Reappraisal of Lung Tap: Review of an Old Method for Better Etiologic Diagnosis of Childhood Pneumonia

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Identification of the etiology of childhood pneumonia is difficult, even in the cases that most likely have bacterial origins. A positive blood culture result is diagnostic but rare (<10% of cases), and other noninvasive microbiological methods are nonspecific or are at least shadowed by interpretation problems. However, lung tap (or aspiration), a method developed a century ago, warrants reappraisal, especially since the prevalence of pneumococcal resistance to penicillin is increasing. An analysis of 59 studies that were published in 6 languages led us to conclude that (1) bacterial etiology is disclosed in ~50% of cases (virological tests were rarely done); (2) lung tap is safer than is generally considered; (3) potential pneumothorax is mostly symptomless and resolves spontaneously without impairing recovery; and (4) in comparison with routine diagnostic tools, lung tap offers so many advantages that it warrants reconsideration at centers where personnel have experience in handling potential pneumothorax.

The increasing prevalence of resistance of *Pneumococcus* species to penicillin is often assumed by clinicians to indicate a need for the use of newer, broader-spectrum, and more-expensive antimicrobial agents. As a consequence, many unnecessary courses of such agents are administered to children with pneumonia, even though parenteral penicillin would usually suffice, especially if used in increased doses [1–6].

On the other hand, the prevailing situation warrants better etiologic diagnosis of pneumonia, for both children and adults. Sometimes precise and rapid identification of the etiologic agent may be a question of life and death [7]. Since blood culture results are rarely positive [8, 9], other available methods [9–14] are insensitive or unreliable (or both), and results may arrive too late to benefit the patient, there is a great need for alternatives.

With this rationale, we scrutinized the world literature on lung tap, a century-old [15] method also known as lung aspiration, lung puncture, thoracic puncture, transthoracic needle aspiration, percutaneous needle aspiration, and needle aspiration. The procedure allows for a sample to be taken directly from the lung tissue. Lung tap was especially relevant 60–70 years ago, when pneumococcal diseases were treated by use of antisera [16]. With the dawning of the era of effective antimicrobial agents, interest in direct sample-taking was abandoned. However, since the prevalence of pneumococcal resistance to penicillin is increasing, the time has arrived to reappraise the lung tap.

METHODS

We reviewed the original reports on the use of lung tap in cases of childhood pneumonia that have been described in the literature since publication of the first description of the method [15]. The reports were written

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in 6 languages, and they represented all 6 continents. Because the older literature is not listed in modern database systems and because important information was probably published in languages other than English, these sources were scrutinized retrospectively in secondary and tertiary citations; therefore, data were found in German, French, Portuguese, Spanish, and Russian, as well as the English language. The initial data on pediatric patients were from 1909 [17], and the most recent were from 1997 [18]. Special attention was given to information on the potential complications of a procedure that is virtually unknown to today's clinicians in the industrialized world.

If the same patients were included in 2 series (this occurred sometimes), the data were used only once. Because >1 lung tap could have been performed on the same child, the number of taps was distinguished from the number of patients. Lung biopsy studies and studies in which fluoroscopic guidance was used were not included. The information was also omitted if it concerned only necropsy findings; patients with pleural effusion; or immunocompromised patients, such as children with cancer. The rationale for these exclusions was that we aimed to characterize the pros and cons of lung tap in regular cases of home-acquired childhood pneumonia, rather than in the special cases for which this technique is widely accepted and is in routine use.

Procedure. Lung tap methods have undergone several modifications over the decades. Initially, a long, thick puncture needle was used, but the procedure that currently used [19] is not far removed from that described in the 1930s [20]. In many respects, it resembles a regular cerebrospinal tap.

The child is held in a supine or sitting position. To create a vacuum in the system, a 5- to 10-mL syringe (with or without saline) is connected to a thin needle (20–22 g). Local anesthetic may be used for the skin and parietal pleura. The needle is then inserted supracostally, with or without fluoroscopic (or other) guidance, either into or in the vicinity of the (alveolar) consolidation, which is identified by pulmonary radiography [21]. The sample is cultured and stained like a CSF sample. The technique is described in more detail elsewhere [16, 22].

RESULTS

It is surprising that the great majority of reports appeared after, not before, World War II, during the era of effective antimicrobial agents. Only 3 studies of childhood pneumonia were reported in the years before or during World War I, followed by 2 in the 1920s, 6 in the 1930s, 1 in the 1940s, 1 in the 1950s, and 8 in the 1960s. The 1970s were represented by 16 studies, the 1980s by 9, and the 1990s by 13. We can say with near certainty that our finding of a preponderance of studies in recent decades did not reflect an inability to locate previously published reports, but, rather, indicated diminished publishing activity during earlier decades. As might be expected, interest in lung tap collapsed with the advent of antimicrobial agents in Europe and North America, where the last reports on lung tap were published in 1956 [23] and 1975 [24], respectively.

Geographic Distribution

Europe. After a series of adult patients had undergone lung tap, performed by Leyden in Germany in 1882 [15], the first 2 pediatric patients to undergo a lung tap were described

Table 1. Findings from lung tap studies of children in Europe.

Country [reference]	Patient age	Lung tap		No. (%) of aspirates that tested positive for organism[a]						Pretreatment with antimicrobial agent, %
		n	No. (%) positive	*Pneumococcus* species	*H. influenzae*	*S. aureus*	*E. coli*	Other	Virus	
UK [17][b]	7 mo, 5 y	2	2 (100)	1 (50)	1 (50)	1 (50)	1 (50)	0 (0)	ND	No
France [25]	ND	8	4 (50)	0 (0)	4 (100)	0 (0)	0 (0)	0 (0)	ND	No
UK [26]	1.5–11 y	13	8 (62)	4 (50)	2 (25)	1 (13)	0 (0)	5 (63)	ND	No
UK [27][c]	ND	74	71 (96)	27 (38)	34 (49)	7 (10)	0 (0)	21 (30)	ND	No
UK [28]	6 w–13 y	46	14 (30)	13 (93)	1 (7)	0 (0)	0 (0)	0 (0)	ND	No
USSR [29]	<2 y	61	36 (59)	36 (100)	0 (0)	0 (0)	0 (0)	0 (0)	ND	ND
UK [23][d]	<2 y	51	33 (65)	ND	ND	23 (70)	ND	ND	ND	ND
Total (yield %)[e]		255	168 (66)	81 (40)	42 (21)	32 (13)	1 (0.5)	26 (13)[f]		

NOTE. *E. coli, Escherichia coli; H. influenzae, Haemophilus influenzae;* ND, no data or not defined; *S. aureus, Staphylococcus aureus;* UK, United Kingdom; USSR, Union of Soviet Socialist Republics.

[a] Sometimes multiple organisms were isolated from the same lung tap specimen.
[b] Two illustrative cases are described.
[c] Cases of measles complicated by pneumonia.
[d] Only staphylococcal pneumonia was investigated.
[e] For totals, $n = 204$, with the exception of *S. aureus* (for which $n = 255$). Yield for each specific agent among aspirates in which it was sought.
[f] Number of gram-positive organisms, 17; no. of gram-negative organisms, 9.

Table 2. Findings from lung tap studies of children in North America.

Country [reference]	Patient age	Lung tap		No. (%) of aspirates that tested positive for organism[a]						Pretreatment with antimicrobial agent, %
		n	No. (%) positive	*Pneumococcus* species	*H. influenzae*	*S. aureus*	*E. coli*	Other	Virus	
US [30]	ND	13	13 (100)	13 (100)	1 (8)	0 (0)	0 (0)	0 (0)	ND	No
US [31]	8 mo–11 y	38[b]	19 (50)	14 (74)	2 (11)	5 (26)	0(0)	2 (11)	ND	No
US [32]	2 mo–11 y	28	5 (18)	5 (100)	0 (0)	0 (0)	0 (0)	0 (0)	ND	No
US [33]	ND	405	122 (30)	ND	ND	ND	ND	ND	ND	No
US [34]	ND	98	27 (28)	24 (89)	1 (4)[c]	1 (4)	0 (0)	1 (4)	ND	ND
US [35]	1.5 y, 3 y	2	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	ND	100
US [36][d]	<2 y	1	1 (100)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1	ND
US [37][d]	3.5 y	1	1 (100)	0 (0)	0 (0)	0 (0)	0 (0)	1 (100)	ND	100
US [38]	6 d–10 y	32	10 (31)	4 (40)	0 (0)	4 (40)	2 (20)	5 (50)	ND	ND
US [24]	2 mo–15 y	27	6 (22)	3 (50)	0 (0)	0 (0)	0 (0)	3 (50)	ND	No
Total (yield, %)[e]		645	204 (32)	63 (31)	4 (2)	10 (5)	2 (1)	12 (5)[f]		

NOTE. *E. coli, Escherichia coli; H. influenzae, Haemophilus influenzae;* ND, no data or not defined; *S. aureus, Staphylococcus aureus;* US, United States.

[a] Sometimes multiple organisms were isolated from the same lung tap specimen.
[b] Four postmortem findings included (all pneumococci).
[c] *H. influenzae* type b.
[d] A case report.
[e] For totals, $n = 240$. Yield for each specific agent among the aspirates in which it was sought.
[f] Number of gram-positive organisms, 11; no. of gram-negative organisms, 1.

by Horder in 1909 [17]. All studies of childhood pneumonia in Europe (table 1) were performed in the United Kingdom [17, 23, 26–28], with the exception of 1 in the Union of Soviet Socialist Republics [29] and 1 in France [25]. A 62% rate of success of bacteriological diagnosis was achieved in 1923; this rate rose to include no less than 96% of patients hospitalized for secondary pneumonia during an epidemic of measles in 1931 [27]. After an interval of >40 years [23], our group (in an ongoing study) appears to be the first in Europe to use this method in the diagnosis of childhood pneumonia [21].

A total of 255 lung taps were performed and reported on the Old Continent between 1909 and 1956. In 168 cases (66%), a bacterial agent was identified. Sometimes >1 agent was found in the same patient [17, 26, 27]. Typing of *Haemophilus influenzae* strains was not performed in any of the studies. No clinically significant complications were reported, with the exception of 1 instance of pneumothorax, for which a chest tube was inserted [23].

North America. All 11 studies that represented North America (table 2) were done in the United States [24, 30–38]; the first study, done in 1917, involved a series of children with lobar pneumonia and 13 isolations of pneumococci [30]. Since the 1960s, 6 reports have been published [7, 24, 35–38]. One involved only 2 children with measles, the use of antimicrobial agents for pretreatment, and negative culture results [35]; 2 were case reports [36, 37]; and 1 was a series of children with cancer [7]. In all, the 645 reported taps done on children without underlying disease yielded bacteria in 204 cases (32%), a considerably lower rate than that found in Europe (168 [66%] of 255). *H. influenzae* was found in 3 studies, but typing was performed only once (table 2).

A high rate of complications probably did not lead to abandonment of the use of lung tap in the United States. With the exception of 2 cases of hemoptysis, the only problem encountered (or reported) was self-limiting pneumothorax, which occurred in 5% of taps (9 of 187 taps).

South America. Eight studies were done in South America (table 3) [22, 39–45], where lung tap was used also to diagnose pulmonary tuberculosis [46]. The report from Chile [22] is notable because it describes the largest published study of lung tap (543 lung taps); 13 infants without pulmonary disease were tapped as well; these individuals account for the only information on healthy children; all cases had negative results on culture.

Sometimes 2 reports covered the same patients [44, 45] or the data from 2 studies were mixed [42, 43]. In all, there were 885 lung taps performed for cases of pneumonia, of which 386 (44%) led to an etiologic diagnosis. *H. influenzae* was found in each study in South America, accounting for 5%–50% of pathogens identified. Serotyping was performed in only 1 study [40].

In terms of complications, interpretation problems were raised by a study in Colombia [41]: "more severe" pneumothorax developed in 11% of patients, but it was not clear how many of those patients required placement of a chest tube. This high rate of "complications" stands in sharp contrast to the findings of most other studies done to date.

Table 3. Findings from lung tap studies of children in South America.

Country [reference]	Country	Patient age	Lung tap		No. (%) of aspirates that tested positive for organism[a]						Pretreatment with antimicrobial agents, %
			n	No. (%) positive	*Pneumococcus* species	*H. influenzae*	*S. aureus*	*E. coli*	Other	Virus	
Chile [39]	Chile	3 mo–10 y	125	67 (54)	24 (36)	17 (25)	14 (21)	ND	12 (18)	ND	ND
Chile [22]	Chile	15 d–6 mo	530	235 (44)	11 (5)	12 (5)	145 (62)	9 (4)	68 (29)	0/47	70
Colombia [40]	Colombia	8 mo–11 y	31	10 (33)	5 (50)	3 (30)[b]	1 (10)	0 (0)	1 (10)	ND	33
Brazil [41]	Brazil	<4 mo–7 y	37	20 (55)	15 (75)	3 (15)	1 (5)	1 (5)	0 (0)	ND	No
Colombia [42][c]	Colombia	5 mo–13 y	21	2 (10)	1 (50)	1 (50)	0 (0)	0 (0)	0 (0)	0/21	ND
Colombia [43]	Colombia	1 mo–14 y	102	21 (21)	5 (24)	4 (20)	8 (38)	0 (0)	2 (10)	2/102	30
Brazil [44, 45][d]	Brazil	ND	60	34 (57)	25 (76)	13 (38)	0 (0)	0 (0)	0 (0)	ND	No
Total (yield, %)[e]			885	386 (44)	85 (10)	52 (6)	169 (19)	10 (1)	83 (10)[f]		

NOTE. *E. coli, Escherichia coli; H. influenzae, Haemophilus influenzae;* ND, no data or not defined; *S. aureus, Staphylococcus aureus.*

[a] Sometimes multiple organisms were isolated from the same lung tap specimen.

[b] Two strains of type b; one diagnosis made on the basis of staining (typing was impossible).

[c] Patients with measles and pneumonia from [43].

[d] Same patients were in both series.

[e] For totals, $n = 885$. Yield for each specific agent among the aspirates in which it was sought.

[f] Number of opportunistic strains [22], 51; no. of *Klebsiella* species isolates, 9; no. of *Pseudomonas* species isolates, 5; no. of others, 18.

Africa. In terms of the number of reports, experience with pediatric lung taps has been greatest in Africa (table 4), where 19 reports have come from 5 countries, including 7 series in The Gambia, 6 in Nigeria, 2 in Egypt, 2 in Zimbabwe, and 2 in South Africa [11, 18, 20, 48–62]. The same patients were reported in 2 different reports [18, 61], whereas in another study, an earlier series was reanalyzed with use of new laboratory techniques (counterimmunoelectrophoresis and latex agglutination) [53, 56].

In all, 659 (66%) of the combined 1000 lung taps resulted in bacteriological diagnosis. Characteristic of findings from this continent, no less than 44% of the bacteriologically documented cases were caused, at least in part, by agents other than pneumococci, *H. influenzae* (serotyped in only 1 study [61]), *Staphylococcus aureus,* and *Escherichia coli.* In at least some studies [51, 59], the different distribution of causative agents was suggested to be due to malnutrition in children. Among those patients, the most common pathogens were *Klebsiella* species and opportunistic organisms, such as diphtheroids and *Bacteroides* species.

Ten studies reported rates of complication that ranged from zero to 32% (10 cases of hemoptysis, 7 of self-limiting pneumothorax, 2 of pneumothorax treated with insertion of a chest tube, and 3 of subcutaneous emphysema). One child, who had measles pneumonitis, died because of a delay in the detection of pneumothorax [49], an incident that underlines the importance of post-tap monitoring of children.

Asia. Studies in India and The Philippines provided the lung tap data from Asia (table 5). At least 10 studies, accounting for 413 taps, have been done in India since 1966 [63–65, 67–73], including the 3 that were reported most recently from Asia [71–73].

The existence of laboratory problems was sometimes obvious. Although the overall rate of identification in Asia ranged from 16% to 62%, in one study [69], not 1 culture of aspirate from 100 children yielded pneumococci (5 isolates were detected by staining) or *H. influenzae;* this is quite an unlikely finding for home-acquired pneumonia in India. Direct smear sometimes was more sensitive than culture of the same specimen when the patient was receiving antimicrobial treatment while undergoing lung tap [69]. *H. influenzae* strains were not serotyped in any of the studies.

Two studies focused on newborns [67, 70], and in 1 study, counterimmunoelectrophoresis complemented the conventional staining and culture methods [70]. In 3 reports [63–65], at least some patients were analyzed more than once.

The 2 studies in The Philippines yielded data on 261 lung taps, and in some cases, a patient underwent >1 lung tap [12, 66]. In all, 674 lung taps were reported in Asia, and a bacterial etiologic agent was disclosed in 343 cases (51%; table 5).

A death that occurred in association with lung tap was described in a report from The Philippines [12]. A pleural drainage device, presumably used for pneumothorax, was inserted into 1 child (age not provided), but it dislodged badly enough for intrapleural bleeding to lead to death. With the exception of this case, lung taps were not reported to have caused any major problems in Asia, where many children were life-threateningly ill.

Oceania. Papua New Guinea was the only country in Oceania [19, 74, 75] from which lung tap data were published

Table 4. Findings from lung tap studies of children in Africa.

Country [reference]	Patient age	Lung tap		No. (%) of aspirates that tested positive for organism[a]						Pretreatment with antimicrobial agents, %
		n	No. (%) positive	*Pneumococcus* species	*H. influenzae*	*S. aureus*	*E. coli*	Other	Virus	
Egypt [47]	4 mo–5 y	52	48 (92)	13 (27)	9 (19)	12 (25)	0 (0)	31 (65)	ND	No
Egypt [20]	ND	233	182 (78)	32 (18)	77 (42)	67 (37)	0 (0)	102 (56)	ND	No
Zimbabwe [48]	11 mo–2 y	7	4 (57)	2 (50)	1 (25)	0 (0)	1 (25)	1 (25)	ND	43
South Africa [49]	5 mo–4 y	22	15 (68)	0 (0)	0 (0)	10 (67)	6 (40)	5 (33)	ND	ND
South Africa [50]	2 mo–9 y	29	5 (17)	1 (20)	2 (40)	0 (0)	0 (0)	2 (40)	ND	No
Nigeria [11]	4 mo–8 y	88	70 (79)	45 (64)	10 (14)	10 (14)	0 (0)	27 (39)	ND	No
Nigeria [51]	ND	56	39 (70)	10 (26)	0 (0)	8 (21)	2 (5)	23 (60)	ND	ND
Nigeria [52]	1 mo–12 y	73	40 (55)	6 (15)	2 (5)	22 (55)	3 (8)	9 (23)	ND	37
The Gambia [53]	2 mo–10 y	51	29 (57)	ND	ND	ND	ND	ND	ND	No
Nigeria [54]	1 mo–14 y	108	72 (67)	0 (0)	0 (0)	22 (31)	6 (8)	44 (61)	ND	5.5
Zimbabwe [55]	2 mo–11 y	40	13 (33)	7 (54)	3 (23)	4 (31)	0 (0)	0 (0)	ND	No
The Gambia [56][b]	2 mo–10 y	42	22 (52)	13 (59)	ND	ND	ND	ND	ND	ND
The Gambia [57, 58]	<9 y	31	14 (45)	11 (79)	0 (0)	3 (21)	0 (0)	0 (0)	0/29	ND
Nigeria [59]	9 mo–5 y	99	78 (78)	0 (0)	0 (0)	30 (30)	8 (8)	39 (39)	ND	No
The Gambia [60]	ND	16	6 (38)	6 (100)	0 (0)	0 (0)	0 (0)	0 (0)	ND	ND
The Gambia [61]	3 mo–5 y	94	43 (46)	31 (70)	8 (19)[c]	2 (5)	0 (0)	6 (14)	28/94	7
Nigeria [62]	ND	1	1 (100)	0 (0)	0 (0)	0 (0)	0 (0)	1 (100)	ND	ND
The Gambia [18][d]	3 mo–5 y	94	43 (46)	31 (70)	8 (19)	2 (5)	0 (0)	6 (14)	ND	7
Total (yield, %)[e]		1000	659 (66)	164 (17)	112 (12)	190 (20)	26 (3)	290 (31)[f]		

NOTE. *E. coli, Escherichia coli; H. influenzae, Haemophilus influenzae;* ND, not defined, insufficient data, or lung tap isolates were not distinguished from blood isolates [53]; *S. aureus, Staphylococcus aureus.*

[a] Sometimes multiple organisms were isolated from the same lung tap specimen.
[b] Same patients as in [53].
[c] Five patients had *H. influenzae* type b.
[d] Same bacteriological data as in [61], but [61] includes virological data.
[e] For totals, $n = 949$. Yield for each specific agent among the aspirates in which it was sought.
[f] Number of *Klebsiella* species isolates, 55; no. of streptococci isolates, 102; no. of *Moraxella catarrhalis* isolates, 33; no. of others, 100.

(table 6); there were 3 reports, 2 of which dealt with the same patients [18, 72]. The yield was high in both series: 8 (44%) of 18 patients and 51 (61%) of 83 patients, respectively.

In the second report, which described 83 children [19], *H. influenzae* was more common than *Pneumococcus* species among the agents identified. However, only 5 (16%) of the 31 strains serotyped were of type b, in contrast to 5 (63%) of 8 isolates in The Gambia. Serotyping of *H. influenzae* was performed in only 2 other lung tap studies [34, 40], and both of these also included small numbers of patients.

The third fatality associated with lung tap performed on children described since World War I occurred in Papua New Guinea [19]. A 4-month-old child who was very ill arrived at the hospital with dual septicemia that was caused by *Pneumococcus* species and *H. influenzae.* Lung tap was performed on admission, and the child died a few hours later. There was no reason to attribute the death specifically to the tap, but a partial association could not be ruled out. On the other hand, in another prospective study, the fatality rate among children in the same study who were equally ill and who did not undergo lung taps was 2 times higher (51 [17.5%] of 297 vs. 9 [11%] of 83) [19].

A geographic summary of the causative agents that were found by means of lung tap is presented in table 7. Studies conducted since 1980 indicate that etiologies of pneumonia found by use of lung tap in Africa, Asia, and Oceania are not the same as those found by use of serological tests in American and European studies (table 7).

Influence of Pretreatment with Antimicrobial Agents on the Yield

Since the 1970s, 22 studies have reported data on children who did not receive antimicrobial agents before treatment [11, 12, 19, 22, 24, 41, 43, 45, 48, 50, 52–55, 59, 61, 67–69, 71, 72, 74]. Of the combined 1159 cases, 651 (56%) were positive for a bacterial etiologic agent, with the percentage of positive bacterial culture results ranging from 17% [50] to 79% [11]. As predicted, *Pneumococcus* species were the dominant agent, with a frequency of 38% (169 of 445) among those cases of identified

Table 5. Findings from lung tap studies of children in Asia.

Country [reference]	Patient age	Lung tap		No. (%) of aspirates that tested positive for organism[a]						Pretreatment with antimicrobial agents, %
		n	No. (%) positive	*Pneumococcus* species	*H. influenzae*	*S. aureus*	*E. coli*	Other	Virus	
India [63]	<4 y	25	11 (44)	3 (27)	7 (64)	0 (0)	0 (0)	1 (9)	ND	32
India [64][b]	<4 y	17	5 (29)	2 (40)	5 (100)	0 (0)	0 (0)	0 (0)	3	ND
India [65][c]	<4 y	18	7 (39)	2 (29)	6 (86)	0 (0)	0 (0)	0 (0)	2/18	ND
The Philippines [66]	2 mo–7 y	68	60 (88)	2 (3)	3 (5)	54 (90)	0 (0)	1 (2)	ND	ND
India [67]	<1 mo	50	31 (62)	14 (45)	0 (0)	14 (45)	0 (0)	3 (10)	ND	82
The Philippines [12]	11 d–14 y	193	103 (53)	17 (13)	11 (8)	47 (36)	10 (8)	46 (45)	ND	90
India [68]	1 mo–11 y	70	36 (51)	18 (50)	2 (6)	5 (14)	0 (0)	11 (31)	ND	29
India [69]	6 mo–14 y	100	50 (50)	5 (10)	0 (0)	25 (50)	0 (0)	20 (40)	ND	50
India [70][d]	<28 d	29	12 (41)	ND	ND	ND	ND	ND	ND	100
India [71]	ND	75	12 (16)	0 (0)	1 (8)	4 (33)	0 (0)	7 (58)	ND	52
India [72]	<5 y	35	17 (49)	4 (24)	1 (6)	2 (12)	2 (12)	10 (59)	ND	77
India [73]	<5 y	12	6 (50)	2 (33)	0 (0)	4 (66)	0 (0)	0 (0)	0/12	ND
Total (yield, %)[e]		674	343 (51)	67 (10)	30 (5)	155 (24)	12 (2)	99 (15)[f]		

NOTE. *E. coli, Escherichia coli; H. influenzae, Haemophilus influenzae;* ND, no data or not defined; *S. aureus, Staphylococcus aureus.*

[a] Sometimes multiple organisms were isolated from the same lung tap specimen.

[b] Some patients might have been included in [63] and [65].

[c] Same bacteriological data as in [64], but it also includes virological data.

[d] Seven postmortem lung taps, of which 3 taps with positive results were included (7 cases were diagnosed by counterimmunoelectrophoresis of aspirate).

[e] For totals, $n = 645$. Yield for each specific agent among aspirates in which it was sought.

[f] Number of *Klebsiella* species isolates, 13; no. of *Streptococcus pyogenes* isolates, 12; no. of other streptococci isolates, 9; no. of *Mycobacterium tuberculosis* isolates, 6; no. of unspecified gram-negative bacteria, 32; no. of others, 27.

etiology. *S. aureus* and *H. influenzae* were the next most common causes, with frequencies of 22% and 17%, respectively. Pneumococci were serotyped only in The Gambia [53, 56, 61] and Papua New Guinea [19, 74]; however, because isolates were not clearly distinguished from blood isolates, it was difficult to make specific conclusions with regard to lung tap serotypes.

The use of antimicrobial agents for pretreatment did worsen the yield [66], but less than one might expect. Results of 810 lung taps done in 14 studies [12, 19, 22, 43, 48, 52, 54, 61, 67–72] of children who had previously received antimicrobial agents showed that bacteria still grew or were detected by use of staining (results not always clearly distinguished) in 320 (40%) of the cases. However, the rate of culture success varied from no success to 63%. In only 1 study were the numbers of recipients and nonrecipients of pretreatment antimicrobial agents equal [69]. Results of direct smears and/or cultures were positive in 58% and 42% of cases, respectively. *S. aureus* was more common in patients who did not receive previous antimicrobial therapy (40% of patients who were not previously treated vs. 10% of previously treated patients), and *Klebsiella* species were more common in previously treated patients (14% of patients who were previously treated vs. 4% of patients who were not previously treated).

Lung Tap versus Blood Culture

Since the 1970s, the diagnostic yield of lung tap has been compared with that of blood culture in the same study in a total of 9 series, including 3 in Nigeria [11, 52, 59], 2 in The Gambia [53, 61], 1 in India [71], 1 in Colombia [40], 1 in the United States [24], and 1 in Papua New Guinea [19]. A total of 558 cases were included. A causative agent was found in 292 (52%) of the aspirates versus 137 (25%) of the blood cultures; the latter percentage is much higher than that in most series that were studied in industrialized countries [9, 21, 76]. In 6% of cases (31 of 558), only blood culture results were positive, and in 33% (185 of 558) only lung tap results were positive; both were positive in 19% (106 of 558). The data are summarized in figure 1. In one Filipino study, only 7% of blood culture results correlated with the results of lung aspirate cultures [12].

Blood culture is not sensitive enough for etiologic diagnosis of childhood pneumonia. A study from The Gambia [18] showed that 3 blood isolates differed from bacteria identified in lung tissue, which suggests that such a dual infection is possible. The Papua New Guinean investigators isolated the same organisms from specimens of the lung and blood, although they were recovered more frequently from the lung specimens [19].

Table 6. Findings from lung tap studies of children in Oceania.

Country [reference]	Patient age	Lung tap		No. (%) of aspirates that tested positive for organism[a]						Pretreatment with antimicrobial agents, %
		n	No. (%) positive	*Pneumococcus* species	*H. influenzae*	*S. aureus*	*E. coli*	Other	Virus	
Papua NG [74]	<10 y	18	8 (44)	7 (88)	1 (13)	0 (0)	0 (0)	0 (0)	ND	No
Papua NG [19][b] [75]	1 mo–5 y	83	51 (61)	27 (53)	41 (80)[c]	1 (2)	0 (0)	23 (45)	5/62	14
Total (yield, %)[d]		101	59 (58)	34 (34)	42 (42)	1 (1)	0	23 (23)[e]		

NOTE. *E. coli, Escherichia coli; H. influenzae, Haemophilus influenzae;* ND, no data or not defined; Papua NG, Papua New Guinea; *S. aureus, Staphylococcus aureus.*

[a] Sometimes multiple organisms were isolated from the same lung tap specimen.
[b] Same patients reported in [75].
[c] Five strains of *H. influenzae* type b.
[d] Number of *Moraxella catarrhalis* isolates, 9; no. of *Staphylococcus epidermidis* isolates, 4; no. of viridans *Streptococcus* isolates, 4; no. of others, 6.
[e] For totals, $n = 101$. Yield for each specific agent among aspirates in which it was sought.

Etiology of Pneumonia with Radiologic Categorization

Although the significance of such findings is disputable, radiological findings were categorized in 17 studies [11, 12, 18, 20, 22, 26, 28–31, 40, 41, 51, 53, 55, 60, 61]. In all, 15 reports described 570 cases of lobar pneumonia and 9 studies described 944 cases of bronchopneumonia; in only 7 instances were these types of pneumonia distinguished in the same study [11, 12, 22, 26, 31, 40, 41].

The etiologic agent was identified in 284 (50%) of the 570 cases of lobar pneumonia and in 515 (55%) of the 944 cases of bronchopneumonia. *Pneumococcus* species were found by means of lung tap in 78% of lobar pneumonia cases and in 13% of bronchopneumonia cases, among those cases for which the etiology was identified; *S. aureus* was detected in 11% and 46% of cases and *H. influenzae* in 7% and 20% of cases, respectively. The yield of lung taps improved in relation to the size of the consolidation and the experience of the person who performed the procedure [80]. The imprecision of radiological findings in relation to etiologic diagnosis was reflected by a case in which only respiratory syncytial virus was cultured from the aspirate of a lung consolidation—a classic sign of bacterial pneumonia [36].

Viral Studies

Investigators in 9 studies made an effort to identify viruses in lung aspirates, by use of culture, immunofluorescence, EIA, or antigen detection [19, 22, 42, 43, 58, 61, 64, 65, 73]. The rate of success was not great, with the exception of 1 study in The Gambia, in which viruses were detected in 28 (30%) of 94 cases [61]. Only 14 (4%) of 352 aspirates proved virologically positive. Respiratory syncytial virus was more common in well-nourished children, and herpes simplex virus was more common in malnourished children [61]. Whereas viruses were isolated in 5 (80%) of 62 cases in Papua New Guinea [19], the yield elsewhere was zero [22, 42, 58, 73] or only a low per-

Table 7. Overall frequency of bacterial agents in studies of pneumonia in children conducted since 1980.

Study, region [reference]	*n*	No. (%) of isolations of organism						
		Pneumococcus species	*H. influenzae*	*S. aureus*	*E. coli*	*Klebsiella* species	*M. catarrhalis*	Other
Lung tap								
Africa [52, 54, 55, 57–62]	462[a]	61 (13)	13 (3)	83 (18)	17 (4)	55 (12)	1 (0.2)	44 (10)
Asia [68, 69, 71–73]	292[a]	29 (10)	4 (1.4)	40 (14)	2 (1)	12 (4)	1 (0.3)	36 (12)
Oceania [19, 74]	101[a]	34 (34)	42 (42)	1 (1)	0 (0)	0 (0)	9 (9)	23 (23)
Serologically-based								
North America [77]	168[b]	35 (27)[c]	ND	ND	ND	ND	ND	22 (13)
Europe [9, 76, 78, 79]	790[b]	188 (24)	52 (7)	0 (0)	ND	ND	21 (5)	85 (11)

NOTE. *E. coli, Escherichia coli; H. influenzae, Haemophilus influenzae; M. catarrhalis, Moraxella catarrhalis;* ND, no data or not defined; *S. aureus, Staphylococcus aureus.*

[a] No. of lung taps
[b] No. of patients.
[c] Percentages are based on the number of patients in whom the specific agent was sought by means of serological testing.

Table 8. Complications of lung aspiration.

Reference	Rate of complications (%)[a]	No. of occurrences of					Needle gauge
		Hemoptysis	Subcutaneous emphysema	Pneumothorax		Death	
				Self-limiting	Suction tube inserted		
[32]	0/28 (0)	0	0	0	0	0	ND
[20]	2/233 (1)	2	0	0	0	0	ND
[34]	2/98 (2)	0	0	2	0	0	ND
[23]	1/25 (4)	0	0	0	1	0	18
[35]	1/2 (50)	0	0	1	0	0	ND
[39]	2/125 (2)	0	0	2	0	0	ND
[63]	2/25 (8)	0	0	1	1	0	20/21
[38]	4/32 (13)	1	0	3	0	0	20
[48]	0/7 (0)	0	0	0	0	0	20
[49]	7/22 (32)	2	0	2	2	1[b]	18
[40]	4/31 (13)	1	0	2	1	0	18
[22]	13/543 (2)	4	0	7[c]	2	0	18/20
[66]	3/68 (4)	2	0	1	0	0	ND
[50]	7/29 (24)	1	0	6	0	0	21
[41]	11/37 (30)	1	0	8	3	0	ND
[24]	3/27 (11)	0	0	3	0	0	ND
[43]	16/102 (16)	0	0	5+11[d]	ND	0	ND
[11]	4/88 (5)	2	1	1	0	0	18/21
[44]	4/60 (7)	2	0	2	0	0	ND
[67]	3/50 (6)	1	0	2	0	0	20/21
[12]	6/283 (2)	2	0	4	0	1[b]	ND
[68]	3/70 (4)[e]	2	0	0	0	0	22
[52]	4/73 (5)	2	0	2	0	0	18
[19]	7/83 (8)	3	0	2	1	1[b]	21
[53]	0/51 (0)	0	0	0	0	0	21
[54]	1/108 (1)	0	0	1	0	0	20
[55]	2/40 (5)	1	0	1	0	0	ND
[69]	4/100 (4)	2	0	1	1	0	18
[70]	3/22 (14)	0	0	3	0	0	23
[58]	0/29 (0)	0	0	0	0	0	ND
[61]	5/92 (5)	3[f]	2	0	0	0	21
[71]	3/75 (4)	0	3	0	0	0	20
Total[g]	127/2658(5)	34/2658 (1.3)	6 (0.2)	73 (2.7)	12 (0.5)	3 (0.1)	

[a] Data are no. of complications/no. of patients in the study (%).
[b] Tap might have contributed to death (see text).
[c] No pneumothorax in healthy control subjects (W. Ledermann, personal communication, 1999).
[d] Eleven cases were deemed "more severe," but there was no indication about whether suction was required.
[e] One child had chest pain and was treated with analgesics.
[f] Hemoptysis as well as a brief episode of central cyanosis and collapse occurred in 1 child.
[g] Values in parentheses denote percentages.

centage [43]. Perhaps the latest techniques would have improved the yield to some degree.

Complications

With the exception of the rate found in a report on only 2 children [35], the highest reported rate of all complications combined was 32% [49]. This finding was clearly an anomaly, however, because the mean rate for the 32 study reports that mentioned rates of complications (for a total of 2658 children) was no greater than 4.8% (table 7).

As expected, pneumothorax posed the greatest risk, and it was observed in 3.2% of all cases. The great majority of these children remained asymptomatic, and the pneumothorax resolved spontaneously. Chest tubes were inserted in 12 children

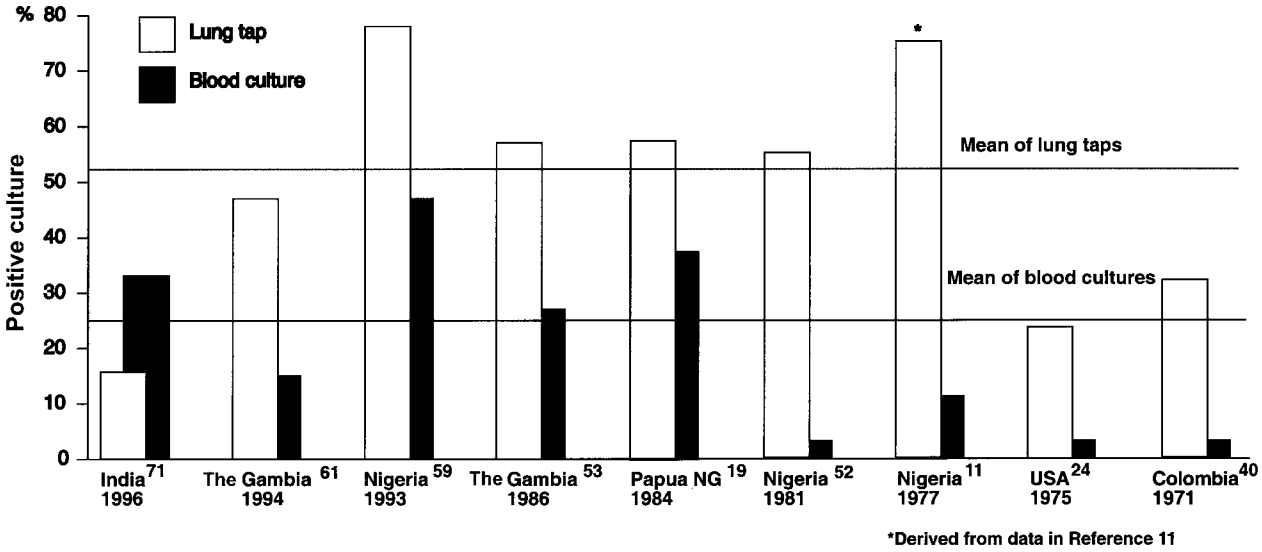

Figure 1. Bacterial yield of lung tap versus blood culture in the studies using both techniques. NG, New Guinea; USA, United Sates.

(0.5% of those for whom such information was available). In 5 cases, a rather large needle (18 gauge) was used for the tap. Hemoptysis—characteristically evidenced by a few strands of blood in sputum—was observed in 1.3% of cases. Subcutaneous emphysema was reported in 0.2% of cases.

In a large study by Bullowa [33] that involved 2500 children and adults, the rate of complications was 1.2%. Among children, pneumothorax was the only complication. However, Bullowa concluded that accidents occurred less frequently after lung tap than after thoracic aspiration of pus.

Factors other than lung tap per se played a key role in 1 of the 3 deaths that were possibly associated with lung tap described during the past 80 years (table 7). It is questionable whether the death of the moribund infant from Papua New Guinea who had dual septicemia [19] had any causal relationship to lung tap. The other 2 deaths were iatrogenic: the Filipino child [12] died of intrapleural bleeding caused by a dislodged tube, and another child in South Africa [49] died because pneumothorax was not detected early enough. Better monitoring of these patients would probably have prevented both deaths.

DISCUSSION

Our analysis of 3560 lung taps that were performed in 15 countries during a period of 120 years (tables 1–6) showed a 51% overall rate of success for bacterial diagnosis of home-acquired childhood pneumonia. A logical question to be asked is whether this rate of success justifies putting a child (nowadays, a child who not infrequently has an underlying disease) at a small but real risk for complications that may warrant further procedures (such as insertion of a chest tube).

As with any invasive technique, the clinician has to weigh the pros and cons: is it likely that the patient will be helped more with than without the procedure? A review of the use of transthoracic needle aspiration biopsy [81], in which (unlike in lung tap) a small piece of the brittle lung tissue is obtained, showed a 13% incidence of pneumothorax, but most patients were entirely asymptomatic. The risk of pneumothorax did not vary significantly according to the location of the lung area that was biopsied, with the exception that the rate of complications increased in relation to the increasing depth of the lesion. It is not surprising that the risk of pneumothorax also increased in relation to increases in the outer diameter of the needle. Asymptomatic and minimal pneumothorax require no treatment [82], but if symptoms and signs develop, insertion of a small chest tube [83] is recommended.

Lung tap specimen culture results have a very low false-positivity rate [84]. False-negative results are more problematic because the yield may underestimate the extent of infection; the needle might miss the focus or obtain a specimen that is too small for culture. The culture media may influence the spectrum of bacteria found, and viruses, *Mycoplasma* species, and *Chlamydia* species require special media. It also should be borne in mind that the overall rate of success of bacteriological diagnosis (50%; tables 1–6) was achieved by use of mostly very basic bacteriology. Had modern microbiological techniques been used, the yield probably would have increased.

When the sensitivity and specificity of lung tap were compared with those of catheter brush biopsy and transbronchial biopsy in an animal model [85], lung tap proved to be the best procedure. Compared with cultures of transtracheal aspirate specimens from adults [86], cultures of lung tap specimens were more likely to have false-negative results than false-positive results. For children, transtracheal aspiration is no less

traumatic than lung tap [7], but it requires anesthesia. A positive lung tap result most probably reflects the patient's disease status accurately [84].

Open-lung biopsy may be considered the "gold standard" for diagnosis of pulmonary infections [87]. However, it is rarely considered if community-acquired pneumonia of bacterial origin is suspected [88]; it is probably more valuable for immunocompromised children or children with chronic lung disease [89]. This procedure is performed, while the patient is receiving general anesthesia, by use of either posterolateral thoracotomy or a small anterior thoracotomy, and a small drainage tube is usually inserted for 24–36 h. The operation takes ~30–45 min [87, 88]. It is a much more complicated procedure than is a lung tap, which can be performed at the bedside in 10 seconds, without sedation and without a drainage tube.

In summary, our scrutiny of reports in several languages (tables 1–6) disclosed a wealth of neglected information from at least 3 previously published reviews [90–92]: the number of lung taps analyzed in the present study was very large (3560 lung taps); both the influence of pretreatment with antimicrobial agents and the superiority of lung tap in comparison with blood culture (figure 1) in pediatric patients were quantified; and all the complications described in reports of 32 studies from 6 continents were analyzed (table 8). Furthermore, radiologic findings were related to the yield from lung taps. There are no studies that directly compared lung tap with other diagnostic methods in cases of childhood pneumonia. However, because of the high bacteriological yield in most studies, we suggest that lung tap—an old, simple, clinically useful technique—warrants reappraisal. It is not a procedure to be used for every case of childhood pneumonia, but in the presence of dense peripheral consolidation, lung tap can provide important, sometimes lifesaving, etiologic information with minimal risk.

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