PERIOPERATIVE MICROBIOLOGIC MONITORING OF TRACHEAL ASPIRATES AS A PREDICTOR OF PULMONARY COMPLICATIONS AFTER CARDIAC OPERATIONS

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The value of preoperative and early postoperative microbiologic testing of tracheal aspirates as a prognostic indicator of the development of pneumonia was evaluated in a prospective study of 213 cardiac surgical patients. Tracheal aspirates were obtained immediately after intubation and after the patient's arrival at the intensive care unit. Diagnosis of pneumonia was accepted if at least three of the following criteria were fulfilled: leukocytosis $>15,000$ cells/mm³, body temperature $>38.5^{\circ}$ C, positive results of auscultation, positive results of radiography (new infiltrates that seemed to be consistent with pneumonia), and increased core-reactive protein for more than 2 days after operation. Potentially pathogenic microorganisms were found in 54 (25.4%) of the preoperative tracheal aspirates and in 27 (12.7%) of the early postoperative tracheal aspirates. Positive microbiologic findings correlated with pneumonia in the postoperative course in 24.1% ($p < 0.001$) if the preoperative culture results were positive, in 48.2% ($p < 0.001$) if the postoperative culture results were positive, and in 44.0% ($p < 0.001$) if both were positive. The risk of pneumonia was increased in male patients ($p < 0.05$) and in patients with chronic obstructive pulmonary disease ($p < 0.05$). Demographic variables, smoking, acute pulmonary symptoms, temperature, leukocyte count at the day of the operation, and data on the operation and the extracorporeal circulation were not significantly related to pneumonia in the early postoperative course. The risk of development of postoperative pneumonia is significantly higher among patients with colonization of the lower respiratory tract. Positive culture results in routine microbiologic monitoring of tracheal aspirates are predictive of pulmonary complications after cardiac operations. (*J Thorac Cardiovasc Surg* 1996;111:1213-8)

Pneumonia is still a serious and frequent complication in the early postoperative course after cardiac operations.¹ This complication increases the risk of prolonged intensive care treatment, raises costs, and frequently results in adverse outcomes.²⁻⁴ Respiratory tract infection occurs in 1.5% to 9% of patients after cardiac surgical procedures.⁵⁻⁸ The goals of infection

management are early detection and both prompt and specific intervention. The best way to diagnose an infectious complication after operation is to maintain a high index of suspicion regarding the presence of infection.¹ The role of preoperative colonization with pathogens of the lower respiratory tract in the development of postoperative pneumonia is not yet completely understood. In a prospective study, the value of preoperative and early postoperative tracheal aspirates in the prediction of pulmonary complications was examined to answer the following questions: (1) Does routine microbiologic testing of tracheal aspirates have prognostic value with respect to postoperative pneumonia? (2) Is there a difference between routine preoperative and early postoperative testing? (3) Is cefamandole, the antibiotic used for prophylaxis in our institution, effective in the treatment of lower respiratory tract colonization?

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Received for publication June 14, 1995; accepted for publication Sept. 19, 1995.

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0022-5223/96 \$5.00 + 0 12/1/69345

Patients and methods

Patients. Two hundred thirteen consecutive patients (158 male, 55 female; 10 emergency cases and 203 elective cases) scheduled to undergo cardiac operations were prospectively studied. The study was approved by the institutional ethics committee, and informed consent was obtained from each patient. Age was 61.5 ± 9.9 years (range 22 to 83 years), and body weight was 75.4 ± 11.9 kg (range 41 to 107 kg). The surgical procedures performed were aorta-coronary bypass ($n = 151$); valve replacement ($n = 27$); combined procedures ($n = 16$); and surgical treatment of hypertrophic obstructive cardiomyopathy ($n = 2$), congenital heart disease ($n = 5$), and heart tumors ($n = 2$).

Patients who received antibiotics before the operation were excluded from the study. Anesthesiologic and surgical techniques, as well as cardiopulmonary bypass and treatment at the intensive care unit, did not differ in any way from routine procedures. Time of bypass was 86 ± 28 minutes (29 to 246 minutes), time of ischemia was 53 ± 20 minutes (19 to 131 minutes), and lowest temperature during bypass was $34.4^\circ \pm 0.2^\circ$ C.

Microbiologic monitoring and antibiotic prophylaxis. Deep tracheal aspirates were taken immediately after commencement of anesthesia (before application of the preoperative antibiotic, time TA1) and after arrival of the patient at the intensive care unit (time TA2). Microbiologic cultures on bacteria or fungi were performed on aspirates from both time points.

After the first tracheal aspiration, antibiotic prophylaxis was performed with 2 g intravenous cefamandole. Two additional doses of cefamandole were given on the day of the operation and two were given on the first postoperative day. Additional tracheal aspirates were taken if pulmonary infection was clinically suspected. If pneumonia was suspected according to the described criteria, the antibiotic regimen was adapted to the antibiogram of organisms previously retrieved by aspiration.

Diagnosis of pneumonia. Pneumonia was suspected if at least three of the following five criteria were fulfilled: (1) leukocytosis $>15,000$ cells/mm³, (2) body temperature $>38.5^\circ$ C, (3) positive results of auscultation, (4) positive radiograph (new infiltrates that seemed to be consistent with pneumonia), and (5) increase in core-reactive protein for more than 2 days after operation. All cases of pneumonia that occurred within 5 days after the operation were included in this study. Mortality analysis included any deaths within 30 days after operation.

The influence of the following factors on the development of pneumonia was investigated: (1) the detection of potentially pathogenic bacteria or fungi in the tracheal aspirates before operation, early after operation or at both time points; age (<60 years, <70 years, >70 years); body weight (<70 kg, <90 kg, >90 kg); sex; New York Heart Association functional classification (II through IV); preoperative leukocyte count and body temperature; preoperative smoking history; chronic obstructive pulmonary disease (COPD); acute pulmonary symptoms on the day of the operation; duration of extracorporeal circulation (<60 minutes, <90 minutes, <120 minutes, >120 minutes); duration of the operation (<120 minutes, <180 minutes, <240 minutes, >240 minutes); intraoperative

fluid balance; and intraoperative opening of a pleural space.

Statistical analysis. Data were analyzed as an array of $k \times 2$ contingency tables. For $k = 2$, the χ^2 test was applied; for $k > 2$, the $k \times 2$ -fields χ^2 test (Brandt-Snedecor) was used. A p value < 0.05 was considered significant.

Results

Results of microbiologic cultures. Potentially pathogenic microorganisms were found in 54 (25.4%) of the preoperative aspirates (time TA1) and in 27 (12.7%) of the early postoperative aspirates (time TA2). In eight of the preoperative and two of the postoperative aspirates, more than one microorganism was detected. In two cases, results of the TA2 culture were positive and results of the TA1 culture were negative. At least one of the microorganisms found in the TA1 culture could be reconfirmed in the TA2 culture in 23 cases (42.5%). In two patients, different microorganisms were found in TA1 and TA2 cultures.

Pneumonia. The criteria for pneumonia in the postoperative course were fulfilled in 23 (10.8%) of the patients. At the time of diagnosis, the patients showed leukocytosis in 43.5%, increased body temperature in 65.2%, positive auscultation in 91.3%, radiographic evidence in 91.3%, and increased core-reactive protein in 87%. In eight of these cases (34.8%), neither TA1 nor TA2 culture results were positive. Positive microbiologic findings were associated with pneumonia in the postoperative course in 24.1% with positive TA1 culture results ($p < 0.001$), in 48.2% with positive TA2 culture results ($p < 0.001$), and in 44.0% with both culture results positive ($p < 0.001$). Negative results at TA1 carried a probability of postoperative pneumonia of 6.3%, negative results at TA2 carried a probability of postoperative pneumonia of 5.4%, and negative results at both time points carried a probability of postoperative pneumonia of 6.4%. In 15 cases, the microorganisms detected in TA1 or TA2 cultures were responsible for pneumonia; in another case, fungi were detected. In the remaining seven cases, no microorganisms could be detected in the tracheal aspirates, blood cultures, or sputum specimens. Table I demonstrates the results of the microbiologic cultures and indicates the frequency of pneumonia associated with each pathogen.

Impact of smoking, COPD, and preoperative pulmonary symptoms on risk of pneumonia. One hundred fourteen patients in this study (53.5%) were smokers. They had a higher incidence of positive microbiologic findings than did nonsmokers ($p <$

Table I. Results of microbiologic testing and incidence of pneumonia

TA1	TA2	Pneumonia		
		Yes	No	Total
Sterile	Sterile	8	149	157
	<i>Enterobacter</i>	1	—	1
	<i>Streptococcus viridans</i>	1	—	1
<i>Candida</i>	Sterile	—	1	1
<i>Escherichia coli</i> and <i>Pneumococcus</i>	<i>E. coli</i>	—	1	1
<i>Enterobacter</i>	<i>Enterobacter</i>	1	—	1
<i>Haemophilus</i>	Sterile	—	1	1
	<i>Haemophilus</i>	—	3	3
<i>Klebsiella pneumoniae</i>	<i>K. pneumoniae</i>	1	1	2
<i>Morganella</i>	<i>Morganella</i>	1	—	1
<i>Neisseria sicca</i>	Sterile	—	1	1
	<i>N. sicca</i>	—	2	2
<i>N. sicca</i> and <i>Pneumococcus</i>	<i>Pneumococcus</i>	1	—	1
<i>Pneumococcus</i>	Sterile	2	6	8
	<i>Pneumococcus</i>	1	3	4
	<i>S. viridans</i>	—	1	1
<i>Pneumococcus</i> and <i>Haemophilus</i>	Sterile	—	1	1
	<i>Pneumococcus</i> and <i>Haemophilus</i>	1	1	2
	<i>Haemophilus</i>	1	—	1
	<i>Proteus</i>	1	—	1
<i>Pneumococcus</i> and <i>Staphylococcus aureus</i>	<i>Pneumococcus</i>	1	—	1
<i>S. aureus</i>	Sterile	—	8	8
	<i>S. aureus</i>	1	—	1
<i>S. viridans</i>	Sterile	—	9	9
	<i>S. viridans</i>	1	2	3
Total		23	190	213

0.05). Pneumonia was diagnosed in 11.4%, with no statistical difference from nonsmokers (10.1%). A significant risk of pneumonia was found among patients with COPD. Pneumonia occurred in 21.2% of these 33 patients, compared with 8.9% of the patients without a specific anamnesis ($p < 0.05$). Among 59 patients with symptoms such as coughing, acute cold, or expectoration, pneumonia occurred in 15.3%, compared with 9.1% of the patients without such symptoms. These differences, however, were not statistically significant. There was no difference in pneumonia rate between emergency (10.0%) and elective procedures (10.8%). Pneumonia was more frequent among men ($p < 0.05$). The incidence of pneumonia was not influenced by the other perioperative factors analyzed (Table II).

Spectrum of resistance. In four cases, microorganisms isolated before operation were not sensitive to cefamandole (*Pseudomonas*, *Enterobacter*, *Haemophilus*, *Morganella morganii*). Three of these patients had pneumonia in the later course.

Outcome. The time on the ventilator was 18.8 ± 6.7 hours for patients with pneumonia in the postoperative course and 15.4 ± 5.6 hours for patients without pneumonia ($p < 0.05$). It was 15.8 ± 4.9

Table II. Factors associated with pneumonia in the early postoperative course

Factor	Significance
Age	NS
Weight	NS
Male sex	$p < 0.05$
New York Heart Association functional class	NS
Smoker	NS
COPD	$p < 0.005$
Leukocyte count before operation	NS
Body temperature before operation	NS
Pulmonary symptoms on day of operation	NS
Operation performed	NS
Positive microbiologic findings	
Before operation	$p < 0.001$
After operation	$p < 0.001$
Before and after operation	$p < 0.001$
Time of extracorporeal circulation	NS
Duration of ischemia	NS
Duration of operation	NS
Fluid balance during extracorporeal circulation	NS
Opening of a pleural space	NS

NS, Not significant.

hours for patients with positive microbiologic findings before the operation and 15.8 ± 6.1 hours for patients without positive microbiologic findings ($p > 0.05$).

Table III. Incidence of pneumonia (%)

Potentially pathogenic microorganism found	Pneumonia	No pulmonary complication
Before operation		
Yes (25.4%)	24.1	75.9
No (74.6%)	6.3	93.7
After operation		
Yes (12.7%)	48.2	51.8
No (82.3%)	5.4	94.6

Eight patients (3.8%) died within 30 days after operation. The causes of these deaths were cardiac failure in four cases, septicemia of unknown origin in two, and pulmonary infection in two (one patient without colonization at TA1 or TA2 died of fungal pneumonia, one patient had streptococcus in TA2).

Discussion

Pulmonary complications after cardiopulmonary bypass are frequent and account for a major number of adverse outcomes. In the early postoperative period, the immunosuppression caused by surgical trauma, extracorporeal circulation, anesthetics or transfusion of blood products¹⁰ favors the development of pulmonary infections. Such physiologic defense mechanisms as the cellular immune response (mononuclear phagocytes, polymorphonuclear leukocytes) are depressed in this situation, as are humoral factors and mucociliary clearance. In addition, artificial ventilation is itself a potent risk factor.¹¹ In this situation, colonization of the lower respiratory tract with pathogens that were suppressed or controlled by the body's defense mechanisms before the operation can lead to postoperative pulmonary infection. Our data, as well as the results of Carrel and associates,⁸ show that colonization of the lower respiratory tract accounts for a significant number of postoperative pneumonias. Interstitial edema or increased extravascular lung water, diffuse atelectasis, lung collapse during extracorporeal circulation, opening of the pleural space (although this last was not a significant factor in our study) are among the factors that may complicate the situation after cardiac surgical procedures.

The incidence of infections after cardiac operations ranges between 4% and 9% among all patients. It is divided into the categories of bacteremia (2%), wound infection (1% to 2%), urinary tract infection (0.5%), and respiratory infection (1.5% to 9%).^{5, 6, 8} Respiratory complications have reported to be more likely in patients with previous pulmonary disease^{12, 13}; this was confirmed by our data.

COPD—but not symptoms of acute respiratory infection—was accompanied by a statistically significant risk of postoperative pneumonia. In contrast to other findings,⁸ smoking was not a risk factor in our study, despite a significantly higher colonization rate among smokers ($p < 0.05$).

The value of deep tracheal aspirates in the diagnosis of lower respiratory tract infection remains under discussion,^{14, 15} as does the use of more invasive techniques to obtain microbiologic specimens.^{16, 17} The main arguments against tracheal aspirates for routine monitoring are possible contamination of the aspirate sample with physiologic upper respiratory tract flora, the fact that colonization does not necessarily mean infection, and the costs of routine bacteriologic monitoring. Possible contamination of lower respiratory tract secretions by upper respiratory and oral bacterial flora may make it difficult to distinguish colonization from a noninfectious inflammatory response, nor can bacteriologic monitoring differentiate tracheitis or bronchitis from pneumonia. Further complicating the interpretation of bacteriologic results, such common lower respiratory tract pathogens as *Haemophilus influenzae* may form part of the normal flora of the upper respiratory tract.¹⁸ Within a short time after intubation, bacteria from the upper gastrointestinal tract migrate past the tracheal tube cuff to colonize the lower trachea.¹⁹ Bacteria can thus be isolated from tracheal suction specimens regardless of whether the patient actually has a lower tract infection. Although these arguments cannot be refuted by our study and are probably valid in many cases, the high incidence of pneumonia after positive microbiologic findings in our series encourages us to recommend this kind of monitoring.

The reported incidences of lower respiratory tract infections after cardiac operations differ.^{5, 6, 8} These variations arise from the criteria used to define pneumonia and the attention placed on diagnosis. In a series of 100 patients, Carrel and associates⁸ found an overall incidence of pneumonia of 9%. Positive microbiologic findings in the tracheal aspirates before operation resulted in pneumonia in 30.7% of their patients, with negative findings in 1.4% within the first 4 days after cardiac operation. In their group, smoking and preoperative pulmonary dysfunction were significant risk factors for postoperative pneumonia.

Our data show that preoperative colonization accounts for most cases of pneumonia after cardiac surgical procedures. Routine microbiologic moni-

toring of tracheal aspirates is helpful in the early determination of risk of postoperative pneumonia and provides antibiograms of the colonizing bacteria before clinical signs of infection. More positive microbiologic findings were documented before the operation. Many such findings could not be reconfirmed on the patient's arrival at the intensive care unit. This is probably a result of antimicrobial prophylaxis. Colonization found on the patient's arrival at the intensive care unit was associated with a 48.2% incidence of pneumonia in the postoperative course. The proof of colonization or infection of the respiratory tract in preoperative or early postoperative tracheal aspirates is therefore helpful in initiating a specific antibiotic therapy in cases of the clinical diagnosis of pneumonia. In our study, documented colonization was followed by changes in the antibiotic regimen only if clinical signs of pulmonary infection were evident. Analysis of tracheal aspirates can be recommended as a technically simple method that avoids or at least reduces unnecessary costs of undirected antibiotic therapy.

Antibiotic prophylaxis in cardiac surgical patients is aimed primarily at preventing infections at the surgical site (sternum, legs, mediastinum) and not at preventing pulmonary complications. Advantages and disadvantages with respect to these complications of different antibiotic regimens have been extensively discussed in the literature.^{5, 20-22} Many institutions, such as ours, use cephalosporins for antibiotic prophylaxis.²³⁻²⁶ Although resistance to cefamandole, the antibiotic used in our study, could be demonstrated in only four cases, this antibiotic could not protect patients from pneumonia in a significant number of cases. Whether this is a question of dosage or this cephalosporin is inadequate for treatment of airway colonization remains unanswered by this study.

Timing of routine microbiologic monitoring is of importance. Specificities at the two time points were comparable (false-negative results with respect to outcome in 6.3% at TA1 vs 5.4% at TA2). Although the high sensitivity at TA2 (pneumonia associated with 48.2% of positive tracheal aspirate cultures) suggests that arrival at the intensive care unit is an adequate time for culture, several aspects favor use of a preoperative tracheal aspirate. The absolute number of positive cultures leading to pneumonia was 13 at each time point. The preoperative antibiotic seems to suppress significant colonization until arrival at the intensive care unit in many cases, or at least it makes the diagnosis from tracheal aspirates

impossible. Contamination of tracheal aspirates with small amounts of blood, resulting from micro-trauma of lung tissue, may account for this. This blood contains the prophylactic antibiotic, which might suppress growing of pathogens. The problem of transfer of oral or gastric bacterial flora into the specimen is at least theoretically minimized by obtaining the tracheal aspirate immediately after intubation.

In conclusion, the risk of development of postoperative pneumonia is significantly higher among patients with preoperative colonization of the lower respiratory tract. A positive culture result from routine microbiologic monitoring of tracheal aspirates is a predictor of pulmonary complications after a cardiac operation.

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