DISSOCIATED PARALYSIS OF THE DIAPHRAGM
FOLLOWING PHRENIC CRUSH AND
PNEUMOPERITONEUM

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In 1939 Douady and others reported for the first time dissociated paralysis of the diaphragm. It occurred in two patients during the course of phrenic alcoholization and pneumoperitoneum therapy for pulmonary tuberculosis. Since then no further cases have been found in the literature. The object of this paper is to report another case and to discuss the therapeutic and anatomical significance of this occurrence.

CASE REPORT

The patient, a soldier, was diagnosed as having pulmonary tuberculosis in September, 1945, when he was aged 29. He had had a four-year history of lassitude and cough and had lost 1½ stone in weight. At the time of diagnosis he had a positive sputum, his blood sedimentation rate was 16 mm. in the first hour (Westergren), and radiography showed considerable productive disease of the right upper lobe with extensive cavitation. In October, 1945, a right artificial pneumothorax was induced, but it was abandoned in November, 1945, due to the presence of extensive adhesions.

On Feb. 6, 1946, a right phrenic crush was performed under local anaesthesia. No accessory phrenics were found at the operation, and complete hemi-diaphragmatic paralysis was obtained. On April 24 screening showed that the diaphragm was recovering its function. The patient was admitted to Preston Hall on June 21, 1946, and at that time he had full diaphragmatic recovery. It was decided to repeat the right phrenic crush and to supplement it by a pneumoperitoneum as a preparation for thoracoplasty. So on July 24 the right phrenic crush was repeated, and again at operation no accessory phrenic nerves were found. Diaphragmatic paralysis with paradoxical movement resulted. On Aug. 2 a pneumoperitoneum was induced (Plate IXa).

Screening on Dec. 11, 1946, showed that a partial diaphragmatic recovery was occurring, and this recovery was of a striking nature. The anterior and medial part of the right hemi-diaphragm remained paralysed and showed slight paradoxical movement, whereas the lateral and posterior portion of the diaphragm was recovering its function, and within a few weeks displayed full active respiratory excursions.

On expiration the right hemi-diaphragm was shaped like a regular arc of a circle and there was only a slight point of demarcation between the paralysed and non-paralysed parts. On inspiration the appearance was strikingly altered. The posterior and lateral part descended actively, producing a very definite demarcation between the paralysed and non-paralysed parts of the diaphragm so that the regularity of contour was lost. This can be seen from the posterior-anterior and lateral films taken on inspiration and expiration (Plate IXb and Plate Xa, b, and c).

The patient was observed for another six months before being transferred nearer home for his operation, and during this time the dissociated recovery of the diaphragm remained unaltered.

The diaphragmatic movement was a muscular contraction, and unlike the irregular movements occasionally produced by the presence of adhesions in the lower part of the pleural space. It differed from the denting of a recovering diaphragm which is occasionally seen in the presence of sub-diaphragmatic adhesions, and it was unlike the serrated appearance of some diaphragms in the presence of a pneumoperitoneum.

Anatomically, the immobile area of the diaphragm appeared to be the right leaf of the central tendon, the muscular fibres of the sternal origin, and the anterior muscle fibres of the costal origin. The area which had recovered its function comprised the posterior costal muscle fibres, the arcuate fibres, and the right crus. Hence, a true dissociated muscular paralysis of the diaphragm was present.

DISCUSSION

Decker (1933) made passing mention of the fact that dissociated paralysis of the diaphragm could occur after phrenic crush. He stated: "In one case only a partial paralysis of the diaphragm was
The right cupula of the diaphragm has an unusual position between the lateral and medial parts of the diaphragm, as is evident.

Although the diaphragm was completely paralysed and immobile, there is no paradoxical movement; the point of demarcation between the lateral and medial parts of the diaphragm was unmistakable.
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**PLATE Xa.**—Inspiration radiograph of May 19, 1947. The diaphragm is now clearly divided into the medial paralysed portion and a lateral portion which has contracted actively.

**PLATE Xb.**—Expiration right lateral radiograph of May 19, 1947. The contour of the right hemi-diaphragm is seen to be smooth and regular, appearing to be a functional whole. The left cupola is also visible.

**PLATE Xc.**—Inspiration right lateral radiograph of May 19, 1947. It can be seen that, whereas the anterior part of the diaphragm has remained immobile, the posterior portion has descended actively on inspiration and the regularity of contour has been lost.
obtained. The central portion seemed inactive, but
the lateral peripheral portion functioned normally.
A second operation was done, and then a sizable
nerve, probably an accessory, was found on the
scalenus medius muscle, overlapped by the
scalenus anterior.” Nehil and Alexander (1933)
had a similar case in their series. Thus, it is
occasionally possible to see a dissociated paralysis
of the diaphragm in the absence of a pneumoperi-
toneum.

On the other hand, in the two cases quoted by
Douady and others, the right hemi-diaphragm
appeared pariesed after the phrenic crush and ex-
hibited movement of diminished amplitude but of
normal direction. It was only when a pneumoperi-
toneum was induced that it was possible to see the
dissociated nature of the paralysis. It would
appear that in these cases the liver had a damping
effect on the movement of the right diaphragm,
thus giving an overall diminished excursion, and it
was only when a cushion of air was introduced
between the liver and diaphragm that the true
autonomy of the muscle was manifest, and the
dissociated nature of the paralysis became evident.
Hence, after phrenic crush, dissociated paralysis
may become evident or may remain latent as an
apparent diaphragmatic paresis only to be recogni-
zied on the induction of a pneumoperitoneum.

Several observers have reported the return of
diaphragmatic function after phrenic avulsion. In
Morin’s (1932) series of 343 cases diaphragmatic
function returned in 2.5 per cent, and in Wirth and
von Jaski’s (1929) 185 cases 12.9 per cent had
diaphragmatic recovery. This recovery was
believed to be due to the presence of accessory
phrenic nerves that were anatomically intact after
the avulsions. It would appear likely that some
of these cases were examples of latent dissociated
paralysis, and that this occurrence is more frequent
than has been realized in the past. In this respect,
it is interesting to consider a case reported by John
Alexander (1937). The patient had had a phrenic
avulsion resulting in a complete diaphragmatic
paralysis lasting for several years. In time almost
complete recovery of respiratory movement was
observed, and at a second operation on the phrenic
nerve a small accessory phrenic was found and
severed. Again complete paralysis resulted.
Alexander comments: “This small root had
presumably gradually assumed the functional load
normally borne by the main phrenic trunk.” At
the initial phrenic avulsion the accessory phrenic
nerve was probably traumatized, with a consequent
interruption of conduction of nervous impulses,
and so complete hemi-diaphragmatic paralysis
resulted. Eventually the accessory phrenic re-
covered, and because of the contact of the
diaphragm with the liver the whole diaphragm
moved. But it is possible that if a pneumoperi-
toneum had been induced in this patient a dis-
sociated paralysis would have been found.

It is important to recognize dissociated paralysis
of the diaphragm. Most tuberculous lesions are
situated posteriorly in the lung, and if after an
operation on the phrenic nerve the posterior and
lateral part of the diaphragm function normally,
as in the reported cases of dissociated paralysis,
the patient with a phrenic crush and pneumoperi-
toneum will probably derive no more benefit from
his treatment than he would from the pneumo-
peritoneum alone.

In the patient reported in this paper it was
decided not to repeat the phrenic crush in view of
the possibility of producing a complete and
permanent paralysis of the right hemi-diaphragm.
This was considered undesirable because a thoraco-
plasty was the ultimate object of treatment.

The anatomical implications are of interest.
Douady and others believe that in man the
anterior and medial half of the diaphragm receives
its nerve supply from cervical 3 and 4 and that the
posterior and lateral portion is supplied by cervical
5. They were able to find an accessory phrenic
nerve in one of their two patients, and division of
this branch produced paralysis of the lateral and
posterior part of the diaphragm. In addition ex-
periments performed on the dog by Rodrigues and
Carvalho (1939) support this opinion, for in one
dog total resection of the right phrenic nerve pro-
duced a complete hemi-diaphragmatic paralysis,
whereas resection of the superior root of the left
phrenic nerve in the same animal produced a
paralysis of the medial part of the left hemi-
diaphragm and the lateral portion continued to
move normally.

In the patient of this report both the phrenic
crush operations produced complete diaphragmatic
paralysis. It was only when four months had
elapsed after the second phrenic crush that the
dissociated paralysis manifested itself. This fact,
together with the apparent absence of accessory
phrenics at both operations, would suggest that
there were no accessory phrenics present in the
patient and that all the phrenic nerve fibres lay in
the one nerve trunk. The rate of regeneration
of nerve fibres is very variable, but the fact that
diaphragmatic recovery involved so exclusively the
lateral and posterior part of the right hemi-
diaphragm suggests that the arrangement of nerve
fibres in the phrenic nerve in this patient were such
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that at the second operation the fibres supplying this area of diaphragm suffered only physiological division, whereas the fibres to the anterior and medical part of the diaphragm suffered anatomical division. If the nerve fibres supplying the anterior and medial parts of the diaphragm occupied a circumferential position in the phrenic nerve, and the fibres to the lateral and posterior parts occupied the central part of the nerve, the latter are less likely to suffer such severe damage as the circumferential fibres. Furthermore, the presence of perineural fibrosis as a result of the first phrenic crush would also protect the central fibres of the nerve at a second operation.

SUMMARY

A case of dissociated paralysis of the diaphragm occurring in the course of treatment of pulmonary tuberculosis by phrenic crush and pneumoperitoneum therapy is described and illustrated by radiographs.

The fact that this condition may not be detected is stressed, and the therapeutic and anatomical significance is discussed.

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