Bacterial Colonization, Tracheobronchitis, and Pneumonia following Tracheostomy and Long-Term Intubation in Pediatric Patients*

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Serial tracheal cultures for aerobic and anaerobic bacteria were obtained from 27 pediatric patients during one year of follow-up. The patients had required tracheostomy and prolonged intubation for periods ranging from 3 to 12 months (average, 7½ months). Cultures of tracheal aspirates yielded 1,508 isolates of pathogenic aerobic (969 isolates) and anaerobic (539 isolates) bacteria. The most frequent aerobic isolates were *Streptococcus pneumoniae* and *Staphylococcus aureus*. The predominant anaerobes were anaerobic gram-positive cocci, *Fusobacterium nucleatum*, and *Bacteroides fragilis*. Replacement of one pathogen by another occurred frequently. Tracheobronchitis occurred in 24 patients, all of whom had episodes of pneumonia. The data suggest that anaerobic bacteria are a part of the bacterial flora in colonization, tracheobronchitis, and pneumonia in patients with tracheostomy and prolonged intubation.

Bacterial colonization of the tracheobronchial tree almost always follows tracheal intubation after tracheostomy.[1] It is sometimes difficult to evaluate the clinical significance of the isolation of pathogenic bacteria from tracheal cultures of patients with tracheostomy, to differentiate between colonization or clinical infection,[2] and to assess various factors influencing the acquisition of those bacteria.[3]

Studies of the bacteriologic colonization and infection in pediatric patients who require tracheostomy rarely have been done, and the role of anaerobic bacteria never has been studied. This report summarizes data from pediatric patients subjected to tracheostomy and prolonged intubation for severe neurologic disorders. The data reflect the mode of colonization and the occurrence of infections with aerobic and anaerobic bacteria in those patients.

Materials and Methods

Twenty-seven pediatric patients were included in this study. Most of the patients had severe brain damage, which was due to congenital or acquired neurologic disorders or occurred as a sequel to drowning or automobile accidents. The patients were hospitalized on a long-term basis and required tracheal intubation after tracheostomy for long periods of time, ranging from three months to one year (average, 7½ months). There were 20 male and seven female patients included in the study; their ages ranged from 2 to 16 years (average, 8½ years).

Tracheal cultures were routinely obtained every two weeks by a trained nurse using an aseptic technique. The collection of the specimens was done through a newly inserted sterile ventilation tube using sterile gloves and a new sterile suctioning catheter. Repeated cultures were done whenever clinically indicated. The specimens were cultured for aerobic and anaerobic bacteria within ten minutes of collection. A direct Gram's and Wright's stain were done on all aspirates. The specimens were plated for aerobic bacteria on blood, chocolate, and MacConkey agars and were plated for anaerobes on prereduced vitamin K_1-enriched Brucella blood and selective blood agar plates containing kanamycin and vancomycin.[4] A thioglycolate broth was inoculated and incubated anaerobically for 14 days. The aerobic plates were incubated in air (MacConkey agar) and 5 percent carbon dioxide and were processed at 24 and 48 hours using conventional methods. The anaerobic plates were incubated in anaerobic jars (Gas Pak jars; BBL) and were processed at 48 and 96 hours according to the *Wadsworth Anaerobic Bacteriology Manual*.[4]

Colonization was defined as the isolation of a potential pathogen in tracheal cultures for at least four weeks, in the absence of purulent tracheobronchial secretions or clinical evidence of infection. An episode of colonization was defined by having an interval of at least four weeks in which the organism was not recovered. Tracheobronchitis was considered to be present when purulent secretions appeared but when physical examination and chest x-ray films showed no evidence of pneumonia. The diagnosis of pneumonia was made only when unequivocal clinical and radiographic evidence of pulmonary parenchymal involvement was present and when patients had leukocytosis and frequently developed fever.

All patients were examined daily, with particular attention to the quantity and character of their tracheal secretions. Chest x-ray films were made when indicated. The patients were treated by postural drainage and frequent suctioning and cleaning of their tracheostomy tubes, which were

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changed once weekly. None of the patients received prophylactic antibiotic therapy to prevent infection; however, they were all treated with antibiotics when pneumonia was suspected. The choice and changes in the therapy with antimicrobial agents were based on the patient's clinical condition and the results of the tracheal cultures.

Results

There were 1,509 bacterial isolates from 444 cultures obtained from the 27 patients during one year of follow-up. This accounts for 2.2 aerobes and 1.2 anaerobes isolated per specimen. Cultures from all 27 patients grew aerobic bacteria. In 21 patients (78 percent), both aerobic and anaerobic bacteria were recovered from the tracheal aspirates, and in six patients (22 percent), only aerobes were isolated.

All of the 27 patients developed colonization with aerobic or anaerobic bacteria (or both). Three patients developed chronic colonization after intubation but never developed infection. Twenty-four (89 percent) of the patients appeared to have developed chronic tracheobronchitis with recurrent episodes of pneumonia.

Eleven of the patients had one or two episodes of pneumonia in one year, seven patients had three to five episodes, and six patients had more than five episodes of pneumonia. There were 68 episodes of pneumonia noted in those 24 patients (2.8 episodes per patient). In about half of the episodes, a change in the bacterial flora occurred during the episode of pneumonia, with the appearance of new pathogens; while in the other half, no change in the bacterial isolates was noted. Although all of the patients responded favorably to the therapy, the bacterial pathogens usually persisted or were replaced by others. The bacteria isolated from the tracheal secretions in the 68 episodes of pneumonia and the number of isolates of each were as follows:

Aerobic and facultative isolates	
Gram-positive cocci	
Streptococcus pneumoniae	5
α-Hemolytic streptococci	. . .
Group-A β-hemolytic streptococci	4
Staphylococcus aureus	13
Gram-negative bacilli	
Hemophilus influenzae	3
Hemophilus parainfluenzae	3
Proteus mirabilis	2
Proteus rettgeri	1
Pseudomonas aeruginosa	1
Serratia marcescens	5
Escherichia coli	7
Klebsiella pneumoniae	15
Enterobacter cloacae	3
Citrobacter diversus	2
Total aerobic isolates	64
Anaerobic isolates	
Gram-positive cocci	
Peptococcus sp	4
Peptostreptococcus sp	16
Gram-negative bacilli	
Fusobacterium nucleatum	9
Bacteroides melaninogenicus	1
Bacteroides fragilis	4
Bacteroides vulgatus	3
Total anaerobic isolates	37

The most frequently isolated aerobic bacteria were *K pneumoniae* and *Staphylococcus aureus*. The predominant anaerobic bacterial isolates were *Peptostreptococcus* sp, *F nucleatum*, and *Bacteroides fragilis*. Thirty-eight samples of blood were drawn and cultured from the 24 patients with pneumonia. There were only two positive cultures of blood; one grew *Streptococcus pneumoniae* and the other *Escherichia coli*. Similar organisms were recovered from the tracheal aspirates of those patients.

Table 1 shows the organisms isolated from tracheal cultures, their proportional appearance in the three clinical conditions (colonization, tracheobronchitis, and pneumonia), and their average length of colonization. The tracheal cultures usually yielded two to five organisms per specimen, and the average number of isolates was 2.3 aerobes and 1.8 anaerobes per specimen.

Statistical analysis of the data using the *t*-test revealed that *Peptostreptococcus* sp and *Bacteroides melaninogenicus* were isolated at a higher prevalence from aspirates of children with episodes of pneumonia than from those with colonization ($P < 0.05$); however, *Bacteroides oralis*, α-hemolytic streptococci, *Proteus mirabilis*, and *Pseudomonas aeruginosa* were more frequently isolated in cases with pneumonia ($P < 0.05$).

Replacement of one pathogen by another occurred frequently and was enhanced by treating the patients with antibiotics. Twenty-one (78 percent) of the 27 patients had been treated with antibiotics for reasons other than pneumonia. In 12 (57 percent) of the 21 patients, a change occurred in the tracheal flora, with the appearance of different pathogens not previously present.

In 22 incidents an organism isolated from the tracheal secretion was concomitantly recovered from another infectious site. The organisms were *Staphylococcus aureus* (11), group-A β-hemolytic streptococci (four), *H influenzae* (four), *Escherichia coli* (three), *Pseudomonas aeruginosa* (two), *Streptococcus pneumoniae* (one), and *Bacteroides fragilis* (one). The sites where those organisms were recovered were as follows: chronic otitis media (eight); decubitus ulcer (five); septic arthritis (three); subcutaneous abscesses (three); blood cultures (two); and ventriculoperitoneal shunt (one).

Organisms previously recovered as colonizers

Table 1—*Bacterial Isolates in 27 Intubated Patients*

Data	Total No. of Isolates	No. of Isolates (percent)			Average Duration of Colonization, wk*
		Colonization Only	Tracheobronchitis	Pneumonia	
Aerobic and facultative isolates					
Gram-positive cocci					
Streptococcus pneumoniae	90	38 (42)	30 (33)	22 (25)	1.1
α-hemolytic streptococci	146	76 (52)**	52 (36)	18 (12)**	6.7
Group-A β-hemolytic streptococci	33	16 (50)	8 (23)	9 (27)	2.8
Staphylococcus aureus	74	38 (51)	16 (22)	20 (27)	4.1
Staphylococcus epidermidis	6	6 (100)	. . .	. . .	3.2
Neisseria sp	26	16 (62)	6 (23)	4 (15)	6.3
Gram-negative bacilli					
Hemophilus influenzae	6	. . .	. . .	6 (100)	2.0
Hemophilus parainfluenzae	6	3 (50)	. . .	3 (50)	1.2
Proteus morgani	3	. . .	. . .	3 (100)	3.5
Proteus rettgeri	6	. . .	3 (50)	3 (50)	4.6
Proteus mirabilis	30	21 (70)**	6 (20)	3 (10)**	3.6
Pseudomonas aeruginosa	276	142 (51)**	86 (31)	48 (17)**	9.5
Serratia marcescens	106	48 (45)	40 (38)	18 (17)	4.9
Escherichia coli	76	28 (37)	22 (29)	26 (34)	5.7
Klebsiella pneumoniae	66	16 (24)	26 (39)	24 (36)	4.3
Enterobacter cloacae	10	. . .	4 (40)	6 (60)	3.1
Citrobacter diversus	9	3 (33)	3 (33)	3 (33)	2.7
Total aerobic isolates	969	451 (47)	302 (31)	216 (22)	. . .
Anaerobic isolates					
Cocci					
Peptococcus sp	81	27 (33)	18 (22)	36 (44)	5.6
Peptostreptococcus sp	81	22 (27)**	16 (20)	43 (53)**	6.3
Veillonella sp	18	8 (44)	6 (33)	4 (22)	3.1
Microaerophilic streptococci	28	12 (43)	2 (7)	14 (50)	2.0
Gram-positive bacilli					
Lactobacillus sp	12	4 (33)	6 (50)	2 (17)	3.8
Bifidobacterium sp	20	8 (40)	4 (20)	8 (40)	4.3
Eubacterium sp	13	6 (46)	4 (31)	3 (23)	3.3
Leptotrichia buccalis	3	2 (67)	1 (33)	. . .	1.8
Gram-negative bacilli					
Fusobacterium nucleatum	50	16 (32)	12 (24)	22 (44)	5.5
Bacteroides sp	18	6 (33)	. . .	12 (67)	6.1
Bacteroides oralis	62	24 (39)**	22 (36)	16 (26)**	7.2
Bacteroides rummi, ssp *brevis*	10	8 (80)	2 (20)	. . .	3.0
Bacteroides melaninogenicus	70	14 (20)**	24 (34)	32 (46)**	8.2
Bacteroides fragilis	31	10 (32)	12 (39)	9 (29)	5.7
Bacteroides vulgatus	42	17 (40)	12 (29)	13 (31)	6.3
Total anaerobic isolates	539	184 (34)	141 (26)	214 (40)	. . .
Total No. of isolates	1,508	635 (42)	443 (29)	430 (29)	. . .

*Duration in weeks of recovery per patient per episode.
**P <0.05 for colonization vs pneumonia.

were isolated in 64 percent (15) of the 24 patients with tracheobronchitis and 52 percent (12) of those 24 patients with an episode of pneumonia.

A longitudinal presentation of one patient who had a one-year follow-up is presented in Table 2. This patient was colonized by different bacteria and had seven episodes of documented pneumonia. It is obvious that different bacteria were present as colonizers prior to the episodes of pneumonia. It is of interest to note that therapy with gentamicin did not eradicate *Pseudomonas aeruginosa* but eliminated *K pneumoniae* in episodes P_1 and P_3. It is also of interest that *Streptococcus pneumoniae* appeared twice in episodes P_1 and P_3 but disappeared following therapy. *Staphylococcus aureus* appeared as a colonizer in the middle of the year. The anaerobic bacteria which appeared during episodes of pneumonia were *F nucleatum* and *Peptococcus* sp, while *Bacteroides melaninogenicus* appeared in two episodes of pneumonia and later persisted as a colonizer.

Discussion

This study demonstrates that colonization of the tracheobronchial tree with potentially pathogenic

Table 2—*Longitudinal Bacteriologic and Clinical Data on 2-Year-Old White Boy*

Data	Weeks																								
	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50
Therapy*	G+PN						PN		AM+G							C+G									C
Aerobic bacteria																									
Klebsiella pneumoniae	x	x	x				x	x	x			x	x												x
Pseudomonas aeruginosa	x		x	x		x			x	x	x	x	x				x		x	x	x				x
Serratia marcescens		x						x	x													x	x		
Escherichia coli							x	x				x	x	x	x	x	x		x	x	x			x	
Citrobacter diversus																x				x					
Hemophilus influenzae																x									
α-Hemolytic streptococci	x				x		x				x	x			x	x			x			x	x		
Streptococcus pneumoniae	x	x				x																			
Staphylococcus aureus								x				x	x	x		x	x	x				x			
Anaerobic bacteria																									
Fusobacterium nucleatum		x	x				x	x							x	x									x
Bacteroides fragilis								x	x																
Bacteroides melaninogenicus			x	x			x	x						x	x	x									
Peptococcus sp		x	x				x	x																	x
Veillonella sp				x	x										x			x				x			
Episodes of pneumonia		P_1					P_2	P_3				P_4		P_5		P_6									P_7

*G, Gentamicin; PN, penicillin; AM, ampicillin; and C, clindamycin.

aerobic and anaerobic bacteria occurs in all of the patients who underwent tracheostomy and had tracheal tubes for long periods of time. The occurrence of anaerobic bacteria in the tracheal secretions in proportionally similar quantities as aerobic bacteria following tracheostomy has not been described before. This could be due to the lack of use of appropriate anaerobic techniques in cultivation of those specimens. Since anaerobic bacteria are part of the normal oral flora, their presence in the tracheal aspirates of those patients is not surprising. Similar anaerobic bacteria were previously isolated from adults[5] and pediatric[6] patients with aspiration pneumonia. The acquisition of the aerobic and anaerobic organisms which are part of the normal oral flora occurs in patients who undergo tracheostomy and intubation because of their inability to clear their secretions and their dependency on mechanical suctioning.

Bacteroides fragilis, which usually is not a part of the normal oral flora, was isolated in many of our patients; however, the occurrence of this pathogen in pleuropulmonary infections was noted by other investigators,[7] especially in patients with poor oral hygiene. Peptostreptococci and *Bacteroides melaninogenicus* were more frequently isolated from patients with pneumonia than from patients with colonization, suggesting the possible role of these organisms in those infections.

Organisms which appeared in the tracheal secretions prior to the acquisition of pneumonia were also present in episodes of pneumonia in half of the patients. These findings confirm data obtained by previous investigators;[1] however, newly acquired pathogens appeared in many other cases of pneumonia, as was demonstrated in the case presented (Table 2).

Routine cultures of the tracheal secretions for surveillance of aerobic and anaerobic bacteria would enable the clinician to predict changes in the tracheal flora and facilitate the selection of appropriate antimicrobial therapy whenever the patient is infected. Repeated tracheal cultures for aerobic and anaerobic bacteria during the course of the pneumonia would allow for adjustment of the therapy if and when the bacteria present change or become resistant to the antibiotics used. Prophylaxis against acquisition of pneumonia is not recommended, since this would only facilitate the selection and acquisition of resistance by the bacteria, which would make it more difficult to treat the patients if and when they did become infected.

Data on surveillance were presented of 27 pediatric patients who were intubated for long periods of

time. All of the patients showed colonization with aerobic and anaerobic organisms, and most had suffered the occurrence of tracheobronchitis and pneumonia. The data presented suggest that anaerobic bacteria participate in the colonization of the tracheobronchial tree after tracheostomy and intubation, and they may also participate in the infectious processes secondary to this procedure.

ACKNOWLEDGMENT: I wish to thank the nursing staff and the staff of the Clinical Bacteriology Laboratories at Fairview State Hospital for their excellent cooperation and Drs. W. Rodriguez and R. Fink for reviewing the manuscript.

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