Clinical Significance of Inferior Phrenic Angiography; special reference to diaphragmatic or paradiaphragmatic lesions

Jun Ikeda, M.D., Yuji Numaguchi, M.D., Takashi Kishikawa, M.D., Yoshiki Tsukamoto, M.D. and Keiichi Matsuura, M.D.

Department of Radiology, Faculty of Medicine, Kyushu University

Research Cord No.: 506

Key Words: Inferior phrenic artery, Diaphragm

下横隔膜動脈造影の臨床的意義

九州大学医学部放射線科学教室

池田　純　沼口　雄治　岸川　高

塚本　良樹　松浦　啓一

（昭和55年3月17日受付）

（昭和55年4月24日最終原稿受付）

下横隔膜動脈造影の正常像および異常像についての検討を行なった．

まず，正常の腹腔動脈造影150例で下横隔膜動脈の分岐状況を調べた．31.0%は腹腔動脈幹から，2.7%は左胃動脈から分岐していた．内径の正常範囲は，0.5～2.5mm であった．

つぎに，下横隔膜動脈に拡張を認めた42症例の検討を行なった．胸膜病変の良性・悪性の鑑別は困難であったが，横隔膜腫瘍の進展範囲や肝腫瘍の横隔膜浸潤等を知るのに有用であった．

INTRODUCTION

The inferior phrenic artery arises from the abdominal aorta, the celiac trunk, the left gastric artery, or the renal artery, and it furnishes branches to the diaphragm, adrenal glands and the cardia of the stomach[1]. The inferior phrenic artery can supply lesions in the diaphragm, adrenal glands, gastric cardia, bases of the lungs, the liver and the spleen. Few reports have been published about the angiographic features of lesions in these sites[2)-6)].

This is a report of our assessment of the diagnostic value of angiography of the inferior phrenic artery. Our review of the normal and abnormal characteristics of the inferior phrenic artery is included.

MATERIALS AND METHODS

The angiograms of 42 patients with pathology in and adjacent to the diaphragm and with dilated inferior phrenic arteries were reviewed and compared with those of 150 normal subjects, all of whom were examined from January 1975 to December 1977. The 150 normal angiograms were also studied

for patterns of origin of the inferior phrenic artery, and for its diameters. Since superimposing the points of origin on the celiac trunks made measurements difficult, a point 2 cm distal to the origin was used as the site for measuring. The inferior phrenic artery may also originate from the aorta or from the renal artery. However, it was difficult to ascertain points of origin using abdominal aortography and the diaphragm is outside the field of renal angiography. Therefore, these two examinations were excluded from our review. The angiograms of the 42 abnormal cases were reviewed for any arterial encasement, neovascularity or hypervascularity, arteriovenous shunts, vascular stains, or vascular pooling. The manifestations according to lesion are shown in Table 1. Fourteen had pleural adhesions, 2 of them confirmed surgically or at autopsy; the remaining 12 were diagnosed clinically. The case of malignant pleural mesothelioma was confirmed by biopsy. The 4 cases of pleuritis carcinomatosa included 1 each of retroperitoneal reticulum cell sarcoma, gastric cancer, pulmonary cancer and malignant thymoma. The first two of these were diagnosed at autopsy; the remainder, clinically. The subphrenic abscess and cavernous hemangioma of the diaphragm were confirmed surgically. The 16 cases of malignant tumors invading the diaphragm consisted of 11 hepatomas, 4 metastatic hepatic tumors, and 1 unclassified primary sarcoma of the left subphrenic retroperitoneal region. Three hepatomas, 2 metastatic cancers, and 1 unclassified sarcoma were confirmed either surgically or by autopsy. The remainder were diagnosed clinically, primarily by angiography.

Table 1　Angiographic Characteristics of the inferior phrenic artery

Diagnosis	Cases (No.)	Diameter (mm.)	Arterial encasement	Neo-vascularity (or hyper-vascularity)	A-V shunts	Vascular stains	Vascular pooling
Pleural lesions							
Post-pleuritic adhesion	14	2.5–4.0	0	14	14*	10	0
Malig. Pleural mesothelioma	1	3.0	0	1	0	1	0
Pleuritis carcinomatosa	4	3.0–4.5	0	4	2*	2	0
Diaphragmatic lesions							
Subphrenic abscess	1	3.0	0	1	1*	1	0
Cavernous hemangioma	1	2.5	0	1	0	0	1
Diaphragmatic invasion	16**	3.0–4.0	10	16	3	5	0
Splenic lesions							
Splenomegaly	2	3.5–4.0	0	0	0	0	0
Post-splnectomy	1	4.0	0	1	0	0	0
Occlusion of hepatic artery	2	4.0–4.5	0	0	0	0	0

*shunt with pulmonary artery.

**11 hepatomas, 4 metastatic hepatic tumors, and 1 unclassified sarcoma of the subphrenic region.

RESULTS

Theoretically, a total of 300 left and right inferior phrenic arteries should have been visualized among the 150 subjects, but celiac angiography demonstrated only 93 (31.0%) arising from the celiac trunk; 8 (2.7%) from the left gastric artery; 2 (1.7%) from the hepatic artery.

The diameters of the inferior phrenic arteries originating from the celiac trunks of the 93 normal subjects ranged from 0.5 to 2.5 mm, with a mean of 1.5 mm ($\pm$0.5 mm). The angiographic features

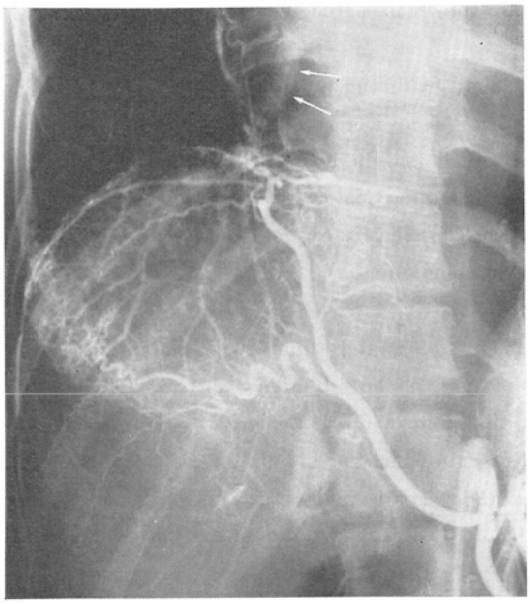


Fig. 1 Thirty-six year old female with fibrous adhesions of the right pleura at autopsy. Selective inferior phrenic angiography revealed dilatation of the right inferior phrenic artery, hypervascularity and vascular stains along the dome of the diaphragm. A shunt with a pulmonary artery can be seen (arrows).

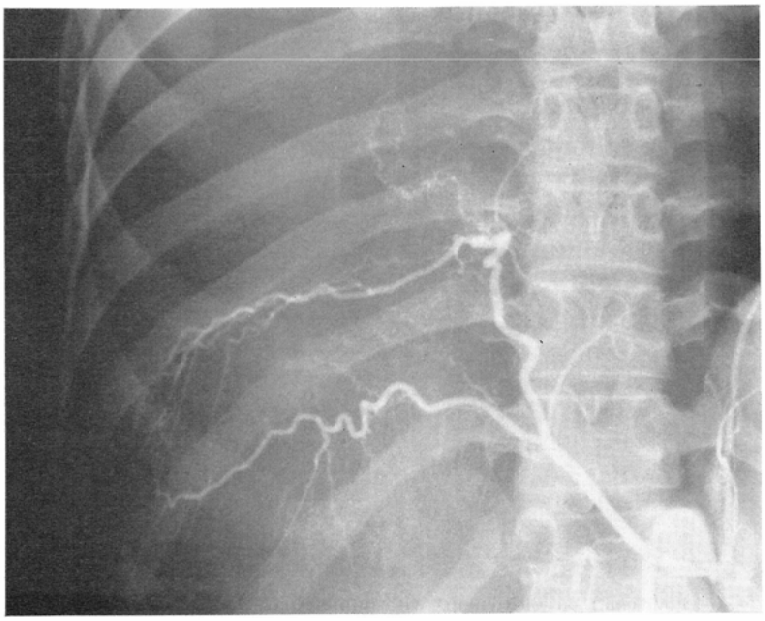


Fig. 2 Twenty-two year old female with malignant pleural mesothelioma by biopsy. Selective inferior phrenic angiography revealed dilatation of the right inferior phrenic artery and irregular tumor vessels. A faint tumor stain can be seen.

of the 42 abnormal cases are shown in Table 1.

A. Pleural lesions

Hypervascularity and shunts with the pulmonary arteries were observed in all cases of pleural adhesions. In 10 of the 14 cases there were vascular stains along the dome of the diaphragm (Fig. 1). In the malignant pleural mesothelioma, there was neither arterial encasement nor arteriovenous shunts, though tumor vessels and faint tumor stains were noted (Fig. 2). Neovascularity without arterial encasement was noted in all cases of pleuritis carcinomatosa. In 2 of these 4 cases, we noted shunts with the pulmonary arteries and vascular stains.

B. Diaphragmatic lesions

Hypervascularity, vascular stains, and shunts with the pulmonary arteries were visualized in sites corresponding to the locations of the subphrenic abscess (Fig. 3). In cavernous hemangiomas of the diaphragm, there was dilatation of the left inferior phrenic arteries, neovascularity and vascular pooling (Fig. 4-A, B). All cases in which the diaphragm was invaded by malignant abdominal tumors, such as hepatoma and metastatic hepatic tumors, exhibited tumor vessels in the tumor sites. Arterial encasement was noted in 10 of 16 cases, and tumor stains were demonstrated in 5 of them (Fig. 5).

C. Splenic lesions

In splenomegaly, only dilatation of the left inferior phrenic artery was observed. After splenectomy, there was only hypervascularity of the splenic bed.

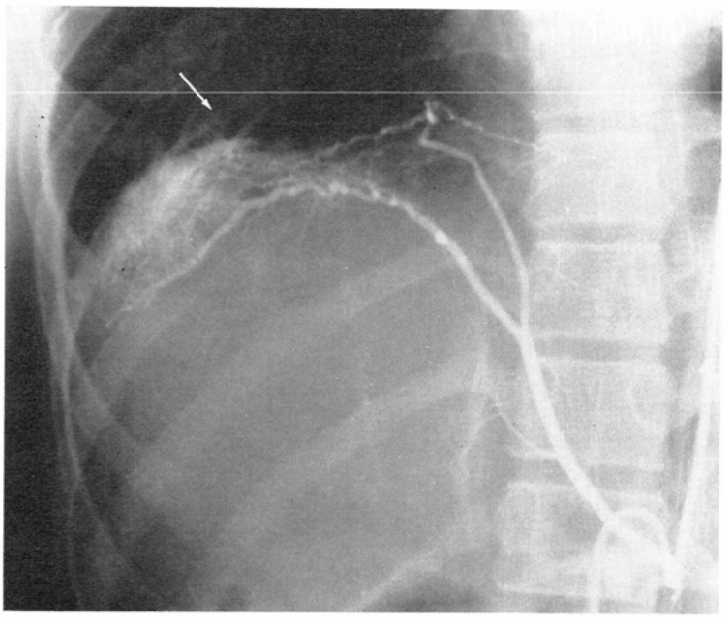
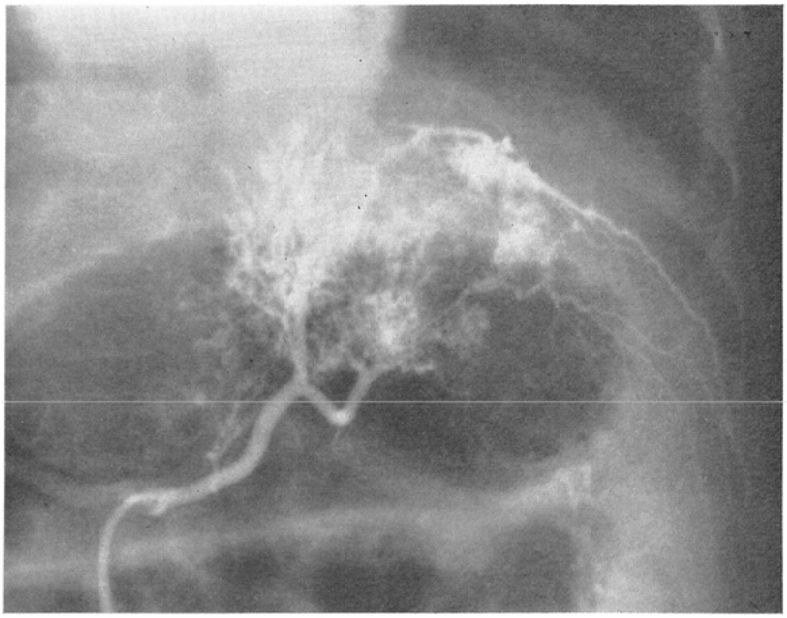
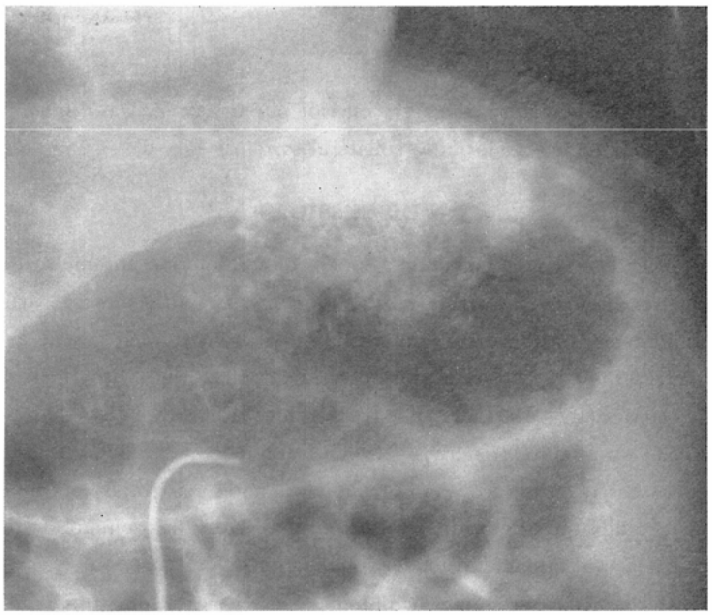


Fig. 3 Fourteen year old female with subphrenic abscess at surgery. Selective inferior phrenic angiography revealed dilatation and tortuosity of the right inferior phrenic artery, with hypervascularity, vascular stains, and a shunt with a pulmonary artery (arrow), which coincided with the site of the abscess.



A



B

Fig. 4 Twelve-month old male with a diaphragmatic cavernous hemangioma and a hemothorax at surgery.

A. Arterial phase: The left inferior phrenic artery was dilated, and there was neovascularity and vascular pooling.

B. Venous phase: Continuous vascular pooling was observed.

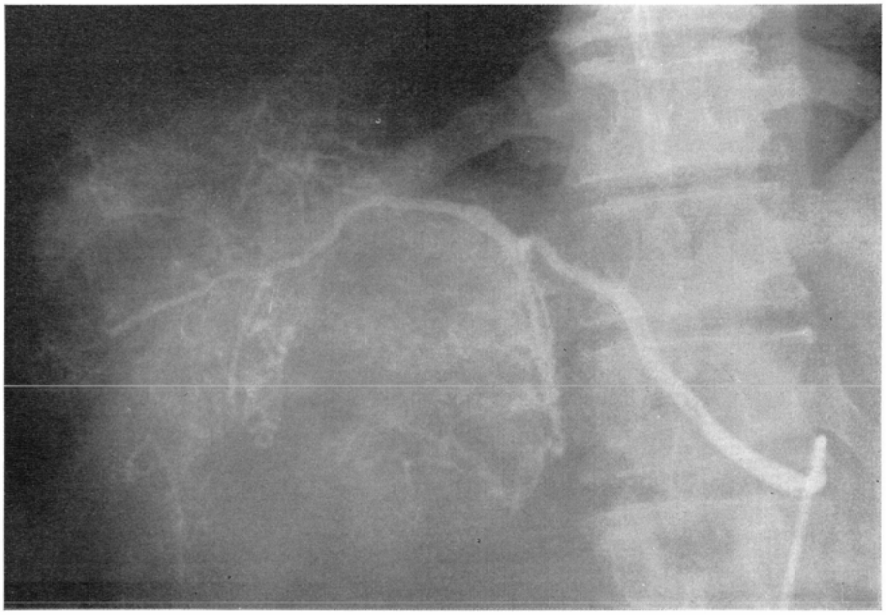


Fig. 5　Fifty-seven year old male with a diffuse hepatoma invading the diaphragm at surgery. Selective inferior phrenic angiography revealed arterial encasement, tumor vessels, and tumor stain.

D.　Occlusion of the hepatic artery

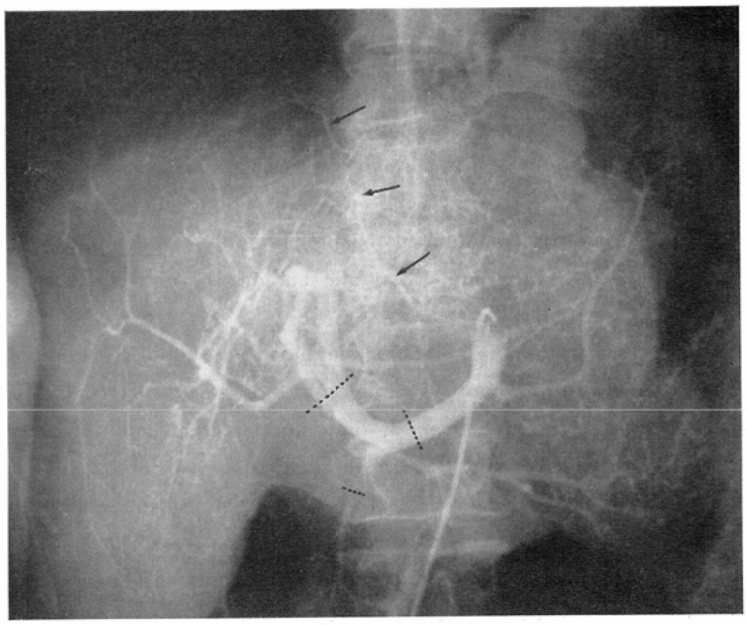
In occlusion of the hepatic artery, the right inferior phrenic artery was dilated and it anastomosed with branches of the hepatic artery, forming collateral systems (Fig. 6).

DISCUSSION

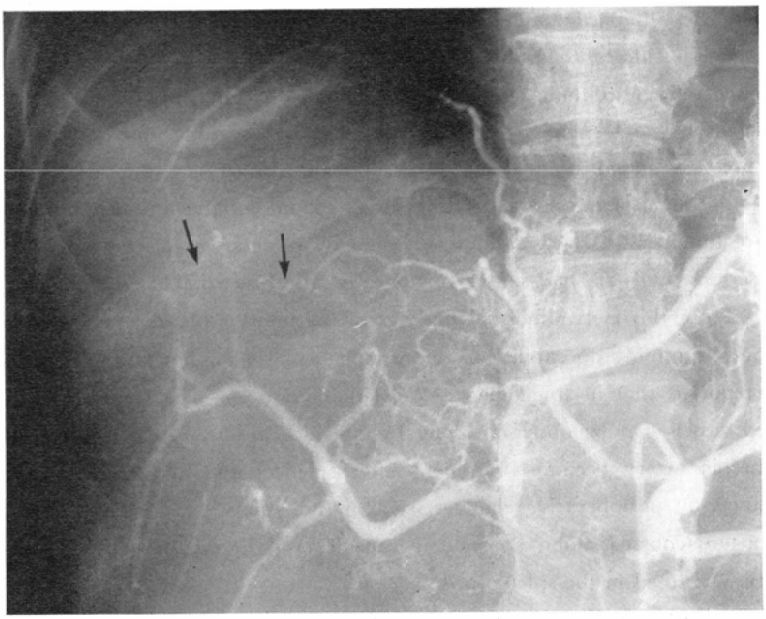
Adachi's study of cadavers[7] indicated that 45.9% of the inferior phrenic arteries arose from the celiac trunk; 4.7%, from the left gastric artery; and 1.4%, from the hepatic artery. Greig et al[1] found that they originated from the celiac trunk in 46.8%; from the left gastric artery in 2.6%; and from the hepatic artery in 0.5%. Our results correlated fairly well with theirs for the left gastric (2.7%) and hepatic arteries (1.7%). Our celiac trunk rates (31.0%) were less than those determined by Adachi and Greig et al using autopsy studies[1)7)]. This difference is probably due to the fact that two groups of studies were based on autopsy on the one hand, and angiography on the other; even though the celiac trunk was actually the origin, the inferior phrenic artery was sometimes not visualized due to inadequate positioning of the catheter tip for its visualization.

The normal mean diameter of the inferior phrenic artery was 1.5 mm; the largest normal, 2.5 mm. When the diameter exceeded 2.5 mm, it was considered definitely dilated. There was no correlation of disease types.

Kahn[2] first reported the techniques for selective angiography of the inferior phrenic artery. He suggested this technique be used to study lesions of the diaphragm, localize subphrenic abscesses, determine adrenal gland size, and to demonstrate tumors of the adrenal gland or other upper



A



B

Fig. 6 Forty-three year old male with hepatoma extending from the liver hilum to the left lobe at surgery.

A. Preoperative celiac angiography failed to show dilatation of the right inferior phrenic artery (arrows). Sites of ligation of the artery are shown (dotted lines).

B. Celiac angiography following ligation of the hepatic artery showed dilatation of the right inferior phrenic artery and anastomosis with branches of the hepatic artery (arrows). The collateral pathway via left gastric artery is also prominent. Tumor vessels caused by the hepatoma are observed.

retroperitoneal structures. Reschke[4] also underscored the value of selective inferior phrenic angiography, particularly for splenomegaly, mediastinal tumors and stomach cancer. Wirtanen et al[5] reported a dilated tortuous inferior phrenic artery supplying post-pleuritic pleural adhesions. Results of the present study show that dilatation, tortuosity, neovascularity and vascular stains also occur in such diseases as malignant pleural mesotheliomas and pleuritis carcinomatosa. Inferior phrenic artery—pulmonary artery shunts were reported by Webb et al[6] in chronic pulmonary infections. However, they also occurred in pleuritis carcinomatosa in the present study. Angiographically the differential diagnosis is often difficult, since there are no specific findings for post-pleuritic adhesions, pleuritis carcinomatosa or malignant pleural mesothelioma.

Abnormalities, such as dilatation of the inferior phrenic artery, also occur in diaphragmatic lesions. Deutsch et al[8] reported 3 cases in whom subphrenic abscesses were detected by displacement of the liver on celiac angiography. In 2 of these 3, only normal right inferior phrenic arteries were visualized. However, using selective inferior phrenic angiography, we observed hypervascularity and vascular stains in a subphrenic abscess. We believe that, when a subphrenic abscess is suspected, selective inferior phrenic angiography is indicated in addition to a search for evidence of displacement of the liver using celiac angiography. The lesion's extent can thus be better assessed.

Primary tumors of the diaphragm are very rare. Benign tumors, including mesothelial cysts, neurofibromas and angiofibromas, are relatively frequent. The malignant ones are usually fibrosarcomas[9]. Though these diaphragmatic tumors are usually diagnosed by laminagraphy, bronchography, barium or radionuclide studies, the findings are usually nonspecific[10]. When such tumors are strongly suspected, selective inferior phrenic angiography is usually worth while, as in the case of cavernous hemangioma reported here. Malignant abdominal tumors invading the diaphragm cause arterial encasement, tumor vessels, and tumor stains. It may be difficult to assess dilatation of, or neovascularity from, the inferior phrenic arteries as indicating direct diaphragmatic invasion as opposed to parasitic blood supplies of tumors[11]. Diaphragmatic invasion by tumors was suspected in 16 cases on angiography in this series. Only six had surgery or autopsy and direct diaphragmatic invasion was verified in all of them. From this fact, abnormal findings of the inferior phrenic artery described above are of great help in determining operability of tumors, particularly for hepatomas.

Reschke[4] reported that in splenomegaly the left inferior phrenic artery is dilated, and that extensively dilated vessels can be observed along the splenic capsule. According to Kahn et al[3], the left inferior phrenic artery became prominent after splenectomy, and there was hypervascularity, presumably caused by postoperative changes, such as adhesions. In the cases of splenomegaly we observed, the artery coursed along the splenic capsule, and in the post-splenectomy case reported, hypervascularity was noted in the splenic bed.

The inferior phrenic artery becomes a collateral pathway in the event of hepatic artery occlusion[5]. Ligation of the hepatic artery has recently been the recommended for hepatoma. We observed two cases in which hepatomas were supplied blood through a collateral pathway. The inferior phrenic artery must therefore be carefully observed to understand adequately the tumor's extent after the hepatic artery has been ligated.

The inferior phrenic artery is small, and its branching patterns vary widely. Selective angio-

graphy is oftern difficult, and the specific findings in inferior phrenic angiography are sparse. However, a dilated inferior phrenic artery may point to abnormalities in the pleura, lung bases, diaphragm, the liver or the spleen. When an abnormality is suspected in or adjacent to the diaphragm, selective inferior phrenic angiography should be performed. Of course, other clinical information should be considered in making a correct diagnosis before this examination. The more detailed the vascular pattern, the more useful it is in diagnosing a pathological condition.

ACKNOWLEDGMENT

We thank Dr. Walter J. Russell for his criticisms and editorial suggestions, and Mrs. Yoko Sakai for her assistance in preparing the manuscript.

REFERENCES

1) Greig, H.W. and Anson, B.J.: The inferior phrenic artery—Types of origin in 850 body-halves and diaphragmatic relationship. Quart Bull Northwestern Univ. M. School, 25: 365—350, 1951
2) Kahn, P.C.: Selective angiography of inferior phrenic arteries. Radiology, 88: 1—8, 1967
3) Kahn, P.C. and Frates, R.E.: The value of angiography of the small branches of the abdominal aorta. Am. J. Roentgenol., 102: 407—417, 1968
4) Reschke, H.: Die Selective Angiographie der A. Phrenica ascendens. Fortschrit Rontgenstr., 107: 200—205, 1967
5) Writanen, G.W. and Kaude, J.V.: Inferior phrenic artery collateralization in hepatic artery occlusion. Am. J. Roentgenol., 117: 615—619, 1973
6) Webb, W.R. and Jacob, R.P.: Transpleural abdominal systemic artery-pulmonary artery anastomosis in patients with chronic pulmonary infections. Am. J. Roentgenol., 129: 223—326, 1977
7) Adachi, B.: Das Arteriensystem der Japaner Bd. II: Maruzen Tokyo, 1928, pp. 14—16
8) Deutch, V., Adar, R. and Mozes, M.: Angiography in the diagnosis of subphrenic abscess. Clin. Radiol., 25: 133—136, 1974
9) Wiener, M.F. and Chou, W.H.: Primary tumors of the diaphragm. Arch. Surg., 90: 143—152, 1965
10) Anderson, L.S. and Forrest, J.V.: Tumors of the diaphragm. Am. J. Roentgenol., 119: 259—265, 1973
11) Sprayregen, S.: Parasitic blood supply of neoplasms. Radiology, 106: 529—535, 1973