of Catania. To evaluate the risk factors associated with increased rate of wound infection, we performed a bacterial analysis of the wound. The analysis was performed by swabbing the subcutaneous tissue of laparotomy wounds after fascia closure and before stapling of the skin.

Bacterial cultures were performed following standard procedures and using selective media (MSA agar, Columbia Agar with 5% sheep defibrinated blood, MacConkey agar). The agar plates were incubated in aerobic atmosphere at 37 °C for 24 h. Identification of bacteria was made by colony and cellular morphology, staining characteristics, motility test. Further bacterial identification was performed using biochemical tests of the VITEK system (bioMerieux) and API 20 A and rapid ID 32 A (bioMereux).

The samples from wound infections were cultured in selective media incubated in aerobic atmosphere and in atmosphere of 10% CO_2 at 37 °C for 48 h and in anaerobic atmosphere (80% N2, 10% H2 and 10% CO_2) at 37 °C for 72 h. The antimicrobial susceptibility was performed using VITEK system (BioMerieux).

The indications for the surgical interventions included clean cases such as incisional hernias, cholecystectomies, clean contaminated procedures such as colon resections and gastric resections and contaminated cases such as strangulated hernias and peptic ulcer perforations. Antibiotic prophylaxis was performed in 46 patients 1 hour prior to the incision of the skin (Table I). Twelve patients with neoplastic disease of the colon received mechanical bowel cleansing with 4 liters of polyethylenglycol solution.

Postoperative assessment of the wound was performed by 2 independent residents who were blinded to the results of the bacterial analysis. The follow up was performed for the duration of 4 weeks after surgery. Statistical analysis was performed using SPSS® statistical software (version 17.0 for Windows®). Yates Chi-squared test was applied for comparison of values. P value less than 0.05 was considered statistically significant.

Results

Forty-eight patients out of seventy-eight (61%) had positive cultures (47 were mono-microbial and only one was poli-microbial) (Table I).

Twenty-three patients out of thirty-two patients (72%) who didn't receive antibiotic prophylaxis were positive to the wound culture whereas twenty-five patients out of forty-six patients (54%) grew positive cultures in the group of patients that received antibiotic prophylaxis (chi square P=0,1840 no statistically significant).

None of the thirty patients with negative cultures developed clinical infection. Only six patients out of forty-eight patients who had positive cultures (12.5%) developed wound infection. The microorganisms responsible for the infection were E.coli in 2 cases, Bacteroides Fragilis in 2 cases, Enterobacter Cloacae in 1 case, Candida Albicans in 1 case. The positive predictive value of the bacterial analysis was 12.5%.

Out of the six cases of wound infections, five occurred in the cohort of patients that didn't undergo antibiotic prophylaxis (5/32, 15%) and only one in the cohort of patients that received antibiotic prophylaxis (1/46, 2.2%). At the univariate analysis a difference not statistically significant was found (P=0.07). Wound infection was more common in class 3 (5/19, 26%) when compared with class 1 and 2 cases pooled together (1/59, 1.6% chi square test statistically different P= 0.0026).

Among patients with positive culture 5 cases occurred in the cohort of patients whose operation was longer than 100 minutes (5/15, 33%) and only 1 wound infection occurred in the cohort of patients whose operation lasted less than 100 minutes (1/33, 3%) chi square analysis statistically significant (P=0.0134) (Table IV, V).

Thirty-five Gram -positive aerobic microorganisms and twelve Gram-negative microorganisms were isolated. One culture also grew positive for Candida Albicans (Table I). Gram positive bacteria isolated were: Staphylococcus aureus in 2 cases, Staphylococcus Epidermidis in 28 cases, Staphylococcus Hominis in 2 cases, Staphylococcus Saprophyticus in 1case, Staphylococcus Simulans in 1 case, Staphylococcus Xilosus in 1 case. Gram negative bacteria isolated were: Escherichia Coli in 7 cases, Enterobacter Spp in 2 cases, Bacillus Fragilis in 2 cases, Serratia Marcescens in 1 case (Table I, II).

Clinical infection occurred in five patients who had gram-negative contamination of the wound. No clinical infection occurred in patients who had gram-positive contamination (p value= 0,0005) (Table II).

The patterns of antibiotic susceptibility and resistance for the contaminant Gram- positive species are shown in Table III. The Staphylococci isolated were sensitive to Synercid and Vancomycin (Table III).

Coagulase negative Staphyococci (CNS) were found to be resistant to penicillin in 88% of cases, to oxacillin in 68% of the cases and to erythromycin in 62% of the cases.

All CNS were sensitive to synercid, vancomycin and minocycline. Resistance rate equal or more than 20% was shown for gentamycin, levofloxacin, cotrimoxazole and tetracycline among CNS positive cultures. Strains resistant to tetracycline were sensitive to minocycline and the majority of strains resistant to penicillin were sensitive to fusidic acid. Out of the two positive cultures of

READ-ONLY COPY PRINTING PROHIBITED

TABLE II - *Characteristics of patients and results of the bacteriology* analysis

Characteristics		Bacterial Culture	
		Positive	**Negative**
Total n. patients	78	48	30
(Male/Female)	(51/27)	(36/12)	(15/15)
Average age	59 (19-86)	58,5 (19-86)	58 (32-81)
Type of surgery	Number of patients and (%)	Right hemicolectomy 4 (5%) Lap. Cholecystectomy 9 (11%) Prosthetic hernioplasty 22 (28%) Left hemicolectomy 4 (5%) Low Anterior Resection. 1 (1%) Appendectomy 1 (1%) Gastrectomy1 (1%) Nephrectomy 1 (1%) Laparoscopic prosthetic plastic 1 Suture liver 1 (1%) Duodenal Ulcer Repair 1 (1%)	Right hemicolectomy 2(2%) Cholecystectomy 12(15%) Prosthetic hernioplasty11(14%) Left hemicolectomy 1(1%) L.A.R. 1(1%) Ileal resection 1(1%) Gastrectomy 1(1%) Laparoscopic plastic 1(1%) Exploratory laparotomy 1 (1%) Splenectomy 1 (1%) Fistulectomy 1 (1%)
Average duration of surgery in minutes.		**85**	72

TABLE III - *Sensitivity (%) and resistance (%) to several antibiotics Gram-positive bacteria isolated from wood swabs during surgery (%).*

Antibiotic	CNS (34)		*S. auerus* (2)	
	S (%)	R (%)	S (%)	R (%)
Penicillin	12	88		100
Oxacillin	32	68	50	50
Erithromycin	35	62		100
Clindamycin	91	6	100	
Synercid	100		100	
Vancomycin	100		100	
Gentamycin	76	20	50	50
Levofloxacin	58	26	50	
Cotrimoxazole	79	20		100
Tetracicline	70	26	100	
Minocycline	100		100	
Fusidic acid	79	6	100	

S.aureus one was resistant to penicillin, erythromycin and cotrimoxazole and one to oxacillin and gentamycin.
Fourtheen Staphylococcus spp cultures were resistant to more than 4 antibiotics.
All the cultures of Enterobacteriaceae (100%) were sensitive to imipenem, azthreonam, metilmicine and levofloxacin; seven out of eight cultures (87.5%) were sensitive to ticarcilli/clavulanic acid, cefotaxime, amikacin, gentamicin and cotrimoxazole, six out of 8 cultures (75%) to piperacillin, and four out of eight cultures (50%) were sensitive to amoxicillin/clavulanic acid. All cultures were resistant to amoxicillin (100%). The pattern of antibiotic sensitivity showed that the strains isolated from the infected wounds were the same strains isolated from the site of the surgery. The two strains of B.fragilis were resistant to amoxicillin, amoxicillin/clavulanic acid and cefotaxime and sensitive to levofloxacin and metronidazolo (data not showed).

Discussion

Post-operative wound infections still represent the most common hospital infection and they are the most important cause of morbidity after surgery [6,7]. Wound infections represent the most common infection after surgery (38%), they require antibiotic therapy and increase the length of stay in hospital as well as medical costs 8-11. The incidence of wound infections varies between 3% and 20% and it was 5.1% in our cohort of patients [12]. Routine clinical surveillance of the surgical wound is the recommended method to reduce the incidence of infections [11-16] and as Nichols et al. pointed out, the incidence of wound infections varies from surgeon to surgeon from hospital to hospital from patient to patient and is dependent on the type of surgical procedure performed [11,16,17]. Duration of surgery, cancer, contaminated procedures are all risk factors for clinical infection [6,14].
An adequate antibiotic prophylaxis, in patients at high risk for infection such as patients undergoing class 2 and 3 procedures and surgical procedures longer than 100 minutes, decreases the incidence of wound infection and it has been shown to be the best strategy [18,19].
The results of our study show that antibiotic prophylaxis doesn't decrease the risk of bacterial contamination of the wound in a statistical significant way (p value=0.1840). In our cohort of patients, wound infections

READ-ONLY COPY PRINTING PROHIBITED

TABLE IV - *Relationship between wound infection, surgical interventions longer than 100min and class of the surgical procedure*

Patients	Sex	Age	Intervention	Class	Minutes duration	Species	Infection
1	M	72	Nephrectomy	II	125	*S. epidermidis*	
2	F	72	Anterior resection of the rectum	III	200	*S. epidermidis*	
3	M	19	Suture repair of liver injury	II	110	*S. epidermidis*	
4	M	47	Right hemicolectomy	III	130	*S. hominis*	
5	M	65	Right hemicolectomy	III	140	*B. fragilis*	*B. fragilis*
6	F	58	Splenectomy	II	110	*B. fragilis*	*B. fragilis*
7	M	86	Right hemicolectomy	III	120	*S. epidermidis*	
8	F	75	Left hemicolectomy	III	180	*S. epidermidis*	
9	M	62	Left hemicolectomy	III	170	*S. epidermidis*	
10	F	47	Duodenal Ulcer Repair	II	130	*E. coli*	*E. coli*
11	M	81	Left hemicolectomy	III	190	*S. epidermidis*	
12	F	81	Right hemicolectomy	III	120	*E. coli*	*E. coli*
13	M	62	Left hemicolectomy	III	170	*S. epidermidis*	
14	M	63	Total gastrectomy	III	240	*E. coli*	
15	M	58	Total gastrectomy	III	190	*Candida albicans*	*Candida albicans*

TABLE V - *Relationship between wound infection and surgical procedures whose duration was less than 100 min and class of the surgical procedure.*

Patients	Sex	Age	Intervention	Class	Duration	Species	Infection
1	M	69	Hernioplasty	I	40	S. epidermidis	
2	M	66	Hernioplasty	I	55	S. epidermidis	
3	M	54	Laparoscopic Cholecystectomy	II	60	S. aureus	
4	M	62	Hernioplasty	I	30	S. epidermidis	
5	M	36	Laparoscopic Cholecystectomy	II	45	S. epidermidis	
6	M	65	Hernioplasty	I	35	S. epidermidis	
7	M	48	Hernioplasty	I	60	S. epidermidis	
8	M	75	Hernioplasty	I	45	S. epidermidis	
9	M	50	Laparoscopic Cholecystectomy	II	55	S. epidermidis	
10	F	35	Hernioplasty	I	35	S. epidermidis	
11	M	56	Laparoscopic Cholecystectomy	II	60	S. epidermidis	
12	F	75	Hernioplasty	I	40	S. epidermidis	
13	M	66	Hernioioplasty	I	35	S. epidermidis	
14	M	75	Hernioplasty	I	40	S. xilosus	
15	M	71	Hernioplasty	I	50	S. epidermidis	
16	F	31	Laparoscopic Cholecystectomy	II	45	S. epidermidis	
17	M	34	Appenectomy	II	55	E. coli	
18	F	49	Hernioplasty(ileal resection)	III	75	E. cloacae	E.cloacae
19	M	57	Hernioplasty	I	50	E. aerogenes	
20	M	65	Laparoscopic Cholecystectomy	II	50	S. marcescens	
21	M	67	Laparoscopic Cholecystectomy	II	45	S. epidermidis	
22	M	61	Hernioplasty	I	30	E. coli	
23	M	77	Hernioplasty	I	40	S. hominis	
24	F	32	Hernioplasty	I	30	S. simulans	
25	M	37	Hernioplasty	I	45	E. coli	
26	M	69	Hernioplasty	I	40	S. epidermidis	
27	M	55	Hernioplasty	I	50	S. epidermidis	
28	M	66	Hernioplasty	I	50	S. epidermidis	
29	M	34	Hernioplasty	I	35	S. aureus	
30	M	57	Laparoscopic Cholecystectomy	II	45	S. saprophyticus	
31	F	65	Laparoscopic plastic	II	70	S. epidermidis	
32	M	66	Laparoscopic Cholecystectomy	II	40	E. coli	
33	M	69	Hernioplasty	I	30	S. epidermidis	

READ-ONLY COPY PRINTING PROHIBITED

were more common if gram-negative organisms were isolated from the wound (p value=0,0005), in surgical procedures classified as class 3 (p value= 0,0026) and in procedures longer than 100 minutes (p value= 0,0134). In our study the positivity of the cultures was not decreased by the antibiotic prophylaxis and was not related to the age of the patients. The infection was more frequent in male patients than female patients (p value= 0,0123). The wounds of patients operated for inguinal hernia had more microbial contamination than the laparo-

scopic cholecistectomy wounds (68% vs 43% respectively, p value=0,36) (Table I, II) but none of the prostheses used got infected. Wound contamination was more frequent in patients undergoing bowel resection (75%). Sensitivity results showed that 88% of CNS was resistant to penicillin, 68% to oxacillin and 62% to erythromycin. With regards to aerobic gram-negative bacilli they showed a high resistance to amoxicillin (100%); the adjunct of clavulanic acid overcame the resistance in 50% of the cases.

Conclusions

Wound cultures and their positivity are predictive tools to identify the patients that are at risk to develop wound infection. Wound infection is more common in patients whose wounds are contaminated by gram-negative bacteria, in surgical procedures longer than 100 minutes and in class 3 surgeries. The positive predictive value of the bacterial analysis of the wound was 12.5%. Negative wound cultures are not associated with wound infection. In view of these results, proper identification of patients at risks for wound infection and subsequent antibiotic prophylaxis may prevent wound infection with reduction of medical costs, morbidity and hospital stay.

Riassunto

Malgrado i progressi nella profilassi antibiotica, l'insorgenza di una infezione del sito chirurgico rappresenta ancora oggi la complicanza postoperatoria più frequente ed un evento che può comportare conseguenze cliniche rilevanti. Si stima che nel 2006 negli Stati Uniti sono stati effettuati più di 30 milioni di interventi chirurgici e secondo i dati del National Nosocomial Infections Surveillance (NNIS) l'infezione del sito chirurgico si è verificata nel 2,6%.
L'infezione del sito chirurgico è un evento imprevisto che complica il decorso post-operatorio di un paziente ed incide negativamente sui risultati e può essere causa di ulteriori interventi chirurgici che potrebbero comportare il decesso del paziente. Inoltre l'analisi batteriologica della ferita chirurgica potrebbe costituire un metodo predittivo di infezione del sito chirurgico dopo chirurgia elettiva addominale. La profilassi antibiotica è utile nel prevenire l'infezione della ferita e limitare gli effetti negativi della infezione sul paziente.
Questo lavoro descrive un studio retrospettivo batteriologico, attraverso l'analisi microbiologica dei tamponi eseguiti nei tessuti molli delle ferite laparotomiche, dopo la chiusura della parete muscolare dell'addome. Il valore predittivo del campionamento batterico viene valutato correlando i germi che più frequentemente sono coinvolti nel determinismo della contaminazione della ferita e i fattori di rischio di infezione della ferita nel corso dell'intervento chirurgico addominale. Inoltre viene valutato il ruolo della profilassi antibiotica nella prevenzione dell'infezione della ferita laparotomica.

References

1. Donald E Fry, Rosemary V Fry: *Surgical Site Infection: The Host Factor.* Aorn Journal, 2007; 86(5): 801-14.

2. Fabiano G, Pezzolla A, Filograna MA, Ferrarese F: *Fattori di rischio di infezione in chirurgia.* Ann Ital Chir, 2004; 75(1): 11-16.

3. Graf K, Ott E, Vonberg RP, Kuehn C, Schilling T, Haverich A, Chaberny IF: *Surgical site infections. Economic consequences for the health care system.* Langenbecks Arch Surg, 2011; 396(4): 453-59.

4. Fa-Si-Oen PR, Kroeze F, Verhoef LH, Verwaest C, Roumen RM: *Bacteriology of abdominal wounds in elective open colon surgery: A prospective study of 100 surgical wounds.* Clin Microbiol Infect, 2005; 11(2):155-57.

5. John MA, Bohnen MD: *Antibiotic therapy for abdominal infection.* World J Surg, 1998; 22:152-57.

6. Velasco E, Thuler LCS, Martins S, Dias LMC, Conalves C: *Risk factors for infectious complications after abdominal surgery for malignant disease.* AJIC, 1996; 24(1):1-6.

7. Song X, Cosgrove SE, Pass MA, Perl TM: *Using hospital claim data to monitor surgical site infections for inpatient procedures.* AJIC, 2008; 36:532-36.

8. Malone DL, Genuit T, Tracy K, Gannon C, Napolitano LM: *Surgical site infections: Reanalysis of risk factors.* Journal of Surgical Research, 2002; 103:89-95.

9. Neville HL, LALLY KP: *Pediatric surgical wound infections.* Seminars in Pediatric Infectious Diseases, 2001; 12 (2):124-29.

10. Persson M, Linden J: *Intraoperative CO_2 insufflation can decrease the risk of surgical site infection.* Medical Hypotheses, 2008; 71:8-13.

11. Kusachi S, Kashimura N, Konishi T, et al.: *Length of stay and cost for surgical site infection after abdominal and cardiac surgery in Japanese hospitals: multi-center surveillance.* Surg Infect (Larchmt), 2012; 13(4):25.

12. Smyth ETM, Emmerson AM: *Surgical site infection surveillance.* Journal of Hospital Infection, 2000; 45:173-84.

13. Leong G, Wilson J, Charlett A: *Duration of operation as a risk factor for surgical site infection: Comparison of English and US data.* Journal of Hospital Infection, 2006; 63:255-62.

14. Miki C, Inoue Y, Mohri Y, Kobayashi M, Kusunoki M: *Site-specific patterns of surgical site infections and their early indicators after elective colorectal cancer surgery.* Dis Colon Rectum, 2006; 49(10):545-52.

15. Vilar-Compte D, Roldan R, Sandoval S, Corominas R, De La Rosa M, Gordillo P, Volkow P.: *Surgical site infections in ambulatory surgery: A 5-year experience*. AJIC, 2001; 29 (2):99-103.

16. Wick EC, Hobson DB, Bennett JL, et al: *Implementation of a surgical comprehensive unit-based safety program to reduce surgical site infections.* J Am Coll Surg, 2012; 215(2):193-200.

17. Macbeth D, Gardner G, Wallis M, Gerrard J: *Surgeons' perspectives on surgical wound infection rate data in Queensland, Australia.* AJIC, 2005; 33:97-103.

18. Noleen J Bennett, Ann L Bull, David R Dunt: *Surgical antibiotic prophylaxis in smaller hospitals.* ANZ J Surg, 2006; 76:676-78.

19. Cannon JA, Altom LK, Deierhoi RJ, et al.: *Preoperative oral antibiotics reduce surgical site infection following elective colorectal resections.* Dis Colon Rectum, 2012; 55:1160-166.

READ-ONLY COPY PRINTING PROHIBITED