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Diagnosis of acute bacterial pneumonia in Nigerian children

Value of needle aspiration of lung and of countercurrent immunoelectrophoresis

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SUMMARY Eighty-eight Nigerian children with untreated, severe, acute pneumonia were investigated by standard bacteriological techniques (blood culture and culture of pharyngeal secretions) and by needle aspiration of the consolidated lung. Countercurrent immunoelectrophoresis (CIE) against grouped pneumococcal and *Haemophilus influenzae* type b antisera was carried out on serum samples from 45 patients.

The aetiology of pneumonia was shown by examination of the needle aspirate in 70/88 patients (79%), by CIE in 9/45 patients (20%), and by blood culture in 4/36 patients (11%). Overall, a bacterial cause for pneumonia was shown in 73/88 patients (83%). The results of pharyngeal culture were misleading when compared with cultures of needle aspirates. The prediction of aetiology from the radiological appearance was also inaccurate, even for lobar pneumonia. Needle aspiration of the lung, with a low (5%) and minor complication rate, merits wider application in the diagnosis of acute pulmonary infections in children. Traditional bacteriological techniques (blood culture and pharyngeal culture) are of very limited value. The place of CIE in the inevstigation of childhood pneumonia still needs thorough evaluation.

It is rarely possible to be certain of the cause of pneumonia in a child. The traditional bacteriological investigations of sputum examination and blood culture each provide the correct answer in a minority of patients and frequently confuse the issue with both false-positive and false-negative results (Loda *et al.*, 1968; Barrett-Connor, 1971; Kinnell, 1973; Glezen and Denny, 1973; Tugwell and Greenwood, 1974; Davidson *et al.*, 1976). In developing nations, disease patterns may be affected by malnutrition, the absence of widespread immunization programmes, and the lack of early medical attention (Morley, 1973). Previous surveys in such areas have shown that, as in the preantibiotic era in Western Europe and America (Rosenow, 1911; Lyon, 1922; Ellison, 1931; Sappington and Favorite, 1936; Butler *et al.*, 1941), there is a high prevalence of bacterial infections of the lower respiratory tract (Abdel-Khalik *et al.*, 1938; Klein, 1969; Mimica *et al.*, 1971). The widespread and early use of antibiotics in more advanced societies may not only render more difficult the diagnosis of bacterial pneumonia (Spencer and Philp, 1973) but may also have contributed to the apparently higher prevalence of mycoplasma and viral respiratory tract infections in children (Nichol and Cherry, 1967; Loda *et al.*, 1968; Gardner, 1971).

From time to time over the last 93 years, direct needling of the lung (needle aspiration of the lung) has been advocated as an accurate means of determining the aetiology of pneumonia (Leyden, 1883; Ellison, 1931; Alexander *et al.*, 1941; Finland, 1969; Hyde *et al.*, 1973), but there have been few thorough assessments of the technique in children. Recently, countercurrent immunoelectrophoresis (CIE) has become available for the rapid identification of bacterial antigens in patients with pneumonia (*Lancet*, 1976). The value of the technique in childhood pneumonia has not yet been established (Lampe *et al.*, 1976; Michaels and Poziviak, 1976).

Our study was set up to identify the bacteria causing severe pneumonia in children living in the area served by Ahmadu Bello University Hospital, using standard bacteriological techniques as well as needle aspiration of the lung and CIE. The environment consisted of a largely traditional Hausa town (Zaria) and its rural environs in the savanna belt of

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West Africa. By establishing the pattern of bacterial pneumonia in the area, we hoped to devise a standard form of management which could be applied without extensive investigation in the future.

Patients and methods

A total of 88 children with severe acute pneumonia who were admitted to the paediatric emergency ward of Ahmadu Bello University Hospital, Zaria, were studied. All were over 3 months of age and none had been given antibiotics during their current illness; all had radiological evidence of pulmonary consolidation. Ages ranged from 4 months to 8 years and a high proportion of the patients were underweight or frankly marasmic (Table 1).

Table 1 *Distribution of patients by age and weight*

	Age (yrs)									
	0–1	–2	–3	–4	–5	–6	–7	–8	–9	–10
No. of patients	23	20	18	4	4	7	6	4	1	1
Underweight*	5	8	9	1	1	4	1	0	1	1
Marasmic†	4	4	6	2	2	1	2	1	0	0

*60–80% of Harvard standard weight-for-age. †Less than 60% of Harvard standard weight-for-age (Nelson *et al.*, 1969).

All children had a clinical history, physical examination, and a chest *x*-ray carried out. The radiological appearance was classified, independently of bacteriological information, into two categories: (i) lobar pneumonia, in which consolidation conformed to segmental (anatomical) boundaries, and (ii) bronchopneumonia, in which there was more widespread or ill-defined consolidation. The *x*-rays of one patient subsequently disappeared without record. The presence of other features (pleural effusions, pneumatoceles) was noted.

In all patients needle aspiration of the lung was carried out, the region of maximum consolidation having been determined by inspection of the chest *x*-ray. In performing needle aspiration the anterior chest wall was avoided, to minimize anxiety and to avoid the possibility of entering the heart with the needle. The skin was sterilized with iodine. A standard 18 or 21 gauge bevelled needle attached to a 10 ml syringe was inserted. As soon as the skin had been pierced, a negative pressure was applied to the syringe and the needle was plunged swiftly into the lung aiming towards the hilum, and removed without a pause. Pressure was released just before withdrawal from the skin. The tiny drop of lung aspirate (up to 0·5 ml) was diluted with 0·5 ml sterile nutrient broth before being used to prepare films for Gram staining and for direct inoculation of standard chocolate and blood agar plates. Colony identification was by standard bacteriological techniques.

Venous blood was taken for blood culture and examination for bacterial antigen by CIE. CIE was carried out with grouped pneumococcal antiserum (Omniserum, Statens Seruminstitut, Copenhagen) and grouped *Haemophilus influenzae* type b antiserum (Hyland Laboratories) using a technique fully described previously (Tugwell and Greenwood, 1975). Finally, a pharyngeal swab was collected during stimulated coughing. The pharyngeal exudate was cultured and bacterial colonies identified.

Patients were kept under close observation in the emergency ward, and further chest *x*-rays were taken if indicated. It was not possible to carry out follow-up chest *x*-rays as a routine procedure.

Results

Lung aspiration (Table 2). In every case lung fluid was obtained. The amount varied from an immeasurably small drop to 0·5 ml, and the consistency from apparently pure blood to opaque yellow fluid. An aetiological diagnosis was made in 70 of the 88 patients (79%): in 54 (61%) by culture of organisms, and in a further 16 (18%) by identification of organisms on the Gram-stained film of the aspirate when culture was sterile. A single organism was isolated in 52 patients, 2 organisms in 14 patients, and 3 organisms in a further 4 patients.

Table 2 *Organisms isolated from lung aspirate*

	By culture of aspirate (no. of patients)	*By Gram stain or culture (no. of patients)*
Pneumococci	31	45
β-haemolytic streptococci	3	3
α-haemolytic streptococci	5	5
Staphylococcus aureus	8	10
Coliforms	7	14
Haemophilus influenzae	9	10
Bacteroides spp.	2	2
Flavobacterium	1	1
Salmonella typhi	1	1
Candida albicans	1	1
No organism isolated	34	18

Note: Mixed infections occurred in 18 patients.

Complications of needle aspiration occurred in 4 patients. 2 had transient minor haemoptyses, expectorating small amounts of freshly blood-stained sputum for about 3 minutes after the procedure. One child had a small pneumothorax which did not require active treatment, and one had subcutaneous emphysema confined to the aspiration site.

There were 4 deaths in the series; 3 patients were moribund on admission to the hospital, with typhoid

pneumonia, algid malaria, and congestive cardiac failure respectively. One child died 6 days after admission after inhaling a peanut. No death was related to needle aspiration; none had clinical evidence of pneumothorax or intrathoracic haemorrhage. Necropsies were not carried out for religious reasons.

Culture of pharyngeal secretions (Table 3). Potential pathogens were isolated from pharyngeal secretions in 45 (63%) of the 72 patients from whom throat swabs were collected. Normal nasopharyngeal commensals were found in the remaining patients. However, the degree of concordance between pharyngeal and lung aspirate cultures was poor. Of the 53

Table 3 *Comparison between pharyngeal culture and lung aspiration*

Lung aspirate	*Pharyngeal culture*		
	No. of patients from whom potential pathogens isolated		*No. of patients from whom only commensals isolated*
	Identical with lung aspirate	*Different from lung aspirate*	
Positive (n=53)	17*	18	18
Negative (n=19)	—	10	9

*Of these, 15 were pneumococci.

patients in whom lung aspirate provided an aetiological diagnosis by microscopy or culture, an identical organism, usually pneumococcus, was found in the pharyngeal culture in only 17 (32%). Cultures of the upper respiratory tract which yielded potentially pathogenic organisms different from those isolated in the lung aspirate (false-positive pharyngeal cultures) were obtained in 18 patients (34%). Falsely negative pharyngeal cultures (yielding only commensal organisms) were obtained in 18 patients (34%). 19 patients had negative lung aspirates and in this group potentially pathogenic organisms were isolated from the upper respiratory tract in 10. The relevance of these isolations is, of course, unknown.

CIE (Table 4). Sera were available from 45 patients for comparison with the lung aspirate cultures. In 7 of the 29 patients with pneumococcal pneumonia (24%), pneumococcal antigen was detected in unconcentrated serum. Pneumococcal antigen was never detected in patients who had other organisms isolated from their lung aspirates. No proven case of *H. influenzae* pneumonia yielded a positive result on CIE, and there were similarly no false-positive results obtained from serum samples of patients from whom other organisms had been isolated from the lung aspirate.

Table 4 *Comparison between countercurrent immunoelectrophoresis (CIE) and lung aspiration*

Organisms identified in lung aspirate	*CIE*		
	CIE negative (no. of patients)	*Pneumococcal antigen identified (no. of patients)*	*H. influenzae antigen identified (no. of patients)*
Pneumococci	22	7	0
H. influenzae	6	0	0
Other bacteria only	4	0	0
Negative	8 (+1)*	1	1 (+1)*

Note: Sera from 45 patients examined by CIE (4 patients had dual infections).
*Result of CIE on pleural fluid.

However, CIE provided the diagnosis in 3 of 11 otherwise undiagnosed cases. The likelihood of these being false-positive results is small since there were no false-positive results in the patients in whom a bacterial aetiology had been clearly established. In 2 patients with pleural effusions, pleural fluid was examined by CIE and in one of these *H. influenzae* antigen was detected in the absence of positive bacterial cultures.

Blood culture (Table 5). Blood cultures were available in 36 patients for comparison with lung aspirates.

Table 5 *Comparison between blood culture and lung aspiration*

Bacteria isolated from lung aspirate	*No. of patients in whom blood culture*	
	Positive	*Negative*
Staph. aureus	0	1
Streptococci	0	3
Pneumococci	4	17
H. influenzae	0	5
Coliforms	0	5
No organisms isolated	0	9

Note: Blood cultures were performed in 36 cases.

Only 4 of the 36 had positive blood cultures, all yielding pneumococci, and all having positive cultures for pneumococci on lung aspirate. These 4 had the classical radiological appearances of lobar pneumonia. Thus, even in pneumococcal pneumonia blood culture was positive in only 4 out of 21 patients (19%). There were no false-positive isolations from blood culture, but the overall yield (11%) was very low.

Radiological changes (Table 6). Of the 43 patients with lobar pneumonia, most (60%) had a pure growth of pneumococci on lung aspirate. Of equal importance, however, was the isolation of staphylococci, streptococci, and Gram-negative organisms

Table 6 *Radiographic appearance of lungs in relation to aetiology*

Organisms identified in lung aspirate	*Radiographic appearance*		
	Bronchopneumonia (n=44)	*Lobar pneumonia (n=43)*	*Pleural effusion (n=13)*
Pneumococci only	7	26	4
Streptococci only	4	1	2
Staph. aureus only	4	2	0
Gram-negative rods* only	8	2	1
Mixed infections	14	4†	3
No organisms isolated	7	8	3

*Includes *E. coli*, *Klebsiella aerogenes*, *H. influenzae*, *Bacteroides* spp.
†Three patients had combined infection with pneumococcus and *H. influenzae*.

from 9 patients (21%) with a purely lobar pattern of consolidation on chest *x*-ray.

A radiological pattern of bronchopneumonia was found in the remaining 44 patients. A wide variety of organisms was isolated from this group, Gram-negative or mixed infections being found in 50% of the patients. In contrast to the patients with lobar pneumonia, a pure growth of pneumococci was isolated in only 7 patients (16%). One patient with widespread consolidation on chest *x*-ray was subsequently diagnosed as having bronchiectasis. Lung aspirate on this child yielded β-haemolytic streptococcus group F. Radiological evidence of a pleural effusion was detected in 13 patients, yielding 10 positive cultures, including a variety of organisms, but no staphylococci.

Overall rate of diagnosis (Table 7). The contributions of blood culture and CIE to diagnosis were relatively small, direct needle aspirate of the lung providing a diagnosis in 79% of cases. In 21 patients lung aspirate (examined by Gram-stain and culture), CIE, and blood culture were all performed and a bacterial diagnosis was obtained in 19 (91%).

Table 7 *Contribution of different techniques to diagnosis*

	No. of patients	*Pathogen identified*
Lung aspirate: Gram film	71	55 (77%)
Culture	88	54 (61%)
CIE (serum)	45	9 (20%)
Blood culture	36	4 (11%)
Any technique	88	73 (83%)
All four techniques	21	19 (91%)

Discussion

Needle aspiration of the lung. The technique of needle aspiration is not new (Leyden, 1883). In the early days it was severely criticized (*British Journal of Children's Diseases*, 1905), but has gained more advocates recently as its safety in children has become established. The technique has changed little since it was first described in the English journals almost 70 years ago, when lung aspiration was used to produce a pure culture of the infecting organisms so that a specific vaccine could be prepared (Horder, 1909). Some of the early studies were carried out to try to understand the natural history of pneumonia after acute infections (Ellison, 1931) and to study the relationship between the clinical and radiological features of pneumonia and its aetiology (Lyon, 1922). The procedure was ocasionally justified by the observation that 'in some cases it appeared to hasten resolution' of the pneumonia (Ellison, 1931). With the advent of antibiotics, needle aspiration again became important as a means of determining the specific aetiology before instituting appropriate therapy (Disney *et al.*, 1956; Klein, 1969; Hughes *et al.*, 1969; Mimica *et al.*, 1971; Davidson *et al.*, 1976).

Our study reaffirmed the value of needle aspiration of the lung, permitting an accurate bacterial diagnosis to be made in 79% of a group of children severely ill with pneumonia. The safety of the technique was amply demonstrated as only minor complications in 4 patients (5%) were attributable to the procedure.

Bacterial isolation rates from lung aspirates have varied from 15% to 80%, being higher in the pre-antibiotic era (Ellison, 1931; Sappington and Favorite, 1936; Abdel-Khalik *et al.*, 1938) and in patients who had not received antibiotics (Mimica *et al.*, 1971). Mimica *et al.* (1971) obtained an isolation rate of 57% in untreated patients, but only 23% in those who had received antibiotics for more than 24 hours before needle aspiration. In our study no patient had received antibiotics during the current illness.

No deaths have been reported in childhood as a result of needle aspiration of the lung. In 6 series of needle aspirations in children (Alexander *et al.*, 1941; Disney *et al.*, 1956; Schuster *et al.*, 1968; Hughes *et al.*, 1969; Klein, 1969; Mimica *et al.*, 1971), complications occurred in 24 out of over 800 children (3%). Of these only 2 were serious, both cases of pneumothorax requiring drainage. Dick *et al.* (1974) reviewed 9000 needle aspiration biopsies performed in adult patients and reported 6 deaths. Some of these deaths have occurred in patients with major complicating factors such as atherosclerosis

(Pearce and Patt, 1974), or after excessive sedation (Meyer *et al.*, 1970). Pulmonary hypertension was thought to be a contraindication too. In one study, pulmonary haemorrhage occurred in thrombocytopenic patients when a Silverman-type cutting needle was used. A bevelled needle is relatively safe (Bandt *et al.*, 1972), as confirmed by our study in children.

Bacterial isolations in our study were probably aetiologically important, as cultures of needle aspirates in the lungs of 13 normal children by Mimica *et al.* (1971) were all sterile. Any growth from a needle aspirate of the lungs appears to be significant.

Culture of pharyngeal secretions. While accepting the accuracy and safety of needle aspiration, it might be claimed that there are other equally accurate and much safer methods of reaching a diagnosis. Even in normal individuals, however, potentially pathogenic bacteria are usually present in sputum, pharyngeal secretions, and tracheal aspirate, and in some subjects in the main bronchi too (Laurenzi *et al.*, 1961). Thus positive bacterial cultures of potential pathogens from sputum or pharyngeal secretions might be expected in many patients, whatever the cause of their illness. Under these circumstances bacterial pneumonia is likely to be overdiagnosed and overtreated while conversely the true diagnosis may be overlooked.

Our study has confirmed the frequent irrelevance of sputum or pharyngeal cultures in children, and provides a warning that cultures from the upper respiratory tract will frequently lead to a false aetiological diagnosis. The false-positive isolates from pharyngeal secretions obtained might have led to the use of dangerous and expensive antibiotics requiring intravenous administration.

Only the isolation of pneumococci in pharyngeal cultures gave some indication of the true cause of the pneumonia; in 15 of the patients from whom pneumococci were isolated from the pharynx an identical organism was responsible for the pneumonia. Previous workers have claimed that in most patients with lobar pneumonia, pneumococci could be identified in both sputum and lung aspirate (Sappington and Favorite, 1936; Alexander *et al.*, 1941; Davidson *et al.*, 1976). However, in normal British children up to 45% may be harbouring pneumococci in the pharynx, while 36% may carry *Staphylococcus aureus* (Brimblecombe *et al.*, 1958). Carriage rates of pneumococci increase during minor respiratory tract infections, when their isolation from the upper respiratory tract is of dubious clinical significance (Brimblecombe *et al.*, 1958).

Other direct techniques for obtaining respiratory tract secretions (bronchial brush biopsy and tracheal aspirate) are technically difficult to perform, may require a general anaesthetic, and are unproven in children. In any case the known presence of potential pathogens in the lower respiratory tree of normal subjects would lend no more confidence to tracheal culture results than to those of pharyngeal or sputum culture (Laurenzi *et al.*, 1961).

CIE. This is a rapid and sensitive technique for the detection of bacterial antigen in body fluids (*Lancet*, 1976). Species- and type-specific capsular polysaccharide antigens are released during a variety of bacterial infections (Lampe *et al.*, 1976) and pneumococcal polysaccharide can be detected in concentrations as low as 0·5 to 1 μg/ml of serum by CIE (Coonrod and Rytel, 1973). The technique is rapid, giving a result within an hour, and its specificity has been amply verified.

The contribution of CIE to the diagnosis of bacterial infections in our patients was small. The 24% rate of detection of pneumococcal antigen in the serum of culture-positive cases of pneumococcal pneumonia was slightly lower than that of other studies (Tugwell and Greenwood, 1975; Spencer and Savage, 1976; Michaels and Poziviak, 1976). The real value of the technique lies in its ability to detect antigen in the absence of any viable organisms. 3 patients were diagnosed by CIE when cultures were negative. Bacterial antigen has been shown to persist for several days after the successful treatment of bacterial pneumonia with antibiotics (Spencer and Savage, 1976), whereas bacterial cultures are notoriously susceptible to prior exposure of patients to antibiotics. It is in these antibiotic-treated patients that CIE may prove of the greatest value. The rate of detection of pneumococcal antigen in lobar pneumonia may be increased to about 50% when urine, concentrated by dialysis, is examined by CIE (Coonrod and Rytel, 1973; Tugwell and Greenwood, 1975) and to 80 to 100% when pleural fluid is examined (Tugwell and Greenwood, 1975; Lampe *et al.*, 1976).

The presence of pneumococcal antigen in the serum of a patient with a respiratory tract infection implies pneumococcal pneumonia (Tugwell and Greenwood, 1975; Spencer and Savage, 1976). The relevance of antigenaemia in other bacterial infections of the respiratory tract has not been thoroughly evaluated.

Blood culture. Normally considered a routine investigation in childhood pneumonia, bacterial isolation rates by this procedure in classical lobar pneumonia have only been 17 to 29% (Lyon, 1922; Sappington and Favorite, 1936; Mufson *et al.*, 1967), similar to the 19% obtained for pneumococcal pneumonia in the present study. In spite of the almost certain

absence of prior antibiotic therapy in our patients, no organisms other than pneumococci were isolated. As special culture techniques were not employed, this rate of isolation provides a realistic view of the place of standard blood culture techniques in the diagnosis of bacterial pneumonia in children.

Radiological findings. It has generally been considered that 'lobar pneumonia is caused by the pneumococcus', whereas bronchial pneumonia 'represents a group of pulmonary infections' (Lyon, 1922). Our study has emphasized the fact that acute segmental consolidation (lobar pneumonia), though usually caused by pneumococcus, may be caused by other organisms. Previous studies carried out in the UK suggesting that lobar pneumonia may occasionally be caused by organisms other than pneumococci (Bath *et al.*, 1964; Kinnell, 1973) have based their bacteriological diagnosis on sputum culture and their conclusions are therefore open to question. It is known that the radiological appearance of consolidation may change during the course of disease; segmental lesions, occasionally seen early in the course of staphylococcal pneumonia (Williams and Phelan, 1975), may later progress to a more characteristic pattern with pneumatoceles and empyema (Disney *et al.*, 1956). It is therefore unwise to assume, even with the aid of sputum culture, that pneumococcal infection is the sole cause of lobar pneumonia.

The wide variety of organisms present in the group defined radiologically as bronchopneumonia may reflect the multiple predisposing factors (measles, whooping cough, malnutrition) in these patients (personal observations). There were few distinguishing characteristics, some of which were misleading. For instance, 2 patients with pneumatoceles each had pneumonia caused by multiple organisms, suggesting that these may have been inhalation pneumonias (Gonzalez-C and Calia, 1975). The patients with pleural effusions again covered the spectrum of bacterial diagnoses, except that no case of staphylococcal empyema was identified. Prediction of the cause of a pulmonary infection from the radiographic appearance was highly inaccurate in this study.

Conclusions. By applying all of the four techniques available in this study (lung aspirate examined by Gram-stain and culture, CIE, blood culture), it was possible to identify a bacterial cause of pneumonia in 19 out of 21 patients. Whether the remaining 2 patients had pneumonia caused by organisms which were undetected by our techniques (viral, protozoal, or mycobacterial) or whether this figure represents the ultimate limitations of our techniques, is not clear. It must be borne in mind that this study was carried out in an area where bacterial pneumonia might be expected to be particularly prevalent and where antibiotic therapy had not previously been given. A similar rate of diagnosis would not be expected in countries where viral respiratory tract infections were more prevalent, or where antibiotic therapy was freely given to patients before admission to hospital.

However, the present study does have relevance to the management of acute lower respiratory tract infections in children in situations other than the savanna belt of West Africa. The technique of lung aspiration has been shown to be of value in the investigation of pulmonary tuberculosis (Schuster *et al.*, 1963), pulmonary infections complicating leukaemia (Hughes *et al.*, 1974), diffuse noninfective lung disease (Gellis *et al.*, 1953), and in children with pneumonia unresponsive to normal therapy or with impaired immunity (personal observations). A simple lung aspirate may safely provide a sufficiently large sample for bacteriology, virology, mycology, and cytology (personal observations).

By the use of CIE, a simple and rapid technique, a diagnostic tool is available whose results are independent of the presence of viable bacteria in specimens. Application of the technique to urine and pleural fluid, and the use of antisera to organisms other than the pneumococcus and *H. influenzae*, may improve its diagnostic yield.

By the application of the techniques described in this paper, it should be possible to identify the cause of bacterial pneumonia in children with the degree of accuracy presently available in the diagnosis of viral infections of the respiratory tract.

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Addendum

In a recently published paper (Chaudhary *et al.* (1977), *American Journal of Diseases of Children*, **131**, 902–907) an incidence of pneumothorax of 32% was reported after needle aspirations of the lung in 202 immunocompromised children with pneumonia. The incidence was 43% in the 121 children with *Pneumocystis carinii* pneumonia. No deaths were reported as a result of the procedure.