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Full Length Research Paper

A prospective surveillance of surgical site infections: Study for efficacy of preoperative antibiotic prophylaxis

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To estimate the incidence and risk factors of surgical site infections, to determine the antimicrobial susceptibility pattern among the organisms isolated and to assess the ability of our protocol for preoperative antibiotic prophylaxis to prevent surgical site infections (SSI), a prospective SSI surveillance in Cairo University hospital using the criteria of the Centers for Disease Control of elective procedures, 881 patients were recruited in six months. Data of surgical procedures, and preoperative antibiotic prophylaxis were collected. Patients were followed up for 30 days after surgery. The incidence of SSI infections was 9.2%. A significant increase was associated with a prolonged preoperative hospital stay, prolonged surgery, contaminated wounds and presence of the drain. The most common organism was *Staphylococcus aureus* (24.3%) then *Klebsiella pneumonia* (18.5%). MRSA constituted 68% of *S. aureus*, ESBL-producing Gram negative bacilli 41.8% and multidrug-resistant 25.4%. This is an insight to risk factors associated with SSI, the causative pathogens and their sensitivity in our hospital that can help in updating the preoperative antimicrobial prophylaxis.

Key words: Surgical site infection, surveillance, preoperative antibiotics policy, antimicrobial prophylaxis.

INTRODUCTION

Surgical site infections are the third most commonly reported nosocomial infection and they account for approximately a quarter of all nosocomial infections (Mangram et al., 1999). They have been responsible for the increasing cost, morbidity and mortality related to surgical operations and continues to be a major problem even in hospitals with most modern facilities and standard protocols of preoperative preparation and antibiotic prophylaxis (Yalcin et al., 1995). The surgical site infection rate has varied from a low of 2.5% to a high of 41.9% (Anvikar et al., 1999). For optimal prophylaxis, an antibiotic with a targeted spectrum should be administered at sufficiently high concentrations in the serum, tissue, and the surgical wound during the entire time, that the incision is open and at risk of bacterial contamination (Craig, 1998).

The use of antimicrobial prophylaxis for selected surgical procedures is one of the measures used to prevent the development of a surgical site infection (SSI) (Mangram et al., 1999). Hence, an ongoing surveillance could play a significant role in the early recognition of a problem and hence, there is a need for early intervention for better management of postoperative wound infections (Kamat et al., 2008). The present study was conducted to estimate the incidence and risk factors of surgical site infections, to determine the antimicrobial susceptibility pattern among the most common bacteria which are associated with postoperative wound infections and to evaluate the preoperative antibiotic prophylaxis (PAP) prescriptions in prevention of surgical site infections (SSI).

PATIENTS AND METHODS

Setting

The study was done on 881 patients who were admitted to five different surgical departments (one for general surgery, one for

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vascular surgery, two for gastrointestinal surgery and one mainly for breast and vascular surgery) at Kasr El-Aini teaching hospital, Cairo University within the duration of 6 months from April to September 2010. The study was limited to frequently performed procedures for which antimicrobial prophylaxis is recommended by the antimicrobial committee of Kasr El-Aini hospital. Surgical departments are divided into two wards one for males and the other for females, with a capacity of 20 to 25 patients in each ward.

Case definition

According to CDC cases are those patients who had infected within 30 days of the operative procedure and involves only the skin or subcutaneous tissue of the incision, this is in case that there is no implant inserted while in case there is implant inserted the duration of the surveillance and follow up for wound infection should be extended up to one year (Petherick et al., 2006).

Data collection

For each patient, the following data was collected:

1) Patients' basic demographic data.
2) Data on surgical procedures: Details that were recorded include the type of surgery by wound class, clean surgeries (Class I-operative wound) / clean-contaminated surgeries (Class II-operative wound), contaminated surgeries (Class III-operative wound) (Wong, 2004).

Only elective procedures were included, so that the normal daily routine of administering antimicrobial prophylaxis would be observed. To avoid assessment of procedures in which antibiotics were given for therapeutic reasons rather than prophylactic, procedures with a dirty or infected wound (that is, wound contamination class IV) was excluded. Risk factors for SSI were recorded namely length of preoperative hospital stays, the duration of the surgical procedure and if the drain was used.

Data on antimicrobial prophylaxis were used according to the antimicrobial prophylaxis guidelines recommended by the antimicrobial committee of Kasr El-Aini hospital. The recommended antibiotic was given 30 min preoperatively with re-dosing the antibiotic at 3 h interval in procedures lasting more than 3 h. An additional dose of prophylactic antibiotic is given if blood loss is greater than 1500 ml (Woods and Dellinger, 2008). 1.5 g ampicillin-sulbactam was given IV as the antimicrobial prophylaxis for clean operations, a combination of ampicillin-sulbactam and 2 to 3 mg/kg gentamicin or 500 mg metronidazole IV for clean-contaminated operations, while ampicillin-sulbactam and metronidazole or metronidazole alone were given for contaminated operations (Mangram et al., 19991; Woods and Dellinger, 2008; National Nosocomial Infections Surveillance (NNIS), 1996)

Surgical wounds were inspected at the time of first dressing and weekly thereafter for 30 days. Wound infection was diagnosed if any one of the following criteria were fulfilled: serous or non-purulent discharge from the wound, pus discharge from the wound, serous or non-purulent discharge from the wound with signs of inflammation (edema, redness, warmth, raised local temperature, fever > 38°C, tenderness, induration) and wound deliberately opened up by the surgeon due to localized collection (serous/purulent). Stitch abscesses were excluded from this study (Petherick et al., 2006).

Swabs obtained from wound suspected to be infected were subjected to Gram staining, culture on blood and MacConkey agar. Identification of isolated microorganisms was done according to routine microbiological identification (Rouff, 2009; Schreckenberger et al., 2009) and for non-lactose fermenter isolates API 20NE was performed for identification of the isolate to the species level. Antimicrobial susceptibility testing was performed using the disk diffusion method as described by the Clinical and Laboratory Standards Institute (CLSI) (2009). Antimicrobial disks used were obtained from Mast diagnostics, England. *Staphylococcus aureus* strains isolated from infected surgical wounds were tested for methicillin resistance. For Gram-negative isolates, the extended spectrum β-lactamase (ESBL) phenotypic screening and confirmatory tests were done according to CLSI. *Escherichia coli* ATCC 25922, *S. aureus* ATCC 29213 and *Pseudomonas aeruginosa* ATCC 27853 were used as quality control strains. Interpretative criteria for each antimicrobial tested were those recommended by the CLSI.

Data was analyzed using SPSS version 10.0 for windows and results were expressed as a percentage, mean and median. Association of SSI with different variables was determined univariate, followed by multivariate analysis and expressed as an Odds Ratio (OR). The variables were shown to be significant on univariate analysis (p value < 0.05) were considered for multivariate analysis. Odds Ratio, 95% confidence interval and p values were calculated. A p value < 0.05 was considered significant.

RESULTS

The total number of patients enrolled in the study was 881 (375 males and 506 females). The mean age of the patients was 34.12 ± 18.95 years (range 0.5 to 80 years). Surgical site infections occurred in 82 of the 881 cases (9.2%). The median day of documentation of surgical site infection was 10.5 days after surgery (range 5 to 16). The surgical site infection rate was 8.2% in clean surgeries, 13.8% in clean-contaminated surgeries and 10.1% in contaminated surgery, a statistically insignificant difference (P > 0.05). Taking the clean wound as the reference, clean – contaminated wounds have no risk, the risk (O.R =1.801) to get infected with 95% C.I, ranges (0.982 to 3.302). Contaminated wounds have no risk (O.R =1. 258) to get infected with 95% C.I, ranges from (0.718 to 2.203) (Table 1). Analysis of different risk factors associated with the occurrence of SSI is shown in Table 1. None of the patients who were operated within the first two days of admission to the ward had a surgical site infection and the difference was found to be statistically significant (P = 0.0034).

In clean surgeries, the highest infection rate was seen in abdominal exploration (60%), followed by splenectomy (40%) while patients with surgeries for nerve repair had no surgical site infection (Table 2). In clean-contaminated surgeries, the infection rate was higher in patients with amputation surgeries (25%) while patients with salivary gland surgeries had no surgical site infection (Table 2).

In contaminated surgeries, the highest infection rate occurred in patients with colonic diseases and tumors (10.8%) (Table 2). One of 82 infected wounds was culture negative. From the remaining 81 infected wounds, a total of 103 isolates were recovered. The most commonly isolated microorganisms were demonstrated in Table 3. Different species of microorganisms isolated in different wound classes were shown in Table 4. All the 25 *S. aureus* strains were resistant to penicillin. 17 out of

Table 1. Analysis of different risk factors associated with SSI.

Operative-related risk factors	Total number (881)	Number infected (%)	% within all infected n=82	Odds ratio	95%CI	P-value
Operative time						
< 3 h	589	35(5.9)	42.7			
> 3 h	292	47(16.1)	57.3			< 0.001
Postoperative fever						
Yes	471	26(5.5)	31.7			
No	410	56(13.7)	69.3			
Wound class						
Clean	576	47(8.2)	57.3	**Reference**		
clean – contaminated	116	16(13.8)	19.5	1.801	0.982-3.302	>0.05
Contaminated	189	19(10.1)	23.2	1.258	0.7180-2.203	
Endoscopy	48	1(2.1)	1.2			
Drain	602	45(5.1)	54.9			
No drain	197	37(4.1)	45.1			<0.001
Antibiotic related risk factors						
Preoperative antibiotic						
Given	881	82(9.3)	100			
Not		0				

Table 2. Infection rate in various surgeries.

Operation	Number performed (%)	Number infected (%)
Clean		
Thyroid	78 (8.85)	5 (6.4)
Vascular	74 (8.3)	11 (14.9)
Skin	91 (10.3)	3 (3.3)
Lymph node	13 (1.46)	1 (7.7)
Nerve	12 (1.36)	0 (0)
Hernias	143 (16.23)	13 (9.1)
Breast	107 (12.1)	8 (7.5)
Spleen	5 (0.56)	2 (40)
Gall bladder (laparoscopic)	48 (5.44)	1 (2.1)
Abdominal exploration	5 (0.57)	3 (60)
clean – contaminated		
Gall bladder (open)	105 (11.9)	14 (13.3)
Salivary Gland	3 (0.34)	0 (0)
Amputation	8 (0.9)	2 (25)
Contaminated		
Colonic diseases and tumors	111(12.6)	12 (10.8)
Genital	27 (3.06)	2 (7.4)
Anal	51 (5.7)	5 (9.8)
Total	881 (100)	82 (9.2)

Table 3. Frequency of various pathogens causing surgical site infection.

Organisms	Number of isolates (%)
Staphylococcus aureus	25 (24.3)
Klebsiella spp.	19 (18.5)
E. coli	18 (17.5)
Pseudomonas aeruginosa	15 (14.6)
Acinetobacter baumannii	8 (7.8)
Coagulase-negative Staphylococcus	7 (6.8)
Proteus spp.	5 (4.9)
Enterococcus spp.	3 (2.9)
Provedencia spp.	1 (0.9)
Non-hemolytic *Streptococci*	1 (0.9)
Citrobacter spp.	1 (0.9)
Mixed infection	20 (19.4)
Total	103

25 (68%) strains were methicillin resistant *S. aureus* (MRSA). The highest rates of MRSA infection occur among clean operation (26.1%) followed by clean-contaminate wounds (20%) then contaminated wounds (6.3%). Co-resistance of MRSA to other antibiotic classes was illustrated in Figure 1.

Fortunately, all MRSA isolates were found sensitive to vancomycin both by MIC and disc diffusion methods. Extended spectrum β-lactamase producing Gram negative bacilli (ESBL) constituted 41.8% of all Gram negative bacilli isolated, 61.1% among *E. coli* isolates, 60.7% among *Klebsiella pneumonia* isolates, and 40% in *P. aeruginosa.* Isolates that exhibit ESBL showed co-resistances to sulfamethoxazole-trimethoprim (24.7%), gentamicin (21.4%), fluoroquinolones (16.5%), amikacin (9.7%) and 3.6% to carbapenems. 25.4% of Gram negative bacilli were multidrug-resistant (MDR) which is defined as isolates intermediate or resistant to at least three drugs in the following classes: β-lactams, carbapenems, aminoglycosides, and fluoroquinolones (Obritsch et al., 2005), 87.5% of *Acinetobacter baumannii* were MDR, 26.6% of *E. coli* isolates, 20% of *P. aeruginosa* and 5.9% of *K. pneumonia* isolates.

The patterns of resistance to colistin and polymyxin were studied by using MIC method (E-test) and disc diffusion method for ESBL-producers and MDR among the most commonly isolated Gram negative bacilli (Table 5). In clean operations were ampicillin-sulbactam is used as the prophylactic antibiotic, a high percentage of resistance to that antibiotic was demonstrated by most of the organisms isolated from this kind of wound. All isolates of *S. aureus, Klebsiella* spp., *E. coli, P. aeruginosa* and *A. baumannii* isolated from clean-contaminated or contaminated wounds were found to be resistant to the antibiotic used as prophylaxis.

DISCUSSION

The overall surgical site infection rate in the present study was 9.23%. The surgical site infection rate reports have differed considerably, some authors reported similar figures, 7.3 in a study done in Nepal (Giri et al., 2008) and 8.95% in an Indian study (Lilani et al., 2005). Lower figures were reported by other authors, 5.2% in a study done in Italy (Petrosillo et al., 2008), 4.3% in a study in Netherlands and 3.1% in another study in the United Kingdom (Geubbels et al., 2000). On the other hand, higher figures ranging from 14 to 22% were reported previously (Petherick et al., 2006; Wilson, 2008; Maksimović et al., 2008). Taking the clean wound as the reference, clean to contaminated wounds have no risk (O.R =1.801) to get infected with 95% C.I, contaminated wounds have no risk also (O.R =1.258) to get infected with 95% C.I. Other authors in India (Anvikar et al., 1999; Lilani et al., 2005), Mexico (Porras-Hernadez et al., 2003) and the United States (Gaynes et al., 1998) found an increase in surgical site infection rate with the increase in the degree of wound contamination.

In our study, the highest infection rate was seen in abdominal exploration (60%), followed by splenectomy (40%). Similarly, Petrosillo et al. (2008) found that higher infection rates were noted after colon resection, gastric and esophageal operations, cholecystectomy and intestinal tumor resection. In our study, analysis of risk factors associated with SSI demonstrated that the length of operation is a significant risk factor as operations lasted more than 3 h were associated with higher SSI (16.1%) compared to operations lasted less than 3 h (5.9%). In accordance, previous studies had found that the duration of operation is a significant risk factor in SSI (Varik et al., 2010). In our study, we found that the use of drain is also a significant risk factor, as the SSI rate in patients who had drains was more than those without drains (54.9% compared to 45.1%). Similar observations were found by other authors (Porras-Hernadez et al., 2003; Varik et al., 2010). We found that none of the patients who were operated within the first two days of admission to the ward had a surgical site infection and a significant increase in rate of surgical site infection was found with a prolonged stay in the hospital before the surgery. Other authors reported the same finding and stated that prolonged preoperative stay with exposure to the hospital environment and its ubiquitous diagnostic procedures, therapies and microflora have been shown to increase the rate of surgical site infection (Anvikar et al., 1999; Lilani et al., 2005; Petrosillo et al., 2008; Lul et al., 2007). In our study, the most widely isolated organisms were *S. aureus* (24.3%) followed by *K. pneumoniae* (18.5%), *E. coli* (17.5 %) and *P. aeruginosa* (14.6%). Mixed infection constituted 19.4%. Similarly other authors reported *S. aureus* as the most prevalent pathogen in SSI (Mangram et al., 1999; Lilani et al., 2005; Takeyama et al., 2005).

Based on the type of surgical procedure, the pathogens

Table 4. Frequency of various pathogens in relation to wound class.

Organism	Clean wounds (% within the wound class)	Clean-contaminated wounds (% within the wound class)	Contaminated wounds (% within the wound class)
Staphylococcus aureus	15 (32.6)	6 (30)	4 (25)
Klebsiella pneumoniae	10 (21.7)	5 (25)	4 (25)
Escherichia coli	10 (21.7)	3 (15)	5 (31)
Pseudomonas aeruginosa	9 (16.9)	4 (20)	2 (12.5)
Acinetobacter baumannii	4 (8.7)	3 (15)	1 (6.3)
Coagulase-negative Staphylococcus	4 (8.7)	2 (10)	1 (6.3)
Proteus spp.	4 (8.7)	0	1 (6.3)
Enterococcus spp.	1 (2.2)	1 (5)	1 (6.3)
Provedencia spp.	1 (2.2)	0	0
Non-hemolytic *Streptococci*	0	1 (5)	0
Citrobacter spp.	1 (2.2)	0	0

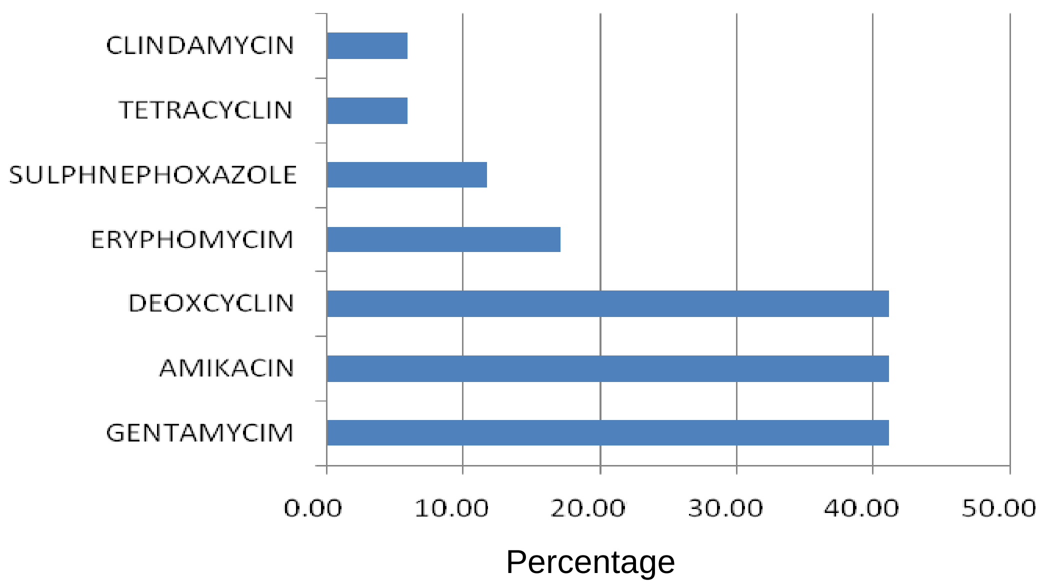

Figure 1. Co-resistance of MRSA to antibiotic classes.

that are isolated from surgical site infections vary. It is found that in clean and clean-contaminated surgical procedures, *S. aureus* was a prevalent organism (32.6 and 30% respectively) whereas in the contaminated wounds the most prevalent organism was *E. coli* (31%). Similar findings were reported in previous studies and the authors stated that in clean and clean-contaminated wounds *S. aureus* from the exogenous environment or the patient's skin flora is the usual pathogen, whereas, in other categories of surgical procedures, including contaminated and dirty wounds, the polymicrobial flora closely resembling the normal endogenous microflora of the surgically resected organ are the most frequently isolated pathogens (Nichols, 1991). In the present study, all *S. aureus* strains isolated from infected wound were resistant to penicillin. Ineffectiveness of penicillin in *S. aureus* has been reported in other studies (Anvikar et al., 1999). Seventeen out of thirty two (53.12%) strains of *S. aureus* were methicillin-resistant but none of the strains were resistant to vancomycin by disc diffusion and E-test.

Other authors reported lower figures for MRSA in SSI ranging from 33 to 37% (Lul et al., 2007; Takeyama et al., 2005).

Some authors suggest that doxycycline in combination with metronidazole is a candidate that should be considered for prophylaxis in areas with high prevalence of MRSA, as it is known as a safe drug causing few clinically important side effects (Baatrup et al., 2009). In our study, ESBL constituted 41.8% of all Gram negative bacilli isolated, 61.1% among *E. coli* isolates, 60.7% among *K. pneumonia* and 40% in *P. aeruginosa.* Isolates that exhibit ESBL showed co-resistances to

Table 5. Relation between different resistance pattern and sensitivity to colistin and polymyxin B by both disc diffusion and MIC.

Organism (Total number)	ESBL			MDR		
	Total ESBL among the spp.	MIC (% of resistant isolates)	Disc diffusion (% of resistant isolates)	Total MDR among the spp.	MIC (% of resistant isolates)	Disc diffusion (% of resistant isolates)
P. aeruginosa(15)	6/15 (40%)	4/15 (26.6%)	3/15 (20%)	3/15 (20%)	3/15 (20%)	0
E. coli (18)	11/18 (61.1%)	4/18 (22.2%)	2/18 (11.1%)	4/18 (26.6%)	3/18 (16.6%)	1/18 (5.5%)
A. baumannii (8)	0	0	0	7/8 (87.5%)	2/8 (25%)	0

sulfamethoxazole-trimethoprim (24.7%), gentamicin (21.4%), fluoroquinolones (16.5%), amikacin (9.7%) and 3.6% to carbapenems. Other authors reported lower figures of ESBL co-resistance (Alicia et al., 2008; Jones et al., 2005). 25.4% of Gram negative bacilli were multidrug-resistant (MDR), 87.5% of *A. baumannii* were MDR, 26.6% of *E. coli* isolates, 20% of *P. aeruginosa* and 5.9% of *K. pneumonia* isolates. In our study, resistance to polymyxin and colistin were detected in 25% of *A. baumannii* by MIC method but not detected in any isolate by disc diffusion, similarly by E-test resistance to polimxin and colistin were detected in 19.4% of *E. coli* isolates compared to disc diffusion (8.3%), the resistance rate was 23.3% in *P. aeruginosa* by E-test and 10% by disc diffusion.

In accordance with our results, other authors reported that MIC method is more reliable than disc diffusion in detecting resistance to polymyxin and colistin (Gales et al., 2001). In our study, the recommended preoperative antibiotic was given 30 min preoperatively to re-dosing the antibiotic at 3 h interval in procedures lasting more than 3 h, this regimen is recommended by other authors (Engelman et al., 2003).

Conclusion

The merit of the study was to start the active surveillance of surgical site infections based on standard definitions and methods to be maintained by cooperation of infection control practitioners and surgical team. Identification of risk factors for surgical site infections has encouraged the development of national recommendations for prevention of SSI in order to achieve the setting goal to reduce the SSI rates in Egypt.

Points for intervention could be reduced of duration of preoperative hospital stay, reduction in the duration of surgical procedures, avoid unneeded drains, in addition to initiation of standardized SSI active surveillance and feedback of relevant data to surgeons that can help to decrease in SSI rates.

In sight of the high incidence of MRSA, ESBL and MDR reported in our study, there is a need for continuous monitoring to determine the susceptibility pattern of the common isolates which are found in our hospital; to emphasize precise empiric therapy, policies on prescription patterns should be reviewed, which will ensure reduced patient stay, morbidity and cost per day in the hospital.

Preoperative screening of patients for colonization by MRSA, ESBL and MDR may be an issue to reduce surgical site infection by these organisms. Moreover, reinforcement of infection control measures is strongly recommended in order to prevent healthcare-associated infections.

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