

ELEVATION OF THE DIAPHRAGM.

UNILATERAL PHRENIC PARALYSIS.

A RADIOLOGICAL STUDY, WITH SPECIAL REFERENCE

TO THE DIFFERENTIAL DIAGNOSIS.

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Jean Louis Petit

Born March 13th 1674

Died April 1760



The writings of Jean Louis Petit were collected and published after his death by his pupil Lesne.

The secretary of the Académie des Sciences of the Institut~~us~~ de France writes — "J'ai l'honneur de vous faire connaître que, d'après les recherches que nous avons pu faire, il semble que ce mémoire n'a jamais été publié du vivant de Jean Louis Petit mais il est dans les 3 éditions de ses œuvres posthumes de 1774, 1780, 1790."

ELEVATION OF THE DIAPHRAGM.

UNILATERAL PHRENIC PARALYSIS.

by
J. M. WOODBURN MORISON, M.B.

My thesis is mainly a radiological study of Elevation of the diaphragm with some observations on the differential diagnosis. I have added to the title that of Unilateral phrenic paralysis for two reasons; firstly, I hope to show during the course of this paper that certain forms of congenital elevation of the diaphragm are probably due to a unilateral phrenic paralysis, and secondly, to present for consideration a number of cases in which paralysis of one or other leaflet of the diaphragm was caused by a definite pathological lesion involving the phrenic nerve in its passage through the thorax.

Elevation of the diaphragm may be permanent or temporary, and permanent elevations may be congenital or acquired.

Under the heading Permanent elevation of the diaphragm we may place Petit's "eventratio diaphragmatica" and also those cases which I shall describe later of unilateral phrenic paralysis.

It is usual in writing of elevation of the diaphragm to begin by stating that "Petit in 1790 described a diffuse relaxation of the diaphragm" or again "Eventration of the diaphragm has been known ever since J. L. Petit reported and named a case in 1790." Many of the writers on this subject have done so. This is unfortunate because Jean Louis Petit died in April 1760 at the age of 86 years. His writings were collected and published by Lesne, his pupil, in ~~1774~~¹⁷⁷⁴, 1780 & 1790.

J. L. Petit, one of the most brilliant French surgeons of the 18th. century, was the first to clearly differentiate the condition known as Eventratio Diaphragmatica from the usual Diaphragmatic Hernia.

In his writings he states that he has seen two diaphragmatic herniae and that other cases had been seen by several of his colleagues. He recognised that congenital defects occurred in the diaphragm and noted the absence of a hernial sac in the first case he recorded. He also commented on the fact that both the hernias of the diaphragm which he had seen were on the left side. His confrères told him that all those which they had seen were likewise on the left side. This led him to suggest that the convex surface of the liver protects the right side of the diaphragm.

The two cases which he described were in adult males, and clinically of long standing.

The first case was one of true diaphragmatic hernia in which, at the post mortem, a great part of the stomach, a portion of the colon and part of the omentum had passed through a defect in the dorsal part of the left diaphragm into the thorax. There was no hernial sac and there were no adhesions.

The second case was also on the left side, and Petit states that he considered it to be a congenital abnormality. At the post mortem, on opening the chest he found a tumour, the size of "a small gourd", formed by a portion of the stomach, colon and omentum, and enclosed in a hernial sac which was formed by peritoneum, diaphragm and pleura. A "thick lymph" of recent origin had caused adhesions to the lower lobe of the lung, and the contents were similarly held together, so that when removed from the sac they kept the shape of the whole tumour.

The death of this patient was attributed to "Inflammation of the Abdomen".

It is thus seen that Petit clearly recognised that his second case was of a different type from the usual diaphragmatic hernia, and to it he gave the name "Event-ratio Diaphragmatica". Since his time ^(Thirty) 30 cases have been recorded. In the early days it was a pathological

description, but since the introduction of X-rays to the study of medicine, and more especially of recent years with the advance of radiology, it has become possible to accurately observe and diagnose these cases during life.

I shall first describe 6 cases which I have classified as Eventratio Diaphragmatica. Group 1.

In group 2. I record a series of cases of Unilateral Phrenic Paralysis which I think throw a good deal of light on the aetiology of group 1.

They follow a short note on Temporary Elevation of the Diaphragm with illustrative cases. Group 3.

The differential diagnosis from cases of diaphragmatic hernia - group 4. - and from other conditions such as localised hydro or pyopneumo thorax and subphrenic abscess will also be considered. Group 5.

Finally I shall discuss the aetiology and the literature and give my conclusions. The Bibliography is attached.

It will also be necessary to make some observations on the anatomy and action of the normal diaphragm during the course of this paper.

Eventratio Diaphragmatica.

It is generally accepted that the term, Eventratio Diaphragmatica, should be applied to those cases of congenital origin in which there is a diffuse relaxation of one half of the diaphragm so that it extends high up into the thorax forming a sac which contains a portion of the stomach, and sometimes a part of the colon and mesentery. All the cases recorded have been on the left side with the exception of one by Eppinger in 1911.

In these cases physical examination may determine varying and anomalous signs at the base of the left hemithorax and also an alteration in the position of the heart, but the radiological examination makes it possible to interpret these signs and arrive at a correct diagnosis.

In the radiological examination the following points require consideration:-

1. The bow line in the chest.

This is present in all cases as an unbroken line extending across the left hemithorax. Sometimes it is slightly irregular on account of the colon lying alongside the air sac of the stomach, a different pressure of gas in the colon from that in the stomach accounting for the slight irregularity. This bow line encloses an air

Plate 2

Eventratio Diaphragmatica.

Group I.

Case 1.

A.O.B. girl. aged 12 years.



Chest. Upright position - Post. Ant.

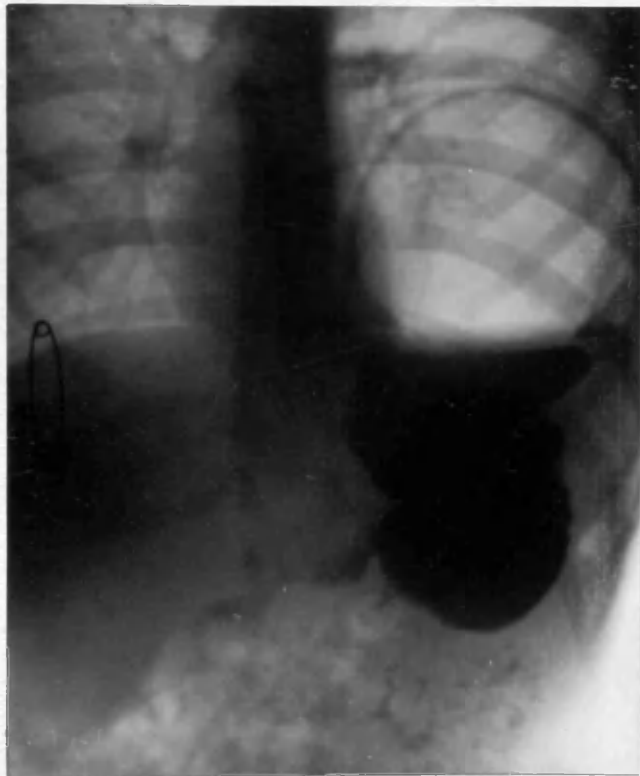
Note the low line in the chest, horizontal line of free fluid in stomach etc.

Creutzfeldt Diaphragmatica

Group I

Case 1.

a. o. B. girl. aged 12 years.



Stomach. upright position. Post. ant.

After a Bismuth meal.

space at the bottom of which there is often seen the sharply defined horizontal line of free fluid in the stomach. The whole forms a dome in the chest and presents a striking picture.

2. Contents of the dome.

The air sac of the stomach is always present and may occupy the whole of the dome. At times a portion of the colon may be found lying alongside it.

3. Lung tissue seen through the dome.

In the cases which I have investigated I have noted that lung tissue was seen through the upper part of the dome.

4. Movements of the bow line.

It is usually stated that no movements of the bow line, (the relaxed, thinned out diaphragm) occur, or if any movements were observed, that they were synchronous with the normal leaflet.

In all my cases I observed reversed movements, but in one case only after adhesions to the lung had been divided and until they reformed.

5. Level of the stomach contents.

The level of the stomach contents is always the level of the cardiac orifice.

6. Palpation of the abdomen.

Splashing and rippling on the surface of the fluid in

Plate H

Eventratio Diaphragmatica

Group I

Case 1.

a. O.B. girl. aged 13 years.



Stomach.

Upright position. Oblique view.
Note the two sacs - the upper spilling
forwards into the lower.

the stomach is easily produced by palpation of the abdomen.

7. The shape of the stomach.

Deformity of the stomach frequently occurs. It is due to the ascent of the greater curvature of the stomach under the elevated diaphragm, with rotation on more or less fixed points. The stomach presents two sacs, the upper spilling forwards into the lower. The rotation may be so great that a volvulus is produced which may require surgical interference. In many of the cases recorded there is a history of stomach trouble.

8. Displacement of the heart.

Part of the heart shadow is usually seen through the air in the dome. The heart may be displaced to the right and in some of the cases recorded this has evidently been a marked feature.

9. Movements of the chest wall.

No difference in the movements of the two sides of the chest were detected in the cases which came under my observations.

Constrictio Diaphragmatica

Group I

Case 1.

A. O. B. girl aged 13 years.



Stomach. Patient lying down.

Note, the contents of the stomach have replaced the air in the air sac and extend high up into the chest, but not beyond the bow line.

Group I. Eventratio diaphragmatica.

Case 1.

In January 1920 a school girl A. O'B. aged 12 years, was brought to hospital having had a cold and cough for two weeks.

The family history was unimportant and there was nothing to suggest the condition found at the X-ray examination.

The screen examination of the chest showed a complete regular dome on the left side, extending as high as the level of the 3rd. rib in front and enclosing an air space through which in the upper part lung tissue was seen. At the bottom of this air space there was a sharply defined horizontal line of fluid on which waves and ripples were produced by palpation of the abdomen.

No definite movements of the bow line in the chest were observed during respiration, although on one occasion I thought there was a slight reversed movement, an upward movement during inspiration and a downward movement during expiration, but I was not quite confident of this.

The dome of the right diaphragm was at the level of the 10th. dorsal vertebra. Its movements were normal.

The heart was slightly displaced to the right.

Plate 6

Excentric Diaphragmatica.

Group I

Case 1.

A. O. B. girl. aged 13 years



Colon.

Patient lying down.
Bismuth food in colon which extends up
under the bow line, where a few flakes of the
food can be seen.

There was an increased density of the root shadows of both lungs.

On giving a bismuth meal the food was held up at the cardiac opening of the oesophagus, the lower third of which was dilated, the obstruction was soon overcome and the stomach was seen to fill in an irregular manner. The cause of this was apparent when the patient, who up to this stage had been examined in the postero-anterior position, was placed in the right anterior oblique position. There were two sacs, the shadows overlapping in the postero-anterior position. The upper sac, when filled, spilled in a forward direction into the lower.

The pyloric end of the stomach was directed backwards and was not well formed.

There was no delay in emptying.

In the lying down position the bismuth meal passed up to the top of the bow line in the chest, displacing the air and completely filling the dome which was not altered in position.

Nothing abnormal was detected in the small intestine.

The colon was well outlined and the splenic flexure was found to rise alongside the air cap of the stomach to the top of the bow line in the chest, but not beyond it. At other times the whole of the dome in the chest was filled

Plate 7
Aneuratio Diaphragmatica.

Group I

Case 1.

A.O.B. girl. aged 13 years.



Colon.

Bismuth food in the splenic flexure.
Note that the colon is not forming part of
the contents of the dome.

by the air cap of the stomach.

A Barium enema confirmed these observations on the colon which was otherwise normal.

This was evidently a case of Petit's Eventratio Diaphragmatica.

Mr. John Morley, F.R.C.S., operated by the thoracic route, and from his notes I have extracted the following:-

"The fundus of the stomach was seen projecting up into the thorax far above the level of the incision. It was at once apparent that a transparent layer of thinned out diaphragm formed a covering for the elevated abdominal viscera and separated them completely from the true pleural cavity. To the highest point of this thin translucent diaphragm the base of the left lung was firmly adherent. These adhesions were fibrous and vascular, and were readily divided. The diaphragmatic sac was now incised. On opening it the splenic flexure of the colon and left extremity of the great omentum and the greater curvature of the stomach were presented. These were quite free from adhesions. The upper pole of the spleen also came into view. The whole diaphragm was merely represented by a thin sheet consisting of pleura above and peritoneum below with some rather

Plate 8
Eventratio Diaphragmatica.



Group I

Case 1.

A. O. B. girl aged 16 yrs

Chest. Upright position. Post ant. (Three years later.)
Note low line in chest.

Plate 9

Eventratio Diaphragmatica.

Group I

Case 1.

A.O.B. girl aged 16 yrs



(3 years later.)

Stomach.

Oblique view after a bismuth meal.
Note the deformity of the stomach.

dense fibrous tissue between. A partial excision of this diaphragmatic sac was determined upon with the object of bringing down its level as near to the normal as possible and so reducing the distortion of the stomach and allowing more expansion of the lungs.'

Convalescence was uneventful and rapid.

Four weeks after the operation I made another X-ray examination of this case.

The lung was fully expanded, the bow line in the chest was not so high, its movements were quite free but reversed, and the stomach presented a more normal appearance, the exaggerated cup and spill formation having disappeared. Subsequent examinations showed that the movements of the bow line became less and less free, finally no movements were observed, adhesions having evidently re-formed.

Microscopical sections of the piece of diaphragm removed showed normal endothelium on the pleural and peritoneal surfaces and between these, dense fibrous tissue with no sign of muscle fibres. No nerve fibres could be made out in sections that were specially stained to show them.

Three years later I took the opportunity of again examining this case - January 1923. The condition was

found to be much the same as at the last examination. She suffers no inconvenience and is engaged in house work.

Case 2.

The second case was a man, B.K. aged 54, who was operated on for pyloric obstruction. At the operation it was found that the left half of the diaphragm extended high up into the chest, and that the obstruction was due to a torsion of the stomach. This was relieved. I had the opportunity of X-raying this man some months later: The screen examination showed the bow line of the elevated left diaphragm rising up into the chest, the line was continuous across the left hemithorax, but not perfectly regular, as both the air sac of the stomach and the splenic flexure could be distinguished, the different degrees of pressure in the two causing a slight irregularity. Some lung tissue could be seen through the upper part of the dome. The horizontal line of fluid in the stomach was observed, but this extended only part of the way across the left chest. Full, free reversed movements of the diaphragm were noted. Palpation of the abdomen produced waves along the line of fluid. On giving a Bismuth meal the stomach was seen to be of the "cup and spill" type. There was no delay

Eventratio Diaphragmatica.

Group I.

Case 2.

B. K. Male. aged 54 yrs.



Chest. Upright position. Post. Ant.
note elevated diaphragm.

in emptying. In the lying down position bismuth food filled up the space under the bow line in the chest occupied by the air sac, and during subsequent examinations the splenic flexure was seen outlined by bismuth. This was evidently a true case of eventration of the diaphragm in which there were no symptoms until the onset of a pyloric obstruction due to an increased rotation causing a volvulus. At the present time this man is in good health and suffers no discomfort.

The third case was a married woman.

Case 3. Mrs. M. H. aged 48 years.

This case was sent for X-ray examination of the chest. It was noted that the cardiac dulness was displaced to the right, this being the only definite physical sign. She complained of indigestion extending over a period of three years with ^{occasional} ~~occasional~~ sickness and vomiting. There was no acute pain but often a feeling of discomfort after food.

The X-ray examination showed a regular and typical dome shaped elevation of the left diaphragm through which some lung tissue could be seen in the upper part. It rose to the level of the 3rd. rib in front. The horizontal line of free fluid in the stomach was present, and the whole of the space beneath the dome at the first examination

Plate 11
Eventratio Diaphragmatica.

Group I

Case 3.

Mrs. M. H. female aged 48 yrs



Chest Upright position - lateral view.

Note. - Elevated diaphragm

was occupied by the air sac of the stomach. At other times the splenic flexure was seen to be rising up alongside the stomach under the dome, but it was not always present. There were complete and free reversed movements of the left half of the diaphragm.

On giving a Bismuth meal the usual deformity of the stomach was found although it was not so marked in this case as in some of the others.

She still suffers from indigestion and evidently from an intermittent obstruction due to drag on the pylorus from mechanical causes.

Case 4. H. B. Aged 41 years.

This man was sent to see me in December 1922. For the past 20 years he had suffered from indigestion. The attacks were intermittent, gradually becoming worse. Dr. Fiddian, of Ashton-under-Lyne, his medical attendant states "He had, on December 15th., an acute attack of epigastric pain with vomiting. I had great difficulty in getting the bowels moved and the stool finally was green and offensive. He has been well purged since, starved for 48 hours and then fed carefully but his pain does not wholly disappear, it comes on two hours or so after food and wakes him up in the night."

A bismuth meal was given and a screen examination revealed a condition similar to those cases already

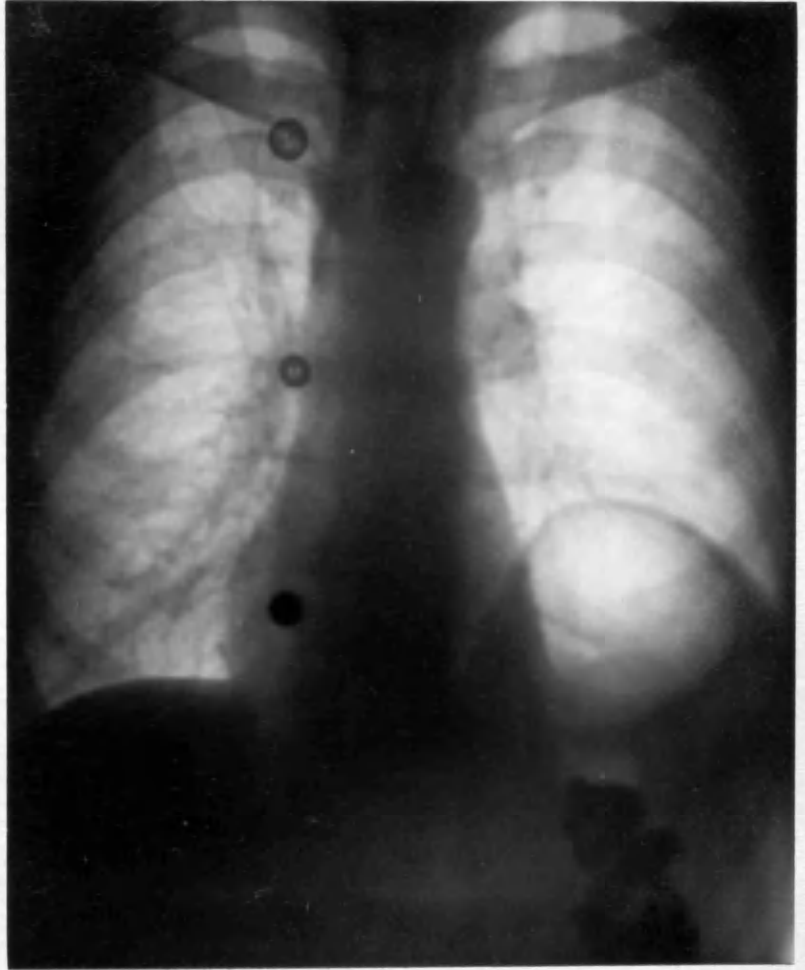
Plate 12

Constrictio Diaphragmatica.

Group I

Case 4

H. B. male. aged 41 years.



Chest.

Upright position. Post. ant.
Note elevated diaphragm.

Plate 13
Eventratio Diaphragmatica.

Group I

Case 4.

H. B. male. aged 41 years



Stomach. After a bismuth meal. Post. ant.

Plate 14.

Eventration Diaphragmatica

Group I

Case 4.

H. B. male. aged 41 years.



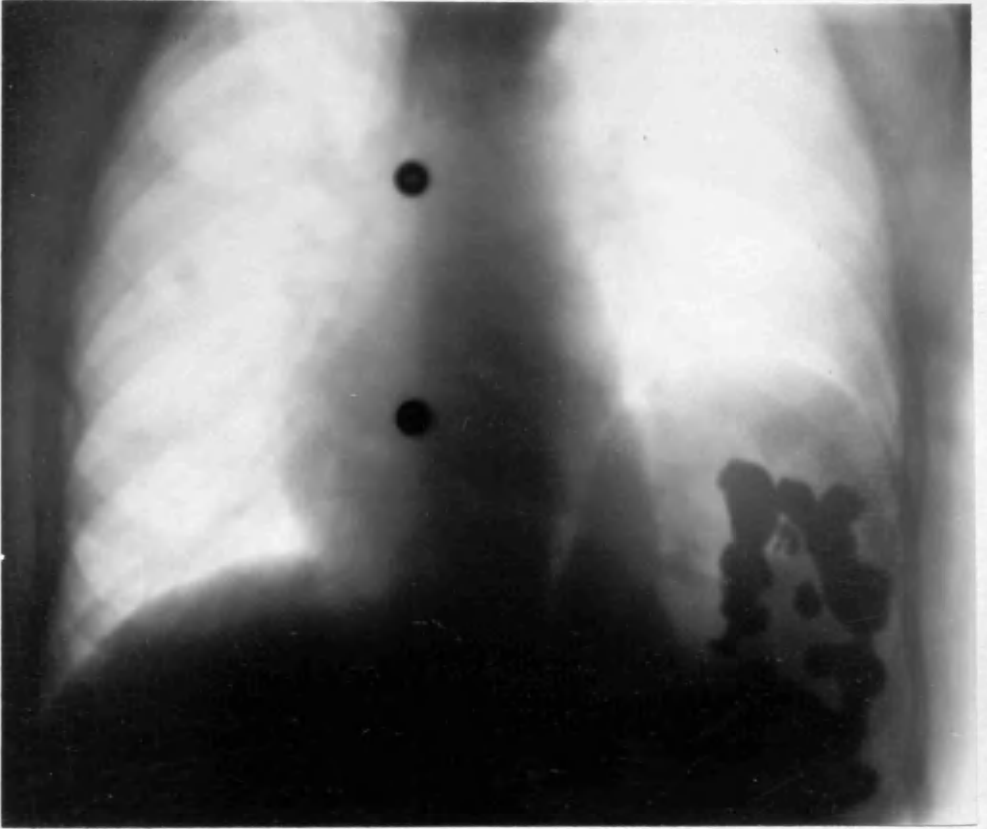
Stomach. Upright position. Oblique view.
After bismuth meal. Note deformity
of stomach

Plate 15
Eventratio Diaphragmatica.

Group I

Case 4.

H. B. male
aged 41 years



Colon. Patient in lying down position.
Note the presence of the colon which is
outlined by bismuth.

described. The left leaflet of the diaphragm was raised and its movements reversed. It presented an unbroken line stretching across the left hemithorax. Through the dome lung tissue was seen and it was noted that sometimes the colon rose up alongside the air cap of the stomach under the dome. Once again the typical deformity of the stomach was present.

Case 5. S.K. Aged 39 years. A stone quarry man.

He had suffered from stomach symptoms during the past 5 years. They were of an intermittent character. He had pains 2 to 4 hours after food which were relieved by taking more food. He often suffered from sickness and retching but never vomited. In writing to me, Dr. Lynch of Hayfield says, "About three months ago I was called to see him during the night. He was suffering acutely, the upper half of his abdomen was very tender. The pain came on very suddenly and steadily grew worse. The clinical picture was suggestive of perforation. As the attack occurred during the night I gave him a hypodermic of morphia and was quite surprised when I saw him early next morning to find him perfectly well".

Here again I found the characteristic picture already described, the left diaphragm elevated, etc.

Constrictio Diaphragmatica.

Group I

Case 5.

S. K. male

aged 39 years



Chest. Upright position. Post. Ant.
Note bow line in chest

34
Plate 17
Eventratio Diaphragmatica

Group I

Case 5.

S. K. male
aged 39 years.

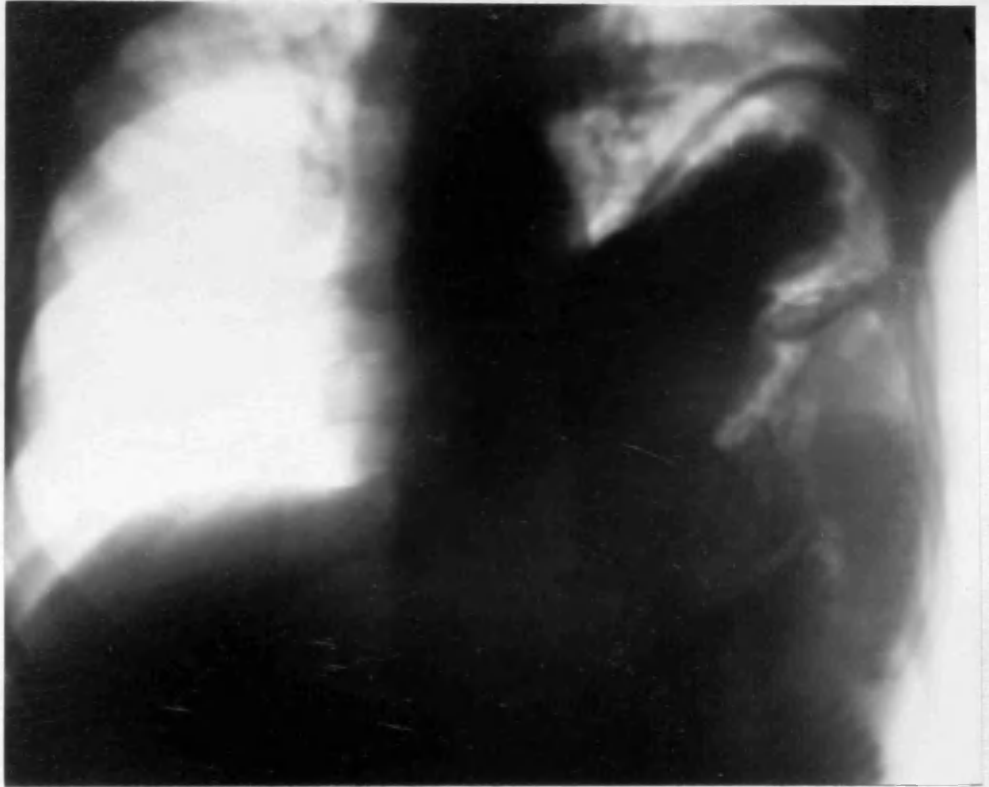


Stomach.

Upright position.

after bismuth meal

Eventratio Diaphragmatica



Group I

Case 5.

S.K. male
aged 39 years

Colon.

Patient in lying down position

All the air has not been displaced from the dome which is not fully outlined by the bismuth food

Case 6.

The sixth and last case which I have seen came to the Manchester Royal Infirmary in January of this year - 1923. J. B. a labourer, aged 51 years. He stated that he was perfectly well until about a month ago when he developed a bad cold. Suddenly he was seized by a pain in the stomach, was sick but could not vomit. Since then he has had difficulty in swallowing solid food but no difficulty with liquids. A bismuth meal was taken without much trouble, and it was noted that there was some delay at the cardiac orifice of the stomach, the unbroken bow line of an elevated left diaphragm was seen extending well up into the chest. Its movements were reversed, the typical deformity of the stomach and all the other radiographic features common to these cases were noted.

It is probable that these cases are much more common than is usually supposed and the individual may go through life without suffering much discomfort.

Most of the cases recorded have been in adults.

Frequently the displacement of the heart to the right found in the course of the clinical examination is the reason for the patient being sent to the radiologist for further investigation, but more often it is the presence of indefinite gastric symptoms.

Plate 19.

Eventratio Diaphragmatica.

Group 1

Case 6.

J. B. male
aged 51 years



Chest.

Upright position. Post. ant.
Note bowline in chest. Colon not present.

Eventratio Diaphragmatica



Group 1

Case 6.

J. B. male
aged 51 years

Chest. Patient in lying down position. Post. Ant.
Note low line in chest. Colon present.

Eventratio Diaphragmatica.

Group 1,

Case 6.

J. B. male
aged 51 years



Stomach. Upright position. Post. Ant.
Stomach after bismuth meal

Plate 22.

Eventratio Diaphragmatica.

Group I

Case 6.

J. B. male
aged 57 years



Stomach

Oblique view.
Note deformity of stomach

Eventratio Diaphragmatica.

Group 1

Case 6.

J. B. male
aged 57 years



Stomach.

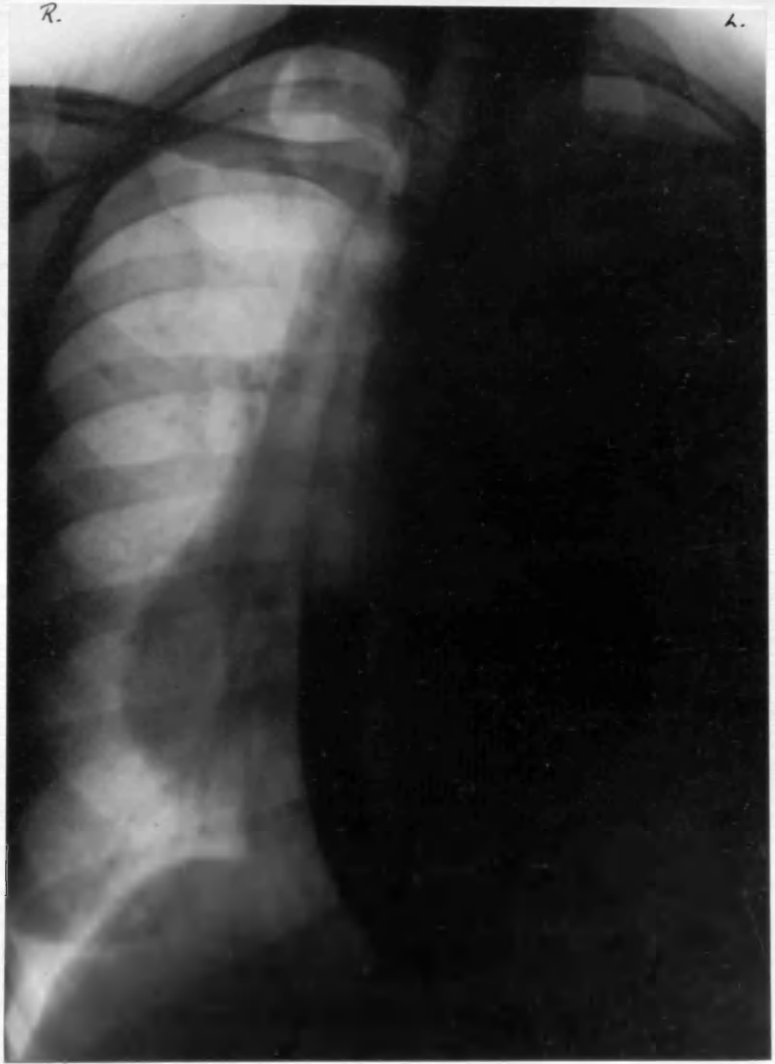
lying down position.
Stomach after bromine meal

The question of displacement of the heart to the right of Eventration of the Diaphragm, large diaphragmatic hernias and in extensive pleural effusions is of interest to the clinician. Dr. R. J. M. Buchanan, Physician to the Royal Infirmary, Liverpool, recently showed at the post mortem examination of a case of extensive diaphragmatic hernia, that the apparent displacement of the heart to the right was in reality a rotation. This is also well seen in the radiograms of cases in which large pleural effusions have been replaced by ~~air~~^{air}. This leads me to suggest that in Eventration of the Diaphragm the apparent displacement of the heart is also a rotation.

Another question of interest is the movements of the chest walls. In the cases I have recorded, neither clinically nor under X-ray examination could any difference in the movements of the ribs on the two sides be detected. This observation also applies to those cases of Unilateral Phrenic Paralysis which are described in group 2.

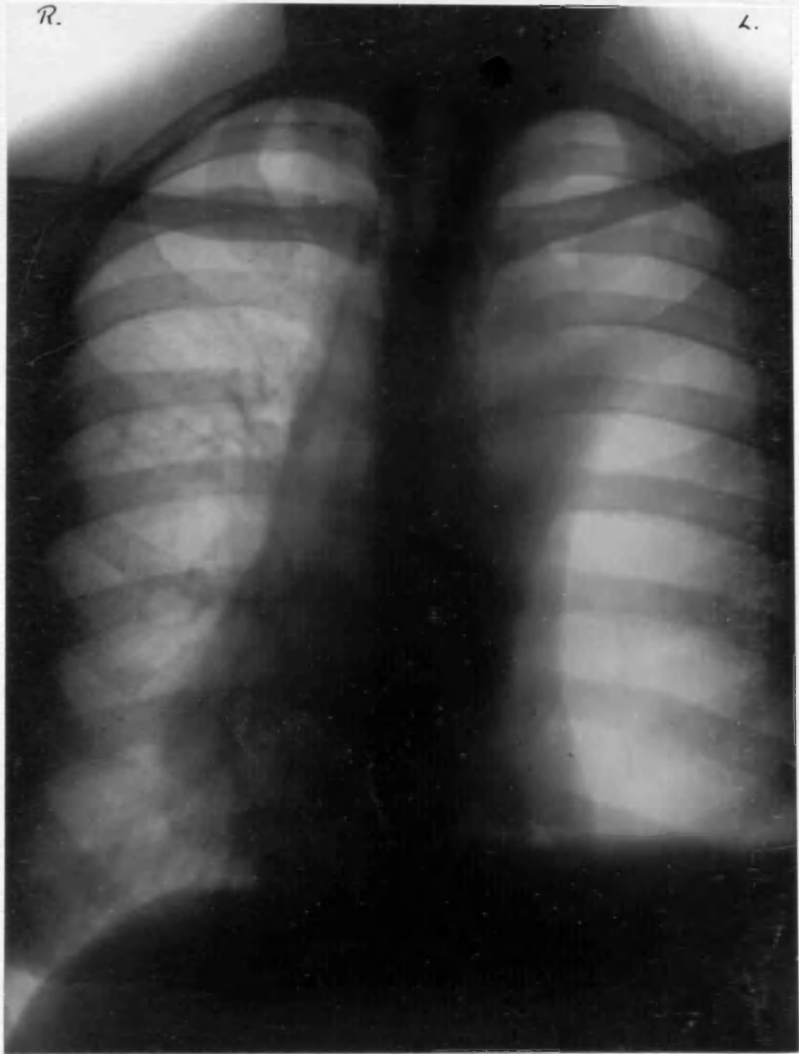
Moreover I have noted that the upward and outward movements of the lower ribs tend to flatten a completely paralysed diaphragm in which reversed movements are taking place.

Plate 24.



Large pleural effusion - left side - edge of which extends beyond the middle line. The heart is shown on the right side — rotation of heart. The electro-cardiographic tracings were normal. Note the displacement of the trachea and of the oesophagus, in which there is a little bismuth food.

Plate 25



The same case as Plate 204 after air replacement of fluid.

It is difficult to reconcile these observations with the statements in the text books of anatomy, where we are taught that one of the principal actions of the diaphragm is to raise the six lower ribs in the act of inspiration.

Unilateral Phrenic Paralysis.

It is stated in Oppenheim's text book of Nervous Diseases 1911. Vol. 1. p. 423, that "paralysis of the nerve is not common", and that "a unilateral phrenic paralysis is difficult to recognise as the functional disorder is very slight . It can usually be detected by careful examination. Absence of the so-called "diaphragmatic sign" (Litten) i.e. the visible movements of the diaphragm accompanying inspiration and expiration, may be of assistance in diagnosing a unilateral or bilateral phrenic paralysis".

I think it will now be generally admitted that unilateral phrenic paralysis is not uncommon. It is a condition which can be definitely diagnosed radiologically. Within the last two years I have seen 9 cases, and in two of these cases I was able to confirm the diagnosis post mortem.

In two of the cases the right phrenic nerve was involved, and in seven of them it was the left. Three of the cases occurred in secondary carcinoma of the mediastinum. One of these cases was secondary to carcinoma of the stomach and the other two were secondary to carcinoma of the breast.

Of the remaining cases three were associated with pulmonary tuberculosis, two with growth ⁱⁿ ~~of~~ the chest and one with aneurysm of the aorta.

In all these cases the diaphragm movements on the ^affected side were reversed, and some of them presented the typical picture described under the heading "Event-ratio Diaphragmatica". Others were complicated by the involvement of the lung in the disease, but my diagnosis of paralysis rested on (1) The elevated diaphragm which presented an unbroken bow line in the chest, (2) The presence of reversed movements.

I was able to obtain post mortem examinations in two of the cases. In one case the phrenic nerve was involved in a cancer nodule as it crossed the root of the left lung, a section of the nerve below this area showed complete degeneration, whilst a section of the diaphragm showed degeneration of the muscle fibres, but the changes in the muscle of the diaphragm were not so advanced as one would have expected.

In the second post mortem the phrenic nerve was involved close to the diaphragm, and again degeneration of the muscle was not so extensive as one would expect.

This suggests some auxilliary innervation of the diaphragm, and in the dissecting room, branches of the

intercostal nerves can be traced into the diaphragm muscle.

✱ "It is sometimes said to receive fibres from the lower thoracic nerves".

✱ Cunningham's Text Book of Anatomy. 4th. Edition.
p.474.

Unilateral Phrenic Paralysis.

Group II

Case 1.

W. S. male. aged 58 years.



Chest

Upright position. Post. ant.

Tuberculosis with paralysis of the left diaphragm.

Unilateral Phrenic Paralysis.

Group. 2.

Case 1. W.S. Male. Aged 58.

This man was suffering from bronchitis and pulmonary tuberculosis. At the X-ray examination I noted very definite reversed movements of the left diaphragm, and on the strength of the reverse movements, I was able to make a definite diagnosis of paralysis of the left diaphragm due to involvement of the phrenic nerve.

Post mortem, it was found that the left phrenic nerve was involved in a mass of fibrous tissue throughout a distance of $2\frac{1}{2}$ inches. There was atrophy of the muscle of the diaphragm on the affected side.

Case 2. H. L. Male. Aged 50.

In this case there was a definite intra thoracic growth, with complete recurrent laryngeal nerve palsy. The screen examination showed a moderate degree of elevation of the left diaphragm, with complete reversed movements; it conformed in all respects with the radiological signs described under eventration of the diaphragm.

Plate 27.

Unilateral Phrenic Paralysis.

Group II.

Case 2.

H. L. male.
aged 50 years



Chest. Upright position. Post. ant.
Intrathoracic growth with paralysis of the
left diaphragm.

Case 3. A.S. Female. Aged 52.

This was a case of secondary carcinoma of the mediastinal glands, 10 months after a radical operation for cancer of the breast. The screen examination showed marked enlargement of glands in the posterior mediastinum and infiltration of a portion of the lower lobe of the left lung, just above the diaphragm. The diaphragm was only slightly raised, and its movements were limited - they were very definitely reversed.

Case 4. C.P. Male. Aged 54.

A case of intra thoracic growth, causing paralysis of the right phrenic nerve with reversed movements of the right diaphragm. The right diaphragm was slightly elevated, but not markedly so, except on deep inspiration.

Case 5. Mrs. B. Female. Aged 45.

A case of secondary mediastinal carcinoma, three years after removal of the left breast. The left diaphragm was elevated, giving the typical bow line in the chest - its movements were reversed, and all the signs present described under eventration.

Case 6. B. O. Male. Aged 47.

A case of tuberculosis of the right root and upper

Unilateral Phrenic Paralysis.

Group II

Case. 3.

A. S. Female
aged 52 years.



Chest. Upright position. Post. Aert.
Secondary carcinoma with paralysis of the
left diaphragm.

Plate 29.
Unilateral Phrenic Paralysis.

Group II

Case 4.

C.P. male
aged 54 years.



Chest. Upright position. Post. Ant.
Intrathoracic growth with paralysis of the
right diaphragm.

Unilateral Phrenic Paralysis.



Group II

Case 5.

Mrs. B. Female
aged 45 years.

Chest.

Upright position. Post. ant.
Secondary carcinoma with paralysis
of the left diaphragm.

lobe in which there was paralysis of the right diaphragm with typical reversed movements.

Case 7. A. M. Male. Aged 56.

A typical case of carcinoma of the stomach in which there was secondary involvement of the mediastinal glands, and invasion of the base of the left lung. The left diaphragm was paralysed, its movements being reversed. There was very little elevation on account of the consolidated lung tissue. Post mortem, the phrenic nerve was found to be involved in a nodule of cancer just below the root of the left lung. Histological preparations of the nerve showed complete degeneration, and sections of the diaphragm of the affected side showed marked degeneration of muscle fibre, though not so marked as one would have expected from the condition of the nerve, this suggesting that there is some additional innervation of the diaphragm, presumably from the lower thoracic nerves.

Unilateral Phrenic Paralysis.

Group II

Case 7.

A. M. male.
aged 56 years.



Chest. Upright position. Post. Ant.
Secondary carcinoma with paralysis of the
left diaphragm.

Case 8. A. G. Male. Aged 59.

Aneurysm of the Aorta.

Clinically all the physical signs of aneurysm of the arch of the aorta were present in this case, and the X-ray examination confirmed the diagnosis. To the left of the aortic arch a shadow could be seen with an irregular edge spreading downwards to the root of the left lung. The left diaphragm was elevated and the movements reversed.

In this case there was evidently paralysis of the left phrenic nerve associated with aneurysm.

Case 9. W.S. Male. Aged 52.

There was extensive tuberculosis of the left lung, and to a lesser extent of the right. The left diaphragm was elevated and partially fixed. Very slight reversed movements were observed.

Unilateral Phrenic Paralysis.

Group II

Case 8.

A. G. male
aged 59 years.



Aneurysm of the aorta.

Chest.

Upright position. Post. ant.
Aneurysm of the aorta with paralysis
of the left diaphragm.

Unilateral Phrenic Paralysis.

Group. II

Case. 9.

W.S. male
aged 52 years



Chest. Upright position. Post. Act.
Old standing tuberculosis with paralysis
of the left diaphragm.

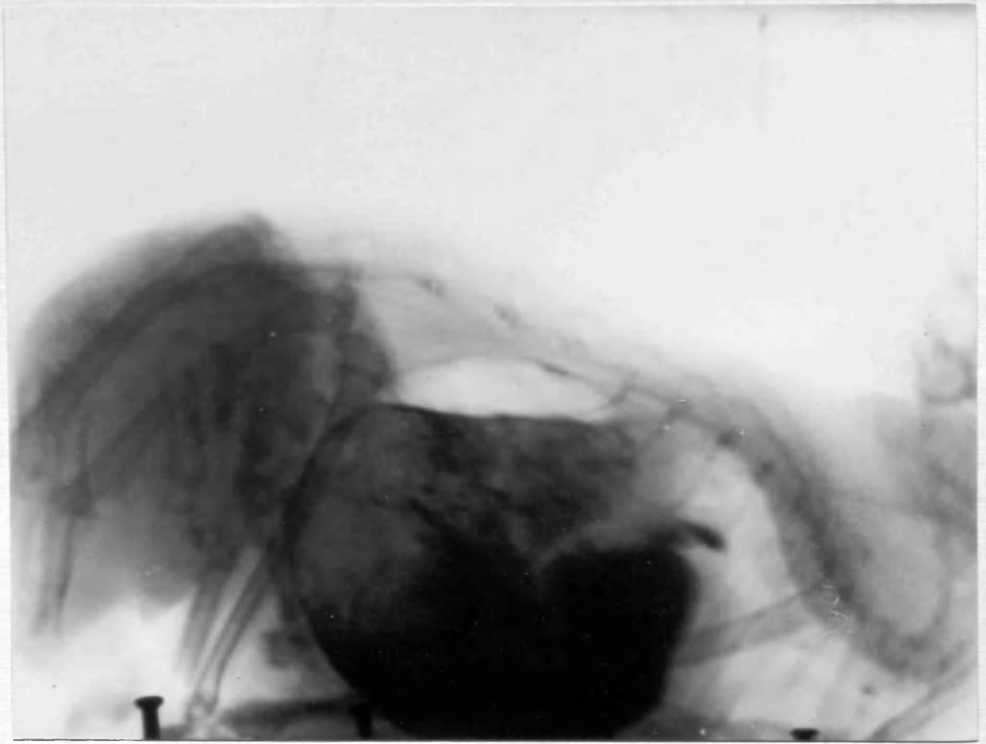
I was able recently to observe the action of the diaphragm in a case in which the left leaflet had been injured. The patient was a man, aged 31. During the war, in 1916, he was wounded by an explosive bullet which tore its way through the left side of the abdomen and chest. The lower ribs were cut through and portions missing. This resulted in a hernia of the splenic flexure of the colon through the chest wall on the left side. He wears an aluminium pad, suffers little inconvenience and is in full work as a manual labourer.

On screen examination the movements of the ^{Left} leaflet of the diaphragm were restricted but the chest wall was moving quite well and the point of special interest was that during inspiration, when the diaphragm descended, the hernia could be seen returning to the abdomen and during expiration when the diaphragm ascended the hernia protruded beyond the ribs. I can only attribute this to a defective diaphragm movement, whilst the movements of the ribs during inspiration and expiration were normal. I think the principal action of the diaphragm is to increase, by its contraction, the vertical diameter of the thorax, and certainly the vertebral portion of the diaphragm arising from the arcuate ligaments and the bodies of the lumbar vertebrae can only have this effect.

Male, aged 31 years.



Colon. Gunshot injury to left side with
hernia of the splenic flexure.



Rabbit - after Bismuth meal.
note air cap of stomach

It should be remembered that the central tendon can be seen to move slightly downwards during a screen examination of the chest. The downward thrust of the diaphragm on the right side depresses the liver etc., but on the left side the air cap of the stomach acts as a buffer taking up the force of the diaphragm movement. The stomach during an X-ray examination can be seen to alter in shape with the action of respiration. During inspiration it becomes shorter and broader, but the lowest part of the greater curvature does not alter in position. This holds good in whatever position the body is placed, although the air in the stomach may not be immediately under the diaphragm. In some of the lower animals, e.g. the dog, cat, rabbit, the air sac does not lie immediately under the diaphragm but it can be seen to take up the thrust of the diaphragm by its elasticity. The air in the stomach is composed of atmospheric air swallowed in taking food. All this, of course, refers only to the normal.

Thus the radiological study of the diaphragm tends to throw some doubt on the teaching in the text books of anatomy, that one of the principal actions of the diaphragm is to raise the six lower ribs in the act of inspiration.

In considering the cases of Unilateral Phrenic

Paralysis (Group 2) the many points of resemblance to Petit's eventration (group 1) are apparent, e.g. the elevation of the diaphragm presenting an unbroken bow line in the chest, the presence of reversed movements, and in some cases, the deformity of the stomach etc.

The thought naturally arose, Could some of the cases of eventration be due to an injury to the phrenic nerve at birth just as the brachial plexus is sometimes injured? We are all familiar with birth palsies. I have looked for such cases, but unsuccessfully. Turning to the literature of the subject, however, I found an excellent account by Weigert, of an injury to the left phrenic nerve at birth with paralysis of the left leaflet of the diaphragm.

I shall return to this subject in discussing the question of aetiology.

Temporary Elevation of the Diaphragm.

This frequently occurs and is caused by gaseous distension of the air sac of the stomach.

In children it is quite common to see the left diaphragm raised well up into the thorax and to find on the following day that it is quite normal in position.

In adults it is often present in pathological conditions of the stomach - particularly in carcinoma. It is usually associated with the "cup and spill" type of a stomach.

In all cases of temporary elevation which I have observed, the movements of the elevated diaphragm have been asynchronous with those of the other half, never reversed. In other words there has been no paralysis.

GROUP 3.

Case 1.

A case of Temporary elevation in a child of 5 years of age. On the following day it was quite normal. All the usual radiological signs of elevation were present but the movements of the bow line were synchronous with those of the other half of the diaphragm.

Case 2. H.P. Male. Aged 60.

A case of carcinoma of the pyloric end of the stomach.

Plate 35

Temporary Elevation of the Diaphragm.

Group III

Case. 1.

Child aged 5 years.



Chest. Upright position. Post. ant.
Temporary elevation of the left diaphragm.

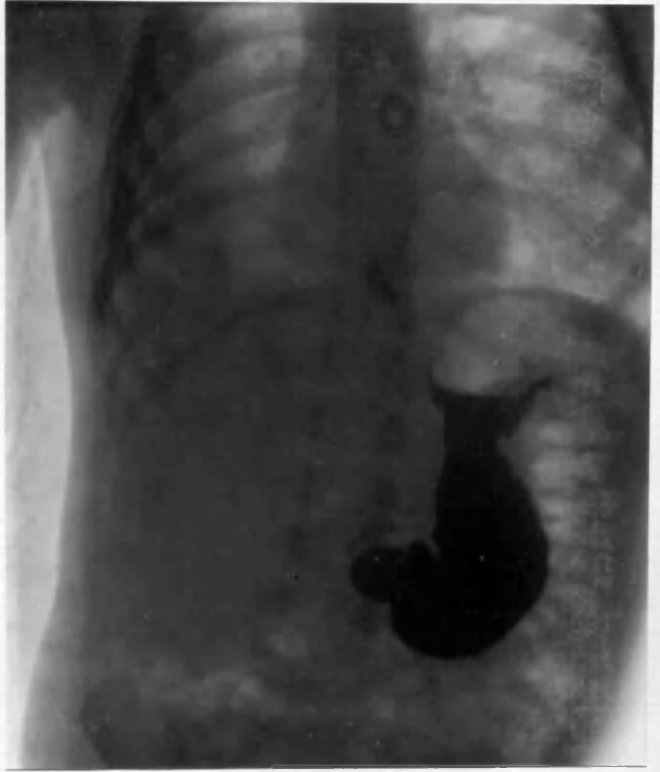
Plate 36

Temporary Elevation of the Diaphragm.

Group III

Case. 1.

Child aged 5 years.



Same case as Plate 35 taken on following day

The left diaphragm was elevated but the movements were regular and in unison with those of the right. The stomach was of the cascade type.

Case 3. R.D. Male. Aged 30.

The left diaphragm was elevated but great distention of the air sac of the stomach was present. The stomach was deformed but no definite pathological lesion was detected. There was no paralysis of the diaphragm, the movements of the two leaflets were synchronous.

Plate 37

Temporary Elevation of the Diaphragm.

Group III

Case 2.

H.P. male
aged 60 years.



Stomach.

Carcinoma of Pylorus with temporary elevation of diaphragm and deformity of stomach.

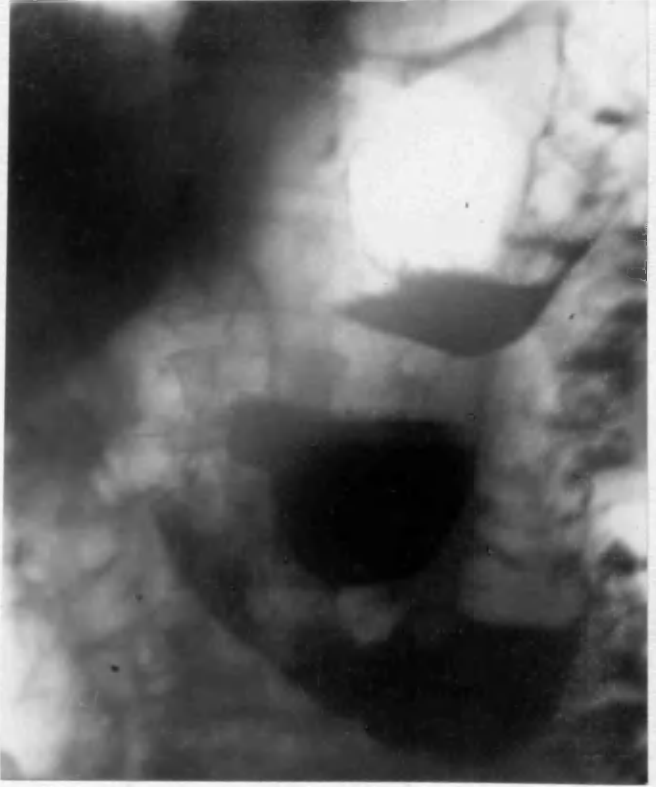
Plate 38

Temporary Elevation of the Diaphragm.

Group III

Case 3.

R. D. male
aged 30 years.



Stomach. Upright position. Post. ant.
Temporary elevation of diaphragm with
deformity of stomach

Differential Diagnosis.

The differential diagnosis of Petit's eventration and unilateral phrenic paralysis from other diaphragmatic conditions has now to be considered. They have to be differentiated from

1. Diaphragmatic hernia - congenital or acquired.
2. Localised hydro or pyo-pneumothorax.
3. Sub-phrenic abscess.
4. Temporary elevation of the diaphragm.

Diaphragmatic hernia may be congenital or acquired, and the congenital defects in the diaphragm were thoroughly investigated by Sir Arthur Keith and recorded in the British Medical Journal October 29th, 1910. If his diagram is taken in conjunction with another diagram by Broman, representing the development of the diaphragm, it is at once seen how these cases occur. So far I have not had the opportunity of observing this type of case. I understand, however, that they are not uncommon. Dr. Campbell Suttie of the Royal Hospital for Sick Children, Glasgow, in writing to me states that this is his opinion. He has seen 3 cases within two years.

A congenital weakness however, may exist during life, inviting a hernia, and in one case which I record a large

diaphragmatic hernia occurred without any definite trauma. (Group IV. Case 1).

In diaphragmatic hernia we place those cases in which there is a prolapse of viscera into the pleural cavity through a gap in the diaphragm. The X-Ray examination shows an elevated irregular broken line extending across the hemi-thorax which can hardly be mistaken for the diaphragm. Lung tissue may or may not be seen through the air underneath this line: the fluid contents may reach high above the level of the cardiac orifice, and rippling on the surface is easily produced by palpation of the abdomen. If the hernia be a small one, as in case 2 (Group IV), the reversed movements of the hernia during respiration are well seen, but if the hernia be extensive, as in case 1, no movements may take place.

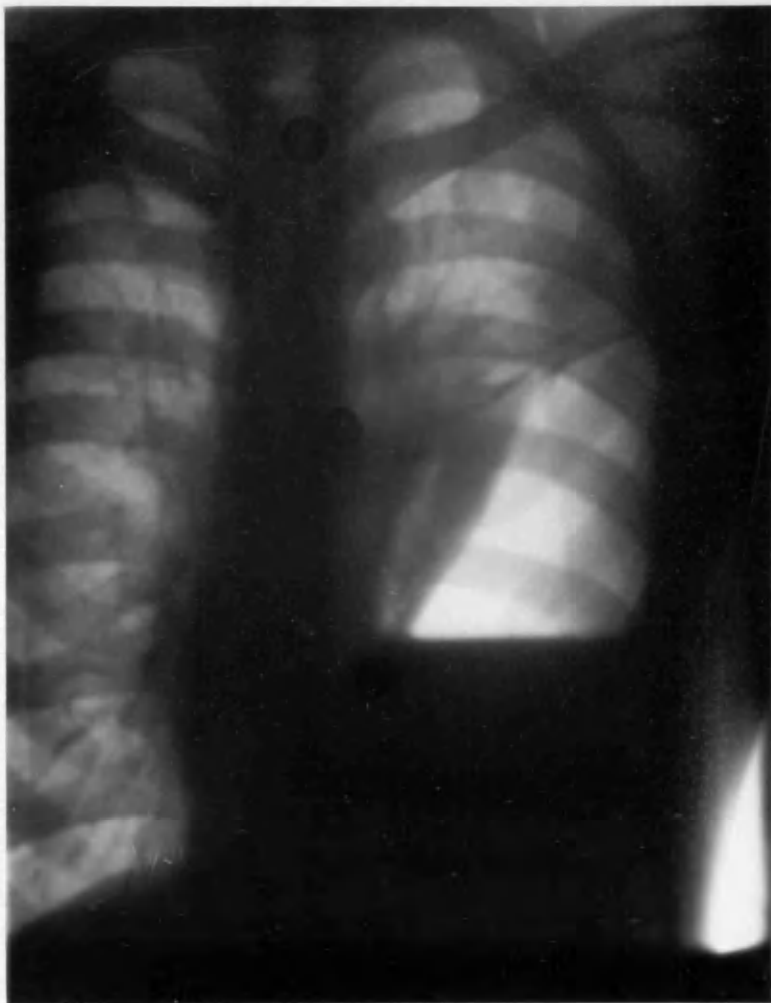
The presence or absence of the colon has also been stressed as a diagnostic point. In eventration it may be absent or present on different examinations of the same patient. In hernia the same observation holds good, although it is practically always present at operation, but then the conditions have been altered by the opening of the abdomen or chest, the opening in the diaphragm appearing much larger than the X-Ray examination would lead one to expect.

The examination of the stomach by means of a bismuth meal is of the greatest importance and should rarely fail to settle the diagnosis.

Group IV

Case 1.

H. P. male
aged 26 years.



Chest. Upright position. Post. Ant.
Large diaphragmatic hernia. The colon is not present
as a part of the hernia. The X-Ray appearances
are those of hydropneumothorax.

PL
c

Group IV

Case 1.

H. D. male
aged 26 years.



Chest

Upright position. Post. Ant.
Same case as Plate 39. on the following day.
Note the presence of the colon which rises to the
level of the fluid. This was the diagnostic
point.

Plate 41.

Group IV

Case 1.

H.D. male
aged 26 years.



Chest. Lying down position. Post. ant.
Same case as Plates 39 + 40.

Diaphragmatic Herniae.

Localised Hydro or pyopneumo thorax.

Sub-phrenic abscess.

GROUP 4.

Case 1. H.D. Male. Aged 26.

There was no history of any injury. The physical examination gave all the signs of a hydro-pneumothorax. The screen examination showed the dark line of fluid extending right across the left chest with a clear air space above it - the air space extending to the height of the 2nd. rib in front, the fluid to that of the 4th. A portion of collapsed lung was noted through this clear air space. No lung tissue was seen apart from the collapsed lung. There was no definite bow line observed and no paradoxical respiratory movements.

Palpation of the abdomen produced ripples on the surface of the fluid. The appearances were quite consistent and, in fact typical of a hydro-pneumothorax. At a later examination however, the splenic flexure was seen rising up alongside the fluid to a height, if anything, slightly above it.

At operation it was found that there was a large rent in the posterior wall of the diaphragm and that practically the whole of the stomach and a large portion

of the colon were in the chest.

Case 2. J.S. Male. Aged 40.

This was a definite case of hernia of the left leaflet of the diaphragm, due to a gunshot wound. The X-ray examination showed an irregular line in the left chest, the inner portion of this irregular line being diaphragm - the outer part stomach. The movements were very plainly seen on the screen and one could see the inner half moving downwards while the outer half moved upwards. The bismuth meal examination very definitely established the diagnosis, for with the patient in the lying down position one was able to run the bismuth backwards and forwards through the opening in the diaphragm and watch the herniated portion of the stomach filling and emptying. This was done by tilting the table top during the examination.

The approximate size and position of the tear in the diaphragm was ascertained, and it is interesting to note that the colon was not seen forming part of the hernia during the X-Ray examination.

At the operation by Mr. A. H. Burgess, F.R.C.S., the abdomen was opened and it was found that the outer and posterior part of the diaphragm had been torn from its attachments. Both stomach and colon formed part

Group IV

Case 2.

J.S. male
aged 40 years.



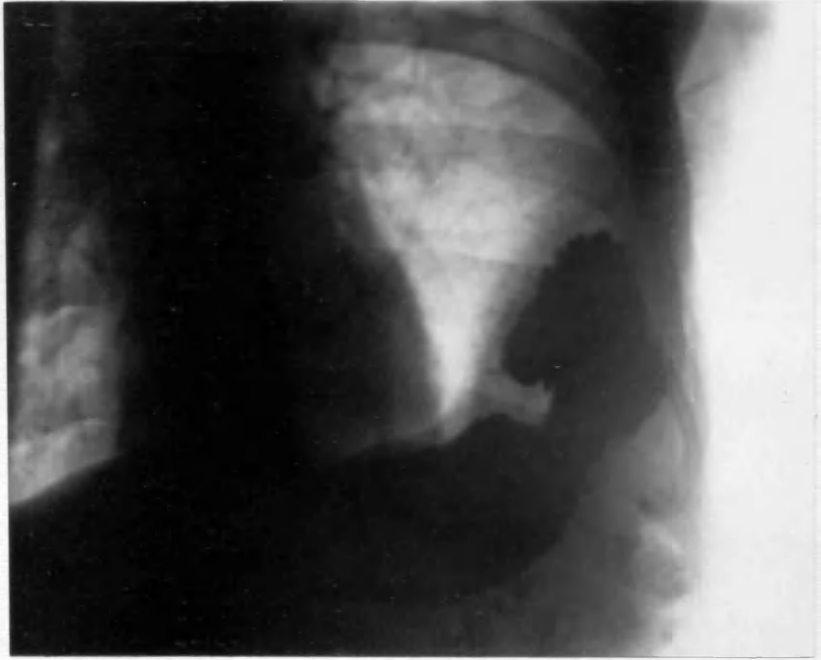
Diaphragmatic hernia. Upright position after
a bismuth meal. Note the irregular bow line
in the chest

Plate 43.

Group IV

Case 2.

J. S. male
aged. 40 years



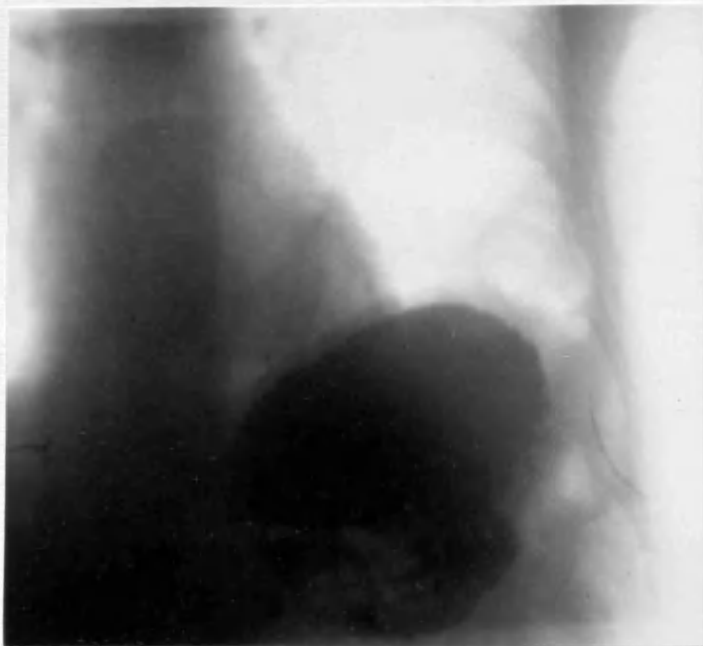
Same case as Plate 43. Lying down position.
Note the herniated stomach outlined by bismuth.

Plate 44.

Group IV

Case 2.

J.S. male
aged 40 years.



Same case as Plates 42 & 43. Lying down position
after operation

of the hernia.

The diaphragm was repaired and later on an X-ray examination showed the result to be excellent.

Case 3. T.B. Male. Aged 30.

Hernia of the right diaphragm, due to a gunshot wound - France 1914. The right diaphragm was fixed but the liver shadow was seen elevated - reversed movements.

Case 4. Girl. Aged 13.

Localised Hydro-pneumothorax. This case was seen one year after operation for empyema. The girl was in excellent health and doing light house work. There was a localised hydro-pneumothorax present. The line of fluid was above the level of the cardiac orifice and each heart beat produced waves along the surface of the fluid.

The position of the diaphragm was easily ascertained by giving a sedlitz powder.

Case 5. G.O. Aged 16.

Sub-phrenic Abscess. In this case a sub-phrenic abscess developed three weeks after operation for acute appendicitis. The appendix was retro-caecal and gangrenous and an abscess was present which was drained. Further trouble developed, however, and at the X-Ray

Group IV

Case 3.

J. B. male
aged 30 years

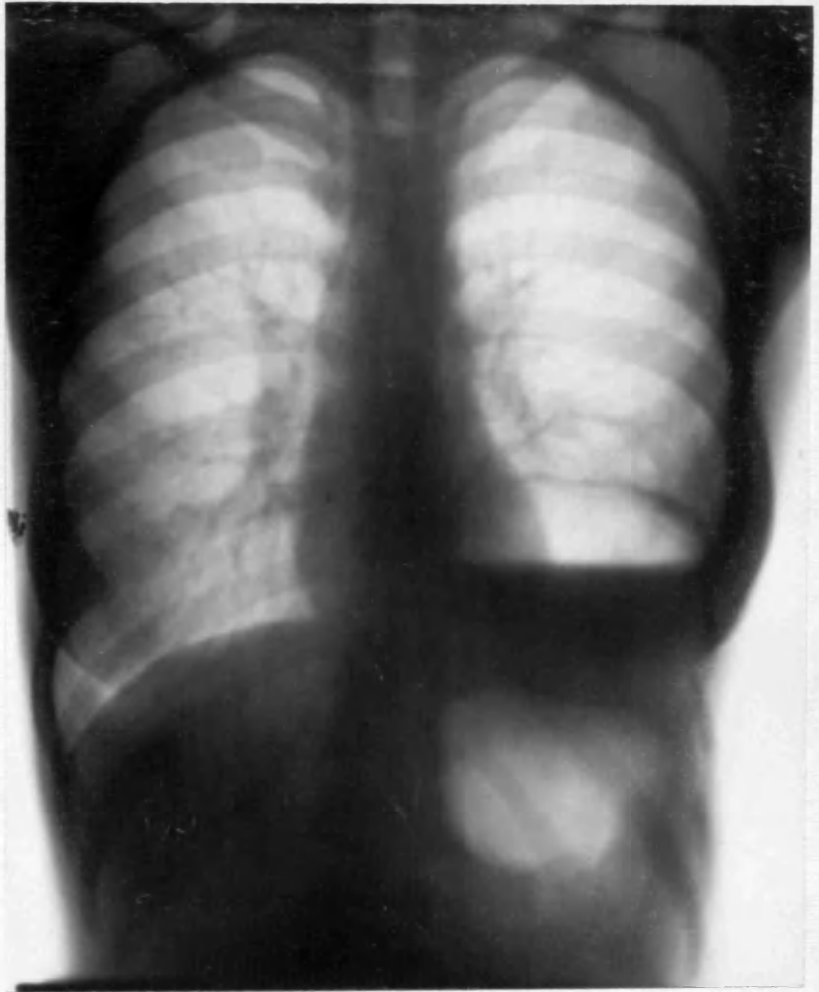


Chest. Upright position. Post. Ant.
Hernia of the right Diaphragm.

Group IV

Case 4.

Girl - aged 13 years



Chest. Upright position. Post ant.
Localized Hydro-pneumothorax

Plate H 7.

Group IV

Case 5.

G. O. aged 16 years



Sub-phrenic Abscess

Upright position

Plate 48.

Group IV

Case 5.

G. O. aged 16 years



Sub-phrenic Abscess.

Lying down position

examination the right diaphragm was found elevated and fixed, with a clear air space underneath, at the lower border of which was a straight line of free fluid. Splashing of the fluid was easily produced, and in the lying down position the air was displaced, the fluid running up into the chest to the level of the bow line. The lower margin of the liver was pushed downwards.

A further operation was done and a sub-phrenic abscess was found containing a large quantity of foul-smelling pus.

Case 6.

W.S. Male. Aged 33.

Sub-hepatic Abscess. On 22.2.23. this man was operated on at the Manchester Royal Infirmary for an acute appendix. A perforated appendix was found with the presence of an abscess. He progressed quite satisfactory and was discharged on 26.3.23. He was re-admitted on 13.4.23. and the X-Ray examination showed elevation of the right diaphragm and liver. There was no fluid detected and no separation of the diaphragm from the liver. No movements of the elevated diaphragm and liver were detected.

At the operation a large sub-hepatic abscess was found and drained.

Plate 19



Group IV

Case 6.

W.S. male
aged 33 years

Sub-hepatic Abscess

AETIOLOGY AND LITERATURE.

The usual statement found in the literature is that the aetiology is still obscure. Petit regarded the condition as being of congenital origin.

Most of the cases recorded have been in adults, but there is one case of an autopsy of a foetus in which eventration of the left diaphragm was found. Another autopsy of a new born infant revealed a similar condition. These were the cases of Pyl and Meckel, and were quoted by Laacher.

Stein records a typical eventration of the left diaphragm in a new born child which lived 26 days.

In this case the left leaflet of the diaphragm was a thin fibrous structure extending high up into the thorax, with no muscular fibres.

Thoma laid great stress on the hypoplasia of the left lung, it having been often noted at post mortem examinations that the lower lobe of the left lung was abnormally small. "When the lung is too small the diaphragm rises to fill the space in the pleural cavity, dragging the intestinal contents with it".

Doering put forward the theory of a congenital

deficiency of the muscles of one side of the abdomen. He points out the deficiency in the muscular tissue of the affected leaflet of the diaphragm and the symmetrical condition of the thorax. The weak diaphragm fails to expand the lung, and assumes the high position dragging the viscera with it. This theory is not supported by the post mortem examinations, as the condition of Atelectasis has never been found. It is interesting to note that Thoma, in support of his theory that the lung is chiefly at fault, cites the presence of muscular fibres in the diaphragm, whilst Doering cites the deficiency of muscular tissue in the diaphragm as a reason in support of his opinion.

Baetse regarded it as developmental, whilst Vogel thought there was a congenital predisposition with degenerative changes in the muscular fibres.

Motzfeldt thought it due to:

- (1) Primary aplasia of the musculature with secondary atrophy and degeneration of the phrenic nerve.
- (2) Primary aplasia and atrophy of the phrenic nerve with secondary muscle degeneration.
- (3) A combination of (1) and (2).

Tennant recorded quite a unique case of a man - aged 60 -

He found post mortem the anterior one-third of the left leaflet of the diaphragm normal, but marked off behind from the rest by a band extended from the 10th. costal cartilage to the central tendon - the posterior two-thirds of the vault was lax, flabby and pushed up towards the neck in the form of a large pouch which contained a large empty stomach and part of the transverse colon. The left crus and remainder of the diaphragm were normal, as were also the lungs and heart. The left phrenic nerve was examined microscopically, but the section did not show any abnormality. There was nothing to support the view that it was caused by any morbid condition of the lungs or pleura. The chest was not contracted. He regarded it as "A case of congenital imperfect differentiation of the diaphragm".

Lawrence, in 1852 reported a case with the post mortem findings in the Lancet and this same case is again reported in the Lancet by Marsh in 1867. It was a typical case of eventration found post mortem in a man aged 33 years who had died of pneumonia. "The left half of the diaphragm was arched up to the 3rd. intercostal space, and the stomach, which was extremely large, was pushed up so high as to be nearly concealed by the ribs". The right side of the diaphragm was normal. The left leaflet was a

grey fibrous translucent structure with "very fine short striae of muscular fibres extending from the inner surface of the ribs and ligamenta arcuata for the distance of 6 - 8 lines". Marsh states further the "Mr. Paget thought the defect a congenital one" and that "there appeared, notwithstanding this defect, to be sufficient respiratory power. The patient breathed very forcibly in his dyspnoea, and in auscultating him the movements of the chest appeared just as in an ordinary double pneumonia. The left side of the chest certainly moved freely, and the patient often lay on the right side".

Sailor and Rhein described a case of a farmer aged 20 years in which post mortem a skiagram was taken which showed an eventration of the left diaphragm. The points of note in this case were the displacement of the heart to the right, the presence of muscular fibres in the left leaflet and the congenital malformation and hypoplasia of the lung.

Other cases similar to these which I have quoted have been recorded by Thoma, Doering, Crispino, Froriep, and Widenmann whose case was also reported by Glaser. In the case of Widenmann and Glaser it is of interest to note that the patient suffered from gastric symptoms, and on two occasions haematemesis occurred.

Injuries to the Phrenic nerve may occur at birth and recently Weigert and Kofferath have recorded cases.

Weigert's case was due to trauma during delivery. The left diaphragm was elevated and all the radiological appearances of an eventration present. He observed this case until complete recovery took place in the course of about two months.

Kofferath describes "a case of right-sided Erb paralysis and paralysis of the phrenicus following forceps delivery". The X-ray examination showed an abnormally high position of the right half of the diaphragm. ^{The right half} ~~was~~ moved in a totally abnormal manner; on inspiration it rose, and descended on expiration. After four days respiration became apparently quite normal and a later examination showed normal conditions.

From the study of my own cases of Eventration and of Unilateral phrenic paralysis, along with those recorded by others, I would suggest that eventration may be due to two causes.

- (1) A developmental defect in the formation of the muscular tissue of the diaphragm.

* The diaphragm, according to Broman, is thus derived from four sources (Fig.198). (1) Its

ventro-pericardial portion from the septum transversum, its lateral portions from (2) pleuro-pericardial membranes plus (3) derivatives from the body wall. The dorsal portion is formed from (4) the dorsal mesentery. In addition to these the striated muscle of the diaphragm, according to Barden (1900) takes its origin from a pair of pre-muscle masses which in 9mm. embryos lie one on each side opposite the 5th. cervical segment. This is the level at which the phrenic nerve enters the septum transversum. The exact origin of these muscle masses is in doubt, but they probably represent ^a portion of the cervical myotome of this region. The muscle masses migrate caudally with the septum transversum and develop chiefly in the dorsal portion of the diaphragm. "

Embryology.

Prentiss & Arey. 1920.

(2) An injury at birth to the phrenic nerve.

That such injuries do occur we have seen in the cases recorded by Weigert and Kofferath, and I do not think it is too much to suggest that these may be the cause of eventrations which may persist throughout life.

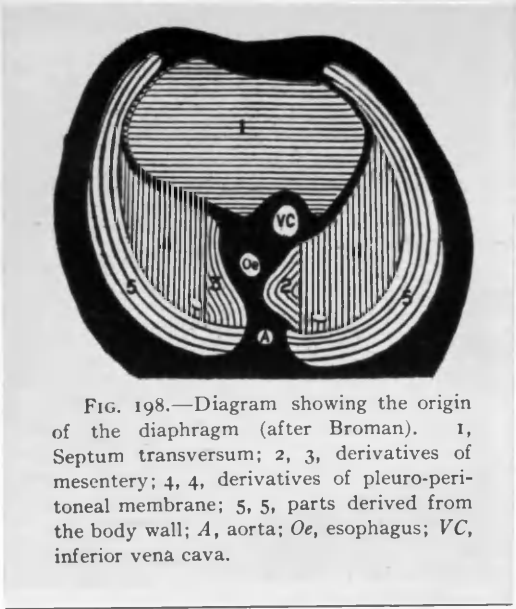


FIG. 198.—Diagram showing the origin of the diaphragm (after Broman). 1, Septum transversum; 2, 3, derivatives of mesentery; 4, 4, derivatives of pleuro-peritoneal membrane; 5, 5, parts derived from the body wall; A, aorta; Oe, esophagus; VC, inferior vena cava.

a.

*Copied from Embryology - Prentiss & Arny
3rd edition - 1920.*

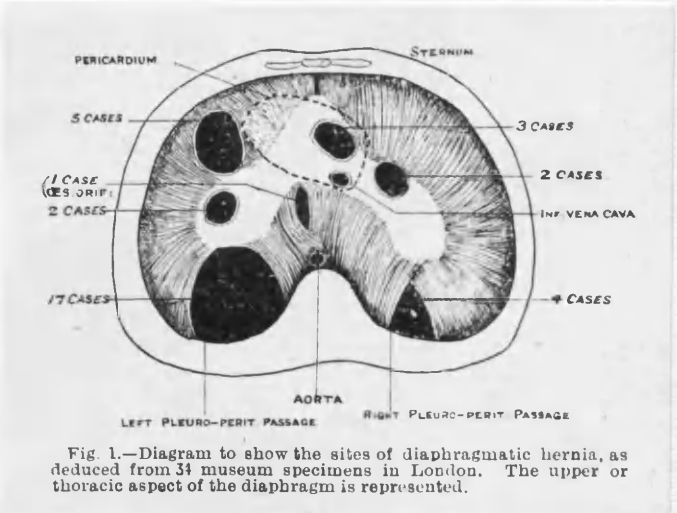


Fig. 1.—Diagram to show the sites of diaphragmatic hernia, as deduced from 34 museum specimens in London. The upper or thoracic aspect of the diaphragm is represented.

B.

*Copied from article by Sir Arthur Keith in the
British Medical Journal October 29th 1910.*



Dissection of neck done in the Anatomy Rooms -
Manchester University.

The *descendens cervicis* is pulled to one side by a
metal hook, to which an arrow points.

The phrenic nerve can be seen rising from the
cervical plexus 3, 4 & 5. in this case

CONCLUSIONS.

- (1) Petit's Eventratio diaphragmatica and unilateral phrenic paralysis are not so uncommon as is generally supposed. Radiographically they present many similar features.
- (2) There is evidence, in a study of the cases presented, and in the literature, that eventration may be due to:- (a) a developmental defect in the muscular tissue of the diaphragm. (b) an injury to the phrenic nerve at birth.
- (3) At first it was a pathological study, it is now possible, with the advancement of radiology, to observe and diagnose these cases during life.
- (4) Many of these cases have exhibited gastric symptoms, and I would draw special attention to the deformity of the stomach due to mechanical causes which I have described. It should be noted that this deformity may become a surgical condition.
- (5) The differential diagnosis, from the radiological standpoint, rests mainly on:-
 - a. the unbroken bow line extending high up into the thorax with its reversed movements, unless adhesions have formed.

- b. the level of the free fluid in the stomach is that of the cardiac orifice.
 - c. the Bismuth meal examination.
- (6) The radiographic study of the diaphragm does not support the teaching of the text books of anatomy, that one of its principal functions is to elevate the lower six ribs during inspiration. It rather suggests that the diaphragm plays little or no part in elevating the lower ribs, and that its principal function is to increase the vertical diameter of the thorax by its contraction.

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