5. No more than modest bronchoconstriction, as indicated by an FEV₁, greater than or equal to 60 percent of predicted value or by other tests of airway caliber.

6. Absence of concomitant illness within the previous four weeks that could increase the risk of bronchoscopy (i.e., upper respiratory infection, bronchitis).

SYMPTOMATIC

Experience also indicates that mildly symptomatic asthmatic subjects with or without therapy, or those undergoing provocation may undergo lavage provided:

1. The clinical pattern of asthma (acute, intermediate or delayed onset) and magnitude of the airway response to provocation in the asymptomatic state (methacholine, histamine or antigen) have been determined previously.

2. At the time of bronchoscopic evaluation, their provocation-induced bronchoconstriction is improving, as indicated by FEV₁ of greater than 60 percent of the predicted value.

Post-procedure Observation

Volunteers should be monitored carefully at regular intervals after the procedure. Serial FEV₁, FVC, and oxygen saturation (ear oximeter) should be obtained for at least two hours and for up to 8-12 hours if a delayed response is expected, as based upon prior observations. If the patient is noncompliant, or if there is a complication during the lavage procedure, observation should be extended to overnight.

SUMMARY

The participants in the workshop reached unanimous consensus that as an investigative tool, BAL has enormous potential for extending knowledge of the immunopathogenesis of asthma. When utilized according to these guidelines, maximum knowledge may be gained with minimal risks to study subjects. However, we wish to emphasize that the extent to which the safety of the procedure applies to those asthmatic subjects with more symptoms and an FEV₁ of less than 60 percent of predicted remains to be established by carefully controlled clinical investigations.

REFERENCES


Positive prick skin test to a putative allergen
Ages 18-45, healthy men and women, nonsmokers
predicted
History of mild seasonal or chronic asthma
No change in pulmonary function
FEV1 before lavage of greater than or equal to 60 percent of predicted
No change in pulmonary function (spirometry) for three weeks

ciausation of the asthmatic syndrome. On the other hand, the effect of premedications, ie, atropine and beta-agonists, on BAL findings has not been elucidated.

At two scientific institutions in the United States, approximately 42 asymptomatic asthmatic patients have been selected for antigen challenge according to the criteria listed in Table 1. Of this group, 26 received antigen in bolus form by aerosol and 16 received antigen directly on selective airways by bronchoscopic delivery. Four antigen-challenged individuals showed no physiologic response, while the remaining 38 showed a 10-20 percent reduction in FEV1; most had visual evidence of bronchial mucosal edema and partial airway obstruction that was reversed by local application of epi-
nephrine as viewed through the fiberoptic bronchoscope. In several of these patients, significant changes in the cellular and humoral constituents of the BAL fluids were noted. None had symptoms or delayed complications. These data suggest that with careful selection of patients, vigorous medical supervision and preparation, and involvement of experienced bronchoscopists, antigen challenge of asymptomatic asthmatic individuals with concomitant BAL is a safe procedure that may provide interesting new data on the pathophysiology of asthma.

EVALUATION AND PROCEDURE

In the opinion of this Committee, the application of bronchoalveolar lavage in asthma is considered a safe research procedure if there is adequate attention to patient selection, performance of the procedure, and post-procedure observation. Details of the recommended procedure follow.

Patient Evaluation

Because of the possibility of precipitating life-threatening bronchospasm or increased airway reactivity, the investigator must obtain a complete pulmonary history including: severity and frequency of the asthmatic attacks, respiratory infec-
tions, current medications, and specific allergies. In addition, a history of other coexisting medical conditions and laboratory data consisting of baseline pulmonary function studies and arterial blood gases for those patients to be challenged should be obtained prior to considering bronchoalveolar lavage. It is advised that asthmatic patients with a history of status asthmaticus and/or mechanical ventilation not be selected.

Performance of the Procedure

Preparation: The procedure should be performed by an experienced bronchoscopist with facilities available for the management of medical emergencies. The procedures should be carried out expeditiously, and antigen challenge plus BAL should generally require less than 20 minutes. A route for injection of intravenous medication must be se-
cured, and continuous supplemental oxygen at 5 L per minute is recommended. Premedication includes administration of parenteral atropine sulfate given at a dosage of 0.8-1.0 mg for all patients; parenteral opiates are recommended to control coughing and anxiety. The preprocedural administration of bronchodilating agents is an important step to prevent complications. Topical anesthesia of upper and lower airways must be achieved with a total dose of less than 400 mg of lidocaine.

Procedure: Normal saline solution or an equivalent iso-
tonic solution heated to 37°C is recommended for the lavage to reduce potential bronchospasm. Intubation is used by some experts for airway management, but is not mandatory. A maximum of 300 ml and a minimum of 100 ml in aliquots is recommended for a suitable lavage. The right middle lobe, lingula, or lower lobes are preferred; upper lobe lavage may have a poor yield of fluid. Lavage fluid should be aspirated with gentle suction. Also, periodic deep breathing by the subject aids in recovery of the effluent. If, however, fluid return for the first 200 ml is less than 40 percent, then the procedure should be terminated. There should be continuous monitoring of both oxygenation (ear oximeter) and electrocardiogram.

Since the antigenic challenge will increase the duration and potential risk of the procedure, dosages of antigen administered by aerosol or by direct local application should not exceed that concentration which produces a positive skin prick reaction. The use of more antigen (ten to 100 times the suggested dose) may be safe, but cannot be advised at this time. Although repeat bronchoalveolar lavages with and without antigenic challenge within 24-96 hours have been reported in a small number of subjects without adverse affect, the safety of repeated lavages has not been established. In addition, other manipulations such as mucosal brushings and biopsies in conjunction with bronchoalveolar lavage cannot be recommended at this time.

Potential Hazards: The potential hazards of bronchoscopic examination in asthmatic subjects include: bronchospasm, laryngospasm, and hypoxemia. Experience indicates that bronchoscopy and lavage are well tolerated by young adult (18-45 yrs old) asymptomatic asthmatic subjects who have been pretreated with bronchodilator medications and treated with supplemental oxygen during the procedure, although modest bronchoconstriction may still occur.

Patient Selection: The criteria for selection are presented in Table 1. If patients are carefully chosen to meet the following criteria they will be able to tolerate moderate worsening of airflow obstruction, during the BAL procedure.

ASYMPTOMATIC

1. Absence of asthmatic symptoms at the time of study.
2. Age range 18-45 yrs.
3. No requirement for bronchodilator medication during the preceding 24 hrs.
4. No spontaneous or sustained flare of symptoms in the past two weeks.

Table 1—Recommendations for Criteria for Selection of Asthmatic Subjects to Undergo BAL following Aerosol or Local Antigen Challenge

| Ages 18-45, healthy men and women, nonsmokers |
| History of mild seasonal or chronic asthma |
| Positive prick skin test to a putative allergen |
| Functional evidence of reversible obstructive airway disease with or without specific or nonspecific airways challenge |
| FEV1 before lavage of greater than or equal to 60 percent of predicted |
| No change in pulmonary function (spirometry) for three weeks |

Normal saline solution or an equivalent isotonic solution heated to 37°C is recommended for the lavage to reduce potential bronchospasm. Intubation is used by some experts for airway management, but is not mandatory. A maximum of 300 ml and a minimum of 100 ml in aliquots is recommended for a suitable lavage. The right middle lobe, lingula, or lower lobes are preferred; upper lobe lavage may have a poor yield of fluid. Lavage fluid should be aspirated with gentle suction. Also, periodic deep breathing by the subject aids in recovery of the effluent. If, however, fluid return for the first 200 ml is less than 40 percent, then the procedure should be terminated. There should be continuous monitoring of both oxygenation (ear oximeter) and electrocardiogram.

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DISCUSSION

This otherwise healthy young female had asymptomatic thrombophlebitis with recurrent pulmonary emboli which caused her complaints of chest pain. This was confirmed by the presence of a proximal deep vein thrombosis in conjunction with abnormalities on the lung scan, both of which resolved under treatment.

Possible explanations for this negative angiogram include false positive lung scan, false negative angiogram, or recanalization. This last option seemed the easiest to accept until the second lung scan was performed and showed a persistent although resolving perfusion defect. It was our impression that this was a false negative pulmonary angiogram due to inadequate angiographic technique. The angiographic method used in this patient could exclude only large emboli. Since perfusion defects were demonstrated on the lung scan, the areas in question should have been studied by selective catheter injections. Oblique views, as suggested by Bossart et al and Gomes et al, may have shown a small right upper lobe artery embolism. In patients with a radionuclide perfusion defect, selective angiograms may be required to demonstrate pulmonary occlusions.

REFERENCES


Excess carbohydrate calories in total parenteral nutrition (TPN) solutions can precipitate acute hypercapnic respiratory failure in patients with chronic lung disease secondary to increased carbon dioxide (CO₂) production. Two young patients recovering from the adult respiratory distress syndrome experienced hypercapnia during weaning as a result of nutritionally related increased CO₂ production. As carbohydrate calories were decreased, CO₂ production diminished and hypercapnia resolved. Hypercapnia as a complication of nutritional support during weaning can occur in patients without chronic lung disease and is corrected by decreasing carbohydrate calories.

Nutritional support of intensive care unit patients is becoming widely practiced as malnutrition and multiple adverse effects of malnutrition are recognized. Multiple complications can occur when nutritional solutions are given as total parenteral nutrition (TPN). Metabolic complications of TPN include increased carbon dioxide (CO₂) production. Acute hypercapnic respiratory failure has been precipitated with the use of TPN in nonintubated patients with chronic lung disease. Excess carbohydrate (CHO) calories were associated with an increased carbon dioxide production resulting in hypercapnia and acute respiratory failure.

We describe a complication related to increased carbon dioxide production associated with TPN use that is clinically recognized, but to our knowledge, previously unreported and not clearly documented. Two previously healthy young patients recovering from the adult respiratory distress syndrome (ARDS) developed hypercapnia associated with increased CO₂ production which became clinically apparent during weaning from mechanical ventilation. Carbon dioxide production decreased concurrently with the PaCO₂ as total carbohydrate (glucose) calories were decreased. Both patients were subsequently weaned. Unexpected hypercapnia during weaning may be nutritionally related.

METHODS

Serial measurements of CO₂ production were performed in each patient in the following manner. After a washout time of approximately two minutes, a four-minute timed air collection was done using the exhalation port of the ventilator. The expired air was collected into a 120 L, nonporous bag; volumes were measured by a Wright respirometer. The collected air was analyzed for carbon dioxide fraction using a Beckman infrared CO₂ analyzer. Carbon dioxide production was then calculated using the following equation:

\[ \dot{V}_{CO_2} (ml) = [FE_{CO_2} - 0.0003] \times V_{E} (L) \times STPD \times 10^3. \]

CASE 1

A 23-year-old white man was treated at the University of Kansas Medical Center for ARDS. After a long (three month) and complicated intensive care unit course, his respiratory status improved and weaning began. Preweaning arterial blood gas levels were a PaO₂ of 90 mm Hg, a PaCO₂ of 38 mm Hg, and pH of 7.43 on an FIO₂ of 0.3. Weaning parameters included a resting minute ventilation of 22 L, a negative inspiratory force of −58 cm H₂O, tidal volume of 611 ml, and a vital capacity of 1.0 L. During a short T-tube trial off the ventilator, hypercapnia (PaCO₂ 53 mm Hg), respiratory acidosis (pH 7.27), and respiratory distress were noted. At that time, he was

Hypercapnia during Weaning*
A Complication of Nutritional Support

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