THE ABSORPTION OF PNEUMOPERITONEUM: A STUDY OF 33 CASES

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INTRODUCTION

In the past fifteen years pneumoperitoneum therapy has attained an increasing prominence in certain respiratory and abdominal conditions, and now has a well established place as a collapse measure in the treatment of pulmonary tuberculosis. The literature, however, contains no study of the period of abandonment of pneumoperitoneum and only a few references to the rate of absorption during the actual course of treatment. The object of this paper is to report the results of a study of the absorption of pneumoperitoneums in a series of thirty-three patients suffering from pulmonary tuberculosis. Observations have been made both on the period of absorption after abandonment, and also on some aspects of the absorption of air during the actual course of treatment. In view of the obvious parallelism between artificial pneumothorax and pneumoperitoneum, the findings have been compared and contrasted at every opportunity with the known facts in artificial pneumothorax, and an attempt has been made to explain any similarities or differences.

Although the literature contains no study of the absorption period of pneumoperitoneum, several authors make brief mention of the rate of absorption of air and other gases during the actual course of treatment. Godwin (1912), who used intraperitoneal injections of oxygen in a variety of abdominal conditions, reported that " if the abdominal cavity is completely filled with oxygen it takes about two weeks to get quite absorbed." Rehberg (1936) induced pneumoperitoneums for pulmonary tuberculosis with 1,000 ml. of air, following this

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with 800 ml. twice a week and then gradually lengthening the intervals. Rilance and Warring (1941) stated that " refills (of air) average 600 c.cm. twice a week. Later 500 to 700 c.cm. weekly are usually enough to maintain the elevation of the hemidiaphragm." Ricen (1942), in an experimental study in six patients, found that 1,000 ml. of air was absorbed in an average time of nine days, whereas in the same patients 1,000 ml. of helium lasted an average of fourteen days, and concluded that helium had possibilities as a substitute for air in the peritoneal cavity. Schmidt (1945) stated that " while refills of oxygen are necessary about twice a week they may as a rule be limited with air to once a week and with nitrogen to once a fortnight."

PRESENT STUDY

Thirty-three patients suffering from pulmonary tuberculosis were studied. Of these, twenty-seven were men and six were women. All had had pneumoperitoneums which had either been abandoned or were in the process of abandonment, thus allowing a study of the abandonment to be made. The average age of the group was 28.5, the extremes being 18 and 47 years.

Some patients had had pneumoperitoneum induced at other hospitals, and complete absorption had occurred in some before the patient was admitted to Preston Hall. In every case included in the series, however, the facts on which this study was based (and which are given in Table I) were known with the degree of accuracy stated in the

appropriate places. Cases in which there was doubt were not included in the series.

The figures given in Table I were obtained from a study of the case notes, refill charts, screening reports, and radiographs, and in some cases from personal fluoroscopy.

Fourteen patients had had a left phrenic nerve crush, fifteen a right phrenic nerve crush; only four had had a pneumoperitoneum alone.

DURATION OF THE PNEUMOPERITONEUM.—In every case, the date of induction of the pneumoperitoneum, and the date of the last refill were known exactly, and the interval between these dates is given in Table I under the heading "Duration of Pneumoperitoneum" and is stated to the nearest week. The average duration of the pneumoperitoneum was 32 weeks, the extremes being 4 and 82 weeks.

SIZE OF THE PNEUMOPERITONEUM.—When dealing with artificial pneumothoraces it is usual to estimate the collapse of the lung as a percentage. This gives a fairly precise method of estimating the relative amount of air in the pleural space. Individual estimates of the percentage of collapse of any one lung are unlikely to vary from observer to observer by more than 10 or at most 20 per cent. However, the problem of accurate estimation of the amount of air in a pneumoperitoneum is more complex. The degree of diaphragmatic elevation gives no clear indication of this, as the air space between the diaphragm and the liver is produced partly by diaphragmatic elevation and partly by visceroptosis (Banyai, 1939). Furthermore, in cases with a phrenic nerve crush, the paralysed hemidiaphragm may be very considerably raised with a large air space present, whereas the air space on the unparalysed side may be only very

TABLE I

DATA RELEVANT TO THE ABSORPTION OF PNEUMOPERITONEUM IN THIRTY-THREE CASES

Case no.	Sex	Age	Duration of pneumo-peritoneum (weeks)	Reason for abandonment	Period of absorption (weeks)	Depth at date of abandonment	Phrenic nerve crush
9	M	26	34	Ineffective	$2\frac{1}{4}$	Shallow	Right
17	M	37	30	Ready for thoracoplasty	2	,,	,,
32	M	28	13	Ineffective; dyspnoea	$3\frac{1}{2}$	,,	None
2	M	24	4	Advance of contralateral disease	5	Moderate	Left
3	M	25	13	Ready for thoracoplasty	7	,,	,,
8	M	25	43	Ineffective	6	,,	,,
12	M	32	53	Obliteration of empyema space	5	,,	Right
14	M	23	20	Ineffective	7	,,	None
20	M	26	18	Ineffective	5	,,	,,
25	M	33	53	Deterioration	6	,,	Right
26	F	20	19	Ready for third-stage thoracoplasty	$3\frac{1}{2}$	,,	Left
27	F	23	9	Advance of contralateral disease	6	,,	,,
28	M	25	19	Deterioration	$5\frac{1}{2}$	,,	Right
29	F	37	23	Ineffective	$5\frac{1}{2}$	,,	Left
30	M	26	31	Advance of contralateral disease	$5\frac{1}{2}$	,,	Right
33	M	21	28	Ready for artificial pneumothorax	$4\frac{1}{2}$	,,	Left
1	M	20	36	Ineffective	$7\frac{1}{2}$	Full	Right
4	M	30	30	Ready for thoracoplasty	10	,,	Left
5	M	27	18	Ready for thoracoplasty	7	,,	,,
6	M	28	82	Ineffective	10	,,	None
7	F	33	12	Obliterative pleurisy initiated	6	,,	Right
10	M	38	43	Ready for thoracoplasty	$6\frac{1}{2}$	,,	,,
13	M	23	24	Ineffective; dyspnoea	$9\frac{1}{2}$	,,	Left
15	M	28	74	Ready for thoracoplasty	$9\frac{1}{2}$	,,	Right
16	M	31	78	Ineffective	9	,,	Left
18	F	47	21	Ineffective	8	,,	Right
19	M	28	69	Ready for thoracoplasty	7	,,	,,
21	M	33	40	Ready for thoracoplasty	$7\frac{1}{2}$	,,	Left
22	M	44	13	Ineffective; dyspnoea	9	,,	,,
23	F	30	37	Ready for thoracoplasty	7	,,	Right
24	M	30	7	Ineffective	8	,,	,,
31	M	18	11	Peritoneal effusion	$7\frac{1}{2}$	,,	,,
11	M	24	36	Ineffective	11	Enormous	Left

shallow. Another variable factor is the degree of abdominal protrusion. In these circumstances it is very difficult accurately to classify pneumoperitoneums into groups according to the amount of air present.

In the present study pneumoperitoneums were divided into three main groups, according to a radiological estimation of the amount of air present. These groups are termed respectively, shallow, moderate, and full, and although there are obvious borderline cases the majority could be grouped without difficulty in this manner, and it is believed that such a classification will be understood by workers accustomed to the radiological appearance of pneumoperitoneums. In addition one pneumoperitoneum (Case 11) is classified as enormous because of the striking difference between its size and that of all the others.

Every patient had had a radiograph taken at the time of abandonment, and it was from this radiograph that the depth of the pneumoperitoneum was estimated. To have used any other radiograph of each patient's series would have introduced a source of error, as most of the pneumoperitoneums varied in depth during the course of treatment.

Using this method the thirty-three pneumoperitoneums were grouped as follows: 3 shallow, 13 moderate, 16 full, 1 enormous.

REASONS FOR ABANDONMENT.—It must be stressed that the present series cannot be considered to represent a fair cross section of the cases treated by pneumoperitoneum therapy, or of the results obtained from this form of treatment. This is because the group is selected in respect of two common factors; first, that the pneumoperitoneum was being abandoned, and second, that

every patient was still in the sanatorium and therefore under active treatment at the time of abandonment. There are no cases in the series in which the treatment had caused arrest of the disease, although these would normally constitute an important group in an unselected series of patients treated by pneumoperitoneum supplemented by phrenic nerve crush.

Table II summarizes the reasons for the abandonment of the pneumoperitoneum treatment.

In nine cases the pneumoperitoneum was abandoned because the patient was now ready for thoracoplasty. In these patients the treatment had been used to diminish the activity of acute lesions and was considered to have played a material and often a vital part in preparing the patient for thoracoplasty. In Case 26, the phrenic crush and pneumoperitoneum therapy was used as an interim measure between the second and third stages of a thoracoplasty in order to facilitate quiescence of an activated basal lesion. In Case 33 the treatment was used to produce quiescence of acute exudative disease of pneumonic type, and—this having been obtained—was abandoned concomitantly with the successful induction of an artificial pneumothorax—constituting a further example of its value in diminishing the activity of acute lesions. In Case 7 the treatment was used to bring the base of the lung into contact with the chest wall so as to initiate an obliterative pleurisy in a tuberculous pyopneumothorax, and it was abandoned when this had been attained. In Case 12 the pneumoperitoneum was induced to aid obliteration of an empyema space, and it was maintained until several months after this was completed. Thus, thirteen patients of the series can be considered to have derived material benefit from the treatment.

The pneumoperitoneum was regarded as ineffective in fourteen cases. These were either unaffected materially by the treatment, or else they improved slightly but not sufficiently to merit the continuance of the pneumoperitoneum or to enable a more effective means of collapse therapy to be substituted. In three of these (Cases 13, 22, and 32), the presence of dyspnoea was a factor contributing to the decision to abandon the treatment. In Case 31 the reason for abandonment was the development of a large peritoneal effusion two months after the induction of the pneumoperitoneum. In Cases 25 and 28, the pneumoperitoneum was abandoned because of deterioration of the general condition of the patient, and in Cases 2, 27, and 30 because of increase in contralateral disease.

TABLE II

REASONS FOR ABANDONMENT OF PNEUMOPERITONEUM

Material Benefit		13
Ready for thoracoplasty	9	
Ready for third-stage thoracoplasty ..	1	
Inactivation of acute exudative disease	1	
Obliteration of empyema space ..	2	
Pneumoperitoneum ineffective		14
Deterioration		6
Deterioration of general condition ..	2	
Flare-up of contralateral disease ..	3	
Peritoneal effusion	1	

THE PERIOD OF ABSORPTION

The period of absorption, namely, the interval between the last refill and the day of the final disappearance of the pneumoperitoneum, is set out in Table I.

In every case the date of the last refill was known exactly, and in the majority of cases the date of final absorption was known exactly or to within a day or two. No case has been included unless the date of final absorption was known to within a week at most, and there were only three cases in the series in which the interval was as long as this. In Table I the period of absorption has been stated to the nearest half week, and this is well within the accuracy of observation of the series taken as a whole.

In the three " shallow " cases the average period of absorption was $2\frac{1}{2}$ weeks; in the thirteen " moderate " cases it was $5\frac{1}{2}$ weeks, the extremes being $3\frac{1}{2}$ and 7 weeks; in the sixteen " full " cases the average was 8 weeks with a range of 6 to 10 weeks; the single enormous case took 11 weeks to absorb.

FACTORS AFFECTING THE RATE OF ABSORPTION OF AIR.—Factors known to produce variations in the rate of absorption of air from pneumothoraces were considered in relation to the effects they might have on the duration of the absorption period in pneumoperitoneums, and also on the interval between refills and the size of individual refills during the actual maintenance of the pneumoperitoneum.

1. *Exercise.*—The rate of absorption of air from artificial pneumothorax generally increases with the amount of exercise. This increase is believed to be due to the improved circulation through the pneumothorax lung which results from increased activity. By analogy, a similar increase in absorption might be expected to occur with activity in patients with pneumoperitoneums. In the present series, however, most of the patients were at rest in bed and only two were up for as much as three hours a day. Hence, exercise was not an important variable factor in the rate of absorption during abandonment in this particular series.

2. *Duration of the pneumoperitoneum.*—In artificial pneumothoraces, the rate of absorption of air gradually decreases so that smaller refills can be given at longer intervals. This is due to the pleural thickening which is associated with long-standing pneumothoraces, and which is detectable on radiographs as a thickened edge to the pulmonary outline, and on fluoroscopy by decreased respiratory excursion of the lung. Correspondingly the refill charts of the present series showed that, in general, the longer the pneumoperitoneum has been established, the longer the interval between refills and the smaller the size of the refills. Trimble and others (1939) as a result of post-mortem studies of twenty cases of pneumoperitoneum, concluded that there is a tendency for gradual thickening of the peritoneum to occur with increased duration of the pneumoperitoneum. This may be the explanation of the decreased rate of absorption. On the other hand, the present series shows no demonstrable relationship between the duration of the pneumoperitoneum and the duration of the period of absorption after abandonment. The series may be too small and the average duration of the pneumoperitoneum too short for such a relationship to be detected.

3. *The amount of air in the peritoneal cavity.*—The impression was obtained, on screening patients during the course of abandonment of pneumoperitoneum, that the rate of absorption was not constant. It appeared to be faster at first, but it slowed down appreciably as the amount of air remaining in the peritoneal cavity diminished and the date of complete absorption approached. In this connexion, Ricen (1942) recorded without comment an interesting and significant fact. Each of his six patients had received refills of 1,000 ml. a week during the maintenance of their pneumoperitoneums. After the pneumoperitoneum had been abandoned and completely absorbed, a single injection of 1,000 ml. of air was given experimentally; the times required for absorption of this 1,000 ml. in the six patients were 8, 11, 7, 9, 10, and 9 days respectively, with an average of 9 days. Hence in established pneumoperitoneums the rate of absorption was 1,000 ml. in 7 days, whereas pneumoperitoneums of only 1,000 ml. took an average of 9 days to absorb.

Stein and Stewart (1920), reporting a series of diagnostic pneumoperitoneums, stated that they used volumes of gas from 2 to 4 litres. Their radiographic illustrations are of pneumoperitoneums of a size at least equal to that of average members of the " moderate " group of the present series. Since the majority of the latter were receiving refills of 1,000 ml. weekly at the time of abandonment, and required an average of $5\frac{1}{2}$ weeks for absorption, their volume, if the rate of absorption remained constant, would have been about $5\frac{1}{2}$ litres. This is in considerable excess of

the 4 litres of the largest pneumoperitoneum of Stein and Stewart's series.

All these observations suggest that the rate of absorption of air is slower in a small pneumoperitoneum than in a large one in the same patient. This is the reverse of what is observed in artificial pneumothoraces, in which, as the lung expands between refills and the pleural air space gets smaller, the rate of absorption increases. Thus it is common experience that a patient who needs weekly refills of 250 ml. may need 600 ml. or more if the interval is increased to a fortnight.

This contrast between artificial pneumothoraces and pneumoperitoneums can be explained by a consideration of the area from which absorption can occur in the two instances. For, in artificial pneumothorax, although the air space is decreasing as the lung re-expands, the pulmonary surface area is increasing, and so a greater pleural surface is in contact with the air and the rate of absorption increases. . In pneumoperitoneums, on the other hand, as the bulk of air in the peritoneal cavity diminishes, so too does the area of peritoneum exposed to the air, and hence the rate of absorption in this case diminishes.

4. *The presence of peritoneal effusions.*—Four patients of the series (Cases 4, 8, 12, and 31) developed peritoneal effusions during the course of pneumoperitoneum therapy. In cases 4, 8, and 12 the effusions were small, and did not interfere with the treatment; the usual refills—which in each case were 1,000 ml. a week—were continued, no apparent reduction in the rate of absorption of air resulting from the presence of the peritoneal effusion. In Case 31 the peritoneal effusion was large and required on one occasion the removal of 80 oz. (2,272 ml.) of fluid, which contained lymphocytes but no tubercle bacilli. Because of the abdominal pain and the constitutional disturbance which resulted from the effusion, the pneumoperitoneum had to be abandoned. The absorption of air, however, was not materially slowed, and was complete within 7½ weeks of the date of abandonment, except for a loculus of air in the left mid-abdominal region, which was still present after a further 17 weeks when the patient left the sanatorium.

The peritoneal effusions in these cases may be compared with corresponding types of pleural effusions during pneumothorax therapy. Those in Cases 4, 8, and 12 can be compared with small benign transient pleural effusions, filling no more than the costophrenic angle, which often produce no alteration in the rate of absorption of air. That

in Case 31, on the other hand, is comparable to rapidly forming large pleural effusions which produce severe constitutional symptoms and great slowing or even cessation of absorption of air. In contradistinction to this, in Case 31, except for the small loculus, the rate of absorption of air seemed in no way diminished by the presence of the large peritoneal effusion. This suggests that in this patient there was still much healthy peritoneum from which the air continued to absorb at an unimpaired rate.

THE ABSENCE OF PERITONEAL EFFUSIONS DURING THE ABSORPTION PERIOD.—A pleural effusion, the so-called " transudate *ex vacuo*," occurs quite commonly when an artificial pneumothorax is abandoned, particularly if the refills are stopped suddenly ; this is often quoted as an indication for " tailing off " refills gradually. In view of this, evidence of peritoneal effusion during the course of absorption of pneumoperitoneum was sought with particular care in the present series, especially as, in every case, once the decision to abandon the pneumoperitoneum had been taken, no more refills were given, so that there was no " tailing off " of refills. In no case, however, was a peritoneal effusion observed to develop.

A possible explanation of this is that whereas in the pleural space very low pressures usually develop during the absorption of the air, thus encouraging the formation of pleural effusions (Alexander, 1925), in the peritoneal cavity, on the other hand, the pressures—which are above atmospheric at the time of abandonment—gradually return to atmospheric but are not below this level except in the subdiaphragmatic region (Overholt, 1930) and even here they are never much below atmospheric.

Another possible explanation is that failure to find peritoneal effusions may be due to difficulties of observation. For, whereas in pneumothoraces it is possible to observe very small effusions on fluoroscopy, in pneumoperitoneums quite large effusions could occupy the pelvis and not be detectable radiologically, especially with a steadily decreasing intraperitoneal air space. That such effusions can occur, especially in cases of advanced tuberculosis, is not in doubt (Trimble and others, 1939 ; Banyai, 1946), but the point at issue is whether they occur as a direct result of abandonment of the pneumoperitoneum. Banyai (1946) stated : " Asymptomatic effusion is usually small and may occupy the space between the liver and the lateral abdominal wall when the roentgenologic examination is made with the patient in the upright position. Occasionally it may be seen in the space between the stomach and the lateral abdominal

wall." No such peritoneal effusions were observed in any patient of the present series.

EFFUSION OVER THE BARE AREA OF THE LIVER DURING THE COURSE OF ABSORPTION.—In one patient (Case 16), an extraperitoneal effusion developed over the bare area of the liver during the abandonment of the pneumoperitoneum. This was apparent on a postero-anterior radiograph as a dense opacity above the superior surface of the liver, between it and the right hemidiaphragm. At first it did not extend upwards to the cupola of the diaphragm (Plate VI*a*), but after a few days it had reached the right hemidiaphragm (Plate VI*b*). Screening showed it to be of an hourglass shape, spreading out so as to overlap the liver shadow below, narrowing in the region of the peritoneal ligamentous attachments, and spreading out again above, over the inferior aspect of the right hemidiaphragm. This effusion was unaccompanied by symptoms and caused the patient no inconvenience or discomfort. Furthermore, fluoroscopy when the absorption of the pneumoperitoneum was complete, showed that the movement of the right hemidiaphragm was not impaired. In three previous patients I have seen transient bare area effusions shortly after the induction of pneumoperitoneums.

The features on which the diagnosis of extraperitoneal effusion was made in Case 16 were:

1. The opacity was dense, and localized to the area normally occupied by the stretched suspensory ligaments of the liver, which can often be seen on radiography or fluoroscopy.

2. Fluoroscopy showed that this opacity encroached upon a supra-hepatic area which had previously been observed to be transradiant.

3. The opacity was biconcave in shape, and spread out over the superior surface of the liver below and the inferior surface of the diaphragm above, with a narrowed " waist " in between.

4. When first observed, the opacity was present just above the superior surface of the liver only, but in the course of a few days it had extended upwards to reach the inferior surface of the diaphragm.

These points have been enumerated because it is necessary to differentiate between effusions over the bare area of the liver and some cases of sheet adhesions in the presence of a pneumoperitoneum. The incidence and nature of peritoneal adhesions associated with pneumoperitoneums have been reported on by several authors as a result of radiological, peritoneoscopic, and post-mortem studies (Trimble and Wardrip, 1937; Bennet, 1938; Banyai, 1946; Hawkins and Thomas, 1946). These adhesions are commonly present in the subdiaphragmatic area, and vary from strings to dense sheets. It is these latter which may be confused with bare area effusions. Thus Fig. 4, page 75 of "Pneumoperitoneum Therapy" (Banyai, 1946), is a postero-anterior radiograph illustrating "sheet adhesions" developing during the course of pneumoperitoneum treatment. This radiograph could equally well be interpreted as showing an effusion over the bare area of the liver. I believe that the diagnosis of "sheet adhesions" cannot be made in any case in which the anatomical localization of the opacity is suitable for a bare area effusion unless the nature and course of development of the opacity have been carefully observed.

SUMMARY

1. The absorption of pneumoperitoneums after abandonment was studied in a series of thirty-three cases of pulmonary tuberculosis.

2. The pneumoperitoneums were classified by radiological estimation of their size into three groups—full, moderate, and shallow. The full pneumoperitoneums took on an average 8 weeks to absorb, the moderate 5½ weeks, and the shallow 2½ weeks. In this selected group, thirteen cases were classified as "materially benefited," fourteen as "ineffective," and six as "deteriorated," when the pneumoperitoneums were abandoned.

3. The rate of absorption of air, both during the course of pneumoperitoneum treatment and after its abandonment, was not significantly affected by exercise in this group. The longer the pneumoperitoneum was maintained, the smaller was the size of the refills, but the duration of the pneumoperitoneum did not affect the time required for absorption after abandonment. The rate of absorption slowed as the volume of residual air in the peritoneal cavity diminished. In three patients peritoneal effusions did not affect the size of refills, and in a fourth, did not materially increase the time required for absorption. These findings are compared and contrasted with those in artificial pneumothorax.

4. Peritoneal effusions were not observed to develop after pneumoperitoneums were abandoned.

5. An extra-peritoneal effusion over the bare area of the liver is described and illustrated by

radiographs. Study of the course of its development enables it to be differentiated from abdominal sheet adhesions.

I wish to thank Dr. F. Temple Clive, Medical Superintendent, for his kind permission to use the clinical material, and Dr. F. R. G. Heaf, Honorary Consulting Medical Director, for his helpful criticisms of this paper.

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