

BRONCHIAL ANGIOGRAPHY IN THE STAGING  
OF BRONCHOGENIC CARCINOMA

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The prognosis of bronchogenic carcinoma is mainly determined by the anatomic extent, or stage of the tumor at the time of diagnosis, but also by the biologic characteristics of the tumor and the immunologic and physiologic condition of the host (SHIELDS et coll. 1972). These factors also influence the choice of therapy.

Various methods have been developed to describe the stage of disease in bronchogenic carcinoma. The most commonly used is the TNM-system (UICC 1974). To determine the local extension of a carcinoma prior to treatment, different procedures are available, such as chest radiography, bronchoscopy, mediastinoscopy, thoracoscopy, pulmonary angiography, and  $^{133}\text{Xe}$  spirometry. Recently also computer tomography and  $^{67}\text{Ga}$  scintigraphy have been utilized (EMAMI et coll. 1978, DE MEESTER et coll. 1978). Though these procedures may suffice for a correct clinical staging in most patients, there is still need for supplementary methods. This is emphasized by MATTHEWS et coll. (1973), who found persistent tumor in 35 per cent of patients who had undergone 'curative' surgery for bronchogenic carcinoma within one month before autopsy. In half of the patients with squamous cell carcinoma the residual tumor was confined to the mediastinum and probably adjuvant therapy would have been helpful in those cases.

Since December 1975 bronchial angiography has been performed at this hospital in connection with intraarterial infusion of cytostatic drugs in patients with broncho-

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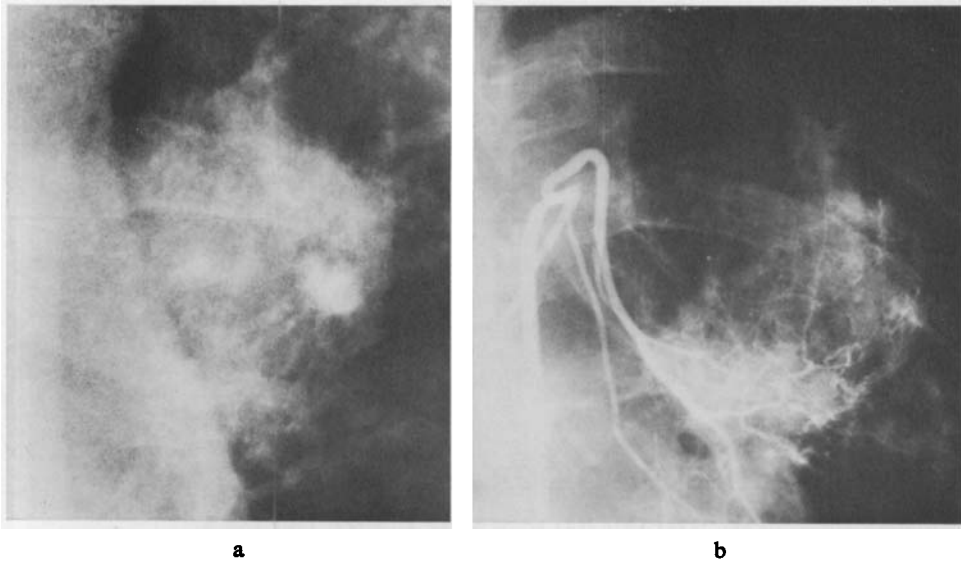


Fig. 1. Centrally located adenocarcinoma in the left lung. a) Chest film. b) Angiography of the left lower bronchial artery; the vascular supply to the lower half of the tumor is demonstrated. Probably the rest of the tumor was supplied by the upper left bronchial artery, which was not examined.

genic carcinoma (HELLEKANT & SVANBERG 1978, HELLEKANT et coll. 1978). Various types of abnormal vascular supply of hilar and mediastinal structures were observed, indicating the tumor extension, which was later confirmed at mediastinoscopy, surgery or autopsy. Since no systematic analysis of the value of bronchial angiography in the evaluation of the local extension of bronchogenic carcinoma has been performed, it was found worthwhile to review the present material in this regard.

#### Material and Methods

From 39 patients referred for bronchial angiography and infusion with cytostatic drugs, the following were selected for this review: (a) patients operated upon after angiography (18 patients, median interval to surgery 30 days), (b) non-operated patients with mediastinal involvement found at mediastinoscopy or tumor growth in the trachea at bronchoscopy (7 patients), and (c) one patient who died 8 days after angiography and underwent autopsy.

Thus in all, 26 patients were found eligible for the review. Twenty-one had squamous cell carcinoma and 5 adenocarcinoma. Before angiography all patients were evaluated with physical examination, chest radiography, bronchoscopy, mediastinoscopy, spirometry and  $^{133}\text{Xe}$  spirometry (MjÖRNER 1968). When clinically indicated also scintigraphy of the skeleton, brain and liver was performed. On the basis of the findings the patients were classified and staged according to the TNM-classification

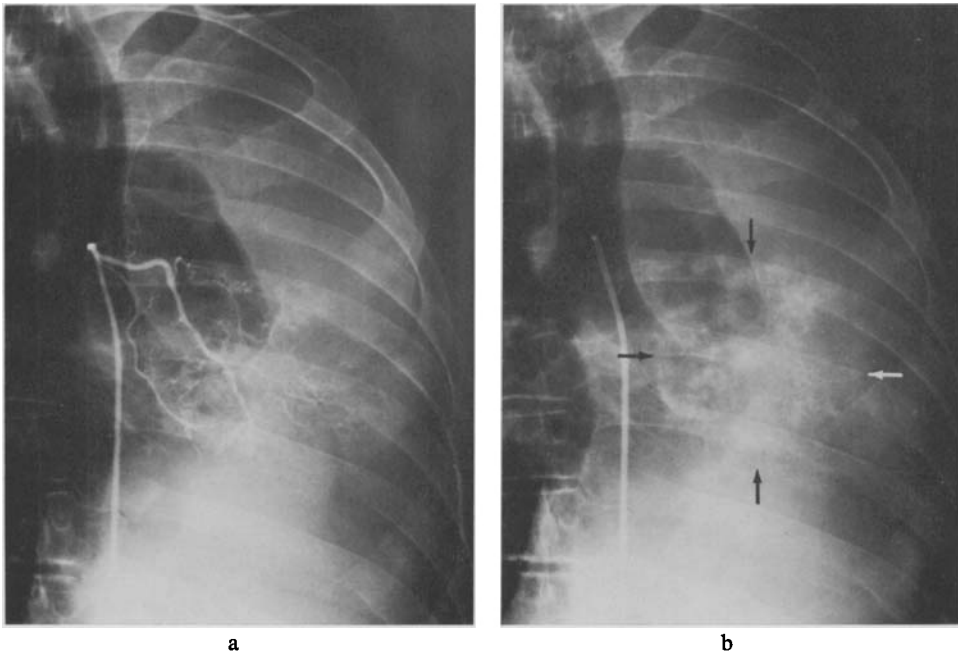


Fig. 2. Squamous cell carcinoma occluding the left main bronchus. Angiography. a) Arterial, b) parenchymal phase. b) Accumulation of contrast medium clearly demonstrates the size of the tumor ( $\rightarrow$ ). The finding was confirmed at autopsy 8 days later.

(UICC 1974). Ten patients belonged to clinical stage I-II (up to T2N1M0), while the other 16 had more extensive disease.

Tumor growth in the mediastinum was confirmed at mediastinoscopy, bronchoscopy or surgery in 15 patients. Five of these had direct tumor extension to the mediastinum without growth in mediastinal lymph nodes (T3N01), 3 had metastases to the lymph nodes without direct tumor extension (T2N2), and 7 had both direct and metastatic spread to the mediastinum (T3N2).

Direct tumor extension to hilar structures or metastatic spread to hilar lymph nodes was surgically confirmed in 12 patients. Six of these also had spread to the mediastinum.

Percutaneous selective catheterization of the tumor feeding bronchial artery was performed using a technique described by HELLEKANT (1979). In connection with repeated infusions of cytostatic drugs, angiography was repeated in 7 patients, and in 4 patients also a pulmonary angiography was performed.

The bronchial angiograms were screened for: (1) The vascular supply of the tumor, its size and distance to the main bronchus, trachea, mediastinum or pleura. (2) Abnormalities indicating tumor extension to structures in the mediastinum, the hilum or the perihilar area, such as encasement of the proximal part of the bronchial artery,

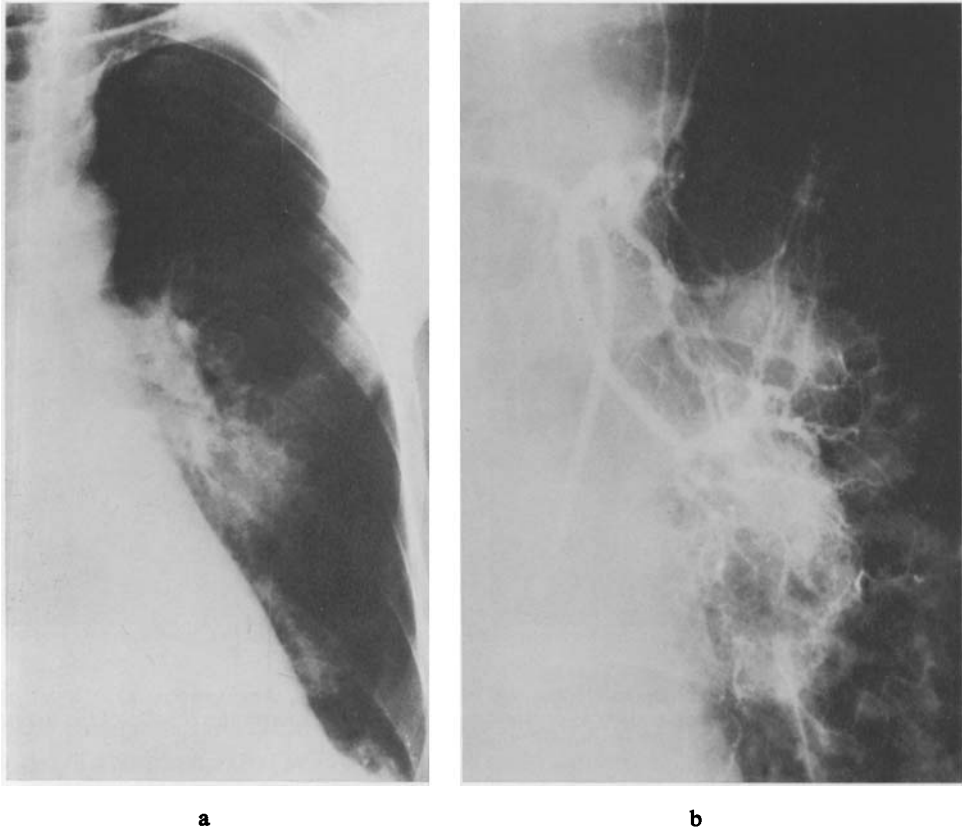


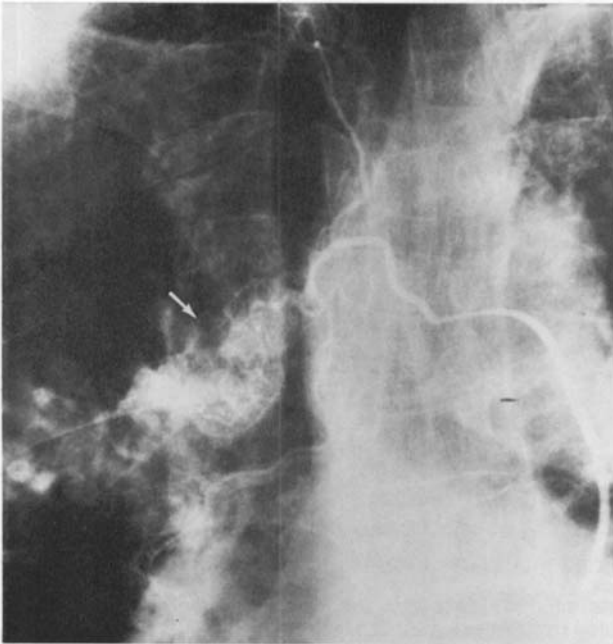
Fig. 3. Bronchoscopically confirmed squamous cell carcinoma. a) Chest film. Perihilar pneumonia obscuring the tumor. b) Bronchial angiography clearly outlines the tumor.

tumor vascularity and accumulation of contrast medium. (3) Evidence of tumor spread to the surrounding lung parenchyma and pleura. (4) The presence of bronchopulmonary arterial shunts.

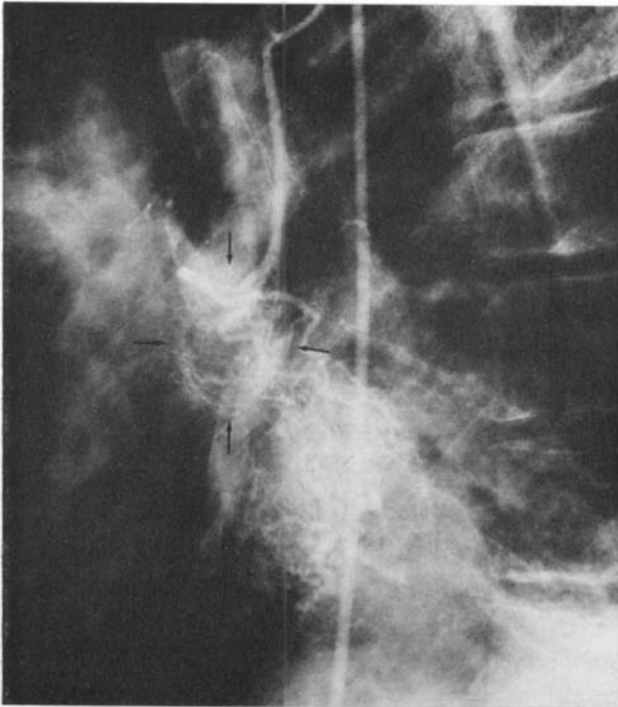
**Table**

*Findings at angiography and mediastinoscopy in 13 patients with confirmed tumor growth in the mediastinum*

Angiography	Mediastinoscopy		Total
	Abnormal	Normal	
Abnormal	4	5	9
Normal	2	2	4
Total	6	7	13



**Fig. 4.** Squamous cell carcinoma in the right lung. No abnormality at mediastinoscopy. Bronchial angiography. Direct tumor extension to the tracheobronchial angle ( $\rightarrow$ ). Confirmed at subsequent surgery.



**Fig. 5.** Squamous cell carcinoma in the left lower lobe. Bronchial angiography clearly outlines the richly vascularized tumor. Irregular vessels in a rounded area above the tumor ( $\rightarrow$ ) are demonstrated. At surgery a large metastatic lymph node was confirmed at this location.

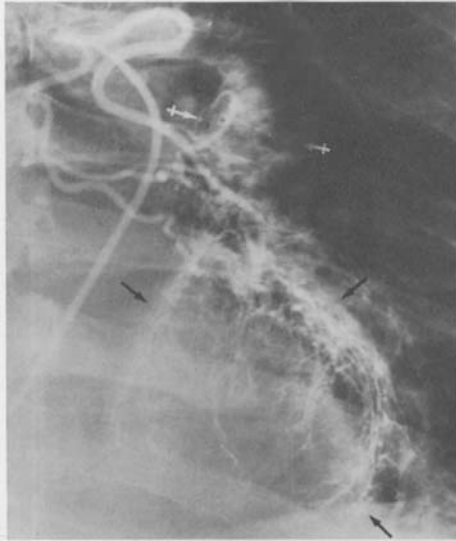


Fig. 6

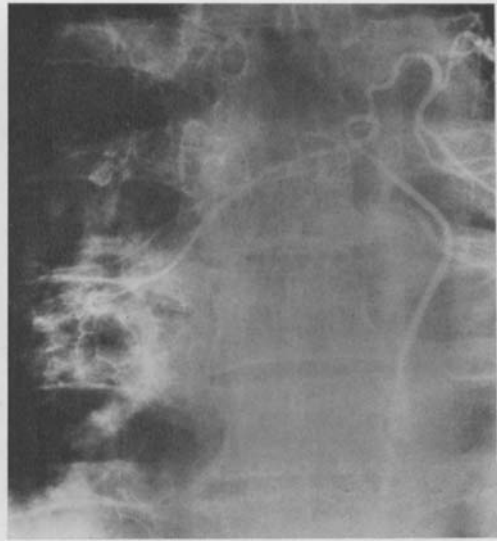


Fig. 7

Fig. 6. Large squamous cell carcinoma in the left lower lobe. Bronchial angiography clearly outlines the tumor (→). Increased vascularity and contrast accumulation in the hilum (↗), where large lymph nodes were found at surgery. Microscopy revealed only inflammatory lesion.

Fig. 7. Two tumors in the left lung undergoing intraarterial chemotherapy. Tumor with increased vascularity below the right hilum supplied by artery from left side.

The findings at bronchial angiography were correlated with chest films and data obtained at bronchoscopy, mediastinoscopy, surgery or autopsy. When available, pulmonary angiograms were also used for correlation.

### Results

*Primary tumor.* Bronchial angiography clearly outlined the tumor in all patients but 3. In one of these the bronchial artery was occluded in the hilum due to tumor growth; in the other it was obvious from comparison with chest films and findings at surgery that the whole tumor supply had not been demonstrated. In both the latter cases the tumor was located on the left side (Fig. 1).

Most of the tumors were fairly richly vascularized. The size and demarcation of the tumor was better demonstrated by angiography in 9 patients compared to chest films obtained in close connection with the angiography. In 5 of these it was not possible to outline the tumor on the chest films due to large atelectases (Fig. 2), and in 2 due to surrounding inflammatory infiltrates (Fig. 3). In the remaining 2 patients the tumor was small and centrally located and therefore difficult to localize on chest films.

*Mediastinal tumor growth.* Angiography correctly suggested mediastinal involvement in 11 patients of 15. At mediastinoscopy no evidence of tumor was found in 5 of

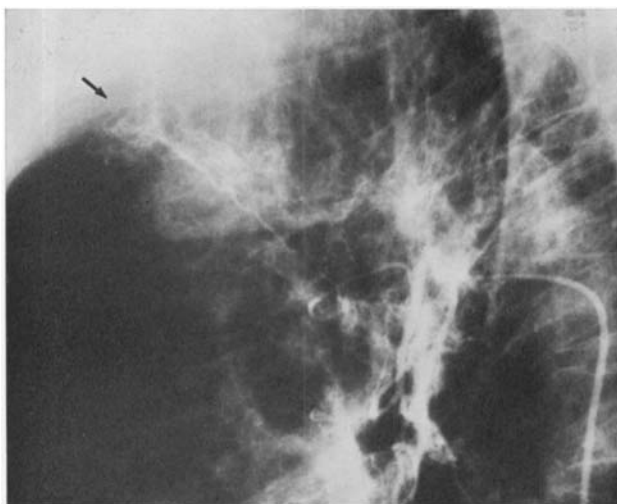


Fig. 8. Centrally located adenocarcinoma in the left lung. Bronchial angiography. Vascularity reaching the anterior pleura (→).

these (Table). In 6 cases with central tumors angiographic indication of direct tumor extension to the upper mediastinum was observed (Fig. 4). In 5 cases with more peripheral tumors the angiographic abnormalities in the mediastinum were considered as representing metastases. It was otherwise not possible to make an angiographic distinction between direct tumor extension to the mediastinum and mediastinal metastases.

In all cases in which tumor involvement of the mediastinum was diagnosed at angiography, this diagnosis was correct, but in 4 patients angiography failed to demonstrate mediastinal growth: 2 with T2N2, 1 with T3N1 and 1 with T3N2. At mediastinoscopy abnormality was found in 2 of these.

Mediastinoscopy was performed in 13 of the 15 patients with confirmed mediastinal growth. In the remaining 2 patients mediastinoscopy was omitted due to tumor growth in the trachea observed at bronchoscopy.

At mediastinoscopy mediastinal involvement was demonstrated in 6 of the 13 patients but was not revealed in 7. Three of these had direct tumor extension to the lower mediastinum, beyond the reach of mediastinoscopy.

In the 7 patients in which mediastinoscopy failed to indicate abnormality, angiography demonstrated the involvement in 5, but failed to do so in 2.

The relationship between the findings at angiography and mediastinoscopy appears in the Table.

*Hilar tumor growth.* In 12 patients with direct or metastatic spread to hilar structures or peribronchial lymph nodes, bronchial angiography showed encasement of the bronchial artery in 3 and in another 3 accumulation of contrast medium and abnormal vessels in small areas corresponding to lymph nodes found at surgery (Fig. 5). In the remaining 6 patients no angiographic tumor spread to the hilum existed.

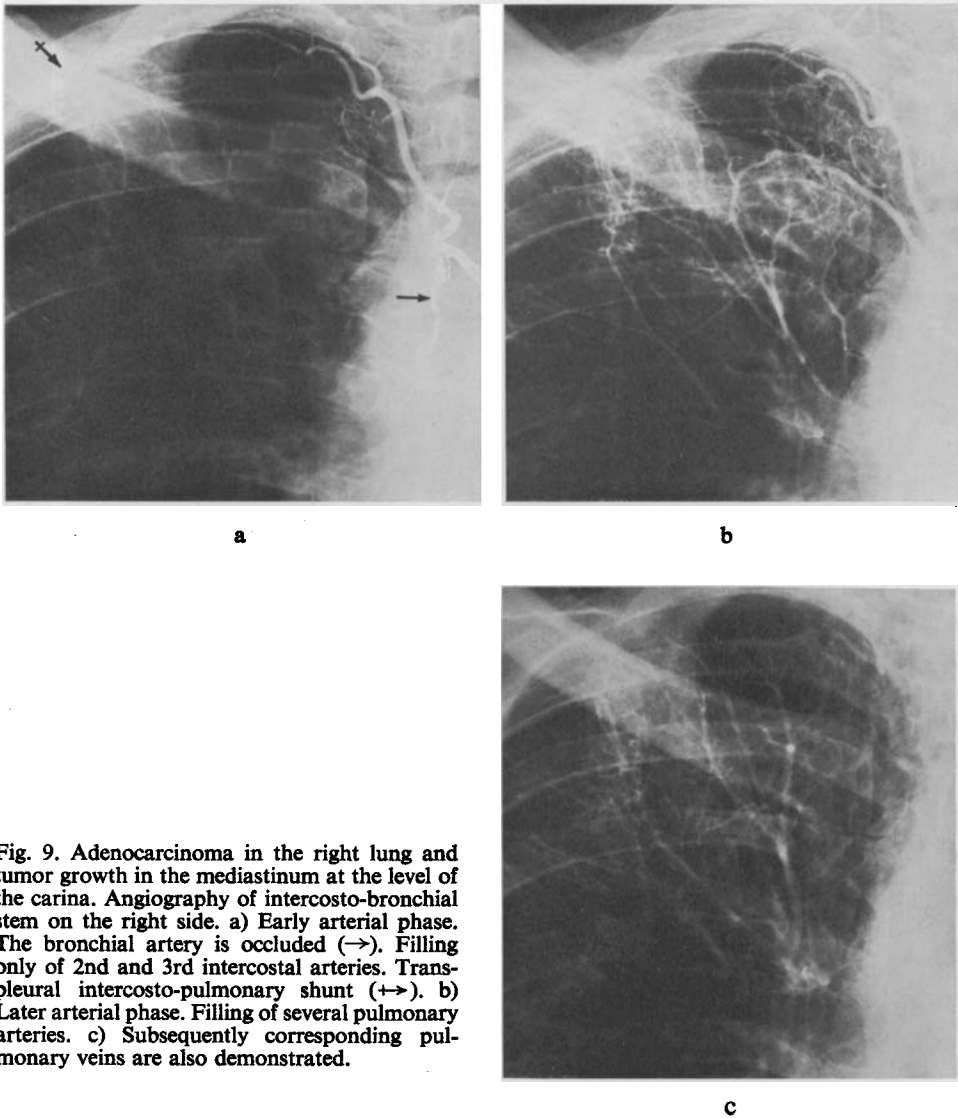


Fig. 9. Adenocarcinoma in the right lung and tumor growth in the mediastinum at the level of the carina. Angiography of intercosto-bronchial stem on the right side. a) Early arterial phase. The bronchial artery is occluded ( $\rightarrow$ ). Filling only of 2nd and 3rd intercostal arteries. Transpleural intercosto-pulmonary shunt ( $+\rightarrow$ ). b) Later arterial phase. Filling of several pulmonary arteries. c) Subsequently corresponding pulmonary veins are also demonstrated.

Angiography erroneously suggested hilar lymph node metastases in 2 patients (Fig. 6). In a third patient with previous tuberculosis a calcified lymph node surrounded by wide tortuous vessels was observed. Its benign nature was correctly suggested at the angiography.

*Tumor spread to the lung parenchyma and pleura.* Metastatic spread to the parenchyma in the same lung as the primary tumor was demonstrated at angiography in one patient. The metastasis was not detectable on conventional chest films.

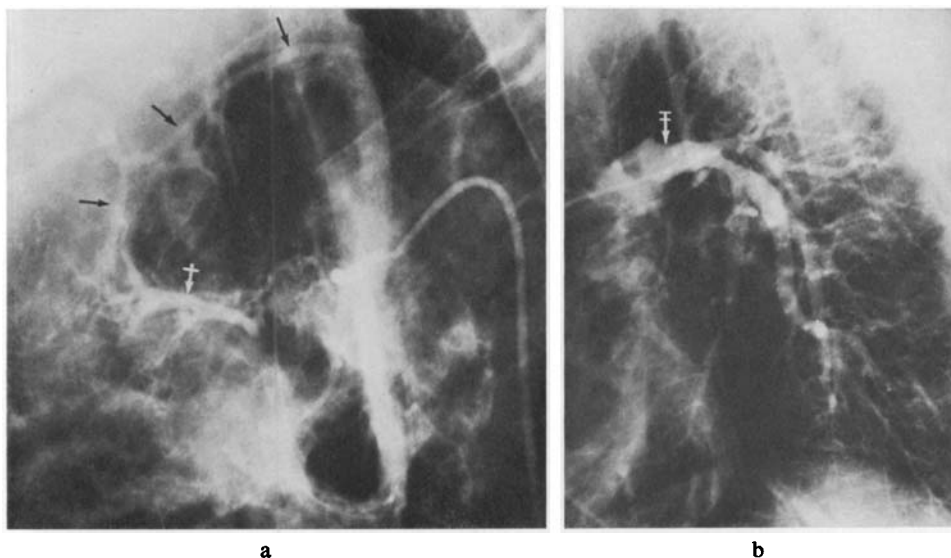


Fig. 10. Centrally located bronchogenic carcinoma on the left side. a) Bronchial angiography. Filling of pulmonary artery in the anterior segment of the upper lobe (+→) and of veins belonging to the hemiazygos system (→). b) Selective pulmonary angiography demonstrates occlusion of the upper lobe artery (+→).

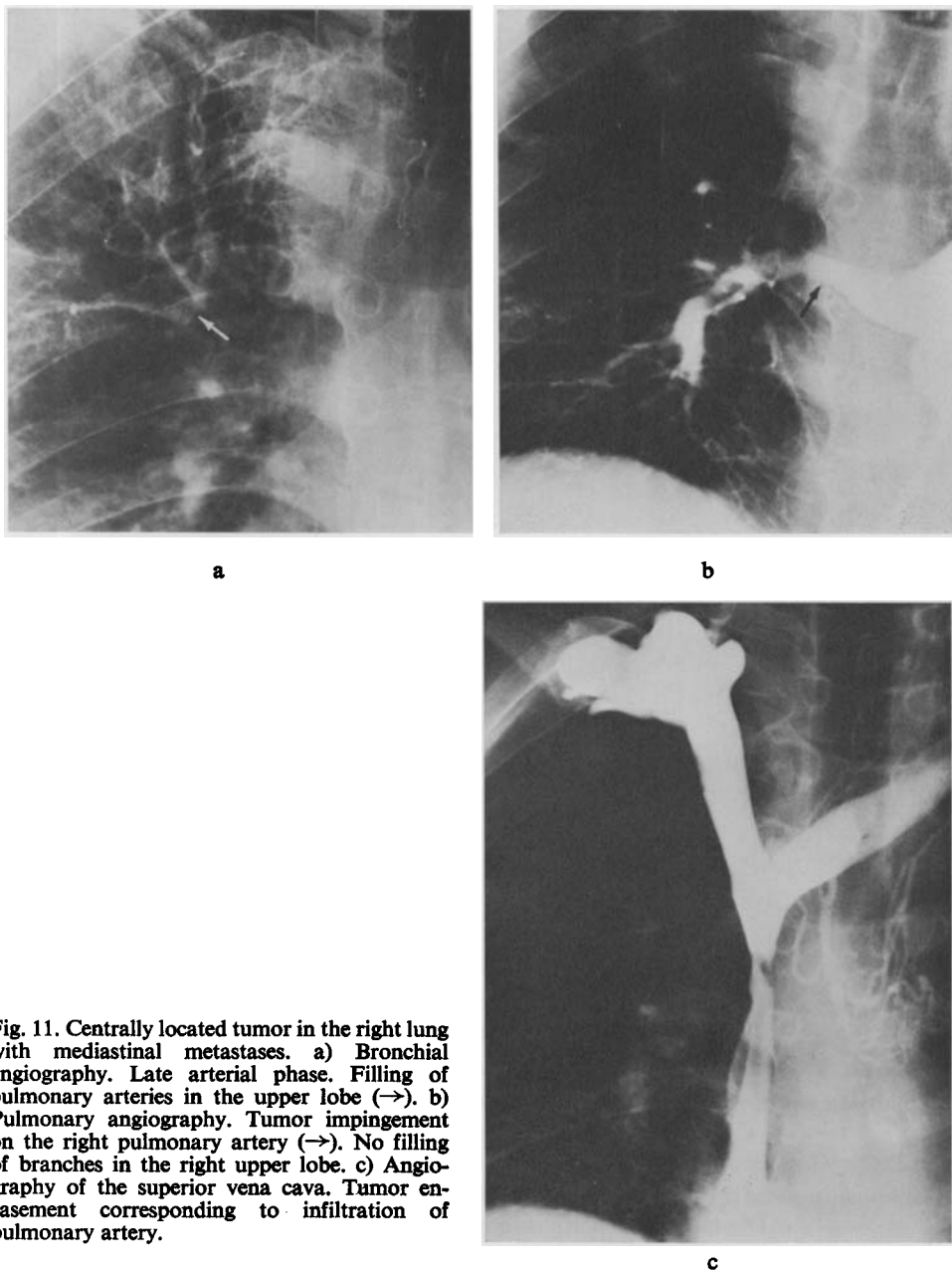
In another patient with two small squamous cell carcinomas centrally in the left lung, one of the left bronchial arteries gave off a branch to the right lung. The patient was treated twice with intraarterial infusions of mitomycin-C in the left bronchial arteries without any evident effect on the tumors. When he returned for a third course 4 months after the first infusion, tumor vessels were demonstrated below the right hilum supplied by the artery from the left side (Fig. 7). At subsequent bronchoscopy a third tumor was found in the right main bronchus. The tumor was not demonstrated on the chest films.

Direct spread to the pleura was demonstrated at angiography in one patient and a pleural metastasis in another. Both were confirmed at surgery. In neither case was there any evidence of pleural involvement on the chest films (Fig. 8).

*Bronchopulmonary arterial shunts* were found in 6 patients. In another case with tumor occlusion of the right bronchial artery an intercosto-pulmonary arterial shunt was demonstrated. All these patients had centrally located tumors.

In 4 patients only a small segment of one or two pulmonary arterial branches was demonstrated (small shunts), but in 3 patients filling of several segmental or lobar branches occurred (large shunts). In two of the latter patients a subsequent filling of the corresponding pulmonary veins also occurred (Fig. 9).

Selective pulmonary angiography was performed in 4 patients with small shunts at bronchial angiography and revealed proximal occlusion of the actual lobar artery in



**Fig. 11.** Centrally located tumor in the right lung with mediastinal metastases. a) Bronchial angiography. Late arterial phase. Filling of pulmonary arteries in the upper lobe (→). b) Pulmonary angiography. Tumor impingement on the right pulmonary artery (→). No filling of branches in the right upper lobe. c) Angiography of the superior vena cava. Tumor encasement corresponding to infiltration of pulmonary artery.

all of them (Fig. 10). In one patient an additional angiography demonstrated tumor encasement of the superior vena cava (Fig. 11).

In one of the patients with a small shunt a lobectomy could be performed. The other 6 were unresectable due to tumor growth in the mediastinum.

The initial clinical staging included 10 patients with stage I-II. Should the findings obtained at bronchial angiography have been taken in account, 3 of these patients should have been referred to stage III.

### Discussion

During the sixties, various attempts were made to use bronchial angiography as a diagnostic tool in pulmonary lesions, but the results were disappointing and the method therefore abandoned.

Though several papers describing the angiographic appearance of bronchogenic carcinoma have appeared (NEWTON & PREGER 1965, REUTER et coll. 1965, VIAMONTE et coll. 1965, NORDENSTRÖM 1965, BOTENGA 1970, NEYAZAKI et coll. 1970) no systematic attempt has been made to use bronchial angiography as an aid in the staging of these tumors.

REUTER et coll. demonstrated tumor vascularity in a mediastinal metastasis, and NEWTON & PREGER tumor supply by an intercostal artery suggesting invasion of the parietal pleura. They proposed the use of bronchial and pulmonary angiography to predict operability of bronchogenic carcinoma. Later SIMEONOV & KARDJIEV (1974) used the method and found it valuable in the estimation of the size of the tumor, but they did not report on any angiographic demonstration of lymph nodes.

BOTENGA (1970) described narrowing of the bronchial arteries as indicating tumor growth in enlarged lymph nodes but found accumulation of contrast medium within nodes to be an unreliable feature. On the other hand he found a good correlation between angiographically demonstrated transpleural vascularization of a tumor (usually from an intercostal artery) and penetration of the pleura by the tumor.

In the present material the size of the tumor was better demonstrated at angiography in 9 patients with central tumors, but in none of them did it affect the clinical staging as all of them had atelectasis of an entire lung or bronchoscopic findings rendering a stage III classification.

However, in 2 of them the tumor was not defined radiographically until demonstrated at angiography. This emphasizes the possibility of using bronchial angiography to localize a tumor in a patient with abnormal sputum cytology but no abnormal finding at chest radiography and fiber bronchoscopy.

Direct spread to the mediastinum may be impossible to detect preoperatively, especially if to a small extent and located in the lower mediastinum. In the upper mediastinum mediastinoscopy offers better diagnostic possibilities but still 15 to 20 per cent of accessible tumor-involved lymph nodes are missed and there are also parts in the mediastinum definitely beyond the reach of mediastinoscopy (LARSSON 1976).

It appears that bronchial angiography may be of help in these cases. In the present material angiography indicated mediastinal tumor growth in 11 of 15 patients; in 5 of the 11 no tumor was found at mediastinoscopy. In 3 of these angiography was the

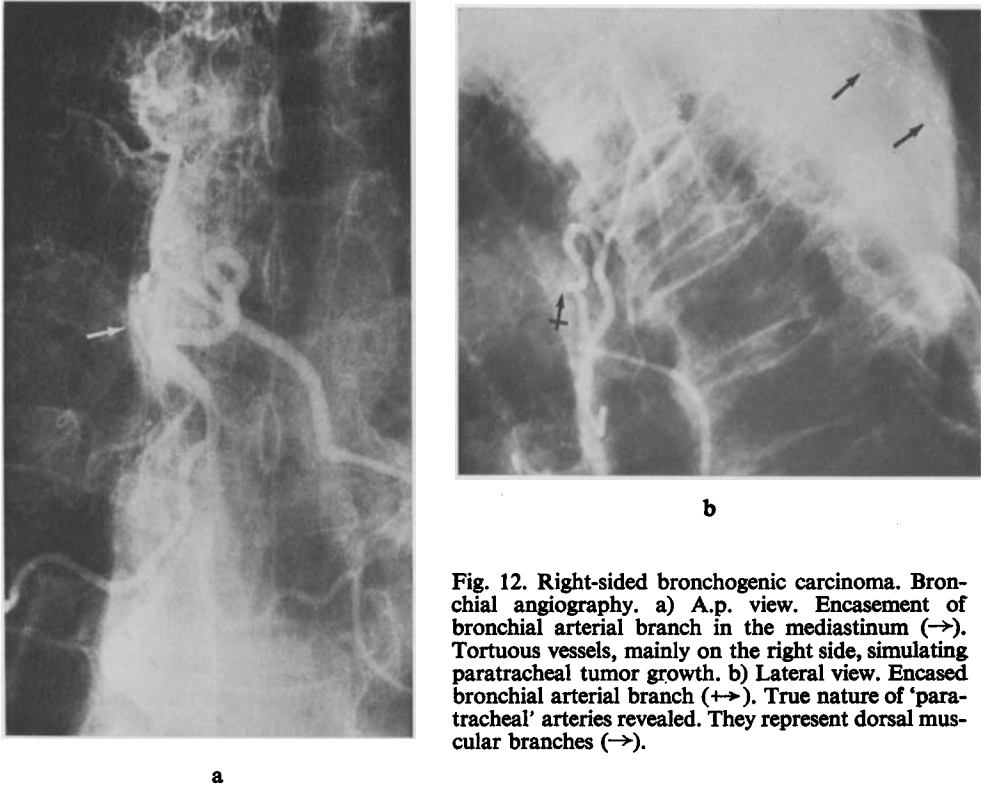


Fig. 12. Right-sided bronchogenic carcinoma. Bronchial angiography. a) A.p. view. Encasement of bronchial arterial branch in the mediastinum (→). Tortuous vessels, mainly on the right side, simulating paratracheal tumor growth. b) Lateral view. Encased bronchial arterial branch (↗). True nature of 'paratracheal' arteries revealed. They represent dorsal muscular branches (→).

only method demonstrating the mediastinal involvement. In the other 2 chest radiography and bronchoscopy suggested the diagnosis.

Especially in areas out of reach of mediastinoscopy, bronchial angiography offers improved diagnostic possibilities. That was the case in 3 patients in the present material.

The angiographic differentiation between direct and metastatic tumor spread to the mediastinum in the present material was based mainly on the location of the primary tumor in relation to the mediastinal growth. When both direct and metastatic spread was present it was not possible to make a differentiation with angiography.

Angiography failed in determining mediastinal involvement in 4 patients, and in 6 patients with both T3 and N2 only one of the two components was demonstrated. This is not surprising. The present material included only angiographies performed for demonstrating the tumor-feeding arteries, but not other bronchial arteries, intercostal or internal mammary arteries, all possible contributors to mediastinal and hilar metastases. It is therefore conceivable that a more extensive angiographic examination should increase the possibility of demonstrating metastases in these locations.

Preoperative assessment of direct or metastatic involvement of the tracheo-bronchial and pulmonary lymph nodes is difficult regardless of the method of in-

vestigation (LARSSON 1973). In the present material angiographic evidence of tumor growth in these nodes was found in 6 patients of 12 as was confirmed at subsequent surgery. Three of these patients had encasement of the proximal part of the bronchial artery, a finding also present in 2 other patients with abnormal mediastinoscopy but not operated upon.

BOTENGA (1970) suggested that such an encasement is a reliable angiographic indication of tumor growth, an opinion which is supported by the present results.

In 2 cases tumor spread to hilar lymph nodes was erroneously suggested. In one patient a faint accumulation of contrast medium occurred in a small area distal to the tumor, but no pathologic vessels were present in or around the area. At operation only anthracotic lymph nodes were present. In the other patient large lymph nodes were seen in the hilum. At operation the nodes were found to be hard and probably malignant. However microscopy only revealed a non-specific inflammatory reaction.

A differentiation between benign and malignant nodes on the basis of contrast accumulation alone therefore appears to be impossible. When combined with encasement of the bronchial artery or tumor vascularity in the area, the diagnosis is more reliable.

Regarding the angiographic diagnosis of paratracheal lymph nodes, a special pitfall is worth mentioning. Especially on the right side where the bronchial artery usually takes off together with an intercostal artery, dorsal muscular arterial branches may simulate paratracheal tumor growth on an a.p. film. A lateral view, however, reveals the true nature (Fig. 12).

The presence of precapillary bronchopulmonary arterial shunts in different pathologic conditions is well documented in the literature (WOOD & MILLER 1938, TURNER-WARWICK 1963, BOTENGA 1968, 1969). The two main circumstances under which they occur have been summarized by LIEBOW et coll. (1958): obstruction and diminished flow in the pulmonary arteries and formation of new tissue in the lung. According to BOTENGA (1970) they represent a non-specific phenomenon and rarely occur in patients with bronchogenic carcinoma. This is not in accordance with the present results.

Bronchopulmonary arterial shunts were demonstrated in 6 of 26 patients and in 5 of them the central tumor extension made a resection impossible. In the sixth patient who underwent a resection after intraarterial chemotherapy no viable tumor tissue was found in the resected lobe. The pulmonary artery to the tumorous lobe was surrounded by fibrous tissue considered to be a remainder of the original tumor. It is conceivable that compression from the tumor caused the shunt to appear at bronchial angiography.

Intercosto-pulmonary anastomoses transverse the pleura and are therefore always considered acquired. They have been described to occur after thoracotomy especially in patients treated for the tetralogy of Fallot but also after chronic inflammatory processes involving the lung and pleura such as tuberculosis of the upper lobes (BOTENGA 1970). The patient with a large intercosto-pulmonary shunt also had a

history of tuberculosis of the upper lobe on the same side as the shunt. It is conceivable that the size of the shunt partly was caused by impaired pulmonary arterial blood flow secondary to tumor impingement on the pulmonary artery.

$^{133}\text{Xe}$  spirometry was also used for preoperative staging. When reduced values are recorded they indicate an impaired circulation to the affected lung and the degree of reduction usually reflects the possibilities of excisional surgery (SVANBERG 1972). Markedly reduced values were observed in 4 of the patients with bronchopulmonary shunts and non-resectable tumors while only a slight reduction of function was found in the other two.

### Concluding remarks

In the selection of patients for this review 13 non-operable patients with no abnormality at mediastinoscopy had to be omitted because of lacking confirmation. Ten of these patients were classified as stage III and in 5 of them bronchial angiography indicated mediastinal or hilar involvement.

Due to the selection used, the present review cannot give full information concerning the number of angiographies which failed to demonstrate hilar or mediastinal tumor spread but the following conclusions appear reasonable:

(1) Bronchial angiography cannot exclude mediastinal or hilar involvement of a bronchogenic carcinoma.

(2) Angiographic indication of tumor spread to the mediastinum is reliable while accumulation of contrast medium within hilar nodes is non-specific in the absence of encasement of the bronchial artery or tumor vascularity in the area.

(3) Angiographic demonstration of a bronchopulmonary arterial shunt in a patient with bronchogenic carcinoma may implicate a central tumor involvement of the pulmonary arteries. A selective pulmonary angiography is therefore indicated before a resection is contemplated.

(4) Bronchial angiography is not suitable as a routine procedure in the evaluation of a patient with bronchogenic carcinoma, but when performed, e.g. in connection with intraarterial chemotherapy, it may contribute to a more precise staging of the tumor.

(5) In patients with positive sputum cytology but with no abnormality at chest radiography and bronchoscopy, bronchial angiography may be of value in locating the tumor.

### SUMMARY

Selective bronchial angiography was performed in 26 patients with bronchogenic carcinoma in connection with intraarterial infusions of cytostatic drugs. The angiographic extension of the tumor was correlated to data obtained at surgery, mediastinoscopy or autopsy. Bronchial angiography is not suitable as a routine procedure in the preoperative evaluation of patients with bronchogenic carcinoma but may contribute to a more precise staging of the tumor.

## ZUSAMMENFASSUNG

Eine selektive Bronchialangiographie wurde bei 26 Patienten mit bronchogenem Karzinom im Zusammenhang mit intraarterieller Infusion von zytostatischen Substanzen vorgenommen. Die angiographisch festgestellte Ausdehnung des Tumors wurde zu den Daten, die bei der Operation, Mediastinoskopie oder Autopsie erhalten wurden, relativiert. Die Bronchialangiographie ist nicht als Routinemethode zur präoperativen Untersuchung von Patienten mit einem bronchogenen Karzinom geeignet, kann jedoch zu einer genaueren Stadieneinteilung des Tumors beitragen.

## RÉSUMÉ

Une angiographie bronchique sélective a été faite en même temps que des perfusions intra-artinérielles de médicaments cytostatiques chez 26 malades atteints de carcinome bronchique. L'extension angiographique de la tumeur a été confrontée avec les constatations per-opératoires, la médiastinoscopie ou l'autopsie. L'angiographie bronchique ne convient pas comme méthode de routine pour l'examen pré-opératoire de malades atteints de carcinome bronchique mais elle peut contribuer à une détermination plus précise du stade de la tumeur.

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