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CT Anatomy of the Diaphragm :
Changes in End Inspiration and End Expiration[1]

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Purpose : To assess the change in configuration of the diaphragm between scans obtained at end inspiration and end expiration.

Materials and Methods : Two series of CT scans at end inspiration and at end expiration were obtained in 37 patients. We evaluated the changes in the type of anterior diaphragm, pseudotumor, undulation of the diaphragm, and diaphragmatic defect during the respiratory phases.

Results : The configuration of the anterior portion of the diaphragm changed between end inspiratory and end expiratory CT scans in 25(67.6 %) of 37 patients. Diaphragmatic defect, diaphragmatic pseudotumor, and undulation of the diaphragm were more frequent at end inspiration (13.5 %, 18.9 %, 37.8 %, respectively) than at end expiration (0 %, 5.4 %, 10.8 %, respectively).

Conclusion : There is a change in the configuration of the anterior portion of the diaphragm and we also observed differences in the visualization of diaphragmatic defects, pseudotumor, and undulation between scans obtained at end inspiration and end expiration.

Index Words : Diaphragm, abnormalities
Diaphragm, CT

Variations in the diaphragm on CT, such as defects and pseudotumors, are the major causes of misinterpretation of diaphragmatic or peridiaphragmatic abnormalities (1 — 4). Although these variations in adults have been well described and attributed to respiratory effects and aging (1 — 6), no systematic analysis of diaphragmatic change with respiration in the same patients has, to our knowledge, been described, except for some case reports (3, 4).

The goal of this study is to assess the change in configuration of the diaphragm between scans obtained at end inspiration and end expiration.

Materials and Methods

The patients were selected randomly from those who had undergone chest and abdominal CT scans between july 1994 and january 1995. We excluded those patients with peridiaphragmatic diseases, such as pleural effusion, ascites, and extensive pulmonary disease, that impaired evaluation of the diaphragm. The 37 patients in the study population comprised 20 men and 17 women ranging in age from 12 to 78 years (mean, 58 years).

CT scans were performed prospectively using a GE 9800 Quick scanner (General Electric Medical Systems, Milwaukee, USA ; 140 kVp, 140 mAs, 2 sec). At end inspiration, 19 patients with chest CT had contiguous 10-mm axial images from the apex to the third lumbar vertebral body, and 18 patients with abdominal CT had contiguous 10-mm axial images from the lower sternum to include the entire diaphragm. At end expiration, CT protocol in all patients involved contiguous 10-mm scans from the lower sternum to the third lumbar vertebral body for the evaluation of respiratory change of the diaphragm. Twenty-eight of 37 patients received Ⅳ contrast material. We excluded those cases

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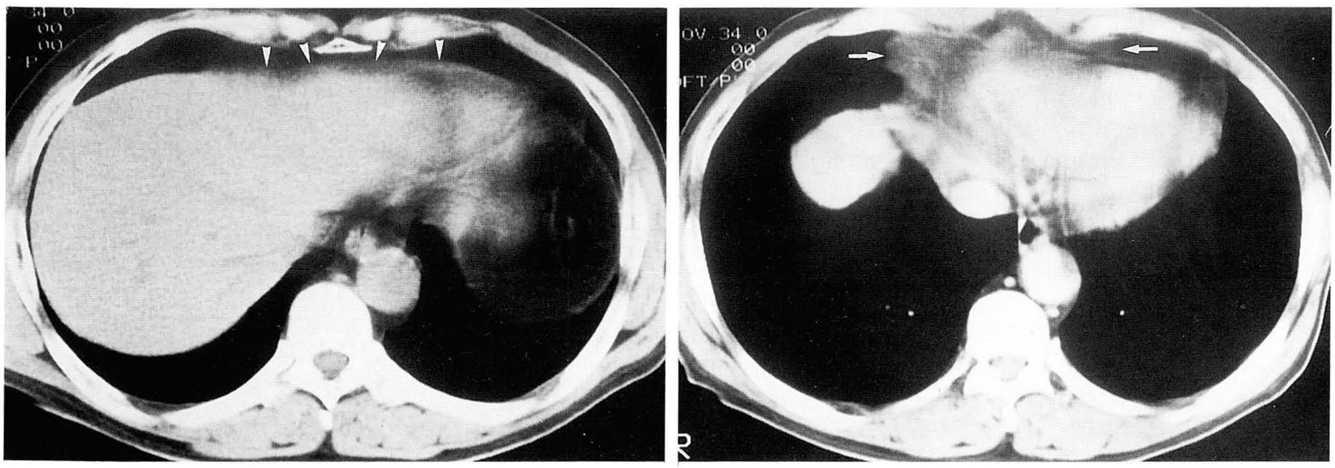
with respiratory movement of the liver of of less than 2 cm, as evaluated on CT scanograms obtained at end expiration and at end inspiration, because the respiratory effort might not have been sufficient to evaluate respiratory change of the diaphragm.

Table 1. Changes of the Diaphragmatic Anatomy at Different Respiratory Phases.

		Inspiration	Expiration
Type of	1	5(13.5%)	20(54.1%)
Anterior	2	19(51.4%)	1(2.7%)
Diaphragm	3	12(32.4%)	16(43.2%)
	Unknown	1(2.7%)	0(0%)
Defect		5(13.5%)	0(0.0%)
Pseudotumor		7(18.9%)	2(5.4%)
Undulation		14(37.8%)	4(10.8%)

We retrospectively evaluated the following entities : change in type of anterior diaphragm, and changes in frequency of diaphragmatic defect, pseudotumor, and undulation of the diaphragm during the respiratory phases. All CT scans were reviewed by two observers, and a conclusion was reached by consensus.

We assessed the various configurations of the anterior portion of the diaphragm according to Gale's classification (7): Type 1 : continuous arc above the level of the xiphoid (Fig. 1A); type 2 : anterior divergence and discontinuity of muscle fibers (Fig. 2); type 3 : broad with poorly defined bands (Fig. 1B). Two types of diaphragmatic defects were defined : Type 1 : a localized defect without herniation of fat (Fig. 3); type 2 : any defect with herniation of fat or



A B

Fig. 1. On the scans at end expiration (**A**), the anterior diaphragm is seen as a continuous line (arrow heads) across the midline at the level of the xiphoid process (type 1). However, the anterior diaphragm (arrows) is seen as a broad, poorly defined band (type 3) on the scans at end inspiration (**B**).

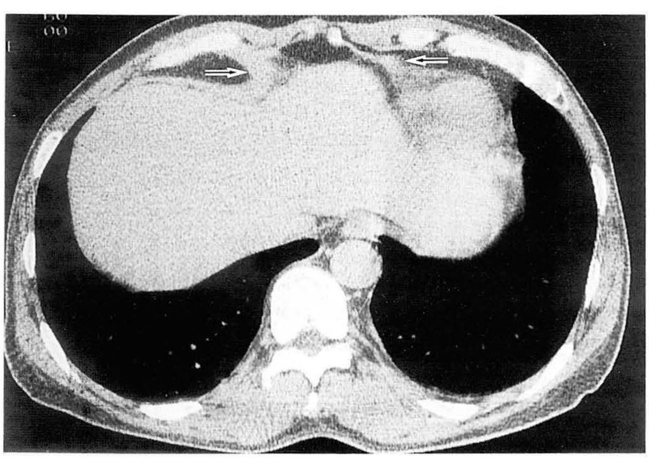


Fig. 2. Type 2 anterior diaphragm. The anterior diaphragm (arrows) is discontinuous, diverging, and opening anteriorly toward the sternum.

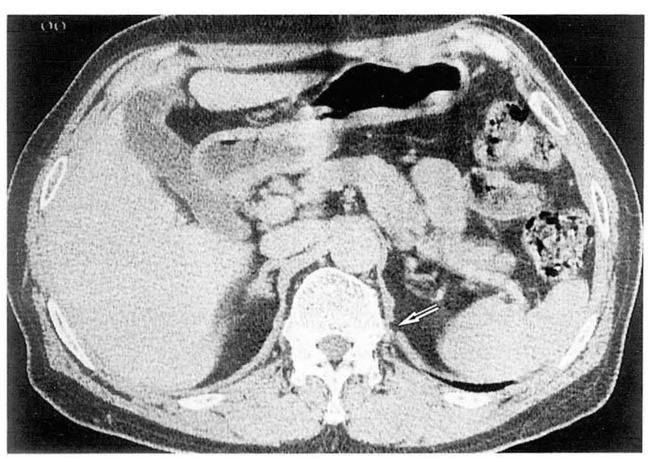


Fig. 3. Type 1 defect. A distinct diaphragmatic discontinuity (arrows) is seen at the posterior diaphragm. However, there is no protrusion of omental fat.

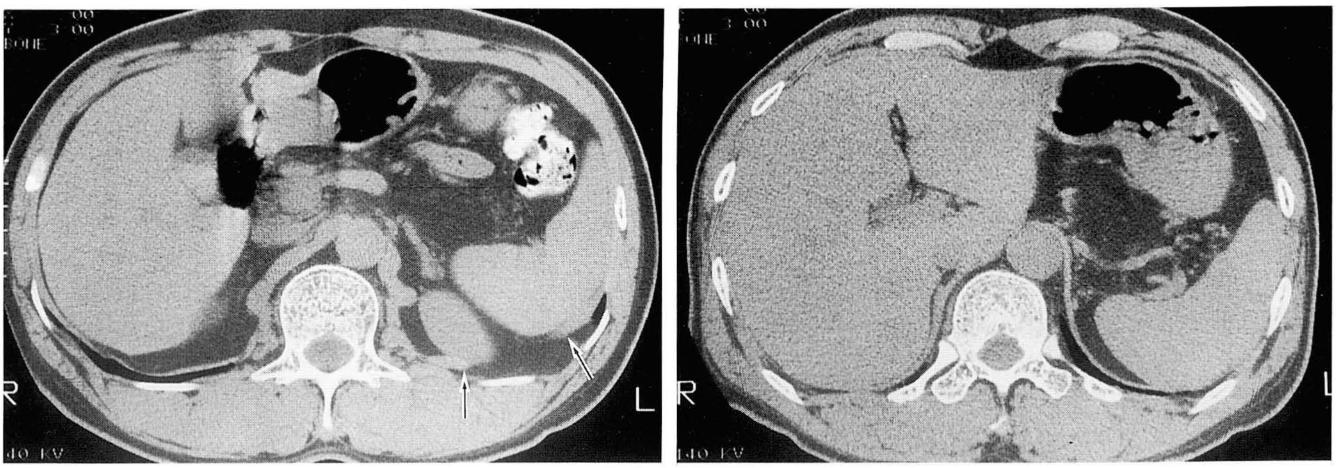
intraabdominal organ (Fig. 4A). Pseudotumors were defined as those nodules with a narrow base toward the costal diaphragm and those on the posterior diaphragm (Fig. 5A). Undulation of the diaphragm was defined as occurring when the nodule had a broad base or the diaphragm was wavy (Fig. 6A).

Results

The common types of anterior diaphragms at end expiration were type 1 (n = 20, 54.1 %) and type 3(n=16, 43.2%); in contrast, these were type 2(n=19, 51.4%) and type 3 (n=12, 32.4%) at end inspiration (Table 1). On CT scans, the configuration of the anterior portion of the diaphragm changed at different respiratory phases in 25(67.6%) of 37 patients. All of these 25 patients showed that the anterior diaphragm descended at end inspiration [i. e., type 1 (n=17) to type 2 (n=10) or 3 (n=7), and type 3 to type 2 (n=8)] (Fig. 1).

Diaphragmatic defects were found in five patients (13.5%) at end inspiration, however, no patient showed a diaphragmatic defect at end expiration (Fig. 4, Table 1). Four of the five patients showed obvious defects (type 2), and one showed type 1. Four of the five defects (type 1 in one and type 2 in three) were on the left.

Diaphragmatic pseudotumors were found in seven patients (18.9%) at end inspiration, whereas they were found in only two patients (5.4%) at end expiration (Fig 5, Table 1). Of the two patients with pseudotumor at end expiration, one showed an increase in the number of pseudotumors at end inspiration, while the other



A B

Fig. 4. Type 2 defect. On the scan at end inspiration, there is apparent discontinuity (arrows) of the diaphragm and protrusion of the intraabdominal fat (**A**). However, on the scan at end expiration in the same patient, there is no evidence of diaphragmatic defect (**B**).

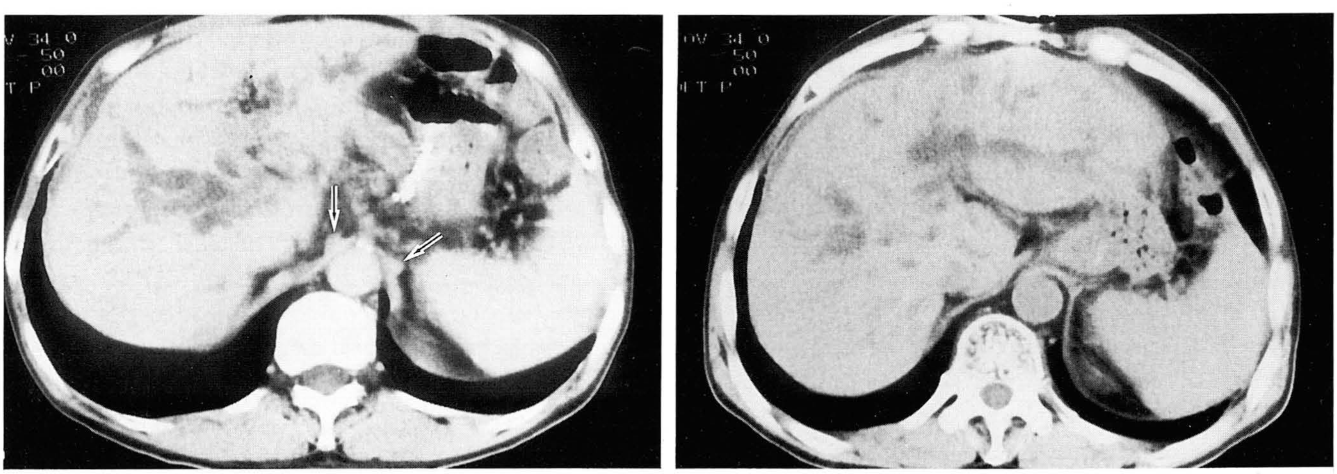


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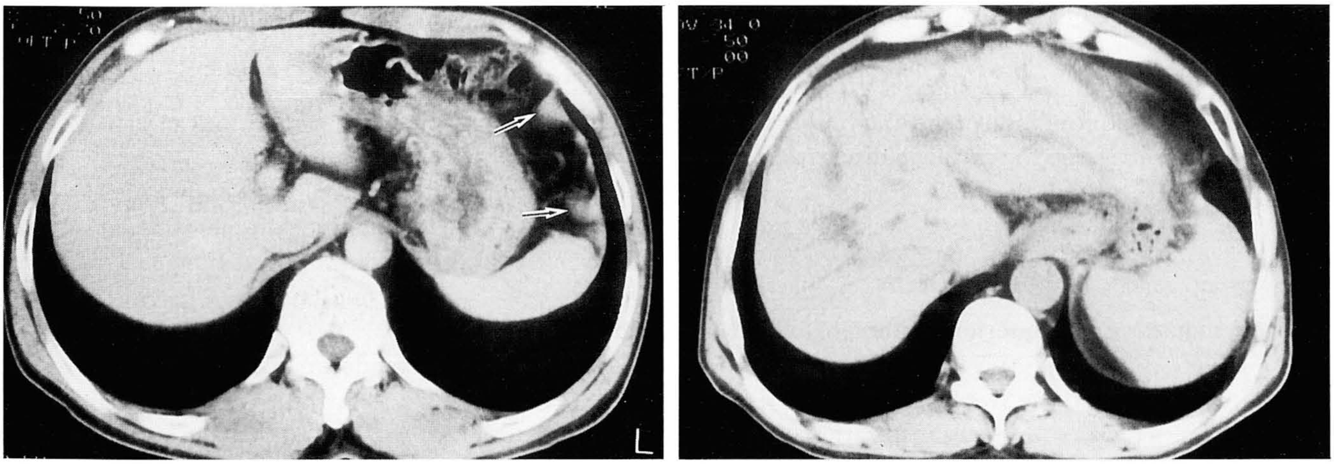
Fig. 5. Pseudotumor. The nodules (arrows) at the diaphragmatic crura are seen on the scan at end inspiration (**A**). However, on the scan at end expiration, there is no abnormality on the diaphragm (**B**).



A B

Fig. 6. Undulation. On the scan at end inspiration, the nodules (arrows) with broad base toward the diaphragm are seen (**A**). However, the diaphragm is smooth on the scan at end expiration (**B**).

did not show any change between the respiratory phases. The locations of the pseudotumors were on the crura in six and on the left costal diaphragm in one.

Undulations of the diaphragm were found in 14 patients (37.8%) at end inspiration, but were found in only four patients (10.8%) at end expiration (Fig. 6, Table 1). In addition, the undulations of these four patients were more prominent at end inspiration than at end expiration. All cases of undulations were seen on the left side, and only one case was also seen on the right side.

Discussion

For an understanding of Morgagni's hernia and pneunoperitoneum, familiarity with the CT appearance of the anterior diaphragm is important. The appearance of the anterior diaphragm was thoroughly analyzed by Gale (7). He reported that the frequency of each type of anterior diaphragm was 48% (type 1), 28 % (type 3), and 11% (type 2). He did not, however, consider the change in appearance of the anterior diaphragm between the respiratory phases, even though his study involved chest and abdominal CT. We think that this may be the major reason for his result not being identical to the results of our end inspiration or end expiration scans (Table 1).

In our study, the configuration of the anterior portion of the diaphragm changed between end inspiratory and end expiratory CT scans in 25 patients (67.6%), all of whom showed downward movement of the anterior diaphragm at end inspiration. This was probably due to respiratory movement of the heart, because the central tendon of the diaphragm is partly blended with the inferior portion of the pericardium (8).

The cause of the diaphragmatic defect seen in the adult age group is partly related to the aging process (6). The most frequent site of such a defect is the left posterior diaphragm; its reported frequency varied from 6% (5) to 37% (6).

In our study, diaphragmatic defects were visualized in five patients (13.5%) at end inspiration but were not visualized at end expiration, despite the fact that the mean age of the patients was 58 years. The reasons for the increased frequency of diaphragmatic defects at inspiration may be related to decreasing intrathoracic pressure and to the exaggeration of the defect due to muscular contraction of the diaphragm at inspiration. This result suggests that CT scans should be obtained at end inspiration if a diaphragmatic defect is suspected.

It is well known that the cause of diaphragmatic pseudotumor is infolding of contracted muscle fiber at inspiration and that this appearance is reversible on expiratory scans (3, 4). To our knowledge, however, there have been no systematic studies in the same patients aimed at evaluating this change, but only some case reports. Diaphragmatic pseudotumor and undulation of the diaphragm, as seen in our study, had in previous studies been evaluated as pseudotumor. We evaluated these two separately, because undulation of the diaphragm, compared with a diaphragmatic pseudotumor, may be easily characterized as diaphragmatic change rather than pleural mass or lymph node. In our study, diaphragmatic pseudotumor and undulation were markedly more frequent on inspiratory than on expiratory scans (18.9% and 37.8%, respectively, compared with 5.4% and 10.8%, respectively). These results are similar to those of previous reports (3, 4).

In conclusivsion, there is a change in the configuration of the anterior portion of the diaphragm and we also observed differences in the frequency of diaphragmatic defects, pseudotumor, and undulation between scans obtained at end inspiration and end expiration.

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횡격막의 전산화단층촬영 해부학 : 흡기와 호기시의 모양의 변화[1]

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목 적 : 이 연구의 목적은 흡기와 호기에서 얻은 CT 영상에 있어서 횡격막 모양의 변화를 분석하는데 있다.

대상 및 방법 : 37명의 환자를 대상으로 흡기와 호기 시에 각각 CT 스캔을 시행하였다. 각 호흡 주기에서 횡격막 전방부의 type, 횡격막의 결손, 가종양(pseudotumor), 그리고 굴곡(undulation)의 변화를 분석하였다.

결 과 : 횡격막 전방부의 모양의 변화는 37명의 환자 중 25명(67.6%)에서 관찰되었다. 횡격막의 결손, 가종양, 및 굴곡은 흡기시(각, 13.5%, 18.9%, 37.8%)가 호기시(각, 0%, 5.5%, 10.8%)보다 좀더 자주 관찰되었다.

결 론 : 호기와 흡기시에 얻은 CT에서 횡격막 전방부의 모양에 변화가 있음과, 횡격막의 결손, 가종양, 그리고 굴곡도 호흡 주기에 따라 변한다는 것을 알 수 있었다.

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