The Esophageal Axis and Its Relationship to the Resectability of Carcinoma of the Esophagus

HIROSHI AKIYAMA,* TAKASHI KOGURE,** YUJI ITAI **

From the 2nd Department of Surgery and Radiology, Faculty of Medicine, University of Tokyo, Tokyo, Japan

THE RATE OF resectability of cancer of the esophagus is still less than 50% which is indicative of the difficulties in early detection. Despite improvement in recent years in detection of esophageal carcinoma, a high percentage of non-resectable cases is still the rule because of early infiltration into the surrounding mediastinum. Preoperative judgment concerning the resectability of a lesion and preoperative evaluation of surgical completeness or palliative procedures is of obvious importance. In evaluating esophagograms we have detected changes in the "esophageal axis" which made it possible to accurately predict the extent of local infiltration into the surrounding tissues.

I. Physiological Esophageal Axis

It is essential to understand the physiologic changes which may occur in the esophageal axis before it is possible to definitely identify pathologic changes.

As Klinkhamer [1] stated, the normal x-ray pattern of the esophagus has major curvings at the aortic arch and at the left main stem bronchus. Otherwise a relatively smooth esophageal axis is usually noted. The x-ray in Figure 1 was taken in the left anterior oblique position; the left main stem bronchus impression is distinctly seen.

The course of the esophagus is by no means constant at different ages. In daily practice, an exaggerated aortic arch impression in the aged, a marked curvature of the esophageal axis due to an enlarged heart, and compression or changes in the course of the esophagus due to abnormal elongation or tortuosity of the thoracic aorta are frequently noted (Fig. 2). In 100 control cases without specific esophageal disease, abnormalities in the esophageal course were studied in relation to age (Table 1). X-ray studies of each case were taken in the dorsoventral, right and left anterior oblique, and lateral position. No abnormalities were noted in the 20–29 age groups but in all other groups esophageal abnormalities were noted and increased in percentage with increasing age. It is in the age range of 50–70, which also shows the most rapid increase of physiologic abnormalities, that esophageal cancer most frequently occurs. In any study of the pathologic "esophageal axis," therefore, such physiologic abnormalities must be taken into consideration.

II. Abnormalities in the Esophageal Axis Due to Diseases Other Than Cancer

Diseases other than esophageal cancer frequently cause abnormalities in the course of the esophagus; these are classified into two groups: intrinsic esophageal diseases and diseases of surrounding organs (Table 2).

Figure 3 shows the aortogram of a 61-year-old man with an aneurysm of a markedly tortuous thoracic aorta. Esophagography revealed marked traction and fixation of the esophagus posteriorly along with the flexed aorta (Fig. 4). The patient did not complain of dysphagia or other symptoms even with this degree of distortion.

Figure 5 is an esophagogram of a 67-year-old man with bilateral apical tuberculosis. The trachea and upper esophagus are markedly retracted towards the right side. Other diseases occasionally show marked esophageal displacement and this fact should be kept in mind when evaluating changes in the esophageal axis.

Submitted for publication July 2, 1971.

* Present address: Dept. of Thoracic Surg., Tokyo Metropolitan Police Hospital, 2-10-41, Fujimi, Chiyoda ku, Tokyo

* * Dept. of Radiology, Univ. of Tokyo.

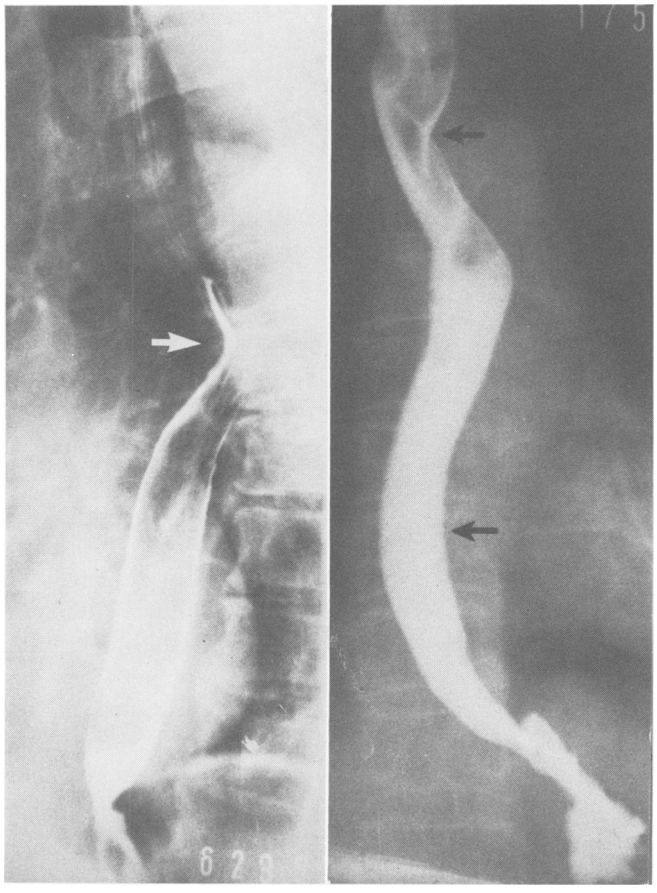

FIG. 1. (left) Distinct left main bronchus impression. FIG. 2. (right) Marked curving of the esophageal axis (65-year-old woman) due to the impression of the aortic arch and tortuous descending aorta.

III. Abnormalities of the Esophageal Axis in Carcinoma of the Esophagus

The esophageal axis was, as a rule, normal in patients with cancerous infiltration not penetrating the adventitia and with excellent mobility of the tumor allowing uneventful resection. The following abbreviations will be used to denote the clinical degree of penetration by the tumor:[2]

A_0: No infiltration into the adventitia
A_1: Slight infiltration into the adventitia
A_2: Definite infiltration beyond the adventitia
A_3: Infiltration of cancer into the neighboring organs

The same criteria were used for histological evaluation and the results were expressed as a_0, a_1, a_2 and a_3, respectively.

For example, Figure 6 is the esophagogram of a 65-year-old man with cancer of the mid-esophagus denoted by the funnel-shaped filling defect. No abnormality is

TABLE 1. *Abnormalities in Esophageal Axis by Age in 100 Control Patients*

Age	No. cases	Abnormal axis (%)
20-29	12	0/12 (0%)
30-39	21	1/21 (4.8%)
40-49	25	4/25 (16.0%)
50-59	20	12/20 (60.0%)
60-69	18	11/18 (61.1%)
70-79	4	3/4 (75.0%)
Total	100	31/100(31.0%)

TABLE 2. *Diseases Which May Produce Abnormalities in the Physiological Esophageal Axis*

A) Diseases of the esophagus itself
  Achalasia
  Esophageal diverticula (+ achalasia)
  Hiatal hernia
  Functional esophageal diseases, etc.
B) Diseases of the surrounding organs
  1) Changes related to aging
    Tortuosity of the thoracic aorta
    Enlarged heart
    Curvature of the vertebral column
  2) Miscellaneous
    Aneurysm of the thoracic aorta
    Pulmonary tuberculosis
    Congenital and acquired heart diseases
    Congenital abnormalities of the aortic arch
    Tumors of the posterior mediastinum, lungs and trachea
    Metastasis from tumors of other organs, etc.

FIG. 3. Aneurysm of the thoracic aorta (aortography) (61-year-old man).

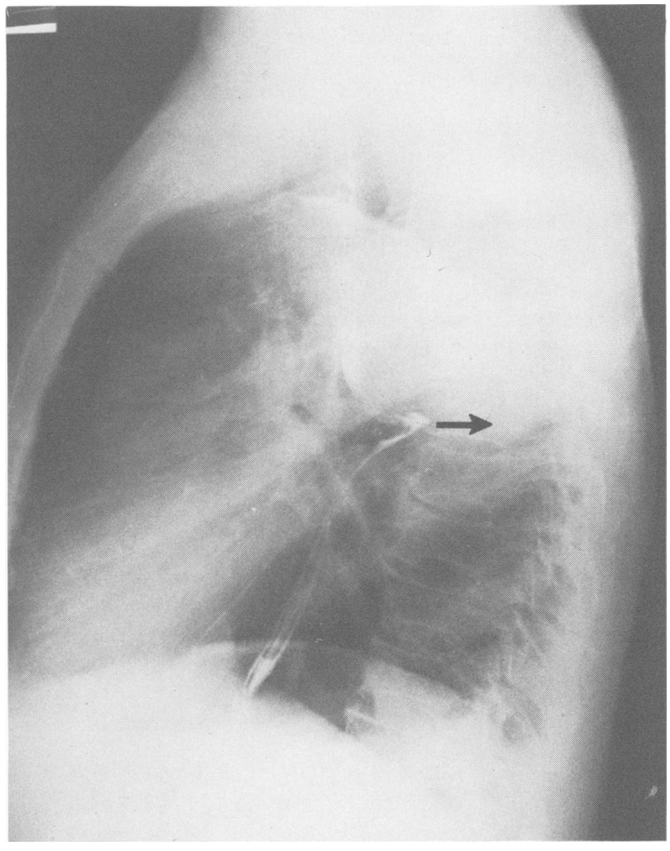

FIG. 4. Roentgenogram of the esophagus in the same patient. The esophagus is flexed and displaced posteriorly with the aorta.

seen in the esophageal axis and the tumor on the whole is located along the line of this axis. During resection, no macroscopic infiltration into the adventitia was noted; histologic examination confirmed this macroscopic evaluation.

Figure 7 is the x-ray of a 58-year-old woman with cancer of the mid-esophagus showing no abnormalities of the esophageal axis. At the time of resection, the macroscopic degree of penetration was A_0, and this was substantiated histologically (Fig. 8). Obvious metastasis to upper mediastinal lymph nodes, however, allowed only a palliative local resection. These cases may be taken as illustrative of the fact that the absence of deviation or flexion of the esophageal axis is very often associated with absence of infiltration into the adventitia. This, of course, unfortunately does not rule out lymphatic metastases.

Analysis of the abnormalities of the "esophageal axis" from the preoperative esophagograms was performed in cases where marked extra-adventitial infiltration had allowed only palliation. The following features were apparent in the studies (Fig. 9):

1) Tortuosity of the proximal side of the tumor.
2) Angulation of the esophageal axis.
3) Deviation of the esophageal axis. (a) Axis deviation above and below the tumor. (b) Axis deviation of the tumor. (c) Abnormality of distance from the spine.

Tortuosity on the oral side of the tumor probably occurs due to fixation of esophagus by tumor infiltration into the surrounding tissues with subsequent dilatation and elongation of the proximal side due to stenosis. The angulation and deviation of the axis are caused by traction which results from tumor infiltration into the adjoining tissues. This is seen especially in cases with deep infiltrating cancerous ulcers. Figure 10 illustrates proximal esophageal tortuosity. In this patient extensive direct infiltration was noted on the membranous portion of the tracheal bifurcation and only exploratory thoracotomy was performed.

Figure 11 is the esophagogram of a 65-year-old man with cancer of the mid-esophagus. The esophageal axis was normal in the right anterior oblique position, but is greatly angulated in the left anterior oblique view. In this case, extensive direct infiltration into the aorta (A_3) made palliative resection the only possible approach. As demonstrated by this case, the absence of axis abnormality cannot be concluded from one view, and observation from multiple directions is necessary.

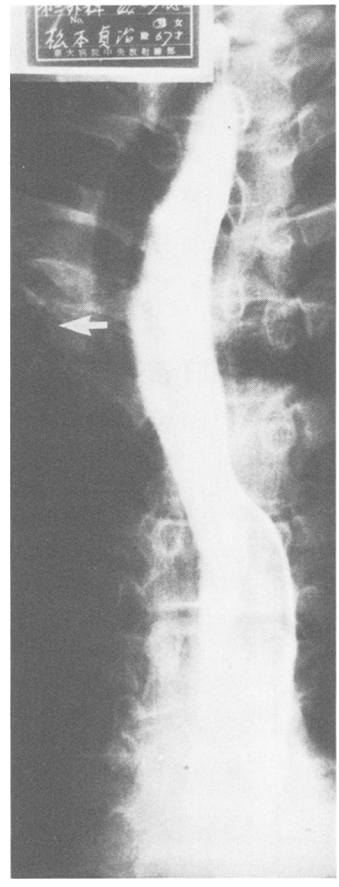

FIG. 5. 67-year-old man, with bilateral apical pulmonary tuberculosis greatest on the right. The trachea and esophagus are markedly retracted towards the right side.

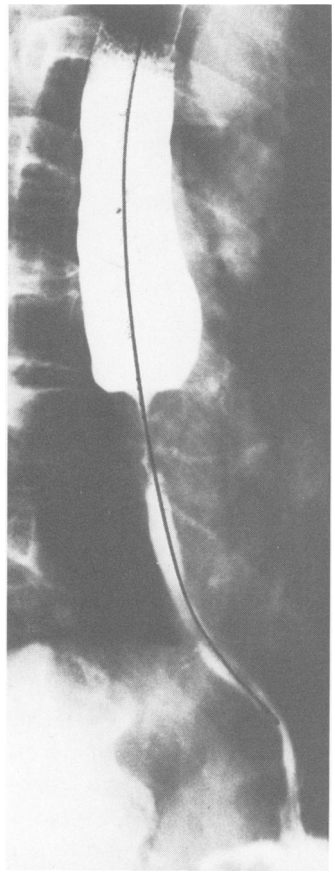

FIG. 6. A 65-year-old man with cancer of the mid-esophagus without an abnormality in the esophageal axis. A complete resection was performed.

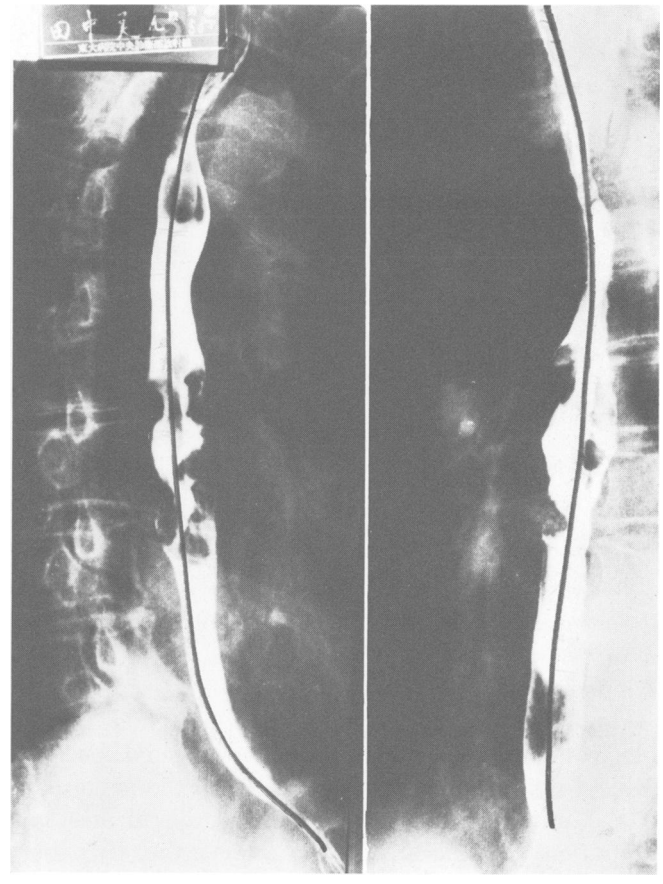

FIG. 7. A 58-year-old woman with cancer of the mid-esophagus. No abnormalities was noted in each direction.

Figure 12 shows the histopathologic findings in the same case. There is obvious adventitial penetration. Figure 13 is the esophagogram of a 65-year-old man, with angulation of the esophageal axis and an increased distance from the mid-line of the vertebral column. Operation revealed direct infiltration into the aorta (A_3) and only exploratory thoracotomy was performed. Figure 14 is a 61-year-old man, with cancer of the lower third of the esophagus. The dorsoventral view revealed axis deviation at the tumor itself. Thoracotomy revealed direct bilateral infiltration into the mediastinal pleura. Only incomplete resection was accomplished.

The relationship between abnormalities in the esophageal axis and operative results: X-ray studies of 82 cases of esophageal cancer collected from 1952–1960 were examined. Table 3 compared the abnormalities found in these x-rays with the results of operation. Among the 40 cases in which complete resection of the main lesion was successful, no abnormalities were found in the esophageal axis of 36 patients (90.0%). Unlike this situation are the 12 patients with palliative resection, 11 of whom (91.7%) showed abnormalities in this esophageal axis. In the 30 patients in whom only exploratory thoracotomy (or laparotomy) was carried out or no operation was performed, abnormalities in the esophageal axis were seen in 20 of 30 (66.7%) representing a somewhat

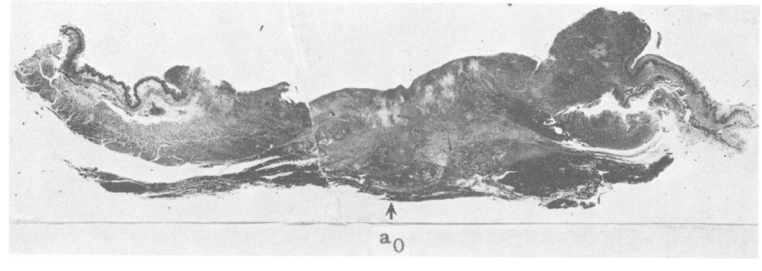

FIG. 8. The same case as shown in Fig. 7. In the center of the tumor the histological degree of penetration is a_0. (No infiltration into the adventitia.)

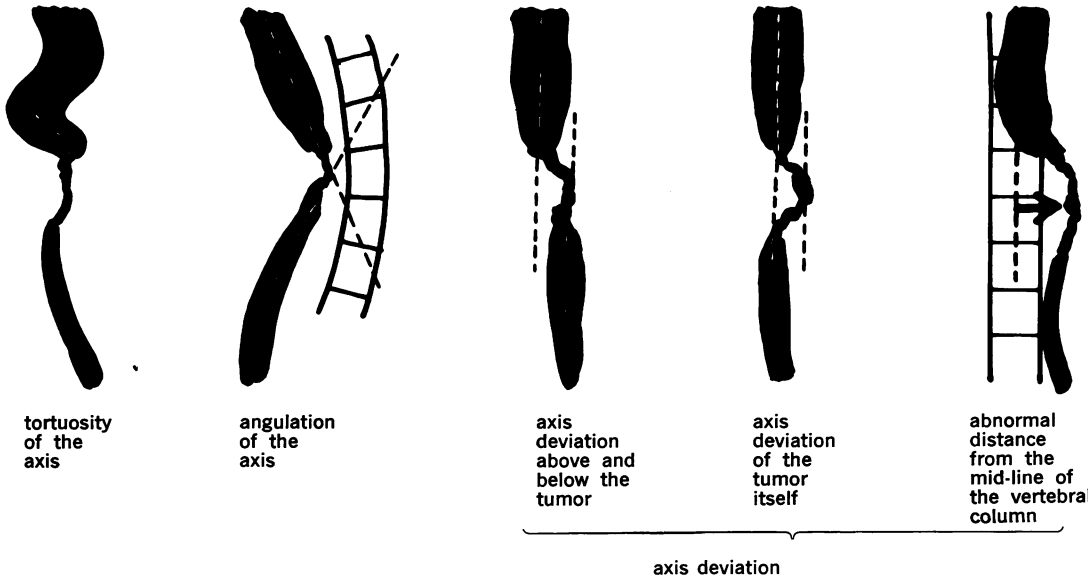

FIG. 9. Abnormal pattern in the esophageal axis due to cancer in which infiltration has exceeded the adventitia.

lower rate. This is probably due to other factors such as organ metastasis, extensive lymph nodes metastasis or a poor general condition.

Abnormalities in the esophageal axis and the histological degree of penetration in the resected specimen: Table 4 shows the relationship between the abnormality in the esophageal axis and the degree of histologic infiltration into the adventitia. Among the 40 patients in whom complete local resection was performed, the 36 patients who had no abnormalities in the esophageal axis also had no infiltration into the adventitia. Among 12 with incomplete local resection, stages a_2 to a_3 were noted in all 11 patients who preoperatively had demonstrated abnormalities of the esophageal axis.

Discussion

At the present time, esophageal cancer is non-resectable in about one half of the occurrences. An accurate preoperative judgment as to resectability of the lesion is therefore of prime importance. In its position as a mediastinal organ, the esophagus is in intimate relation with other vital organs of the thorax; it is understandable that esophageal cancer very early in its course becomes incurable. Modes of evaluation stated previously include azygography, radiography of the thoracic duct, mediastinoscopy, pneumomediastinum, and bronchoscopy. While each of these are useful methods, their actual examination is sometimes complicated and frequently does not give adequate information to help in evaluation.

Judgment of the resectability and prognosis of esophageal cancer has been attempted by numerous investigators based on the length, type[3] and site of the filling defect seen on esophagogram. A tumor with a long diameter of less than 5–6 cm. by x-ray was considered by many to represent a potentially curable lesion. Other workers considered a diameter of less than 10 cm. as an indication, provided preoperative irradiation was used. It became apparent that the length of the filling defect by itself was an inadequate criteria to base the resectability of a lesion. We have examined a series of cases, and by assessing the "esophageal axis" have attempted to determine the local condition of the tumor and its degree of infiltration into the surrounding tissues. A complete

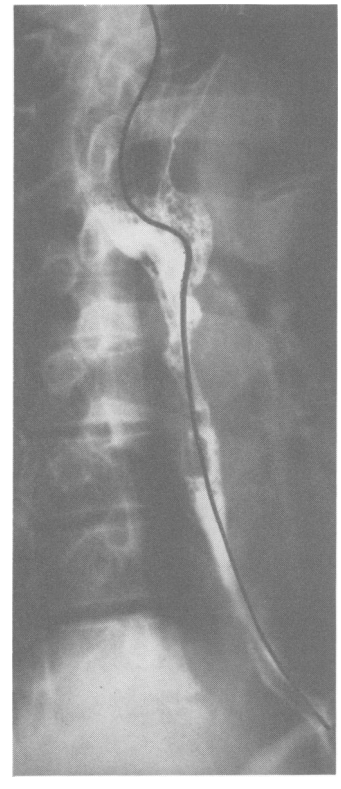

FIG. 10. A 59-year-old man with cancer of the mid-esophagus demonstrated tortuosity on the proximal side of the tumor. Due to the presence of extensive infiltration into the bronchus (A_3), only an exploratory thoracotomy was performed.

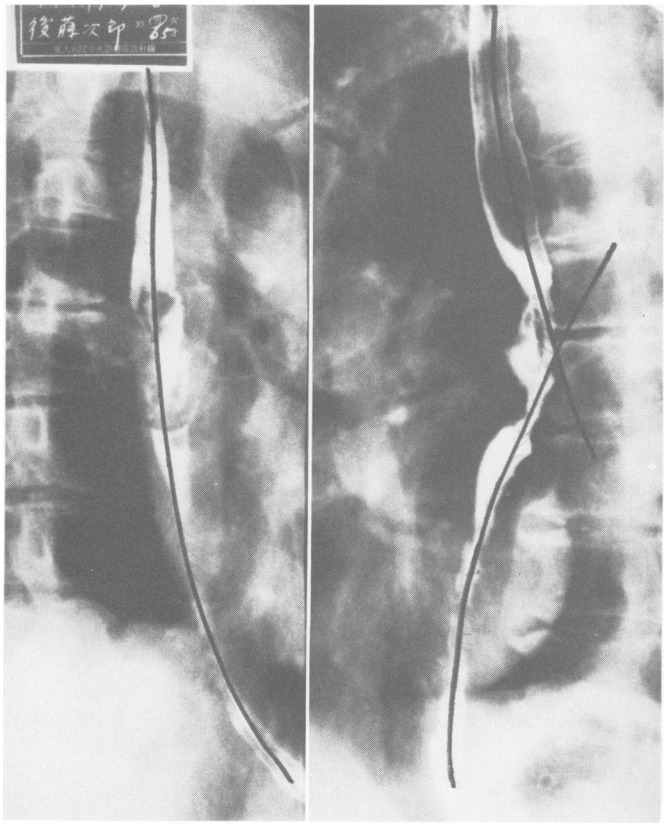

FIG. 11. 65-year-old man, Cancer of the mid-esophagus: the right anterior oblique position, the esophageal axis was normal, but the axis shows angulation in the left anterior oblique view. Extensive direct infiltration into the aorta (A_3) limited surgery to an incomplete resection.

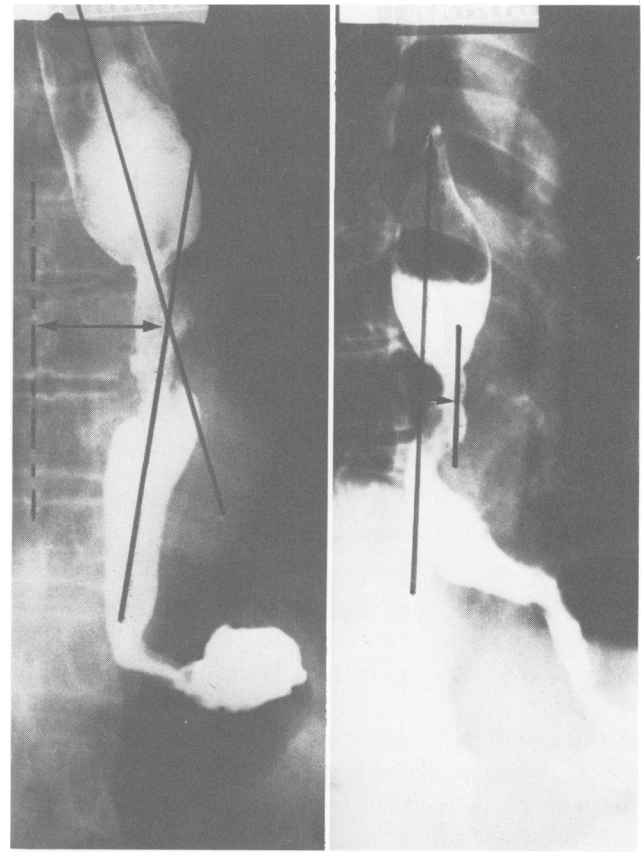

FIG. 13. 65-year-old man, Cancer of the mid-esophagus; angulation of the esophageal axis and an increased distance from the mid-line of the vertebral column is noted. FIG. 14. 61-year-old man, Cancer of lower third of the esophagus: Axis deviation of the tumor itself is present. Infiltration into the mediastinal pleura bilaterally limited operation to an incomplete resection.

study of the esophageal axis must include the physiologic course and natural changes seen with aging, and it is important to avoid the confusion which may arise with these "normal" axial changes seen as a result of aging. Abnormality of the esophageal axis due to non-cancerous diseases should also be kept in mind.

When esophageal cancer showed marked infiltration through the adventitia and/or into the surrounding tissue, abnormalities in the esophageal axis such as tortuosity on the proximal side of the tumor, angulation of the esophageal axis, and deviation in the esophageal axis was observed. These findings showed excellent agreement with the operative and histologic observations. By application of these facts, useful criteria are available for the evaluation of resectability of each particular tumor, in addition to the conventional x-ray classification or simple measurement of the long diameter of the tumor. In view of cases in which unresectability was found despite a preoperative diagnosis of resectability based on the length of a filling defect, and in other cases with scarcely any adventitial infiltration despite a long length of a tumor, it is apparent that other criteria of

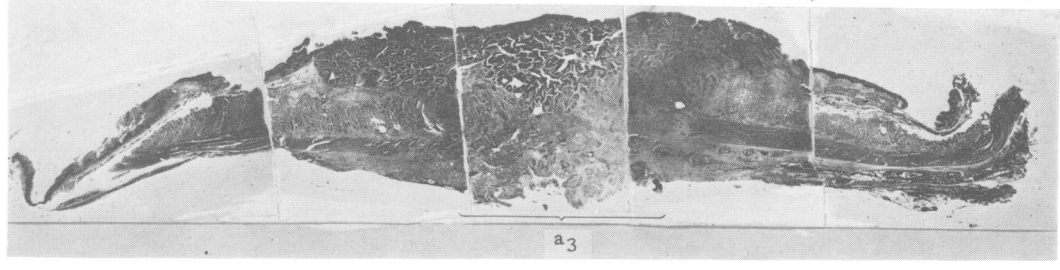

FIG. 12. Histopathological findings of the case shown in Figure 11 (a_3).

TABLE 3. *Abnormalities of Esophageal Axis and Results of Operation*

Results of Operation	No. Patients	Abnormalities of Axis (+)	Abnormalities of Axis (−)
Curative resection	40	(4/40) 10.0%	(36/40) 90.0%
Non-curative resection	12	(11/12) 91.7%	(1/12) 8.3%
Non-resectable	30	(20/30) 66.7%	(10/30) 33.3%
Totals	82	(35/82) 41.5%	(47/82) 58.5%

preoperative evaluation such as the "esophageal axis" must be utilized.

Conclusions

Evaluation of the resectability of esophageal cancer was approached by studying the "esophageal axis" in 82 patients. By detection of abnormalities in this parameter, cancerous infiltration into the adventitia or surrounding organs may be predicted with considerable accuracy, according to this retrospective study of operative findings correlated with histopathological observations. Abnormalities of the esophageal axis present as 1) tortuosity on the proximal side of the tumor 2) angulation of the esophageal axis and 3) deviation of the esophageal axis consisting of a) axis deviation above and below the tumor, b) axis deviation of the tumor itself c) or abnormal distance from the mid-line of the vertebral column. While these facts are straightforward and may well have been utilized vaguely by many workers, a comparison with operative and histological findings is reported and improved preoperative prediction is suggested.

TABLE 4. *Abnormalities of Roentgenological Esophageal Axis and Depth of Cancer Invasion*

Microscopic Depth of Invasion	Curative Resection		Non-curative Resection	
	Abnormalities of Esophageal Axis			
	(+)	(−)	(+)	(−)
pmc		4		
pml	1	3		
a_1	3	29		
a_2			3	1
a_3			8	
Totals	4	36	11	1

Key: pmc: up to the circular muscle
pml: up to the longitudinal muscle
a_1: beyond the muscle layer but not into the adventitia
a_2: definite infiltration beyond the adventitia
a_3: infiltration into the surrounding organs.

Acknowledgment

The kind permission by Drs. Akira Ueno and Yusuke Tada for use of the findings shown in Figures 3–4 is appreciated.

References

1. Klinkhamer, A. C.: Esophagography in Anomalies of the Aortic Arch System. Excepta Medica Foundation, Amsterdam, 1969.
2. Japanese Society for Esophageal Diseases: Descriptive Rules for Carcinoma of the Esophagus. Kanehara, Tokyo, 1969.
3. Nakayama, K. and Hirota, K.: Experience of about 3000 Cases with Cancer of the Esophagus and the Cardia. Austr. New Zeal. J. Surg., 31:222, 1962.