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Bacterial Colonization of Epidural Catheters Used for Short-term Postoperative Analgesia

Microbiological Examination and Risk Factor Analysis

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Background: **The authors conducted this prospective study to determine the incidence, potential routes, and risk factors of microbial colonization of epidural catheter used for postoperative pain control.**

Methods: **Two-hundred five patients with epidural analgesia for postoperative pain were studied. On removal of the catheter, five samples were sent for culture: the infusate, a swab from inside the hub of the epidural catheter connector, a swab from the skin around the catheter insertion site, the subcutaneous segment, and the tip of the catheter. Clinical data related to the catheter insertion, management, and general patient conditions were collected.**

Results: **The positive culture rates for the subcutaneous and tip segments of the catheter were 10.5% and 12.2%, respectively. The most common organism in the culture was coagulase-negative staphylococcus. There was a strong linear relationship between bacterial colonization in the skin around the catheter insertion site and growth from the subcutaneous and tip segments of catheter ($P = 0.000$). Catheter-related events at ward, blood transfusion, and positive culture from the skin at the insertion site were risk factors for bacterial colonization of epidural catheters. Inflammation at catheter insertion site, catheter indwelling time, and level of catheter insertion were not predicators for epidural catheter colonization.**

Conclusions: **The authors' results suggest that bacterial migration along the epidural catheter track is the most common route of epidural catheter colonization. Maintaining sterile skin around the catheter insertion site will reduce colonization of the epidural catheter tip.**

EPIDURAL analgesia is an effective method for postoperative pain management. However, infection may occur after the procedure. Although the reported rates of epidural catheter-related infection are low,[1–3] some of these infections, such as epidural abscess, are serious and life-threatening without early diagnosis and treatment.[3–5] For this reason, many case reports and retrospective reviews have been published.[1,3,5–12] However, very few studies have aimed to identify the route of infection and examine the risk factors for epidural infection.

Although unproven, microbial colonization of the epidural catheter may be a source of epidural infection. For this reason, some studies have been performed to determine the incidences of epidural catheter colonization under various clinical conditions.[13–18] It has also been suggested that microbial colonization of the epidural catheter could result from contamination of the infused fluid or the delivery system, hematogenous seeding at the catheter tip, and invasion of organisms present at the insertion site along the catheter track.[2,5] The relative importance of each of these routes in the colonization of epidural catheters used for postoperative pain control is currently unresolved, although the invasion of organisms present at the insertion site along the catheter track is thought to be the most common route.[5,12,19] We conducted this prospective study to determine the incidence of microbial colonization of epidural catheters used for postoperative pain control, the potential routes, and the risk factors for this colonization.

Materials and Methods

This is a prospective, nonrandomized study that was approved by the institutional review board of Taipei-Veterans General Hospital (Taipei, Taiwan, R.O.C.). Informed consent was obtained from all patients.

Study Subjects

Patients who received epidural analgesia for postoperative pain control between March 2004 and July 2006 at Taipei-Veterans General Hospital and gave consent to the study were eligible. Patients were included in the study if the principal researcher (H.B.Y.) was able to remove the catheter and collect specimens for culture. The only exclusion criterion was if clinical data regarding the difficulty of the epidural catheter placement were not properly recorded. Among the total 3696 patients eligible, 205 patients—102 male (mean age 66.2 ± 14.9 yr) and 103 female (mean age 53.6 ± 17.3 yr) including 25 parturients (mean age 35.4 ± 4.1 yr)—were studied. Among the studied patients, 32 were scheduled for thoracic surgery, 68 for general surgery, 51 for orthopedic surgery, 25 for obstetric surgery, and 29 for

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other surgeries including gynecologic/urologic/colonic procedures. We did not specifically use prophylactic antibiotics for epidural catheterization. However, all patients received antibiotics during the perioperative period. Antibiotic therapy, including the drug choice and the timing and duration of the drug administration, was decided by the surgical team based on the surgical procedures and the patient's clinical presentation. Because patients with various surgical procedures were recruited into the study, no unified antibiotic protocol for the patients was used in the study.

Epidural Catheter Placement and Management

Epidural catheters were placed either immediately before induction of anesthesia (91 patients) or 1 d before surgery (114 patients) at a level suitable to cover the corresponding dermatome of surgical incision. To shorten anesthesia turnover time, we placed the epidural catheter 1 d before surgery in patients scheduled for major operations. Standard procedure during catheter insertion included the use of sterile gloves and drapes and wearing of caps and face masks. All patients were placed in a lateral decubitus position. Skin preparation was with sterile povidone-iodine solution followed by 70% alcohol, allowing skin to dry before the epidural catheterization was started. Tuohy needles (17 gauge) and epidural catheters with bacterial filters (Flex Tip Plus; Arrow International, Reading, PA) were used for patients scheduled for thoracic or upper abdominal surgeries (106 patients). Tuohy needles (18 gauge) and epidural catheters without bacterial filters (Perifix; B. Braun, Melsungen, Germany) were used for patients scheduled for lower abdominal or lower extremity operations (99 patients). A paramedian approach and loss-of-resistance technique with air were used to identify the epidural space. The epidural catheters were threaded into the epidural space at least 5 cm (average 7 cm) in an intended cephalad direction.

All catheters were tested for intravascular or subarachnoid placement with 2 ml 2% lidocaine with epinephrine. Catheter was fixed in place by a clear sterile adhesive dressing (Tegaderm; 3M Company, St. Paul, MN) over the site of needle puncture and an adhesive dressing (Micropore; 3M Company) over the patient's back. The distal end of the epidural catheter, which was outside the patient's body, was kept in the sterile plastic connector provided in the epidural catheter set and was taped to the patient's chest. Continuous infusion plus patient-controlled bolus epidural analgesia were commenced at the end of the surgery. Epidural medications were single-use and preservative-free local anesthetics with or without opioids in sterile normal saline and were prepared by pharmacists under sterile conditions. These medications were administered sterilely to patients in a closed infusion system (Abbott Ambulatory Infusion Manager Plus, List 13967; Abbott Lab, Chicago, IL).

Each patient was examined by a staff member once daily or whenever there were any calls for pain management, malfunction of catheters, and evaluation of catheter-related infection. Patients were instructed to report any problems related to the use of epidural analgesia, including signs of infection, such as fever, neck pain, pain or tenderness at the site of epidural catheter insertion, or weakness in the lower extremities. Epidural dressings were not routinely changed unless they had been partially removed. Nursing staff were asked to report to the pain management team whenever there was any soiling or peeling of the epidural dressings, disconnection of the catheter, and sign of discharge from the insertion site.

Culture and Microbiology

All epidural catheters were removed by the same anesthesiologist (H.B.Y.) when epidural analgesia was not required. On removal of the catheter, five cultures were taken as follows.

(1) The contents of remaining infusates. A 2-ml solution was aspirated from the infusate-containing bag with a sterile needle and syringe after the puncture site was prepared with sterile povidone-iodine solution, followed by cleaning with 70% alcohol. The aspirate was placed in a sterile tube and sent to the laboratory for aerobic and anaerobic culture.
(2) The catheter hubs (injection ports). A swab was taken inside the hub with a sterile cotton-tipped stick moistened with sterile normal saline.
(3) Skin at the catheter insertion site. A sterile cotton-tipped applicator moistened with sterile normal saline was used to take a swab from the skin around the catheter insertion site after the adhesive dressing and tegaderm were removed and the catheter was still *in situ*.
(4) The tip of the catheter. After the skin around the catheter insertion site was disinfected with sterile povidone-iodine solution, followed by cleaning with 70% alcohol, catheters were removed aseptically by H.B.Y. wearing sterile gloves and a mask. Great care was taken not to contaminate the catheters during the removal. A 5-cm catheter tip was cut off for culture with a pair of sterile scissors.
(5) The subcutaneous section of the catheter. A 4- to 5-cm catheter segment in the subcutaneous tissues was cut off with sterile scissors.

These catheter segments were placed in separate sterile containers. The infusate, swabs, and the catheter segments were sent immediately to the microbiology laboratory. The infusate/swab was inoculated onto a blood agar plate/eosin-methylene blue plate/chocolate-agar plate and incubated for 3 d aerobically, then inoculated onto an anaerobic brucella-agar plate and incubated for 7 d anaerobically. Bacterial growth found only

in the first quadrant of the inoculated plate was defined as low grade of growth; in the second and/or the third quadrant was moderate growth; and in the fourth quadrant was heavy growth. Semiquantitative cultures of the catheter segments were performed according to the method of Maki *et al.*[20] The catheter segments were rolled onto blood agar plates at 35°C under aerobic and anaerobic conditions. All bacterial isolates were identified and reported by organism type, low grade/moderate/heavy growth for infusate/swab culture, and number of colonies for catheter segment culture at 1 week. The epidural catheter tip was considered to be colonized if the culture yielded at least 15 colony forming units (CFU) of an organism. All patients were followed up for the possibility of clinical infection at 1 week, 1 month, and 3 months after removal of the catheter.

Clinical Data Collection

The following data were collected: catheter insertion site, the number of attempts taken to identify the epidural space (one attempt was defined as an action to reposition the needle, which included removal of the needle from the patient and reinsertion); time taken to place the epidural catheter (from the initiation of skin infiltration with local anesthetics to the beginning of catheter fixation); the training levels of the performers (junior/senior residents or visiting staffs); the requirement of performer switch because of technique difficulty, the use of bacterial filter; events of catheter line integrity breaks; type of epidural infusion solutions; duration of catheter *in situ* (from insertion to removal, rounded to the nearest hour); interim events including hub disconnection and tegaderm change resulting from discharge at the catheter insertion site; adjustment of catheter position or tegaderm peeling off while the catheter was in place; perioperative temperature; infection of other sites; antibiotic therapy before catheter insertion, at the time of catheter placement, and removal, and the duration (days up to the day of catheter removal); the use of ventilator and blood transfusion during catheter *in situ*; and comorbidities. Patients with the following immunomodulation therapies or conditions were recorded and were considered to have immunodepression: long-term steroid therapy, neoplasia, hematologic malignancy, diabetes, chronic alcoholism, autoimmune disease, organ transplantation, uremia, liver cirrhosis, and lung tuberculosis. The presence of local inflammation at the catheter insertion site was recorded at the time of catheter removal. Local inflammation was defined as presence of erythema, tenderness, or induration/swelling.

Data Analysis

Data are expressed as means ± SD or number of patients and percentage as appropriate. χ^2 test for linear-by-linear association was used for the correlation among the culture results from skin, subcutaneous segment, and tip segment of the catheters. Fisher's exact test for categorical variables and two-sample *t* test or Mann–Whitney U test for continuous variables were used for univariate analysis. Multiple logistic regression with forward stepwise analysis was used to examine the risk factors for catheter tip colonization. Power analysis was performed for the identified risk factors using sample power 2.0 with a set point at $\alpha = 0.05$, two-tailed. SPSS 14.0 (Chicago, IL) was used to conduct all the statistical analyses. $P < 0.05$ was accepted as significant.

Table 1. Culture Results at Various Sites

Sites	Cultures Taken	Positive Culture, N (%)
Infusates	194	3 (1.5)
Hub	205	1 (0.5)
Skin	205	78 (38.0)
Epidural catheter		
Subcutaneous segment	201	13 (6.5)* 8 (4.0)†
Tip segment	205	14 (6.8)* 11 (5.4)†

* Between 1 and 14 colony forming units (CFU). † At least 15 CFU.

Results

The culture results of various samples from the 205 patients are demonstrated in table 1. Two of the three

Table 2. Correlation among the Positive Culture Results in Skin, Subcutaneous Segment, and Tip Segment of the Catheter

	Tip Segment			
	None	1–14 CFU	≥15 CFU	*P* Value
Subcutaneous segment				
None	175/177 (98.9)	4/14 (28.6)	1/10 (10.0)	0.000‡
1–14 CFU	2/177 (1.1)	9/14 (64.3)	2/10 (20.0)	
≥15 CFU	0/177 (0.0)	1/14 (7.1)	7/10 (70.0)	
Skin culture				
None	124/179 (69.3)	2/14 (14.3)	1/11 (9.1)	0.000‡
Moderate*	49/179 (27.4)	6/14 (42.9)	2/11 (18.2)	
Heavy†	6/179 (3.4)	6/14 (42.9)	8/11 (72.7)	
	Subcutaneous Segment			
	None	1–14 CFU	≥15 CFU	*P* Value
Skin culture				
None	124/179 (69.3)	0/13 (0.0)	0/8 (0.0)	0.000‡
Moderate*	48/179 (26.8)	6/13 (46.2)	2/8 (25.0)	
Heavy†	7/179 (3.9)	7/13 (53.8)	6/8 (75.0)	

Values are expressed as n/N (%).

* Bacterial growth found in the first or second/third quadrant in the culture plate. † Bacterial growth found in the fourth quadrant in the culture plate. ‡ $P < 0.01$ with χ^2 test for linear-by-linear association.

CFU = colony forming units.

Table 3. Isolated Microorganisms from the Samples

	Epidural Catheter					
	Tip Segment		Subcutaneous Segment		Skin	
Organisms	N (n*)	%	N (n*)	%	N (n†)	%
CNS	12 (7)	42.9	9 (5)	42.9	35 (10)	40.2
Propionibacterium acnes	9	32.1	8	38.1	35 (6)	40.2
Corynebacterium sp.	1 (1)	3.6	1	4.8	10 (1)	11.5
Micrococcus sp.	2	7.1	0	0.0	0	0.0
Enterococcus sp.	1 (1)‡	3.6	1 (1)	4.8	2	2.3
Staphylococcus aureus	1 (1)§	3.6	1 (1)	4.8	1 (1)	1.1
Acinetobacter baumanii	1 (1)‖	3.6	1 (1)	4.8	1 (1)	1.1
Acinetobacter sp.	1	3.6	0	0.0	1 (1)	1.1
Peptostreptococcus spp	0	0.0	0	0.0	2	2.3
Total#	28 (11)		21 (8)		87 (20)	

* Number of cultures with ≥15 colony forming units. † Number of cultures with heavy growth (bacteria growth found in the fourth quadrant of the culture plate). ‡ Patient underwent cesarean section. § Patient underwent total knee arthroplasty. ‖ Patient with tuberculosis pleurisy. # Total number of isolated organisms is more than the total number of positive cultures because some cultures had two different organisms.

CNS = coagulase-negative staphylococcus; N = the number of cultures with ≥1 colony forming units.

patients with positive infusate cultures had negative cultures in the other samples collected, and the third patient had growth of different bacteria in the skin culture. The only patient with a positive hub culture had negative culture in other sites. All positive cultures from infusates and hubs exhibited a low grade of bacterial growth. These findings suggest that the positive cultures found in the infusates and hub may be from contamination during sample collection and may not contribute significantly to the catheter colonization/infection.

Of the patients, 38% had positive cultures in their skin around the epidural insertion site. Among these, 20 cultures had heavy growth. The positive culture rates for the subcutaneous and tip segments of catheter were 10.5% and 12.2%, respectively, for ≥1 CFU and 4% and 5.4%, respectively, for ≥15 CFU (table 1). No patient had a clinical infection related to the epidural catheterization during the follow-ups for 3 months. One patient with both subcutaneous and tip segment colonization died 2 months after the removal of the catheter as a result of multiple organ failure.

The results in table 2 showed a strong linear relationship of bacterial colonization in the skin around the epidural catheter insertion site and the subcutaneous and tip segments of the epidural catheter. Moreover, the same types of microorganisms were isolated in these

Table 4. Risk Factors for Positive Epidural Catheter Tip Culture (≥15 CFU)

		95% CI		
Variables	Odds Ratio	Lower	Upper	*P* Value
Transfusion during EA	15.53	1.73	139.49	0.014*
Catheter-related events at ward	35.01	3.17	387.23	0.004*
Positive skin culture	18.10	4.44	73.84	0.000*

CFU= colony forming units; CI = confidence interval.

* $P < 0.05$ according to multiple logistic regression–forward stepwise analysis adjusted for patients with immunodepression, antibiotic therapy at the time of catheter insertion, number of catheter line integrity breaks, type of operation, blood transfusion during epidural analgesia (EA), catheter-related events at ward, and positive skin culture.

Table 5. Distribution of Patients According to Inflammation at the Catheter Insertion Site and Culture Results

Inflammation (+), n = 38		
Skin (+), n = 18	SC (+) n = 7	Tip (+) n = 5 Tip (–) n = 2
	SC (–) n = 11	Tip (+) n = 2 (1)* Tip (–) n = 9
Skin (–), n = 20	SC (+) n = 0	Tip (+) n = 0 Tip (–) n = 0
	SC (–) n = 20	Tip (+) n = 0 Tip (–) n = 20
Inflammation (–), n = 168		
Skin (+), n = 61	SC (+) n = 13	Tip (+) n = 13 (9)* Tip (–) n = 0
	SC (–) n = 48	Tip (+) n = 3 Tip (–) n = 45
Skin (–), n = 107	SC (+) n = 1	Tip (+) n = 0 Tip (–) n = 1
	SC (–) n = 106	Tip (+) n = 2 Tip (–) n = 104
Total = 206†		

Four patients with missing SC data, including one patient with tip culture ≥15 colony forming units are not included in this table.

* Number of tip segment cultures with ≥15 colony forming units. † Total number = 206 because 5 patients' data were counted repeatedly because of concomitant different organisms isolated with a different distribution pattern over the three culture sites.

Inflammation = the presence of erythema, tenderness, or induration/swelling at the catheter insertion site; SC = bacterial culture from epidural catheter segment in the subcutaneous tissues; Skin = skin culture; Tip = tip segment culture.

Table 6. Data of Patients with Epidural Catheter Tip Culture ≥15 CFU

Patient	Age, yr/Sex	Operation	Immune Status	Attempt, n/time	Level	Break, n	Catheter Duration, h
1	56/F	TKA	(−)	1/5 min	L3-4	1	73.0
2	47/F	TKA	Alcohol	1/5 min	L3-4	1	74.0
3	37/F	C/S	(−)	1/5 min	L3-4	2	101.4
4	80/M	TKA	(−)	1/10 min	L3-4	1	75.0
5‖	47/F	Methothelioma/thoracotomy	TB/CA	1/10 min	T7-8	2	120.0
6	73/F	TKA	(−)	2/7 min	L3-4	1	74.8
7	39/F	C/S	(−)	1/5 min	L3-4	1	73.8
8	75/M	Whipple	DM/CA	2/§	T9-10	2	119.8
9	69/F	TKA	(−)	1/3 min	L4-5	2	77.4
10	59/M	Lung CA/thoracotomy	TB/CA	1/5 min	T8-9	2	119.2
11	40/M	Esophageal CA/ thoracotomy	Alcohol/liver/CA	4/26 min	T6-7	3	116.5

* Antibiotic therapy during epidural analgesia. † Subcutaneous segment of catheter. ‡ Accidental hub disconnection. § Missing data. ‖ Patient died 2 months later from multiple organ failure.

Ab = acinetobacter baumanii; CA = cancer; CFU = colony forming units; CNS = coagulase-negative staphylococcus; C/S= cesarean section; DM = diabetes mellitus; H = heavy growth; L = lumbar; MG= moderate growth; T = thoracic; TB = tuberculosis; TKA = total knee arthroplasty.

three sites (table 3). These results suggest that the bacterial origin of the catheter colonization may be mainly from skin flora.

Types of isolated microorganisms and their relevant prevalence are demonstrated in table 3. Most of the isolated organisms came from normal skin flora. The most commonly identified organism in each culture group was coagulase-negative staphylococcus (CNS), followed by P. acnes. The organism most commonly isolated from skin cultures that were heavy growth or from catheter samples that had ≥15 CFU in culture was also CNS (table 3). The total number of isolated organisms may be more than the total number of positive cultures because some cultures had two different organisms.

Univariate analysis showed significant correlation between catheter tip colonization and tegaderm change and/or accidental hub disconnection ($P = 0.003$), blood transfusion during catheter *in situ* ($P = 0.029$), and positive culture from the skin around the catheter insertion site ($P = 0.000$). The power for identifying these three positive risk factors for catheter tip colonization with our sample sizes was more than 87%. A trend of increased amount of blood transfusion in patients with epidural catheter colonization was also found (6.9 ± 11.9 *vs.* 2.6 ± 5.4 units, $P = 0.260$). However, the degree of technical difficulty to place the epidural catheter (including the number of attempts, time taken to place the catheter, initial performer, and performer switch), insertion level, catheter line integrity breaks, duration of catheter *in situ*, insertion site inflammation, and patients with immunodepression did not significantly increase the rate of positive tip culture. Placement of the epidural catheter 1 d before the surgery was not correlated with skin positive cultures or colonization of epidural catheter tip (4 patients with tip colonization of 114 patients having their catheters placed 1 d before surgery, $P = 0.222$). The therapies of antibiotic, either the duration or the timing of administration, and the use of bacterial filter also did not affect the culture results. However, there was a tendency toward a high positive culture rate in the catheter tip in patients undergoing orthopedic, thoracic, and obstetric surgeries ($P = 0.081$).

Variables with $P < 0.2$ in univariate analysis were further analyzed with multiple logistic regression–forward stepwise analysis. After adjustment for patients with immunodepression, antibiotic therapy at the time of catheter insertion, events of catheter line integrity breaks, type of surgeries, blood transfusion during catheter *in situ*, catheter-related events, and positive skin culture, the results showed that blood transfusion during catheter *in situ* ($P = 0.014$), catheter-related events ($P = 0.004$), and positive skin culture ($P = 0.000$) were risk factors for a positive catheter tip culture (table 4).

Results in table 5 show the relationship between inflammation at the catheter insertion site and the culture results. Patients with inflammation at the catheter insertion site but without a positive culture in the sample taken from the skin around the catheter insertion site did not have a positive culture in the catheter tip. However, patients without inflammation at the catheter insertion site but with a positive culture in samples from the adjacent skin and subcutaneous catheter segment almost all had a positive culture in the catheter tip.

The information of 11 patients with catheter tip colonization is shown in table 6. Most of the isolated organisms

Table 6. Continued

Antibiotic Therapy Duration,* days	Events at Ward	Postop Peak Temp, °C	Transfusion	Removal Condition	Skin Culture	SC† Culture (CFU)	Bacteria
3	Hub‡	38.5	(+)	Hub disconnect	(−)	§	Corynebacterium
4	(−)	38.2	(+)	Tegaderm damaged	H	1	CNS
5	Occlusion/change tegaderm	37.6	(−)	(−)	MG	15	Enterococcus
1	Tegaderm damaged	37.4	(+)	(−)	H	>15	Staphylococcus aureus
6	(−)	38.6	(+)	(−)	H	>15	Ab
2	Hub‡/change tegaderm	§	(+)	(−)	H	>15	CNS
4	(−)	37.0	(−)	Tegaderm damaged	H	>15	CNS
6	Change tegaderm	37.4	(+)	(−)	H	>15	CNS
2	(−)	37.4	(+)	Local inflammation	H	(−)	CNS
5	Hub‡/catheter partial dislodged/change tegaderm	37.0	(−)	(−)	H	>15	CNS
5	(−)	39.0	(+)	(−)	MG	4	CNS

came from the skin flora (seven CNS, one corynebacterium, and one staphylococcus aureus). One obstetric patient had enterococcus that may have originated from the gastrointestinal or genitourinary tract. The other patient had acinetobacter baumanii, an opportunistic infection bacterium. All 11 patients had the same organisms isolated from the three culture sites: the skin, the subcutaneous segment, and the tip of the catheter.

Discussion

With the increasing use of epidural analgesia for postoperative pain relief and an increase in the population of patients with significant comorbidity, catheter-related infections may be seen more frequently in the future.[21] There are only three prospective studies on bacteriologic surveys of epidural analgesia and risk factor analyses of epidural catheter colonization in recent years.[22–24] However, these studies did not identify a risk factor for epidural catheter colonization. Moreover, some studies did not have measures of disinfection before removal of the catheters,[22,23] which could contaminate the catheter tip during removal. Thus, we designed this prospective study to determine the route and risk factors for epidural catheter colonization.

The reported incidence of epidural catheter colonization usually varies from 0% to 28%,[13–18,22–24] but has been reported top be as high as 53.1%.[19] Our study showed that 12.2% and 5.4% of epidural catheter tips had ≥1 CFU and ≥15 CFU bacteria, respectively. These numbers should reflect the true bacterial colonization rate at the catheter tip because we disinfected the skin around the catheter insertion sites before catheter removal.

The organism most frequently isolated from the epidural catheter and the skin around the insertion site in our study was CNS, which was similar to the results found in other studies.[15–19,22,23] Although CNS, including Staphylococcus epidermidis, has been considered to be a common microorganism of normal skin flora with limited clinical significance, it can be a serious, although not frequent, source of hospital infection[25] and is the pathogen in many clinically significant epidural-related infections.[1,5,12,21,26,27] However, despite the frequency of catheter colonization with this and other bacterium, the definitive causative relationship between epidural catheter colonization and catheter-related infection has not yet been established, possibly because of the very low incidence of clinically significant infection. Thus, routine culture of epidural catheter tips has not been suggested in clinical practice.

There are several routes that cause catheter colonization: contamination during catheter insertion, including contamination from the performer of the blockade and later on by the infusates and/or the delivery system; bacterial migration along the catheter tract; and hematogenous spread.[2,5,28] By using a novel approach involving culturing samples along the epidural line, we found a significant linear correlation between the degree of bacterial colonization in the skin around the insertion site and in the subcutaneous segment and the tip of the catheter (table 2). We also found that colonization of the skin around the insertion site was a strong predictor for the colonization of the epidural catheter tip (tables 4 and 5). In addition, all 11 patients with colonization of the catheter tip had the same organisms colonized at the three culture sites: the skin, the subcutaneous segment, and the tip of the catheter. Thus, our study clearly demonstrates that bacterial migration along the epidural catheter track is the most common route of epidural catheter colonization. Thus, thorough disinfection of the

skin around the catheter insertion site during catheter placement and maintaining the area's sterility while the catheter is *in situ* are critical to reducing the incidence of catheter colonization.

We have also identified catheter-related events at ward and blood transfusion while the epidural catheter is *in situ* as risk factors for epidural catheter colonization by bacteria. Catheter-related events, such as accidental hub disconnection and damage of tegaderm, are usually not managed immediately with strict aseptic procedures at ward and may cause contamination.

Blood transfusion has been associated with the development of epidural abscesses. Triulzi *et al* reported significantly higher rates of epidural infection in transfused patients after spinal surgery.[29] We found that blood transfusion increased the risk of epidural catheter colonization. Severe hemorrhage could result in immunosuppression and increase susceptibility to sepsis.[30,31] Allogeneic blood transfusion could also decrease immune functions.[32,33] These immunomodulatory effects may explain our results. However, consistent with previous studies,[24,34] we did not find a correlation between catheter colonization and other immunomodulatory conditions (table 4). Of note, we did not design our study to specifically detect the association between catheter colonization and immunomodulatory conditions. Therefore, our study may be underpowered to detect this association.

Number of attempts and the time taken to place the epidural catheter, the insertion site, duration of catheter *in situ*, and the inflammation of local tissues around the insertion site have been suggested as risk factors for the bacterial colonization of epidural catheter tip in some studies[1,17–19,22,35,36] but not in other studies.[1,16,18,22–24,26,37,38] Our study did not indicate that these factors are predicators for catheter tip colonization. Like other studies,[22,23,39,40] our study failed to find infection in other locations, the absence of a bacterial filter, and fever to be predicators for the catheter tip colonization. Our results showed a tendency toward a high positive tip culture rate in patients undergoing orthopedic, thoracic, and obstetric surgeries. Future studies with more patients are needed to examine this issue. In this regard, it is interesting to note that obstetric patients represent a unique group of patients. These patients are usually young and healthy. However, neuraxial infection (including spinal abscess and meningitis) was the most common complication leading to malpractice claims after neuraxial blockage in the obstetric patients but not in the nonobstetric patients, as shown by the data of the American Society of Anesthesiologists closed claims project.[28,41]

In our hospital during the study period, we did not routinely use bacterial filters in patients receiving epidural analgesia for lower abdominal or lower extremity surgeries. Bacterial colonization of the epidural catheter may result from contamination in the infusion connection or epidural solution. However, we did not find the absence of a bacterial filter and the positive cultures in the infusates and hub to be predicators for catheter tip colonization. Consistent with our study, results from a previous study suggest that a bacterial filter is not needed in continuous epidural analgesia for healthy obstetric patients.[39] However, caution is needed to interpret these results regarding filter use because patients receiving epidural analgesia without a bacterial filter often had a shorter duration of epidural analgesia, were relatively healthier, and received less invasive surgeries than patients who had a bacterial filter in their epidural infusion line. In addition, our results are from epidural catheters used for short-term postoperative analgesia.

One area that was not well controlled in this study was antibiotic administration. We did not use a unified antibiotic protocol because patients undergoing various surgical procedures were included in this study. This practice could affect the culture results. However, two studies have examined the effect of antibiotic prophylaxis in long-term (many weeks) epidural catheterization: one showed a reduction in catheter infection,[27] and the other did not.[42] Other studies, performed in surgical patients[23] and patients in the intensive care unit[22] with epidural catheters in place for 2-4 d, found that catheter colonization with skin flora occurred irrespective of the administration of antibiotics for surgical prophylaxis or therapeutic use. We also did not find that antibiotic therapy, including the duration or the timing of the antibiotic administration, affected the culture results. These results suggest that antibiotic therapy is not effective in preventing epidural catheter colonization. However, caution is needed to interpret these results because we did not standardize the antibiotic therapy and specifically design our study to determine the effects of antibiotic therapy on bacterial colonization in the epidural catheter.

In summary, we have identified that catheter-related events at ward, blood transfusion, and positive culture in the samples taken from the skin around the catheter insertion site are risk factors for bacterial colonization of epidural catheters. Our data also suggest that a common route for catheter colonization is *via* migration of bacteria along the catheter track. We conclude that a strict aseptic practice during catheter placement and careful management to maintain sterile skin around the catheter insertion site at ward will reduce colonization of the epidural catheter tip and may decrease the catheter-related infections.

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