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Microbiological profiles of tracheostomy patients: a single-center experience

Abdulaziz Alrabiah,[1,2] Khaled Alhussinan,[3] Mohammed Alyousef,[3] Ahmed Alsayed,[1] Abdullah Aljasser,[1] Shatha Alduraywish,[4] Ahmed Alammar[1]

[1]Department of Otolaryngology-Head & Neck Surgery, King Saud University Medical City, College of Medicine, King Saud University, Riyadh
[2]Department of Otolaryngology-Head & Neck Surgery, Prince Sultan Military Medical City, Riyadh
[3]King Saud University, College of Medicine, King Saud University Medical City, Riyadh
[4]Department of Family and Community Medicine, Prince Sattam bin Abdulaziz Research Chair for Epidemiology and Public Health, College of Medicine, King Saud University, Riyadh, Saudi Arabia

ABSTRACT

Background: This study compared the prevalence of common microorganisms in obstructed and non-obstructed cases across the four quarters on the first post-tracheostomy year.

Methods: A retrospective chart review of the microbiological profiles of all adult patients who underwent a tracheostomy was conducted between June 2015 and September 2019 at our hospital. Based on the tracheostomy indications, patients were allocated to obstructed or non-obstructed group. Any patient with at least one positive sample was followed up quarterly for a year. The first culture result obtained was recorded at least one month following the last antibiotic dose in each quarter.

Results: Out of the 65 tracheal aspirate results obtained from 58 patients (mean age, 57.5±16.48 years), the most common procedure and indications were surgical tracheostomy (72.4%) and non-obstructed causes (74.1%), respectively. Moreover, 47.7% of the culture results indicated *Pseudomonas aeruginosa*, which showed significantly different proportions across the quarters (p=0.006). Among obstructed patients, *P. aeruginosa* was the most common (35%), followed by methicillin-resistant *Staphylococcus aureus* (MRSA; 23.5%).

Conclusions: The most common post-tracheostomy microorganism was *P. aeruginosa*. MRSA showed a strong association with tracheostomy for obstructive indications.

Key words: Microbial colonization; methicillin-resistant *Staphylococcus aureus*; tracheal culture; tracheostomy; tracheotomy.

Introduction

A tracheostomy is a channel cut in the neck midline to connect the trachea to the skin, and it is among the oldest known surgical operations [1]. The most common indication for tracheostomy in adults is prolonged respiratory failure. Other indications include poor airway reflexes and decreased level of consciousness. Furthermore, a tracheostomy can be performed to bypass an obstruction, thereby facilitating tracheobronchial suction [2-4]. Bacterial colonization can occur following tracheostomy; specifically, microorganisms can colonize the tracheobronchial tree of patients with endotracheal tubes or tracheostomies, which increases the risk of respiratory events, especially those necessitating ventilatory assistance [5-7]. The rate of colonization (i.e., the presence of microorganisms without a corresponding host response) in adult patients who have undergone tracheostomy ranges from 80% to 100%; in contrast, 100% of pediatric patients develop colonization [1]. Persistent tracheobronchial colonization may increase the susceptibility to symptomatic infection and is associated with more clinical illnesses. Additionally, patients with persistent colonization undergo antibiotic treatment and develop purulent tracheobronchitis more frequently than patients without persistent colonization [8]. Pediatric patients undergoing open reconstruction procedures have a high prevalence rate of methicillin-resistant *Staphylococcus aureus* (MRSA; up to 32.5%). Studies have reported that preoperative treatment in patients with MRSA colonization results in no postoperative MRSA infections and similar postoperative infection rates as those in patients without MRSA colonization [9].

However, to the best of our knowledge, there have been few epidemiological studies on colonization associated with tracheostomy. This study aimed to describe the colonization distribution in the tracheal aspirate of all tracheostomy patients during the first post-tracheostomy year, in three-month increments and to compare the microbiological profiles of patients who underwent tracheotomy for obstructive indications *versus* those who underwent tracheostomy for non-obstructive indications. Further, we aimed to compare the demographic variables, indications for tracheostomy, and comorbidities of patients in both the groups.

Methods

In this retrospective study, 65 tracheal aspirate results obtained from 58 adult patients who underwent tracheostomy between June 2015 and September 2019 at King Saud University Medical City were reviewed. This study was approved by the Institutional Review Board of King Saud University Medical City (research project no. E-20-4606). The need for informed consent was waived due to the retrospective nature of the study. Basic demographic data, including age, sex, height, weight, body mass index (BMI), major underlying comorbidities (diabetes, hypertension, chronic pulmonary diseases, etc.), and type of surgical procedure were collected. The patients were divided into obstructed and non-obstructed groups based on the underlying tracheostomy indication. The inclusion criteria were as follows: patient age >18 years, tracheostomy performed within the designated time frame, and at least one positive microbiological sample taken from the patient from the date of surgery till one year thereafter. Moreover, we documented the date of tracheal aspiration associated with the surgical procedure. The first post-tracheostomy year was divided into four quarters (3 months each), with the first culture result obtained at least one month following the last antibiotic dose in each quarter being recorded.

Data were collected using Cerner, which is an electronic health record system (E-Sihi) with ensured patient privacy and confidentiality; therefore, all patient records were deidentified.

Statistical analysis

Categorical variables were presented as the total numbers and percentages of patients, while continuous variables were presented as means and standard deviations (SDs). Between-group comparisons of the categorical demographic variables were performed by using chi-square tests, and the p-values were reported based on Fisher's exact tests. Between-group comparisons of the continuous variables were performed using the analysis of two-sample *t*-tests, and the p-values were reported. The confidence intervals for the proportions were reported using the Z-statistic, while the proportions within the four quarters were compared using Fisher's exact tests. Confidence intervals for the relative risks were computed using the log-relative risks and their standard errors. Since

Table 1. Descriptive statistics of the demographic variables for patients who underwent obstructive or non-obstructive tracheostomy.

N	Tracheostomy indication			Chi-square/F-statistic	Relative risk/mean difference	p
	Non-obstructive 43	Obstructive 15	Total 58			
Sex				0.079		0.778
Female	19 (44.2%)	6 (40.0%)	25 (43.1%)		0.880 (0.36, 2.15)	
Male	24 (55.8%)	9 (60.0%)	33 (56.9%)			
Smoking status				1.199		0.273
Non-smoker	39 (90.7%)	12 (80.0%)	51 (87.9%)		1.821 (0.68, 4.89)	
Smoker	4 (9.3%)	3 (20.0%)	7 (12.1%)			
Type of tracheostomy				4.432		0.035*
Percutaneous	15 (34.9%)	1 (6.7%)	16 (27.6%)		0.188 (0.03, 1.31)	
Surgical	28 (65.1%)	14 (93.3%)	42 (72.4%)			
Age, years	60.44 (15.34)	49.13 (17.27)	57.52 (16.48)	5.664	-11.31 (-20.83, -1.79)	0.021*
Height, cm	160.37 (12.22)	161.23 (9.56)	160.60 (11.51)	0.061	0.86 (-6.12, 7.84)	0.806
Weight, kg	95.14 (35.37)	77.28 (16.30)	90.52 (32.39)	3.532	-17.86 (-36.9, 1.18)	0.065
BMI, kg/m²	39.44 (15.80)	29.59 (6.07)	36.89 (14.56)	5.492	-9.85 (-18.27, -1.43)	0.023*

Categorical and continuous variables are presented as N (%) and mean (SD), respectively; BMI, body mass index; *statistically significant.

the data available concerned the presence or absence of specific microorganisms for each patient, only proportions could be tested using Fisher's exact tests to compare the presence or absence of a microorganism among all the patients in each quarter; $p<0.05$ was considered statistically significant. All data were analyzed using SPSS software version 26 (IBM Corp., Armonk, NY, USA).

Results

Table 1 summarizes the demographic variables grouped based on the tracheostomy indications. Among the participants, 57% (n=33) were male, and the mean age was 57.5 years (SD=16.48). Only 12% of the participants were smokers. Most of the participants (72.4%) underwent surgical tracheostomy. There were no significant differences between the groups in sex; however, patients in the non-obstructed group were significantly older than those in the obstructed group (mean age, 60.44±15.34 years *vs* 49.13±17.27 years, p=0.021) There was a significant difference between the groups in the tracheostomy type (p=0.035). The non-obstructed group had a significantly higher average BMI than did the

obstructed group (F=5.592, p=0.023). The normality of the continuous measurements of age, height, weight, and BMI for the non-obstructed and obstructed groups were recorded using Shapiro-Wilk tests. Due to the small sample size, the test results were not accurate, but the p-values of the obstructed group were greater than 0.05, suggesting that they were not significantly different from normal. However, due to the presence of an outlier in the non-obstructed group, the measures appeared to be significantly different from the normal. Figures 1 and 2 show each patient's classification according to the tracheostomy indication. Forty-three patients (74.1%) underwent tracheostomy for reasons excluding airway obstruction. These patients were further grouped as either having decreased consciousness (39.5%) or in need of ventilatory support, usually due to respiratory failure (Figure 1). The remaining 15 patients (25.9%) underwent tracheostomy when the airway obstruction, including angioedema, bilateral vocal cord paralysis, head and neck tumor, and subglottic stenosis, was the primary cause (Figure 2). Table 2 summarizes the comorbidity statistics of the patients, grouped based on their tracheostomy indications. The non-obstructed group had a significantly higher proportion of patients with cardiovascular disease (72.1%), chronic kidney disease

Table 2. Summary statistics of comorbidities for patients who underwent obstructive or non-obstructive tracheostomy.

Comorbidity N	Tracheostomy indication			Chi-square	p
	Non-obstructive 43	Obstructive 15	Total 58		
Respiratory disease	6 (14.0%)	3 (20.0%)	9 (15.5%)	0.310	0.578
Cardiovascular disease	31 (72.1%)	5 (33.3%)	36 (62.1%)	7.096	0.008*
Chronic kidney disease	11 (25.6%)	0 (0.0%)	11 (19.0%	4.735	0.030*
Cancer	4 (9.3%)	2 (13.3%)	6 (10.3%)	0.195	0.659
Neurological/neuromuscular disease	8 (18.6%)	0 (0.0%)	8 (13.8%)	3.237	0.072
Metabolic disease	31 (72.1%)	5 (33.3%)	36 (62.1%)	7.096	0.008*
Musculoskeletal disease	2 (4.7%)	1 (6.7%)	3 (5.2%)	0.092	0.762
Infectious disease	1 (2.3%)	0 (0.0%)	1 (1.7%)	0.355	0.551
Gastroenterological disease	5 (11.6%)	1 (6.7%)	6 (10.3%)	0.295	0.587

*Statistically significant.
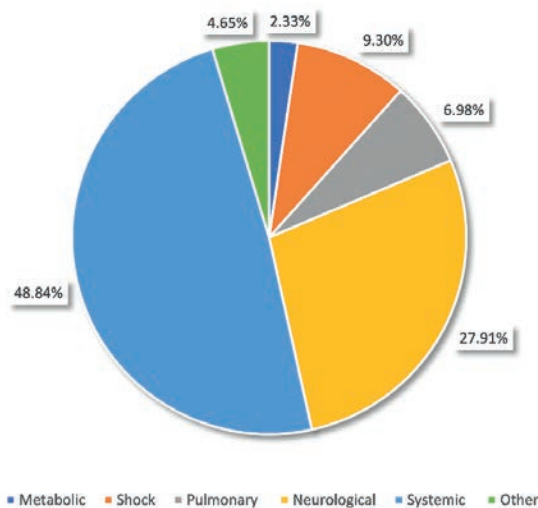
Figure 1. Indications for non-obstructive tracheostomies.
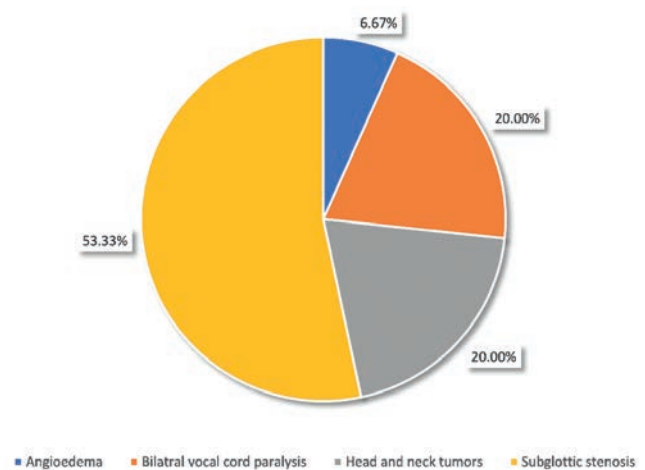
Figure 2. Indications for obstructive tracheostomies.

(25.6%), and metabolic disease (72.1%) than did the obstructed group [33.3% (p=0.008); 0.0% (p=0.030); and 33.3% (p=0.00), respectively]. Table 3 presents the distribution of microorganisms across the four quarters in the first post-tracheostomy year. The most commonly observed microorganism was *Pseudomonas aeruginosa* (47.7%), followed by *Acinetobacter baumannii* (15.4%). Only the

proportions for *P. aeruginosa* showed significant differences across the quarters (p=0.006; 95% confidence interval, 0.36, 0.60). As shown in Table 4, there were no differences between the groups in the proportions for all microorganisms at a 5% level of significance except for MRSA and *S. aureus*, which were significantly higher in the obstructed group than in the non-obstructed group.

Table 3. Microorganisms present over the four quarters in samples from patients who underwent obstructive or non-obstructive tracheostomy.

Organism	Quarter 1 N (%)	Quarter 1 CI	Quarter 2 N (%)	Quarter 2 CI	Quarter 3 N (%)	Quarter 3 CI	Quarter 4 N (%)	Quarter 4 CI	Overall N (%)	Overall CI	p
Pseudomonas aeruginosa	13 (31.7%)	(0.17, 0.46)	10 (71.4%)	(0.48, 0.95)	7 (87.5%)	(0.65, 1.10)	1 (50%)	(-0.19, 1.19)	31 (47.7%)	(0.36, 0.60)	0.006
Acinetobacter baumannii	8 (19.5%)	(0.07, 0.32)	2 (14.3%)	(-0.04, 0.33)	*	#	*	#	10 (15.4%)	(0.07, 0.24)	0.500
Klebsiella pneumoniae	7 (17.1%)	(0.06, 0.29)	*	#	*	#	*	#	7 (10.8%)	(0.03, 0.18)	0.204
Yeast	3 (7.3%)	(-0.01, 0.15)	*	#	*	#	*	#	3 (4.6%)	(0.00, 0.10)	0.606
Escherichia coli	3 (7.3%)	(-0.01, 0.15)	*	#	*	#	*	#	3 (4.6%)	(0.00, 0.10)	0.606
Other gram-negative bacteria	3 (7.3%)	(-0.01, 0.15)	1 (7.1%)	(-0.06, 0.21)	1 (12.5%)	(-0.10, 0.35)	*	#	5 (7.7%)	(0.01, 0.14)	0.932
MRSA	3 (7.3%)	(-0.01, 0.15)	1 (7.1%)	(-0.06, 0.21)	1 (12.5%)	(-0.10, 0.35)	*	#	5 (7.7%)	(0.01, 0.14)	0.932
Stenotrophomonas maltophilia	3 (7.3%)	(-0.01, 0.15)	*	#	*	#	*	#	3 (4.6%)	(0.00, 0.10)	0.606
Staphylococcus aureus	2 (4.9%)	(-0.02, 0.11)	2 (14.3%)	(-0.04, 0.33)	1 (12.5%)	(-0.10, 0.35)	1 (50%)	(-0.19, 1.19)	6 (9.2%)	(0.02, 0.16)	0.143
Enterobacter aerogenes	1 (2.4%)	(-0.02, 0.07)	*	#	*	#	*	#	1 (1.5%)	(-0.01, 0.05)	0.898
Morganella morganii	1 (2.4%)	(-0.02, 0.07)	1 (7.1%)	(-0.06, 0.21)	*	#	*	#	2 (3.1%)	(-0.01, 0.07)	0.765
Enterobacter cloacae	1 (2.4%)	(-0.02, 0.07)	*	#	*	#	*	#	1 (1.5%)	(-0.01, 0.05)	0.898
Haemophilus influenzae	1 (2.4%)	(-0.02, 0.07)	*	#	*	#	*	#	1 (1.5%)	(-0.01, 0.05)	0.898
Moraxella catarrhalis	1 (2.4%)	(-0.02, 0.07)	*	#	*	#	*	#	1 (1.5%)	(-0.01, 0.05)	0.898
Serratia marcescens	1 (2.4%)	(-0.02, 0.07)	*	#	*	#	*	#	1 (1.5%)	(-0.01, 0.05)	0.898
Streptococcus pyogenes	*	#	1 (7.1%)	(-0.06, 0.21)	*	#	*	#	1 (1.5%)	(-0.01, 0.05)	0.296
Total	41		14		8		2		65		

*No growing organism was found; #statistical analysis not applicable; CI, confidence interval; MRSA, methicillin-resistant *Staphylococcus aureus*.

Table 4. Comparison of the overall presence of microorganisms between patients who underwent obstructive tracheostomy and those who underwent non-obstructive tracheostomy

Organism	Non-obstructive N (%)	Non-obstructive CI	Obstructive N (%)	Obstructive CI	Total N (%)	Total CI	Relative risk	p
Pseudomonas aeruginosa	25 (52.1%)	(0.38, 0.66)	6 (35.3%)	(0.13, 0.58)	31 (47.7%)	(0.36, 0.60)	1.48 (0.73, 2.97)	0.275
Acinetobacter baumannii	10 (20.8%)	(0.09, 0.32)	*	#	10 (15.4%)	(0.07, 0.24)	7.71 (0.48, 124.99)	0.151
Klebsiella pneumoniae	7 (14.6%)	(0.05, 0.25)	*	#	7 (10.8%)	(0.03, 0.18)	5.51 (0.33, 91.65)	0.234
Yeast	3 (6.3%)	(0.00, 0.13)	*	#	3 (4.6%)	(0.0, 0.10)	2.57 (0.14, 47.37)	0.526
Escherichia coli	3 (6.3%)	(0.00, 0.13)	*	#	3 (4.6%)	(0.0, 0.10)	2.57 (0.14, 47.37)	0.526
Other gram-negative bacteria	4 (8.3%)	(0.01, 0.16)	1 (5.9%)	(0.0, 0.17)	5 (7.7%)	(0.01, 0.14)	1.42 (0.17, 11.81)	0.748
MRSA	1 (2.1%)	(0.0, 0.06)	4 (23.5%)	(0.03, 0.44)	5 (7.7%)	(0.01, 0.14)	0.09 (0.01, 0.74)	0.025
Stenotrophomonas maltophilia	3 (2.1%)	(0.00, 0.13)	*	#	3 (4.6%)	(0.0, 0.10)	2.57 (0.14, 47.37)	0.526
Staphylococcus aureus	2 (4.2%)	(0.0, 0.10)	4 (23.5%)	(0.03, 0.44)	6 (9.2%)	(0.02, 0.16)	0.19 (0.04, 0.90)	0.037
Enterobacter aerogenes	1 (2.1%)	(0.0, 0.06)	*	#	1 (1.5%)	(0.0, 0.05)	1.13 (0.05, 26.37)	0.942
Morganella morganii	1 (2.1%)	(0.0, 0.06)	1 (5.9%)	(0.0, 0.17)	2 (3.1%)	(0.0, 0.07)	0.36 (0.02, 5.47)	0.463
Enterobacter cloacae	*	#	1 (5.9%)	(0.0, 0.17)	1 (1.5%)	(0.0, 0.05)	0.12 (0.01, 2.67)	0.192
Haemophilus influenzae	1 (2.1%)	(0.0, 0.06)	*	#	1 (1.5%)	(0.0, 0.05)	1.13 (0.05, 26.37)	0.942
Moraxella catarrhalis	1 (2.1%)	(0.0, 0.06)	*	#	1 (1.5%)	(0.0, 0.05)	1.13 (0.05, 26.37)	0.942
Serratia marcescens	*	#	1 (5.9%)	(0.0, 0.17)	1 (1.5%)	(0.0, 0.05)	0.12 (0.01, 2.67)	0.192
Streptococcus pyogenes	*	#	1 (5.9%)	(0.0, 0.17)	1 (1.5%)	(0.0, 0.05)	0.12 (0.01, 2.67)	0.192
Total	48		17		65			

*No organism was observed; #statistical analysis not applicable; CI, confidence interval; MRSA, methicillin-resistant *Staphylococcus aureus*.

Discussion

We identified the most common microorganisms and their colonization distribution in the aspirates of post-tracheostomy patients over a time frame of four quarters of the first post-tracheostomy year. Further, we compared the microbial profiles of obstructive and non-obstructive cases. Unlike any previous study, the findings of this study demonstrated the baseline microbiological profiles of post-tracheostomy patients.

Widely varying non-obstructed tracheostomy indications have been reported (46%-91.7%) [10,11]. In our study, non-obstructed cases were the most common ones (74.1%), which is within the aforementioned range. In contrast, a study conducted at the Bugando Medical Centre reported that upper-airway obstruction is the most common tracheostomy indication (83%), which had a rate of 25.5% in our study [12]. In contrast, the most common indication in the pediatric age group is airway obstruction [13-17].

In our study, 82.4% of the patients were colonized, with the most common organisms being *P. aeruginosa*, followed by *Enterobacteriaceae* species, *A. baumannii*, and *S. aureus*. *P. aeruginosa* was found in 47.7% of the positive samples, as either the only organism colonizing the tracheostomy tube or in addition to other organisms, which was within the 22%-54% range reported in previous studies [4,8,18].

Enterobacteriaceae species include *Klebsiella pneumoniae, Escherichia coli, Stenotrophomonas maltophilia, Enterobacter aerogenes, Enterobacter cloacae,* and *Serratia marcescens.* Numerous studies have reported *Enterobacteriaceae* species and *P. aeruginosa* as the predominant isolates [18], while several other studies have shown *S. aureus* to be the most common organism. A prospective observational study reported that 44% of patients with neuromuscular or neurological disorders who underwent tracheal sample aspirate had *S. aureus* as the colonizing organism [19]. Moreover, Harlid *et al.* reported *S. aureus* as the most common organism in patients with chronic tracheostomy [4]. Notably, the overall proportion of patients with *S. aureus* in our study was approximately 9.2%.

There have been no studies comparing patients with obstructed and non-obstructed airways in terms of bacterial colonization of tracheostomy tubes. *P. aeruginosa* was the most common organism in both the patient groups. Additionally, MRSA and *S. aureus* were the second most common in the obstructed group, reaching 23.5% (p=0.025); this was consistent with the finding a previous study [9]. The association between MRSA and obstruction remains unclear; moreover, tracheal aspiration should be considered before an open reconstruction procedure. To our knowledge, there has been no study reporting the incidence of MRSA in adult patients undergoing tracheostomy. The high prevalence of MRSA in obstructive cases suggests the importance of implementation of screening and enhance the need of possible treatment protocol to reduce MRSA-related postoperative complications as demonstrated by Statham *et al.* for pediatric patients undergoing open reconstruction procedures [9]. Additionally, to the best of our knowledge, there has been no study evaluating the profiles of colonization in the first year following tracheostomy; however, several studies have reported that *P. aeruginosa* and *A. baumannii* were the most common organisms colonizing the tube in a period less than 30 days after tracheostomy [20,21]. This is consistent with our findings, where *P. aeruginosa* and *A. baumannii* were the two most abundant organisms in the first quarter. Notably, culture results in the last two quarters did not yield *A. baumannii*.

The study design allowed accommodation of the highest possible number of organisms; however, as the year progressed, there was a consistent decrease in the number of organisms. Specifically, there were 49 (84.4%) positive results in the first quarter, while the remaining quarters had only 25 positive results (24%, 13.8%, and 5.2% for quarters two, three, and four, respectively). This could be attributed to some patients being decannulated, discharged without regular follow up, and shifted to long-term facilities or dying.

Percutaneous tracheostomy has become a more popular alternative within the last two decades. This could be owing to the several advantages of percutaneous tracheostomy over surgical tracheostomy; therefore, most centers prefer percutaneous tracheotomy to surgical tracheostomy [10,11,22]. Remarkably, our findings show that surgical tracheostomy was performed more often than percutaneous tracheostomy.

This study has several limitations, including the relatively small sample size for an epidemiological study. Moreover, not all of the patients had culture results for all the quarters for a more accurate analysis. A larger prospective multicenter study on patients who have undergone tracheostomy that compares colonization between obstructive and non-obstructive tracheostomy indications is needed.

Conclusions

In conclusion, the most common organism in all quarters after tracheostomy was *P. aeruginosa*, followed by *Enterobacteriaceae* species, *A. baumannii*, and *S. aureus*. Moreover, MRSA and *S. aureus* showed a strong association with obstructive tracheostomy.

Acknowledgements

Abbreviations

MRSA: methicillin-resistant *Staphylococcus aureus;*
BMI: body mass index;
SD: standard deviation.

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