
Correlation of Bronchoalveolar Lavage with Radiographic Evidence of Pneumonia in Thermally Injured Children

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The diagnosis of pneumonia in the critically ill patient is very difficult because the usual signs and symptoms are unreliable in the intensive care setting. Bronchoalveolar lavage (BAL) is a diagnostic tool with a reported sensitivity of 70%. The purpose of this study was to determine the efficacy and specificity of BAL in severely burned pediatric patients. An analysis was performed in which BAL cultures were compared and correlated to chest radiographs. Patient characteristics, such as age, sex, burn size, depth of burn, and the presence of inhalation injury were evaluated. Over a period of 18 months, 58 thermally injured children were identified who underwent 101 BALs. The mean age was 6.5 ± 5 years, mean TBSA was $39 \pm 27\%$, and inhalation injury was diagnosed in 20 patients (35%). Of 101 BALs, 48 were positive, and of the 101 chest radiographs, 20 demonstrated signs of pneumonia. Ten of those were associated with a positive BAL and 10 with a negative BAL. Thus, the positive predictive value of BAL was 21%, whereas the negative predictive value was 81%. Interestingly 80% of patients with tracheobronchitis from inhalation injury demonstrated a positive BAL. We conclude that in pediatric burn patients BAL correlates poorly with radiographic signs of pneumonia. (*J Burn Care Rehabil* 2003;24:382–385)

Pneumonia has been a significant cause of morbidity and mortality in the intensive care unit (ICU) for many decades.^{1,2} Despite improvements in antimicrobial therapy and the emergence of new treatment modalities for multisystem organ failure, pneumonia often supervenes and may lead to prolonged ventilator dependence or even death.³ In the United States alone, approximately 300,000 cases of nosocomial pneumonia are reported per annum, with an estimated mortality rate of 20 to 50%.^{3–5} Unfortunately, the usual signs and symptoms of pneumonia, such as fever, leukocytosis, and tachypnea, are often present in critically ill patients whether they have pneumonia

or not. Therefore, it is very difficult for the physician to make the correct diagnosis.^{6,7} Thus, a more exact diagnostic approach has become necessary.³ Little attention, however, has been paid to this clinical entity, and few efforts have been made to develop new or to improve current diagnostic criteria.⁸

Diagnostic methods have been established in the ICU over the past decade, such as sputum examination, bronchoalveolar lavage (BAL), and transbronchial lung biopsy.^{8–10} Sputum examination of orally obtained specimens represents a noninvasive approach; however, the sputum is often contaminated with oropharyngeal flora. Furthermore, Gram stain of organisms, although fairly sensitive, is a very nonspecific measure. Transbronchial lung biopsy has been advocated in some studies, but the high incidence of pneumothorax and other complications has precluded its routine clinical use. BAL is a noninvasive method that attempts to circumvent problems and complications of these methods. By directly sampling the more distal airways, there is a significantly lower contamination rate and a larger volume of obtained sample associated with BAL when compared with other diagnostic techniques.^{8–10} For these reasons, BAL has become standard practice at our institution.

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However, the efficacy of BAL in thermally injured children has not yet been defined. Therefore, in the present study we attempted to establish the diagnostic efficacy of BAL and enhance our understanding of its role as a diagnostic tool in the pediatric burn population.

PATIENTS AND METHODS

The medical records of all thermally injured children who underwent BAL over a period of 18 months at the Shriners Hospital for Children, Galveston, Texas, were reviewed. We identified 58 patients who underwent 101 BALs. Data collected included patients characteristics, age at date of admission, sex, percent TBSA burn, percent third-degree burn, and the presence or absence of inhalation injury. Inhalation injury was suspected if the following signs and symptoms were present: hoarseness, lacrimation, dyspnea, wheezing, stridor, facial burns, or carbonaceous sputum. In each of these cases, inhalation injury was confirmed by fiberoptic bronchoscopic findings of mucosal erythema, ulceration, infraglottic soot, and hemorrhage.

Patients underwent the standardized care that is practiced at our institution.⁹ This includes early wound excision and grafting, management of fluid and electrolyte balance (fluid resuscitation was given according to the Galveston formula), metabolic and nutritional support with enteral feedings, as well as aggressive pulmonary toilet and respiratory therapy. Routine intraoperative bronchoalveolar lavage was performed at the time of wound excision and grafting by an experienced anesthesiologist. A pediatric bronchoscope was wedged into the most possible distal lung segment and was lavaged with 10 ml of sterile saline on both sides. The BAL fluid was then cultured and findings were used to direct antimicrobial therapy. BALs were considered "positive" if at least one organism at a concentration of $\geq 1 \times 10^3$ /ml was grown. Patients received antibiotics perioperatively as well as for positive blood, urine, and quantitative wound cultures. Generally, we give one dose of antibiotics perioperatively; therefore, it is not likely that the single dose of antibiotics affects the yield from BAL.

The results of quantitative culture data from BAL specimens were compared with chest radiographs taken at the same time during the hospital course. Chest radiographs were reviewed by an experienced pediatric radiologist who was blinded to the clinical course and outcome of the patients in this study. Chest films were designated as normal (clear with no radiographic abnormality whatsoever), abnormal but not consistent with

pneumonia (signs of noncardiogenic pulmonary edema, atelectasis, or acute respiratory distress syndrome), or consistent with pneumonia (radiographic evidence of homogeneous consolidation and patchy infiltrate without volume loss). In cases where differentiation of pneumonia from diffuse lung injury was difficult, serial radiographic changes were reviewed to determine progression in a suspicious infiltrate. Permission for record review was obtained from the Institutional Review Board for human studies at the University Texas Medical Branch, Galveston, Texas.

RESULTS

We identified 58 patients at our institute who underwent a total of 101 BALs. Patient characteristics were as follows: mean age was 6.9 ± 5 years (range, 0.5–17.5 years), with 38 males (66%) and 20 females (34%). The mean total percent body surface area burned was $39 \pm 27\%$ (range, 5–95%), with a third-degree component of 29 ± 31 (range, 0–95%). Forty-three patients (74%) suffered a flame burn, 10 patients (17%) suffered scald burns, four patients (7%) sustained electrical injury, and one patient received a contact burn (2%). Inhalation injury was identified in 20 of the 58 patients (34%).

Of the 101 BAL specimens obtained, 48 demonstrated growth of at least one organism at greater than 1×10^3 /ml and were considered positive for pneumonia. The remaining 53 BAL specimens revealed no growth, growth of organisms at less than 1×10^3 , or growth of normal flora. Table 1 summarizes the organisms most commonly isolated from positive BAL specimens.

Twenty chest radiographs revealed infiltrates or consolidation consistent with pneumonia. Ten of these radiographs were from patients who had a positive quantitative BAL on the same day and 10 from patients who had a negative BAL on the same day.

With respect to radiographic evidence of pneumonia, there were 10 true-positive and 38 false-positive

Table 1. Distribution of organisms isolated from "positive" bronchoalveolar lavage specimens

Organism	Incidence
Methicillin-sensitive <i>Staphylococcus aureus</i>	21
<i>Klebsiella pneumoniae</i>	11
Methicillin-resistant <i>Staphylococcus epidermidis</i>	11
<i>Pseudomonas aeruginosa</i>	10
Methicillin-sensitive <i>Staphylococcus epidermidis</i>	10
<i>Enterobacter cloacae</i>	8

Data presented as percentages.

BAL specimens. Based on this data, we can calculate the positive and negative predictive value of BAL, as demonstrated by the following equations:

Positive predictive value = true positive/total positive = $10/48 = 21\%$

Negative predictive value = true negative/total negative = $43/53 = 81\%$

Perhaps the most striking difference noted is that 16 of 20 patients (80%) with inhalation injury had a positive BAL at some point during their hospital course. This is in sharp contrast with patients without inhalation injury, in which only 16 of 38 patients (42%) had a positive BAL. However, although 80% of these patients had a positive BAL, only 6 of 21 (29%) had classic radiographic evidence of pneumonia, therefore showing a discrepancy between BAL and radiographic signs of pneumonia (Figure 1).

When considering the spectrum of radiographic findings in all patients with positive and negative BAL, there was virtually no difference between positive and negative BAL. In both groups approximately 20% of radiographs were consistent with pneumonia, 40% were read as abnormal but not consistent with pneumonia, and 40% were normal (Figure 2).

DISCUSSION

Classically, pneumonia is divided into two major categories, community-acquired pneumonia and hospital-acquired, or nosocomial pneumonia.^{3,4} The former is generally associated with gram-positive organisms, is often amenable to oral antibiotic therapy, and can usually be reliably diagnosed by clinical signs, including fever, leukocytosis, sputum production, and physical findings. Nosocomial pneumonia, how-

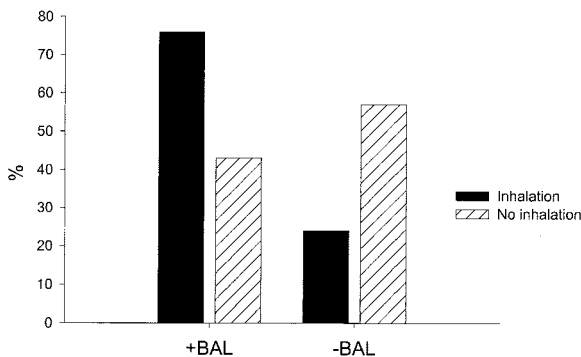


Figure 1. Correlation between bronchoalveolar lavage (BAL) and inhalation injury. Eighty percent of patients with inhalation injury demonstrated a positive BAL during their hospital course, whereas only 43% of patients without inhalation injury had a positive BAL. Data presented as percentages.

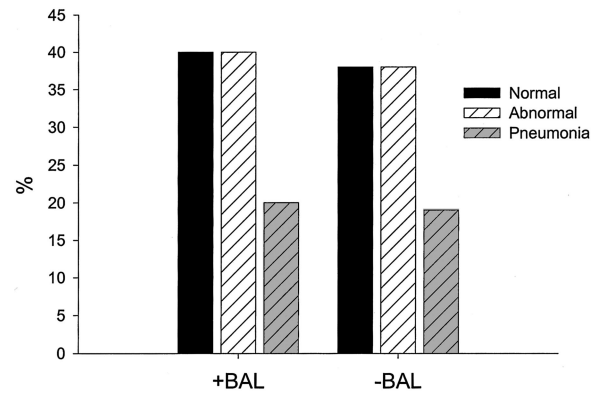


Figure 2. Distribution of radiologic findings. In the spectrum of radiographic findings in all patients with positive and negative bronchoalveolar lavage, no difference was found. Data presented as percentages.

ever, is usually caused by gram-negative organisms, often requires intravenous antibiotic therapy, and is misdiagnosed in a large percentage of cases based on the above clinical findings thus demanding a new diagnostic tool with high sensitivity and specificity.^{3,4} We showed in this study that BAL when compared with radiographic findings has a low sensitivity (positive predictive value) and a relative high specificity (negative predictive value) for the diagnosis of pneumonia. However, we also demonstrated that BAL might be a helpful tool for the diagnosis of tracheobronchitis associated with inhalation injury.

Many previous studies, notably those by Herndon and Pruitt,^{6,9} documented the increased mortality of burn victims with a concomitant inhalation injury. This increase in mortality is at least partly caused by a higher incidence of pneumonia in these patients.⁹ Inhalation injury therefore amplifies the importance of accurate diagnosis of pneumonia in this population. In a large series of patients, Pruitt et al⁶ demonstrated that the incidence of inhalation injury was 35% based on bronchoscopic findings and xenon scan. Furthermore, there was a 38% incidence of pneumonia in the patients with inhalation injury.

When inhalation injury and pneumonia both present in association with a large burn, they carried a combined mortality of 60%.² In light of these findings, it is imperative that the clinician quickly and accurately diagnoses pneumonia so that proper treatment can be initiated before irreversible pulmonary insufficiency ensues. Inhalation injury is a tracheobronchitis caused by the inhalation of smoke and other products of incomplete combustion, and it is characterized by mucosal erythema, ulceration, hemorrhage, and extensive necrosis of respiratory epithe-

lium, which predisposes patients to secondary bacterial invasion and subsequent development of pneumonia.⁶ Positive BAL correlates better with the presence of tracheobronchitis than with true pneumonia, which is consistent with the finding in the present study, where 80% of patients with inhalation injury had a positive BAL during their hospital course yet only 29% had classic radiographic evidence of pneumonia.

Although the efficacy of BAL has been demonstrated in the diagnosis of opportunistic infection in immunocompromised medical patients with a reported sensitivity of 70%, it has shown less effectiveness in the intensive care setting.¹⁰ Chastre and Fagon⁸ found almost no difference in quantitative BAL data in intubated patients with and without infection. The present study seems to bolster the notion that BAL is not discriminating in identifying pneumonia in the critically ill patient, especially in the pediatric burn population. In the present study, the positive predictive value of 21% for BAL with respect to radiographic findings is disappointing, although the negative predictive value is more encouraging (81%). There are many possible explanations for this. First of all, many of these patients were ventilator dependent and, as such, they often had tracheostomies. This has clearly been shown to be associated with increased colonization and inflammation of the tracheobronchial tree.³ Furthermore, although only 20 radiographs demonstrated infiltrate or consolidation consistent with pneumonia, there were a large number of abnormal radiographs. Findings of atelectasis, pulmonary edema, and diffuse hazy infiltrates can make radiologic diagnosis of infection difficult. Aspiration pneumonitis can also complicate the radiographic picture in these patients.

In an attempt to determine what the positive predictive value is for BAL, there is the possibility that the chest x-ray is underdiagnosing the presence of pneumonia and that some of the patients with a positive BAL and negative chest x-ray have a pneumonic process or one that is evolving. However, the chest

x-ray always correlated with the patient's clinical course and the presence of microbial in the airway.

Although BAL has its shortcomings, it is the best currently available tool and has been useful in directing antimicrobial therapy. In the ICU population, however, one must be cognizant of its limitations and of the many confounding variables. For this reason, it is of paramount importance that the clinician remains vigilant and assimilates BAL findings in the context of the overall clinical picture.

Although there was no problem in collecting the specimen, nonbacteriostatic, sterile saline was used to wash, and after the BAL the volume retrieved indicated an adequate sample. We conclude from our data that "positive" BAL findings do not correlate well with classic radiographic evidence of pneumonia in the severely burned child. However, BAL appears to correlate well with the presence of tracheobronchitis, thus being a supportive tool for the diagnosis.

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