Chapter 128: Diagnosis and Management of Tracheal Neoplasms

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The condition

Tumors of the trachea are much less common than neoplasms of the larynx and bronchi. Primary malignant neoplasms of the trachea represent only 2% of all upper airway tumors (Baraka, 1984). They are equally distributed between the sexes and most commonly occur between the third and fifth decades of life. These tumors are most frequently located in the distal third of the trachea and at the level of the carina (Houston et al, 1969). Most primary tumors are malignant in adults and benign in children. They may arise primarily from the tracheal wall or involve the trachea by direct extension from adjacent organs or by metastatic hematogenous spread.

Historical notes

Before 1960, tracheal resection was limited by the belief that only short segments of trachea (2 to 3 cm, corresponding to up to four tracheal rings) could be resected circumferentially and reconstructed by primary end-to-end anastomosis (Barclay et al, 1957; Belsey, 1950). During these early years there were many experimental and clinical attempts to replace segments of resected trachea with a variety of prostheses using different materials and both solid and porous surfaces. Belsey (1950) reported the first intrathoracic reconstruction in a patient using homologous fascia lata reinforced with a coil of stainless steel wire. Beall et al (1963) reported experimental and clinical experience with a porous prosthesis of heavy (Marlex) mesh, and we subsequently reported out preliminary clinical experience with this same prosthesis (Pearson et al, 1968).

Neville introduced a solid silicone prosthesis for tracheal and carinal replacement (Neville et al, 1972) and recently updated his results with this prosthesis in a significant number of patients (Neville, 1987). Unfortunately, since none of these prosthetic reconstructions is incorporated by the host tissues, a high incidence of morbidity and mortality exists as the result of failure of epithelialization and erosion of adjacent structures such as the innominate artery (Deslauriers et al, 1975). No prosthetic substitute for the trachea that is reliably effective for long-term replacement is yet available.

Between 1960 and 1970, significant technical advances in tracheal surgery have resulted from increasing experience with postintubation tracheal injuries produced by cuffed tubes and mechanical ventilation. Techniques of mobilization that were developed (Grillo et al, 1964) made it possible to resect up to half the length of the average adult trachea and achieve reconstruction by primary end-to-end anastomosis. Furthermore, techniques that permit circumferential resection and primary reconstruction at both the subglottic (Pearson et al, 1975) and carinal levels (Grillo, 1982a) have been developed.

Pathology

Benign tracheal neoplasms

Benign tumors of the trachea may arise from any component of the tracheal wall and account for 90% of primary neoplasms in children. Conversely, fewer than 10% of primary neoplasms of the adult trachea are benign. Papillomas are the most common benign tumors of the trachea, occur primarily in the pediatric population, and are usually multifocal with involvement of the larynx, trachea, and bronchial tree. Juvenile papillomatosis almost always undergoes regression after puberty. The origin of this condition remains obscure: both viral and endocrine disorders have been considered as causative factors, and improvement is reported in patients given Interferon therapy (Goepfert et al, 1982). Treatment of symptomatic lesions remains primarily surgical using various modalities of endoscopic ablation. Another "benign" tumor of epithelial origin is the neuroendocrine carcinoid tumor (Briselli et al, 1978; Perelman and Koroleva, 1987). Although listed in this benign category, these tumors are almost certainly of low-grade malignancy with histologic evidence of direct invasion of contiguous structures. Tumors of mesenchymal origin include chondroma, neurilemmoma, schwannoma, fibroma, and lipoma. Of these, chondromas occur most frequently and are usually located at the upper trachea and cricoid levels (Neis et al, 1989). It is very difficult for the pathologist to distinguish between a benign chondroma and a low-grade chondrosarcoma. Rarer mesenchymal tumors include leiomyoma, hemangioma, and benign epithelial polyps (Grillo, 1978; Perelman and Koroleva, 1987; Xu et al, 1987).

Malignant tracheal neoplasms

Primary neoplasms

Squamous cell carcinoma is the most common primary malignancy of the trachea and comprises 25% to 50% of such tumors in reported series (Grillo, 1978; Houston et al, 1969; Larsson et al, 1987; Xu et al, 1987). Like bronchial carcinoma, it occurs almost exclusively in smokers and may arise at any level in the trachea; the lower trachea and carina are the most prevalent locations. This tumor is frequently locally advanced with regional lymph node metastases at the time of presentation and diagnosis.

Adenoid cystic carcinoma of the trachea is the next most common primary malignancy. This tumor was first described by Billroth in the preceding century (1859). Initially, this lesion was considered to be a benign adenoma, or "cylindroma", because of both gross appearance and slow progression and enlargement. It is clear, however, that all of these tumors are malignant, with the universal histologic finding of local invasion in the tracheal wall, which frequently extends for significant distances beyond the groslly defineable confines of the tumor (Fig. 128-1 and 128-2). Such spread occurs in the submucosa and in the perineural lymphatic spaces (Pearson et al, 1974). Metastases to regional nodes occur in approximately 10% of patients. Hematogenous metastases occur most commonly to the lungs and occasionally to brain and bone (Pearson et al, 1974). The natural history of this tumor, even in untreated cases, is frequently that of a very slow and insidious progression. In the experience of one of the authors (F. G. Pearson), local recurrences after surgery have been observed more than 20 years after a presumably complete resection.

The remaining primary malignancies in the trachea occur much less commonly; they include the following sarcomas: chondrosarcoma, spindle cell sarcoma, leiomyosarcoma, and carcinosarcoma. Mucoepidermoid carcinoma and mixed adenosquamous carcinoma may arise from the epithelium. Monocytic leukemia and plasmacytoma have been reported (Grillo, 1978; Hadju et al, 1970; Kairalla et al, 1988; Neis et al, 1989).

Secondary tracheal neoplasms

Direct invasion of the trachea may be associated with malignancies originating in adjacent organs: larynx, esophagus, thyroid, and thymus. Secondary invasion of the trachea is commonly associated with malignancies of the mediastinal lymph nodes such as lymphoma or metastatic lymphadenopathy arising from lung, esophagus, thyroid, or breast. Malignant tracheoesophageal fistula may complicate direct invasion from the adjacent esophagus.

Hematogenous metastases to the trachea are infrequently reported. Primary sites include colon, kidney, uterus, and adrenal glands (Baumgartner and Mark, 1980; Morency et al, 1989).

Most patients with secondary involvement of the trachea are incurable, and surgical resection is rarely indicated. An exception, however, involves selected patients with primary carcinoma of the thyroid gland and direct invasion of the underlying trachea. Some of these patients have tumors that are amenable to a complete and potentially curative resection combining thyroidectomy with tracheal resection and reconstruction (Grillo, 1989).

Diagnosis

Clinical features

The clinical presentation of tracheal tumors may be the result of upper airway obstruction, surface irritation and ulceration, direct invasion and involvement of contiguous structures, or distant metastatic disease. The most common among these presentations is upper airway obstruction, which, for a number of reasons, is understandably and frequently misdiagnosed.

Abnormalities in the mediastinum and changes in the tracheal air column are poorly defined in plain chest films. Tracheal neoplasms are sufficiently uncommon that they are rarely, if ever, encountered by the family practitioner. Upper airway obstruction is characterized by the symptoms of dyspnea, stridor, wheezing, and cough. These are common symptoms of respiratory dysfunction, and many patients with tracheal tumors have been treated for "asthma" or "chronic bronchitis" for long periods before a correct diagnosis was made. Furthermore, many of these tumors grow very slowly (benign tumors, adenoid cystic carcinoma, carcinoid tumors, mucoepidermoid carcinoma), and symptoms of obstruction may continue for months and years without the development of life-threatening airway impairment.

Unfortunately, most neoplasms are locally advanced at the time of presentation, because dyspnea and wheezing are not observed clinically unless 70% or more of the luminal diameter is compromised (Neis et al, 1989). In Perelman's reported series (Perelman and Koroleva, 1980), symptomatic upper airway obstruction was the indication for referral to his

unit in more than 30% of cases. Patients with symptomatic airway obstruction have significant difficulty in raising and clearing tracheobronchial secretions.

Hemoptysis may be a presenting symptom if the tumor surface is ulcerated, and an irritative nonspecific cough is common. The tumor may extent beyond the trachea to involve adjacent structures, such as the recurrent laryngeal nerve, producing hoarseness, or the esophagus, causing obstruction and dysphagia. Initial presentation caused by the primary effects of distant metastases is uncommon.

Radiology

On occasion, plain chest films may delineate the tracheal air column clearly and identify a filling defect in the lumen. This pertains only to that short segment of cervical trachea that lies above the upper sternum in the neck. The interpretation of irregularities in the air column of the mediastinal trahea is notoriously prone to error. Anteroposterior and lateral tomograms provide excellent diagnostic accuracy (Fleming et al, 1962) and are still considered an appropriate option when computed tomography (CT) is unavailable. (Contrast tracheography using Iopydol (Hytrast) has been used extensively in our practice at Toronto General Hospital since the early 1960s. This provides detailed and accurate imaging of the inner walls of the tracheal lumen from larynx to carina. Unfortunately, Hytrast is not available for use in the USA.)

Computed tomography of the chest and mediastinum is now the best and most instructive technique for noninvasive imaging of the upper airway. This study evaluates both the intraluminal and the extraluminal extent of the tumor and provides accurate information regarding the relationship to adjacent structures. Computed tomography is recommended in all cases for staging and for directing management (Morency et al, 1989). A barium swallow or the use of any other contrast medium in the esophagus at the time of CT scanning identifies esophageal involvement.

The role of magnetic resonance imaging (MRI) is still under review and has yet to be clearly defined. A major advantage of MRI is its production of sagittal and coronal images of the trachea, which clarify the spatial view of luminal dimensions and the extent of extramural disease (Naidich, 1990). It is noted, however, that this same detail can be reconstructed from fine cut CT scanning.

Endoscopy

Bronchoscopy is an essential procedure for these neoplasms. It provides the simplest and most reliable apprach to biopsy and tissue diagnosis in most cases. The extent of intraluminal involvement is ascertained, the length and degree of luminal obstruction are determined, and secretions may be cleared from the distal airway in severely obstructed cases as a therapeutic maneuver. In those cases under consideration for surgical resection, we strongly recommend the use of rigid bronchoscopy, usually under general anesthesia. In cases of severe obstruction or significant hemoptysis, the operator has much better control of the airway and ventilation with a rigid bronchoscope. Indeed, a rigid bronchoscope may be used to establish the airway in cases of critical obstruction and is infinitely preferable to an emergency tracheostomy, which frequently complicates subsequent management. Precise

measurements define the extent and position of the tumor in relation to the main carina below and the vocal cords above. This information is particularly important in the planning and actual conduct of any surgical resection. Biopsy specimens taken at and beyond the margins of visible tumor may detect microscopic extension of disease and further facilitate judgments concerning the feasibility or extent of surgical resection.

Pulmonary function studies

Pulmonary function tests may alert the physician who is investigating the patient with unexplained dyspnea, wheezing, or "asthma" to the possibility of upper airway obstruction and to the correct diagnosis. A predominantly obstructive pattern and lack of response to bronchodilator medication may suggest a fixed upper airway obstruction. Flow volume loops may clearly indicate obstruction in the upper airways, as plateauing of the inspiratory or expiratory phase indicates extrathoracic or intrathoracic obstruction. With fixed obstructions, both limbs of the loop are flattened (Fig. 128-3). The problem of false-negative results that may be observed with this test has been addressed by Gelb (1988). Fredberg (Fredberg et al, 1980) has devised a technique to measure upper airway diameters by acoustic reflection directly at the patient's mouth. These "tracheal echograms" provide relatively accurate quantitative measurements of airway diameter at levels of obstruction and demonstrate lesses areas of obstruction that would not be detected in flow volume curves.

Treatment

Surgical treatment

Anesthetic management

Two particular anesthetic problems are encountered in patients undergoing tracheal resection and reconstruction: at the outset the anesthetist is frequently confronted with a severely obstructed airway, which makes intubation both difficult and hazardous. Resection of circumferential segments necessitates intubation of the distal airway, which is managed by variations in equipment and technique that depend on the level of transection.

In many cases, the preintubation status of the airway is best assessed with the rigid bronchoscope under general anesthesia. During bronchoscopy, ventilation can be maintained by the Venturi technique. The ease or difficulty of passing an endotracheal tube beyond the obstructing tumor can be evaluated. In some instances, endoscopic removal of intraluminal tumor may facilitate safe intubation. The airway beyond points of obstruction should be cleared of secretion before intubation.

After transection of the airway, the distal tracheal segment is usually intubated directly with a sterile endotracheal tube carried across the operative field. At the level of the carina, it may be necessary to intubate one or both main bronchi intermittently (Therman et al, 1976). Intermittent removal of the endotracheal tube and interruption of ventilation provide access for reconstruction and anastomosis and constitute a very safe technique in appropriately controlled circumstances. Digital pulse oxymetry greatly facilitates this technique and should be used in all cases. Jet ventilation using a small-bore catheter is a useful alternative technique (McClish et al, 1985), and is particularly applicable for resections in the more distal

and smaller airways. Although cardiopulmonary bypass has been used to provide oxygenation at the time of tracheal resection (Neville, 1987), this technique is never essential for cases of tracheal resection and adds unnecessary morbidity and potential mortality risks.

Tracheal resection and primary reconstruction

With few exceptions, surgical excision is the best treatment for those tracheal neoplasms that can be completely resected and continuity restored by primary reconstruction. For practical purposes, all malignant tumors are assumed to extend through and beyond the external tracheal wall (Fig. 128-4). Endoscopic resection (including laser resection) is almost inevitably incomlpete, and therefore inadequate, in otherwise operable patients. A cervical collar incision provides adequate access for most tumors confined to the cervical and upper mediastinal trachea. The mediastinal trachea is well exposed throughout its length through a median sternotomy, although a right posterolateral thoracotomy may provide a preferable exposure for some tumors that require a concomitant carinal resection (Pearson et al, 1984).

It is possible to remova half of the length of the adult trachea and achieve reconstruction by primary end-to-end anastomosis. Exceptions are more common in the elderly because of loss of pliability in the aged trachea. Such extended resections require mobilization of the anterior and lateral aspects of the trachea from top to bottom and may necessitate the addition of a number of release procedures: superior laryngeal release (Dedo and Fishman, 1969), suprahyoid release (Montgomery, 1974), and intrapericardial hilar release (Grillo et al, 1964). The judgment to add these release procedures is made by the surgeon intraoperatively and is based on an assessment of acceptable degrees of tension at the primary anastomosis.

Intraoperative frozen section evaluation of the final resection margins is of critical importance. This facility should be available and used in every resection undertaken for malignant disease. Otherwise, microscopic tumor may remain in cases that are completely resectable and potentially curable. Extension far beyond the gross limits of tumor is a common feature of adenoid cystic carcinoma.

Most surgeons prefer an anastomosis using an interrupted technique with absorbable sutures (Vicryl, Maxon, or PDS) in diameters of 3- to 4-0. If there is any question of ischemia at the anastomosis, the closure may be reinforced with a vascularized pedicle such as muscle, pericardium, thymus, or omentum. Such support is considered essential if the anastomosis involves previously irradiated trachea.

Particular technical problems beset resections at the upper and lower ends of the trachea. The numerous approaches to carinal resection have been well described by Grillo (1982b; 1990). In selected cases, neoplasms involving the subglottic airway may be managed by circumferential resection of the distal cricoid using a technique described by Pearson et al (1975; 1986). In selected cases, this approach may permit a complete resection without the loss of voice associated with laryngectomy.

Prosthetic reconstruction

Reference to experience with prosthetic replacement of the trachea is provided in the beginning and historical notes. We again emphasize the fact that at least half of the average adult trachea can be resected circumferentially and reconstructed by primary anastomosis. Benign or malignant lesions requiring still more extensive resections are uncommon, and at present, in our opinion, there is still no predictably safe and satisfactory method for prosthetic replacement. Nor has there been documented success with homograft replacement of the trachea.

There are, however, clear indications for the use of endotracheal stents for the palliation of upper airway obstruction caused by tracheal neoplasms. The most popular stent is the Montgomery molded silicone T-tube (Montgomery, 1968), or some variant thereof. The endotracheal arm of the T-tube is positioned to extend above and below the obstructed segment, and the T-arm that protrudes in the neck (Fig. 128-5) secures the tube in position. With the T-arm corked, the patient continues to breathe through the normal nasopharyngeal and oral channels and maintains speech as long as the upper limb of the endotracheal arm lies below the vocal cords. These tubes can be left in place for very long periods since they are well humidified so long as the T-arm is occluded. They do not suffer the complication of crusting and obstruction that occurs regularly with any open tracheostomy tube. A T-Y design was first designed for the management of obstruction at the carina and the origin of the main bronchi by Westaby in 1982. More recently, we have reported out experience at Toronto General Hospital with silicone stents in a series of 53 patients (Cooper et al, 1989). Eleven patients in this series were stented for the palliation of malignant disease, and the technique of insertion and management is detailed in this report.

Irradiation therapy

Both squamous cell carcinoma and adenoid cystic carcinoma, which are the two most common primary malignancies of the upper airway, are usually responsive to irradiation therapy. Although adenoid cystic carcinoma was originally thought to be radio-resistant (Hadju et al, 1970), technical improvements achieved with Cobalt-60 established irradiation as an effective therapeutic modality for this tumor (Richardson et al, 1973). Aside from anecdotal reports of "cure" with irradiation, radiotherapy alone is not considered curative therapy (Cheung, 1989). Tracheal resections for primary carcinoma inevitably result in resection margins that lie within millimeters of the margins of the resected tumor. This problem is the result of the unresectable anatomic relations of the great vessels and esophagus, which intimately surround the mediastinal trachea. The extent of longitudinal resection is also limited. For these reasons, adjuvant therapy have yet to be assessed by any randomized prospective trial, and the rarity of these neoplasms makes the feasibility of future trials unlikely. We have described our own experience with adjuvant radiotherapy (Pearson et al, 1984), as well as experimental studies to evaluate the effects of preoperative irradiation on subsequent healing at a tracheal anastomosis (Tsubota et al, 1975). Our current practice is to proceed with resection and to restrict adjuvant radiotherapy to the postoperative period. After surgery, radical irradiation of the remaining airway is possible without impairment of tracheal healing. Endotracheal brachytherapy has also been reported as effective palliation in some cases (Macha et al, 1987). At present, there is a paucity of reported experience of the role of chemotherapy in the management of primary tracheal neoplasms.

Complications of Resection and Reconstruction

Early complications

The perioperative and postoperative mortality for resection of upper airway tumors is generally very low. In those cases managed by a cervical incision only, reported mortality rates are usually well below 5%. For intrathoracic resections and reconstructions, complications such as dehiscence of the anastomosis are potentially more lethal and reported mortality rates are significantly higher.

Wound infections are rare in the cervical area. Although all of these cases are contaminated intraoperatively with oropharyngeal secretions (endotracheal intubationand an open airway), the good quality of the circulation in cervical soft tissues probably explains the infrequency of significant wound infection. Factors predisposing to postoperative wound infection are previous irradiation or defects of immunologic competence such as thay which occurs in transplant patients. When wound infections do occur in the neck, they usually resolve promptly with adequate open draining, even in the presence of dehiscence at the anastomosis. In patients who require thoracic resections, however, infection is a much more serious potential problem if dehiscence occurs or an air leak results in a residual space in either the mediastinum or pleural spaces. It is our practice to use perioperative antibiotics in these "clean, contaminated cases": 1 g of cefazolin sodium (Ancef) intravenously at the time of anesthetic induction, repeated at six hourly intervals thereafter for two additional doses. We have found it useful to obtain biopsy specimens of areas of ulceration or granulation tissue in patients with benign strictures and submit some of the biopsy material for culture and sensitivity analysis. It is surprising how frequently we have cultured pathogenic organisms that were not recognized on culture of the airway secretions. *Staphylococcus* is the most common organism identified by this technique.

Anastomotic dehiscence is the result of either ischemia, undue tension on the anastomosis, or a combination of both. Risk factors for ischemia are undue circumferential mobilization of the airway proximal and distal to the abnormality, and previous irradiation in the operative field. It is again emphasized that approximately half of the adult trachea can be resected and reconstructed by primary anastomosis using the appropriate release procedures at the upper and lower ends of the airway. Neck flexion during the postoperative period is of critical importance. Dehiscence is inevitable if an extended resection is carried beyond these limits in most cases. Judgment concerning acceptable levels of tension at the anastomosis must be made intraoperatively and "equivocal" cases require the evaluation of an experienced surgeon. The most common dilemma for the operating surgeon occurs during resection for malignant neoplasm (adenoid cystic or squamous carcinoma) when the pathologist reports residual tumor at the resection margin when the surgeon judges that a maximal resection has already been done. In this situation, we have chose to perform a primary anastomosis, leaving the areas of residual malignancy. This is a safer alternative than pressing on with a potentially curative operation in the face of almost certain postoperative dehiscence. It is surprising how well these anastomoses (with malignant disease at the margins) heal, and the problem can be managed with some benefit by postoperative irradiation. If the surgeon does anticipate problems in postoperative healing caused by ischemia or undue tension, anastomotic healing may be enhanced by the apposition of well-vascularized tissue around the anastomoses. At the cervical level, the thyroid gland and muscles are available. In the thorax, pedicled grafts

of pericardium and thymus are easily mobilized and applied. On occasion, an omental pedicle may be mobilized through a short upper abdominal incision to provide an excellent scaffold for early revascularization (Mathisen et al, 1988). A pedicled intercostal muscle bundle may also be used (Grillo et al, 1986), though we consider this the least desirable alternative because of technical difficulty in mobilization and uncertainty concerning the circulation in the distal end of the graft. A vascularized pedicle enveloping the anastomosis should always be used in reconstructions for patients who have received prior radiotherapy (Mathisen et al, 1988).

Retained secretions with atelectasis and possible pneumonitis are common complications of intrathoracic tracheal reconstructions. We believe these are more likely related to the thoracotomy than to the airway surgery itself. Prophylaxis and management are no different than for any patient undergoing thoracotomy.

A variety of circumstances predispose to problems with aspiration after tracheal resection. Causes of this postoperative difficulty are transection of one or both recurrent laryngeal nerves, release procedures at the upper end of the airway (superior laryngeal and suprahyoid releases), and manipulation and denervation, which occur in resections at the subglottic or cricoid level. The precise reasons for this latter problem remain uncertain, but there is undoubtedly some disruption of the normal neuromuscular swallowing mechanisms. Fortunately, the problem resolves in almost all of these patients within a few days to a few weeks. Exceptions occur in patients who have lost the normal mobility of the larynx and related structures as a result of previous heavy irradiation or surgery. In these cases, significant long-term problems with aspiration may ensue. The elderly patient also has more difficulty with prolonged problems of aspiration. It should be noted that early problems with aspiration do not preclude oral intake of clear fluids: if the patient is otherwise well with normal reflexes and a vigorous cough, the aspiration of clear fluids does not result in morbid complications, and continued attempts to "learn to swallow again" can be made by the patient. These circumstances are completely different from the severe complications of aspiration produced by gastroesophageal reflux.

Recurrent nerve palsy is a common complication among patients with upper airway tumors. The tumor itself may ablate nerve function, it may be necessary to divide a recurrent nerve as part of the cancer resection, or the nerve may be divided inadvertently at operation because of its close relationship with the trachea. The loss of one recurrent nerve results in hoarseness and usually creates a marked impairment in the effectiveness of cough. In selected cases, this disability may be managed by vocal cord augmentation (glycerine transiently, Teflon permanently) in the early postoperative period. Bilateral recurrent nerve palsy may create obstruction of the glottis requiring intubation or distal tracheotomy. The problem of voice loss and hoarseness is managed electively. In general, augmentation of a vocal cord should be deferred for at least 3 to 6 months. In some cases the nerve may be intact but functionless and regain function within that time. During the first 6 months after recurrent nerve palsy, the position of the paralyzed cord frequently changes, and in some instances there is an adequate return of vocal function and further intervention is not required.

Tracheal-innominate artery fistula is a devastating and usually lethal complication of tracheal resection. On occasion, it complicates cervical resections, though it is more commonly seen in patients requiring resection of the mediastinal trachea. In young women

in particular, the innominate artery occupies a high position and may be palpable at the level of the suprasternal notch. If the arterial wall has been bared during the dissection, fistulization may result from pressure from a postoperative tracheotomy tube or from abrasion of the wall by the suture material in the anastomosis lying immediately behind the vessel. It is for this reason that we prefer suture material that has a soft, relatively flat knot (such as 4-0 Vicryl). Other sutures (such as Prolene and PDS) require five or six loops on the knot, are relatively stiff materials, and produce a hazardous "sharp" projection if they abut the innominate artery. When the surgeon anticipates the possibility of tracheal-innominate artery fistula at operation, some vascularized soft tissue should be interposed between the anastomosis and the artery. In the neck, a pedicle of muscle is easily mobilized. In the thorax use of pedicled flap of pericardium and thymus is the simplest method of interposition. The problem of tracheal-innominate artery fistula associated with prosthetic replacement has already been discussed. In these rare cases, it may be desirable to resect the overlying innominate artery at the time of operation, because soft tissue interposition may not guarantee protection against fistulization. The emergency management and attempts at salvage of patients with this complication are exceedingly difficult. On occasion, patients may have a transient, brisk hemoptysis. Such patients should be taken to the operating room immediately and receive bronchoscopy to assess the status of the anastomosis, and the wound should be reopened to define the status of the artery. There are a few reported cases of patient salvage using this approach (Couraud et al, 1984; Deslauriers et al, 1975). Unfortunately, most patients with this complication suffer an abrupt exsanguinating hemorrhage from the airway, and there is no opportunity to treat them.

Late complications

Some formation of granulation tissue on the luminal aspect of the anastomosis is relatively common and most frequently related to the sutures in the tracheal wall. Suture materials such as Vicryl and PDS are preferable (in earlier days we used catgut for all of these anastomoses). Even these less inert materials, however, provoke an inflammatory reaction with granulation tissue in rare instances. Braided, nonabsorbable sutures such as silk, Tevdec, or Mersilene frequently produce troublesome granulation that may persist and recur until the suture is actually removed. This problem is easily managed by endoscopic removal of the irritating suture material seen at rigid bronchoscopy. On occasion, such sutures may be removed by the small biopsy forceps and the flexible scope, but success with this instrumentation is less predictable. Postoperative granulations at the anastomosis or vicinity of the surgical site may be due to infection or necrosis of the adjacent and underlying cartilage. This is particularly troublesome if the cricoid cartilage is involved, since the posterior cricoid is a large structure and chronic infection may persist for months or years due to slow, liquefaction and dissolution of the infected cartilage or sequestrum. Patients with significant involvement of the underlying cricoid cartilage usually required reoperation and debridement before a successful outcome is achieved.

Restenosis occurs in a relatively small proportion of appropriately managed cases as a result of ischemia or undue anastomotic tension, or both. Except for patients who have received previous radical irradiation, this complication is preventable. A wound infection with abscess formation external to the anastomosis may produce necrosis of the adjacent airway, with loss of tissue and replacement fibrosis with restenosis. Whenever an abscess is recognized or suspected, prompt drainage is essential and requires wide exposure through the

cervical incision, or rethoracotomy. In the past, restenosis resulted from fibrosis in the chronic granulations associated with braided, nonabsorbable sutures. Relatively mild short segments of restenosis may be managed by endoscopic dilatation; four-quadrant laser incision of short segment strictures (Shapshay et al, 1987) may be effective treatment. With longer segments of fibrotic restenosis, operation and reresection are usually necessary if functional impairment is sufficient.

Persistent aspiration is a very difficult management problem. The cause of this complication has been discussed. In that small group of patients in whom this late complication occurs, there is no predictably effective definitive therapy. Management includes educational programs often provided by speech pathologists. It is questionable whether or not augmentation of a vocal cord with reduction in diameter of the posterior glottis results in predictable and significant improvement. In severe cases that are complicated by recurrent bronchitis and pneumonitis, it may be necessary to exclude the airway at or just below the glottis and to establish a permanent distal tracheostomy.

The problem of local recurrence of malignant neoplasms is common among patients who have resected upper airway tumors. This problem is due to the anatomic relations of the trachea (particularly the mediastinal trachea), which preclude a wide excision with a margin of uninvolved tissue beyond the limits of the tumor. The most common primary neoplasms encountered are squamous cell carcinoma and adenoid cystic carcinoma. Fortunately, both are usually responsive to irradiation. The management of local recurrence includes radiotherapy (including brachytherapy), endoscopic débridement or palliation, or insertion of an endotracheal tube (silastic T-tube or endotracheal stent) to maintain the airway (Cooper et al, 1989; Westaby et al, 1982).

Results of Resection and Reconstruction

Few institutions anywhere in the world accumulate a large and significant experience with the management of these rare neoplasms. The Mayo Clinic reported experience with 56 patients with primary tracheal tumors in 1969 (Houston et al, 1969). Eleven of the 56 patients were managed by resection and primary reconstruction; 7 of the 56 patients were long-term survivors, for whom the average follow-up period was 10 years. We reported our Toronto General Hospital experience with 44 primary tumors in 1984 (Pearson et al, 1984). Forty-two of the 44 were malignant and 33 were managed by circumferential resection and primary anastomosis. There were three operative deaths in this group. An additional six patients were managed by prosthetic replacement using heavy-duty Marlex mesh (Pearson et al, 1968), and three of the six succumbed to early postoperative innominate artery erosion by the rigid Marlex graft. All but one of these prosthetic replacements was made before 1970, at a time when the present principles for extended tracheal resection and primary anastomosis were not known. Three of our 44 patients were considered nonresectable, and palliation was achieved with a Montgomery T-tube. Two additional nonresectable cases were managed by radiotherapy only.

Perelman and Koroleva (1987) reported on a large series of 135 primary tracheal tumors managed by resection or endoscopic removal. Forty-five of the 135 cases were benign. Among the malignant tumors, 56 were adenoid cystic carcinomas and 20 were squamous cell cancers. The 10-year survival rate in this series for adenoid cystic carcinoma was 56%, and

13% for squamous cell tumors.

The most extensive and comprehensive review has been reported by Grillo and Mathisen (1990) from the Massachusetts General Hospital. During a 26-year period, they saw 198 patients with primary tumors of the trachea and carina. One-hundred and forty-seven were managed by resection, and 132 of the 147 resections were reconstructed by primary anastomosis (50 carinal, 82 tracheal). Forty percent of these tumors were adenoid cystic cancers, and 36% were the squamous cell cancers. Excellent results were obtained: an overall operative mortality of 5% and a 5-year survival rate of 75% for adenoid cystic tumors and 49% for squamous cell cancer. Postoperative irradiation was used in almost all cases of resected squamous and adenoid cystic tumors.

Summary

Tracheal neoplasms are relatively rare and certainly much less common than tumors of the oropharynx and larynx. Benign neoplasms predominate in children and malignant neoplasms in adults. The usual presentation is that of upper airway obstruction, and these signs and symptoms usually are manifested at a time when tumor is already locally advanced. Misdiagnosis of conditions such as bronchitis and asthma can occur. Acute or life-threatening upper airway obstruction caused by neoplasm is best managed by rigid bronchoscopy. Diagnosis is achieved with flexible or rigid bronchoscopy, and staging of the lesion has improved with the advent of CT scanning. The most common primary neoplasms are squamous cell carcinoma and adenoid cystic carcinoma. In cases of localized and completely resectable disease, the best treatment is surgical resection with reconstruction by primary anastomosis. Segmental resection of approximately half of the adult trachea and primary reconstruction are usually possible. There are few indications for more extensive resections and prosthetic replacement. As yet no tracheal prosthesis is predictably satisfactory. Homotransplantation remains unsuccessful at the present time. A wide en bloc resection of primary upper airway tumors is rarely possible because of the adjacent unresectable anatomical structures. With experience, curative resections can be achieved in a significant number of malignant cases with low operative mortality and 5-year survival results of up to 50% for squamous cell carcinoma and 65% for adenoid cystic carcinoma.