

Treatment of the Superior Sulcus Tumor by Irradiation Followed by Resection *

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BRONCHOGENIC carcinomas that develop peripherally and invade the chest wall produce a painful syndrome that has been therapeutically difficult to control. The parietal pleura rather than being a barrier to extension invites spread of the neoplasm as soon as the lymphatics in the endothoracic fascia have been invaded. This is particularly true of neoplasms developing peripherally in the upper lobes invading the superior sulcus of the chest. Intercostal nerves, and the lower roots of the brachial plexus become involved causing severe unrelenting pain in the shoulder and down the arm. Invasion of the sympathetic chain causes the Horner's syndrome. Generally such neoplasms have been considered unsuitable for surgical therapy. It is the purpose of this paper to report the authors' experience with 18 patients having bronchogenic carcinomas that invaded the chest wall in the region of the superior sulcus who were treated by means of preoperative irradiation followed by surgical resection.

Introduction

Pancoast⁷ described these lesions and the signs and symptoms they produce, in 1924. Since then they have been called Pancoast tumors or superior sulcus tumors. He did not recognize them as being primary bronchogenic carcinomas and in a later paper, in 1932,⁸ suggested that they arose

from embryonal epithelial rests of the last branchial cleft. He suggested that they be called superior sulcus tumors although he admitted that better knowledge of the histopathology of the growth "may change this new designation." Among the observations that Pancoast made concerning the superior sulcus tumor two are particularly significant. In the cases he observed he wrote that "Death occurred as a result of what seemed to be a comparatively trivial growth without detectable metastases roentgenologically" and that in regard to prognosis the growth had "resisted all efforts at irradiation treatment, it is obviously not subject to surgical removal although it is accessible, and it is rather rapidly fatal." Further experience has demonstrated that the superior sulcus tumor is responsive to irradiation therapy (though seldom curable) and that the growth if not too extensive is accessible and can be resected after preoperative irradiation. Further, it has been found that certain patients subjected to such a regimen not only receive palliation from the painful syndrome but survive without evidence of recurrence for a sufficient period of time to suggest that cure may be possible.

The diagnosis of this neoplasm is often not apparent when the patient first consults his physician. The initial complaint is a steady localized pain in the shoulder and upper chest, often knifelike in severity, that is referred along known anatomic nerve pathways. The pain typically affects the ulnar distribution of the arm. Roent-

* Submitted for publication December 5, 1960.

Read at annual meeting of the Southern Thoracic Surgical Association, Nassau, Bahamas, November 17-19, 1960.

genograms of the chest by regular technics may not suggest an abnormality. However, planigrams and films taken to show bony detail may reveal a lesion in the superior sulcus with evidence of bone erosion. The additional presence of a Horner's syndrome, completing the Pancoast syndrome, is diagnostic of a neoplastic process invading the superior sulcus of the chest. Tumefaction in the cervical fossa and massive erosion of the posterior ends of the upper ribs and transverse processes of the vertebrae are signs of an advanced neoplasm that could have been recognized earlier in its life history. Physicians should be alert to the significance of steady localized shoulder pain referred along known nerve pathways and employ suitable radiographic technics in an attempt to demonstrate the etiologic lesion.

The patient who comes to the doctor's office cradling the elbow of an arm in the palm of the opposite hand, having an expression of pain on his face, and with an obvious Horner's syndrome needs special studies only for confirmation. The diagnosis of a superior sulcus tumor is apparent. Usually the patient is already taking narcotics for relief of pain. The clinical course will be progressively downhill. Increasing doses of narcotics and neurosurgical procedures for relief of pain may all be required until death brings relief. In our experience the longest survival following diagnosis in six patients not treated with specific therapy has been ten months. Nine patients received irradiation therapy with some temporary relief of pain but the longest survival was only 13 months. Eight patients had surgical resection followed by irradiation therapy. Only three survived more than a year with the longest survival being 27 months. Local recurrence occurred in all of these patients and in all eight death was due to neoplasm. Intramedullary tractotomies were done on several patients in the terminal phase of their illness. From the standpoint of patient

suffering this is probably the most distressing form of bronchogenic carcinoma.

Surgical Treatment

Surgical attempts to eradicate superior sulcus tumors producing the Pancoast syndrome have been disappointing and the lesion has been considered technically inoperable. The problems in attempting to completely excise the growth are formidable, and in most cases the surgeon has been content with a biopsy specimen of the tumor. Irradiation therapy frequently is advised following thoracotomy, and although some palliation might result it is short lived and the pain almost always recurs. Dontas² recently has reported treating eight patients having superior sulcus carcinomas with incomplete resection followed by irradiation therapy. Although temporary palliation resulted the longest survival was 35 months in those treated more than a year at the time of the report. He advised operation as a palliative measure and concluded that "The combination of surgical treatment with radiotherapy would give the best hope in the management for this type of growth." Other sporadic attempts to resect the lesion have been reported but the tumor invariably recurred and the operation was thought to have been of little benefit. Walker⁹ in reporting a case of superior sulcus tumor in 1946, stated "Death has occurred in all cases recognized up to the present time. In no instance has it been possible to remove the tumor surgically. However, with increasing knowledge of the syndrome earlier recognition may render surgical cure in some cases possible."

The prediction of Walker⁹ was borne out by the report of Chardack and MacCallum³ in 1953, that they had carried out a successful *en bloc* resection of a bronchogenic carcinoma in a right upper lobe which had invaded the dome of the chest involving the sympathetic chain and the

brachial plexus. Three weeks following operation irradiation therapy was begun and in 54 days, 6,528 r were delivered to the general tumor area. In a follow up report of this same patient in 1956,⁴ they stated that he lived a normal life five years and ten months following the combination of surgical and irradiation treatment handicapped only slightly by neurologic defects in the right hand. Postmortem examination, after death from an unrelated cause, revealed no evidence of recurrence or metastases. This case of Chardack and MacCallum is the only reported cure of a superior sulcus tumor. As will be developed in the discussion that follows adequate surgical resection was probably responsible for the cure and it is doubtful that the subsequent irradiation therapy contributed to the final result.

The superior sulcus tumor is usually a rather orderly epidermoid or adenocarcinoma. In the confined space at the apex of the lung, invasion of the chest wall occurs more readily than spread toward the hilum. As soon as the pleura and intercostal nerves are invaded, pain results which quickly calls the patient's attention to it, although unfortunately there may be some delay before the true cause of the pain is recognized due to the absence of pulmonary symptoms. Even though the neoplasm invades the subpleural lymphatics, ribs, intercostal structures and the ulnar division of the brachial plexus it may remain a localized lesion for many months. Patients succumbing to the neoplasm may have no evidence of metastases at postmortem examination. It would seem that such a neoplasm should be detected in its early biologic phase and that surgical removal would be feasible.

The chief deterrent to the surgical attack on the superior sulcus tumor has been its relative inaccessibility and the reluctance to excise structures invaded. With adequate exposure by a long parascapular incision the growth is surgically accessible.

Furthermore, none of the structures usually found to be invaded are necessary to the economy of the body and therefore can be sacrificed. Ribs, intercostal structures, sympathetic nerves, brachial plexus roots, transverse processes, and even portions of the bodies of the vertebrae can all be excised *en bloc* along with the involved pulmonary segment. The fact that permanent neurologic defects may result is of little consequence in respect to the total problem. The crippled arm, free of pain, is still a more useful member of the body than the arm was when every motion causing a tug on the brachial plexus resulted in excruciating pain. The symptom producing lesion is a neoplasm and structural and cosmetic faults must be accepted as a residual of its eradication. Involvement necessitating resection of a portion of the subclavian artery would be a more serious deterrent to operation but experience has shown that resection of the artery should seldom be necessary (once in 18 patients in this series). Replacement by means of grafts is also possible. Thus, the superior sulcus tumor is a neoplasm often detected in an early biologic phase, accessible to surgical excision, and usually involves structures that can be sacrificed leaving minimal disability. Unfortunately, spread of the growth in the subpleural lymphatics and perineural sheaths necessitate such wide surgical excision that it seems almost impossible to encompass the growth. It is for this reason that recurrence has been the rule following resection.

Irradiation Therapy

The superior sulcus tumor is more radioresponsive than is reflected by reports in the literature. Pancoast,⁵ a radiologist, in his second report (1932) said these growths "Resisted all efforts of irradiation treatment." Walker⁹ believed, "irradiation has not been of even palliative benefit." Herbut and Watson⁶ in 1946 stated, "Roentgen therapy so far appears of no

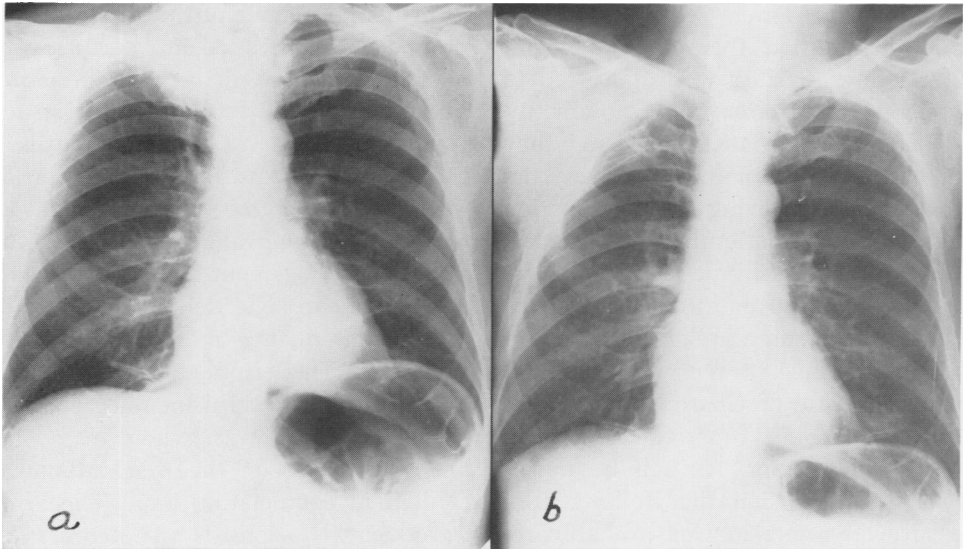


FIG. 1a. Peripheral squamous cell carcinoma (Pancoast tumor) involving chest wall and invading brachial plexus causing severe pain in upper chest, shoulder, and along the ulnar distribution to the right arm. One month following irradiation therapy the neoplasm was excised en bloc removing the apicoposterior segment of the upper lobe and involved portions of ribs and bodies of the vertebrae. b. Appearance of chest one year following resection. The patient is well without pain 51 months following surgery.

avail." Haas, Harvey, and Langer⁵ more recently, however, (using 23 MEV betatron equipment) have reported treating four patients having superior sulcus tumors. One patient was living and well 34 months following therapy. The second received relief of pain and worked for 17½ months before dying at home of an unknown cause. A third was working without symptoms eight months following treatment and the fourth had had early relief of pain. Haas *et al.*⁵ employed a half curative tumor dose (5,000 r with betatron unit—equivalent to 3,000 r with 400 KV). Many of the earlier reports of therapy dealt with irradiation given either after the tumor has been disturbed by the surgeon at thoracotomy or diagnosed late when there was massive involvement of the upper thorax and neck. Time may prove that irradiation therapy given over undisturbed growths in an early biologic phase may not only give palliation but be curative.

There is no evidence that irradiation following resection improves results over operation alone. On the contrary there is

much evidence that irradiation over a partially resected neoplasm is powerless to check advance of the residual neoplasm. In certain instances when a neoplasm has been observed to grow slowly over a period of years incomplete resection leaving behind no visible neoplasm will cause an explosive invasion of tissue by the residual neoplasm which irradiation is powerless to check. There are no reports of successful eradication of a superior sulcus tumor following partial resection and subsequent treatment with implantation of radium needles, radon seeds, or deep irradiation therapy. It is for this reason that it was observed above that the cure reported by Chardack and MacCallum⁴ probably was due to an adequate *en bloc* surgical resection of the neoplasm and that subsequent irradiation therapy added nothing of value.

Present Series

The present series consists of 18 patients with bronchogenic carcinoma in the superior sulcus treated by means of a combination of preoperative irradiation and

surgical resection. Fourteen of these patients were men and four were women. Their ages varied from 34 to 73 years, being distributed as follows: age group 30 to 39—3; 40 to 49—6; 50 to 59—7; 60 to 69—1; and 70 to 79—1.

The dose of preoperative irradiation employed in the 18 patients reported here has been in the range of 3,000–3,500 r given in a period of approximately two weeks. This is not considered a curative dose but is one which limits growth, blocks lymphatics, and destroys nests of malignant cells in the perineural sheaths. Irradiation has been given with the Cobalt 60 unit when convenient because it seems to be better tolerated by the patient and causes less skin reaction. It has not been shown, however, on examination of resected specimens after irradiation that irradiation with Cobalt 60 resulted in greater injury to the neoplasm than therapy using conventional 250 KV therapy units.

Pathologic examination of resected growths one month following irradiation with either standard equipment or Cobalt 60 and maxitron units has shown that therapy has profoundly altered the neoplasm (Fig. 1a, b, 2a, b, c). The subpleural lymphatic channels surrounding the neoplasm have been fibrosed and no neoplastic

cells can be found in them. The periphery of the tumor has been reduced to an amorphous fibrous mass so that it is necessary to take sections deep within the lesion to find neoplastic cells. In the intermediate zone scattered pyknotic nuclei can be seen as remains of damaged cancer cells. Observation of these growths one month following irradiation indicate that they have been sharply localized and that it should be possible to carry the line of the dissection much closer to the neoplasm without fear of subsequent local recurrence. This observation along with the demonstration by roentgen studies before and following irradiation therapy showing reduction in the size of the tumor suggest that the chances of successful surgical eradication of the tumor are enhanced by giving preoperative irradiation.

The timing of the operation approximately one month following completion of irradiation therapy is empirical but does rest upon certain clinical impressions. This period of time allows evaluation of the radioresponsiveness of the neoplasm (Fig. 5a, b). As a rule there is some palliation of pain and the patient eats and sleeps better and thus comes to operation in an improved state. A period of a month allows time for the skin reaction to partially sub-

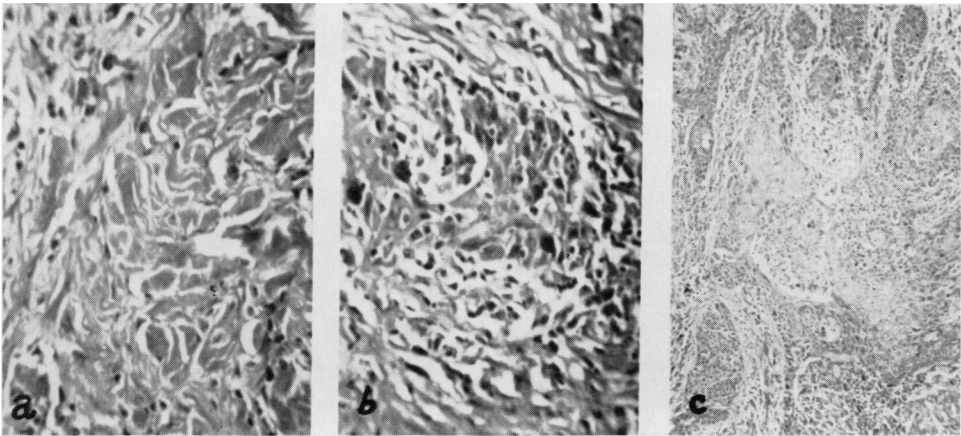


FIG. 2. Photomicrographs of sections of neoplasm excised in first patient of this series (Fig. 1a, b) showing postirradiation changes. a. Peripheral zone showing marked sclerosis with no recognizable neoplasm. b. Intermediate zone showing pyknotic nuclei presumably remains of neoplastic cells. c. Central zone showing typical squamous cell carcinoma.

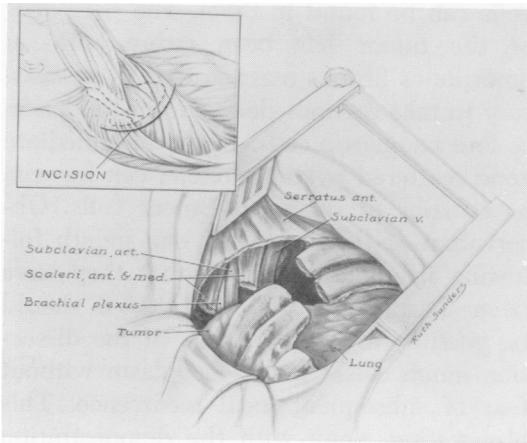


FIGURE 3.

side permitting better healing of the incision. Also the lapse of time may permit distant metastasis to make its presence known and thus avoid fruitless operation. It has not been found that the dissection of structures neighboring the neoplasm has been made more difficult due to irradiation fibrosis if the operation is done at this interval following therapy.

The surgical technic may vary to some degree depending upon the size of the growth but in general the approach is uniform (Figs. 3, 4). A long parascapular incision should be used starting just above the spine of the scapula and extending around the lower tip of the scapula and ending in the anterior axillary line. It should not be necessary, and is not desirable from the functional standpoint, to cut completely through the upper portion of the trapezius and levator scapulae muscles since they support the shoulder girdle. Almost complete sectioning of the anterior serratus muscle will allow good elevation of the shoulder to expose the apex of the thoracic cage. A long length of the fourth or even the third rib is removed avoiding at first the posterior portion or a suitable interspace may be entered for exploration. The pleural cavity is opened sufficiently wide to allow appraisal of the extent of the growth. The superior external oblique muscle is sepa-

rated at its insertion on the ribs and preserved for later use in closing the thorax. The sacrospinalis muscle is separated by sharp dissection from the upper ribs and transverse processes to the lamina. The incision is then carried through the ribs and intercostal muscle bundles anterior to the growth allowing an adequate margin of normal tissue. After the first rib is cut the end of the portion to which the growth is attached is pulled downward to put under tension the cervical structures involved in the tumor.

Dissection of the subclavian artery away from the growth may be tedious. Branches of the artery including the internal mammary, transverse cervical, and at times the vertebral may have to be sacrificed. After freeing the subclavian artery attention is turned to the roots of the brachial plexus. All roots obviously involved are sacrificed. Usually only that part of the plexus coming from the eighth cervical and first thoracic nerves which goes to the ulnar nerve is involved. When the plexus has been freed from the growth the musculotendinous tissue is divided by sharp dissection above the first rib and transverse process down to the lamina of the vertebra. The musculotendinous tissue beneath the lowermost uninvolved rib is then divided to the lamina. At this point there remains a mass of bony attachment made up of ribs, transverse processes, and involved portions

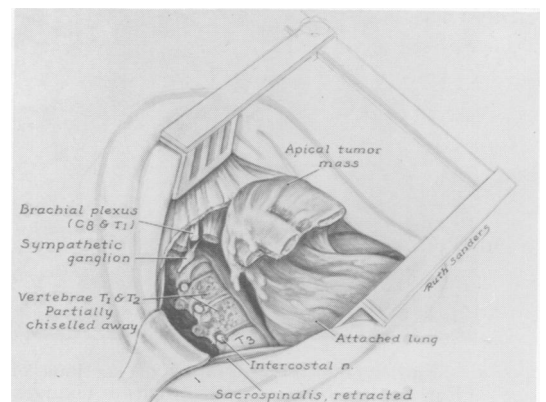


FIGURE 4.

of the bodies of the vertebrae with included intercostal vessels and nerves. The ribs and transverse processes are cut with bone shears. If possible, it is desirable at this point to tense the intercostal nerves so that they can be divided behind the ganglion in the intervertebral foramina. The remaining bony attachment is chiseled away cleanly using a flat orthopedic chisel. As much as one fourth of the bodies of the involved vertebrae have been removed in this manner without disturbing the spinal support. A gauze pack temporarily controls the bleeding from the intercostal vessels and cancellous bone. When the pack is removed active bleeding points are controlled. If there is escape of cerebrospinal fluid when the dural cuff surrounding an intercostal nerve is cut across this can be controlled by suturing an excised portion of muscle into the intervertebral foramina. The resection of the growth is now completed by segmental resection or upper lobectomy. Lymph nodes in the upper mediastinum should be dissected and removed. Attention is now turned to closure of the chest. Adequate pleural drainage should be established bearing in mind the raw surfaces in the dome of the chest. The preserved posterior superior oblique muscle is used either to control oozing from the raw bony surfaces or to aid in the closure of the defect in the bony cage. Large defects in the chest wall where paradoxical motion may prove troublesome can be bridged by the use of plastic mesh. However, usually the remaining defect can be covered adequately by closure of the muscles of the shoulder girdle, subcutaneous tissue, and skin.

Complications

Complications following resection of superior sulcus tumors have been few. Subcutaneous emphysema, in spite of the large chest wall defect created, has not been troublesome. Because of oozing from the exposed raw surfaces of the apex of the chest it is usually necessary to leave

the intercostal drainage tubes in place longer than with the usual lobectomy. Excessive bleeding into the pleural space has not occurred. Raising of secretions and re-expansion of the remaining pulmonary segments has not been a problem.

The most severe complication encountered was persistent drainage of cerebrospinal fluid in one patient which led to an eventual meningitis (Fig. 5a, b,-7a, b). This was finally brought under control by massive doses of antibiotic drugs and the patient is now free of central nervous system residua. This patient was very ill during a portion of his postoperative course and his period in the hospital was prolonged. It is felt that this complication could have been prevented by giving more attention to sealing the leak with a plug of muscle at the time of operation or by removing the spinal fluid by thoracentesis rather than by prolonged use of an intercostal tube.

A persistent air leak occurred in one patient that led to a small apical empyema that required prolonged open tube drainage. This finally healed and although the patient died nine months later of a cerebral metastasis this complication did not contribute to the the end result since postoperatively the patient was free of pain in the shoulder and arm. One patient developed a staphylococcus empyema that was considered to be unrelated to the type of resection. The empyema healed with antibiotic therapy and adequate drainage.

The neurologic defects remaining following resection of the superior sulcus tumor are in general not crippling and will be minimized by early detection of the neoplasm. In the usual case nerves C8 through T3 must be sacrificed along with the stellate ganglion and upper fibers of the sympathetic chain. This produces numbness along the ulnar distribution of the hand and the undersurface of the arm to the elbow. More distressing is the loss of fine motions of the hand which in the

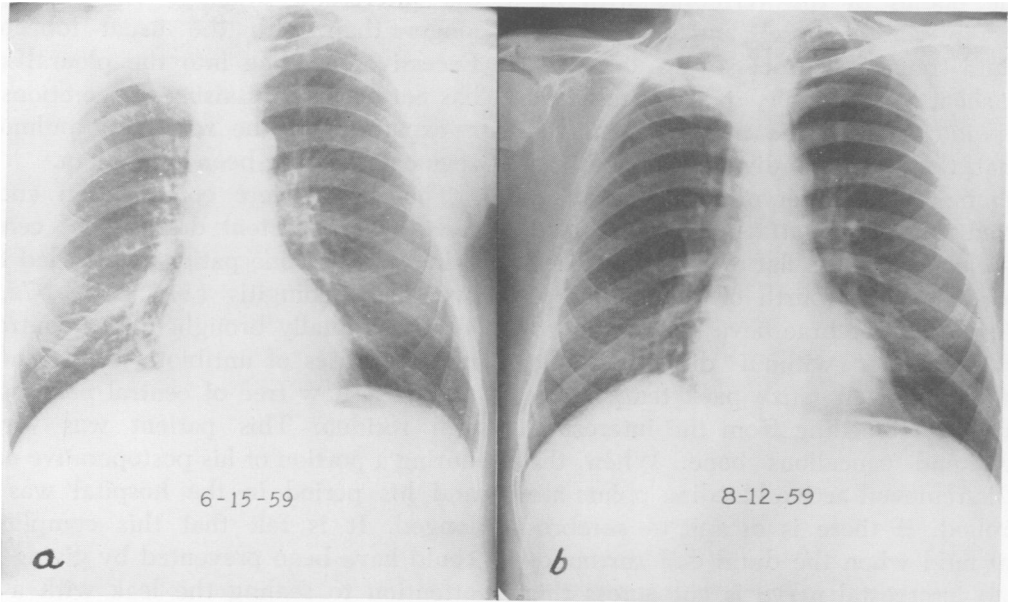


FIG. 5a. (Case 9). Superior sulcus tumor (squamous cell carcinoma) causing typical Pancoast syndrome. Note extension of tumor along the upper thoracic vertebrae. b. Roentgenogram of same patient two months later (one month postirradiation). Note resolution of the neoplasm. At this time the patient was almost free of pain.

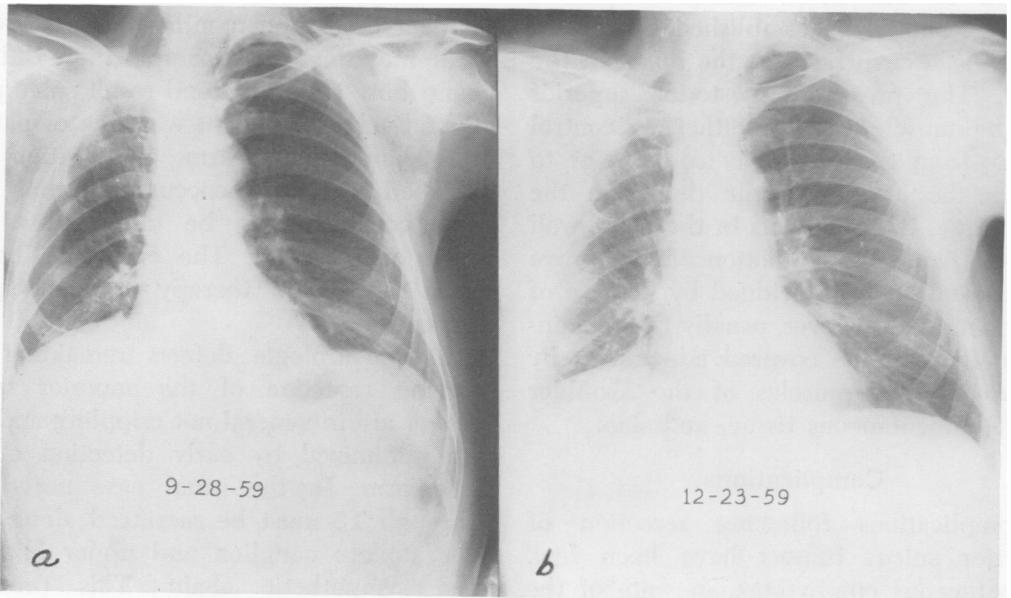


FIG. 6a. (Case 9). Six weeks following resection a small air pocket remains at apex of right chest. This patient developed a severe meningitis due to persistent drainage of cerebrospinal fluid during the postoperative period which yielded to massive antimicrobial therapy. b. Appearance of chest three and one-half months following resection. Patient is well free of pain 15 months following irradiation and surgery.

case of the predominant hand may necessitate re-education of the involved hand or the opposite hand for tasks calling for manual dexterity, such as writing, needle work, etc. One patient who had an extensive neoplasm making it necessary to resect the subclavian artery and more than one cord of the brachial plexus has been left with a completely useless but painless arm. The numbness in the upper anterior chest usually is ignored. The Horner's syndrome and the dryness of the face, shoulder and arm on the involved side are the subject of curiosity but prove to be no true disability. These signs of destruction of the upper sympathetic chain tend to disappear with the passage of time. In all patients in whom pain has been relieved by irradiation and operation the resulting neurologic defects are less crippling than the pain prior to treatment. Causalgia has appeared in two patients which may have been due to local recurrence of neoplasm.

Results

Eighteen patients having peripheral bronchogenic carcinomas invading the chest wall in or near the superior sulcus of the chest have been treated by irradiation followed by resection.

Nine patients were treated more than a year ago (Fig. 8a). Five of these are alive and comfortable without evidence of recurrence 51, 37, 16, 16 and 15 months, respectively. Two patients who did not survive a year had known metastases before therapy. They received palliation but died of distant metastases nine and 13 months following operation. One patient thought to have a localized lesion survived comfortably for seven months and succumbed to metastases. The remaining patient was the only therapeutic failure since local recurrence became evident in the brachial plexus causing excruciating pain

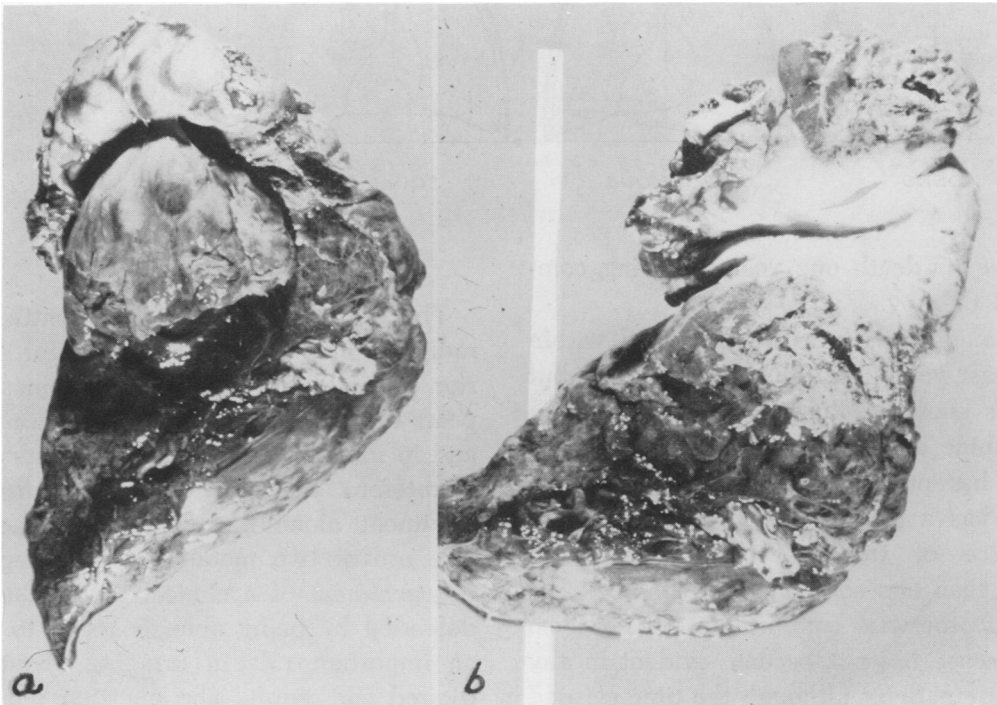


FIG. 7a. (Case 9). Photograph of surgical specimen. Note cap on lung composed of neoplasm invading the ribs, intercostal structures and a portion of the bodies of three vertebrae. b. Cut section through the tumor revealing the small component of the neoplasm in the lung with the much larger mass in the structures of the chest wall.

SUPERIOR SULCUS TUMORS

Irradiation Followed by Resection

(Shaw-Paulson-Kee)

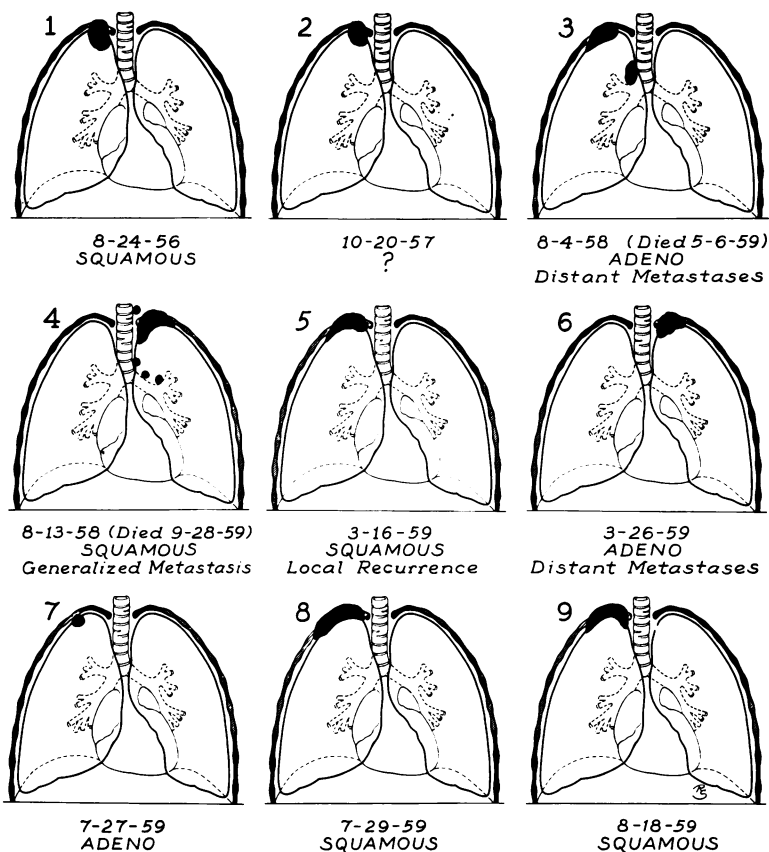


FIG. 8a. Schematic representation of neoplasms in nine patients treated more than a year ago. Cases 1, 2, 7, 8, and 9 are well without signs of recurrence of neoplasm.

before his death one year following combined therapy.

Nine patients have been treated within the past year (Fig. 8b). All are alive but one is known to have bony metastases in the spine and a femur, and another patient has pulmonary metastases. One patient has a severely crippled arm due to sacrifice of the subclavian artery and more than one cord of the brachial plexus but is otherwise comfortable. So far local recurrence has not become evident in any of these patients although the time elapsed is too short for evaluation of more than palliation. This has been satisfactory in all nine patients.

Discussion

The combination of preoperative irradiation and surgical resection for superior sulcus bronchogenic carcinomas appears to yield satisfactory palliative results and in some cases long periods of survival. Heretofore the use of either form of treatment alone has been unsatisfactory. The use of two modalities of therapy in the treatment of a clinical entity must be defended by being able to assign to each an important role in bringing about the desired end result. The question must be answered as to whether the use of either alone might not suffice. Certain bronchogenic carcinomas are radioresponsive and

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(Shaw-Paulson-Kee)

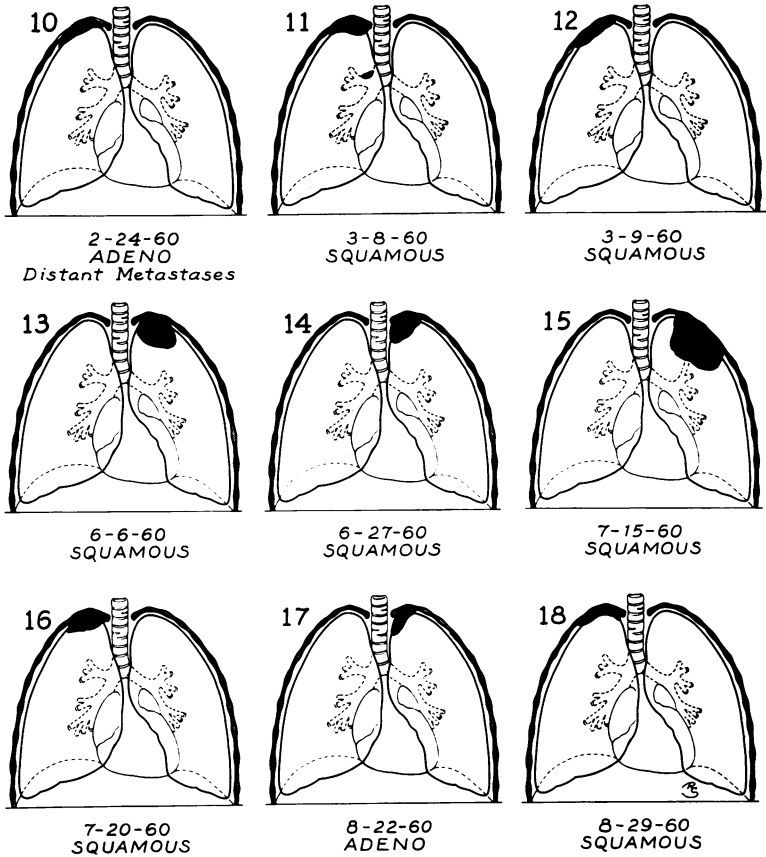


FIG. 8b. Nine patients treated during past year. Case 10 now has metastases to the spine and right femur. Case 18 already has multiple pulmonary metastases. All other patients are free of pain with no evidence of recurrence or metastases.

despite the discouragement resulting from early attempts of therapy by this method we have the reports of Haas *et al.*⁵ which indicate that with improved technics cure may be possible when a small biologically early lesion is treated. Examination of resected specimens following irradiation in this series suggests that in at least two patients the tumor was destroyed by irradiation, almost beyond recognition, and may well have been rendered incapable of further growth. In all others, however, apparently viable neoplastic cells could be seen.

The case reported by Chardack and MacCallum^{3,4} seems to indicate that

adequate surgical resection alone is capable of eradicating certain well localized superior sulcus tumors. The two lesions cited above that seemed to have been destroyed by irradiation probably could have been adequately resected surgically employing a wider line of excision. The conclusion seems justified from experience with the combination of therapy that irradiation cannot be trusted to eradicate a superior sulcus tumor but can so damage the periphery of the lesion, especially the spread in the endothoracic lymphatics and nerves, that it is rendered a lesion more suitable for removal by a more limited resection, thus safely preserving important anatomic structures.

The practice of employing preoperative irradiation over a lesion not proven histologically to be a neoplasm may be condemned on the grounds that other lesions may produce the Pancoast Syndrome. Herbut and Watson⁶ pointed out that in addition to primary bronchogenic carcinoma, metastatic carcinoma from the lung and other primary sites, mesothelioma, and Hodgkins granuloma may all produce the Pancoast syndrome. Ashe, McDonald, and Clagett¹ reported a case of fibrosing pneumonitis that had produced this syndrome in a young woman. In actual practice, however, lesions other than primary bronchogenic carcinoma producing this syndrome can usually be differentiated from bronchogenic carcinoma by clinical findings. Even when this differentiation cannot be made little harm results from the preliminary irradiation therapy and almost without exception surgical resection is indicated both for curative and palliative reasons. So far in employing this regimen of therapy in 18 patients the clinical diagnoses of primary bronchogenic carcinoma has been substantiated in every case by examination of the resected specimen. During the period this regimen has been used a patient having a Pancoast syndrome caused by Hodgkins granuloma has been observed but was not subjected to resection. The use of needle biopsy confirmation of the clinical diagnosis in patients having superior sulcus tumors should not nullify this plan of therapy but it is believed exploratory thoracotomy with surgical biopsy of the exposed lesion not only represents an unnecessary major surgical procedure but also would jeopardize by tumor dissemination the chance of ultimate successful eradication of the neoplasm.

Summary

Bronchogenic carcinomas invading the chest wall—especially those in the region of the superior sulcus—have generally been considered unsuitable for excisional sur-

gery with expectation of cure. Palliation following partial resection of the neoplasm with concomitant interstitial irradiation or followed by deep irradiation therapy has been disappointing. Irradiation alone has proven to be of palliative value in certain patients but rarely brings about an apparent cure. The biologic nature of many of the superior sulcus tumors allows them to remain as local slowly invasive neoplasms for months and even years. Limited experience with 18 patients shows that irradiation over the undisturbed neoplasm followed in four to six weeks by *en bloc* surgical resection may be capable of eradication of the primary lesion with little sacrifice in the way of physical disability of the involved arm and shoulder.

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