Circumferential Resection and Reconstruction of the Mediastinal and Cervical Trachea *

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A SYSTEM of surgery which will treat primary and secondary tumors or stenoses of the trachea effectively must permit extensive circumferential resection and provide for dependable reconstruction at any level. Adequate resection has often been inhibited by the belief that only about a 2-cm. length of trachea may be removed circumferentially and end-to-end suture accomplished safely.[3, 11, 20] The use of prostheses in the mediastinum has given only scattered satisfactory results because of occurrence of early leakage or late stenosis.[8] In the neck, complex, multiple-staged methods have been devised and sometimes employed with success.[5, 17] Unpredictable or delayed healing and cicatricial narrowing have remained problems.

Surgical solution of these problems requires means of access to the entire trachea and complete confidence that reconstruction may be effected whatever the extent of resection dictated by the lesion. Reconstruction ideally should provide a laterally rigid tube, primarily lined with epithelium and structured of full thickness tissues which will not contract and which will heal dependably. In the mediastinum, repair must be airtight immediately. Staging is permissible in the neck but should be minimized. The least possible amount of foreign supporting material should be utilized. Foreign material should not be in contact with unhealed or epithelial surfaces but should be buried in the connective tissue at the outset.

Methods which meet these criteria have been developed in the laboratory and applied clinically in a limited number of cases. Following extended resection of the *mediastinal trachea,* reconstruction may generally be accomplished by direct anastomosis of the patient's own tracheobronchial tissue by systematic and extensive anatomic mobilization of mediastinal structures. In lesions of the *cervical trachea,* where it is inadvisable to add a wide mediastinal dissection just to gain length for primary suture, reconstruction may be accomplished in accord with the stated criteria and at the time of the initial resection by infolding a tube of full thickness skin and platysma supported by buried plastic rings. Reconstruction is completed in a simple second stage.

Mediastinal Trachea

Primary end-to-end suture, without excessive tension, is recognized to be the ideal method of reconstruction of the trachea. Demonstration that over one half of the trachea may be resected and direct anastomosis performed has largely removed the need for intrathoracic prostheses with their attendant risks.

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Laboratory Studies

In a previously reported [8] series of dissections in 40 unselected adult cadavers, ranging from 33 to 88 years in age, the limit of resection permitted by successive steps in anatomic mobilization was determined. Over one half of the trachea (6.4 cm., 13 rings) was found to be removable (Fig. 1). (I) Full mobilization of the right hilum, with division of the inferior pulmonary ligament, permitted an average advancement of 3.0 cm. (range: 2.0–4.2). (II) Detachment of the left main bronchus, which can not be elevated because of the overhanging aortic arch, with its reimplantation into the advanced bronchus intermedius, developed another 2.7 cm. (1.5–6.5). (III) Dissection of the pulmonary vessels from the pericardium added 0.9 cm. (0.3–1.8). The total resectable length measured from a minimum of 5.7 cm. to 10.0 cm. (11–18 rings). The tension developed during approximation, after successive 1-cm. segments were resected, rose from an average of 25 Gm., following removal of 1 cm., to an average of 675 Gm. (maximum: 1,100 Gm.) after 7 cm. had been removed. This is well beneath the 1,700-Gm. level after which disruption occurred experimentally in dogs.[4]

If a greater length than 6.4 cm. of mediastinal trachea must be resected, it still seems possible to effect primary tracheal anastomosis intrathoracically. The lower cervical trachea has been found to fall readily into the upper mediastinum when traumatically divided. This segment may be transected electively 1 to 2 cm. below the cricoid cartilage and advanced into the upper mediastinum for end-to-end anastomosis with the remaining thoracic segment, leaving intact the lateral blood supply which originates from the inferior thyroid artery.[8, 16] The recurrent nerves are spared. More complex reconstruction is thus transferred to the neck where it may be done safely and, if required, in stages. A method for such reconstruction is described in Part II.

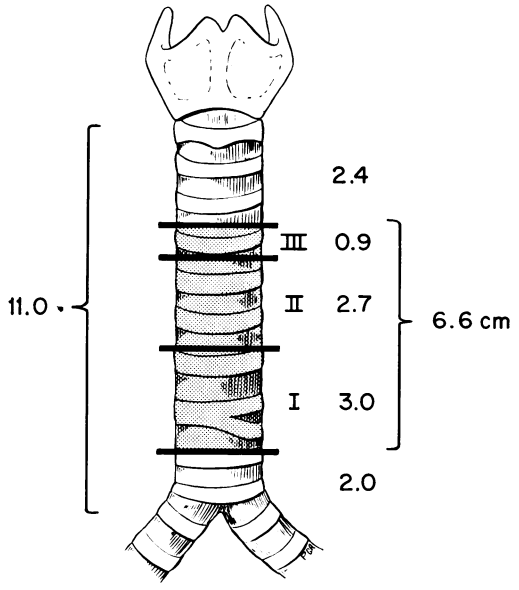


FIG. 1. Diagram of average amount of trachea which may be removed by steps in mobilization and still permit end to end anastomosis. The average total length from inferior border of cricoid cartilage to bottom of carina is 11 cm., unstretched. I. Right hilar dissection and division of pulmonary ligament. II. Division of left main bronchus at carina and reimplantation. III. Dissection of pulmonary artery and veins from pericardium.

Clinical Application

The concept of wide anatomic mobilization to permit resection and primary anastomosis of intrathoracic trachea has been applied in four patients (Table 1, Fig. 2). Two of these cases have been reported in the past.[7] In all patients resection was approached with certainty of approximation so that adequate circumferential resection was encouraged at the outset. Varying degrees of mobilization were required in each case. Primary healing, without adjuvant tracheostomy, was obtained in each case. In Case 4 obstructive pneumonia was present bilaterally at operation. This had not yielded to prior therapy but cleared promptly after establishment of a normally dimensioned airway. Postoperative courses were uncomplicated. Case 1 was readmitted with minor

TABLE 1. *Results of Wide Anatomic Mobilization for Resection and Primary Anastomosis of Intrathoracic Trachea*

No.	MGH No.	Age Sex	Diagnosis	Date of Operation	Extent of Resection*	Post-operative Hospital Stay (Days)	Result
1	1213917	48 F	Cylindroma	11/26/62	Lower trachea and carina (4 cm.): hilar mobilization, bronchial reimplantation	17	Good
2	1213780	64 F	Squamous papilloma	11/29/62	Lower trachea (3 cm.): hilar mobilization	13	Good
3	1289159	56 M	Squamous ca. of trachea	6/ 2/64	Lower trachea (3.5 cm.): hilar & intrapericardial mobilization	12	Good
4	1303057	31 F	Cicatricial stenosis	1/ 7/65	Mid-trachea (2 cm.): hilar & intrapericardial mobilization	15	Good

* Measurements made from resected specimens, after shrinkage.

hemoptysis in February, 1965, 27 months after resection. A small tab of granulation tissue, found at the site of left main bronchial reimplantation, was removed by bronchoscopy. Case 3 was again bronchoscoped and exfoliative cytology studied in September, 1964. These examinations were negative. All are doing well at present.

Operative Technic

Some degree of airway obstruction exists in all of these patients. In severe degrees of obstruction, such as was present in Cases 1 and 4, induction of anesthesia must be accomplished with great care, The details of anesthetic technic used in Case 1 have been described.[7]

When the full length of the lesion can not be established definitely preoperatively, when the lesion extends well into the mid-thoracic trachea or is located in the upper thoracic trachea, the most versatile exposure is obtained through vertical midline division of the sternum from the notch to the level of the fourth interspace, where the incision angles to the right into the interspace and runs posteriorly to the anterior border of the latissimus dorsi muscle (Fig. 3). Through this incision the entire length of trachea becomes accessible, although it is crossed by the innominate artery and the left innominate vein. The latter may be divided if further exposure is needed. The patient is positioned obliquely with his

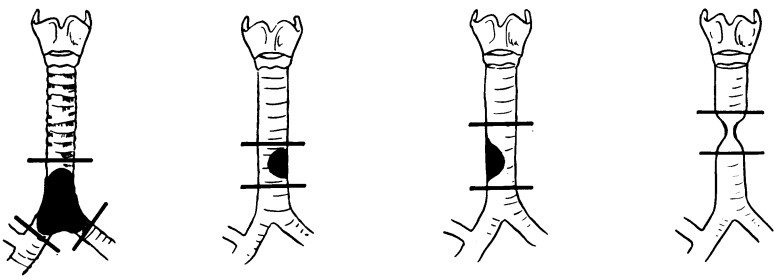
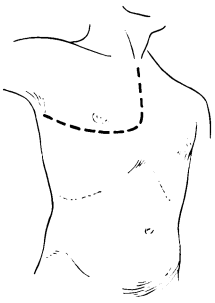


FIG. 2. Diagram of location of lesions and resection in Cases 1–4. See Table 1.



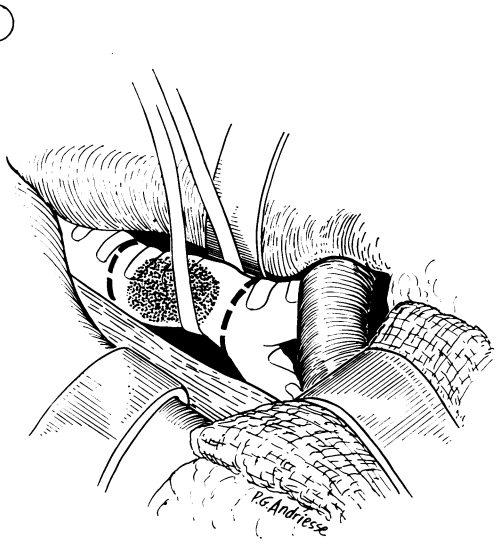


FIG. 3. Intrathoracic tracheal resection and reconstruction. Operative technic. Drawings are from photographs of Case 3. (1) Inset shows the most versatile incision. Lower trachea is also approachable through high posterolateral thoracotomy. Trachea is isolated and the tumor palpable. Dotted lines indicate segment to be resected. Carina is fully available. Right pulmonary artery is cleared. Superior vena cava is retracted gently.

right side raised 30 degrees. A laterally tilting table is helpful for adjustments of position during operation. The patient's head is maintained in neutral position since hyperextension of the neck draws the upper mediastinal trachea into the neck, placing tension upon it. The entire cervical trachea may be exposed concurrently, if necessary, preferably by a low collar incision which crosses the top of the vertical midline incision over the sternum. Where the lesion is known to be confined to the lower 4 to 5 cm. of trachea and carina, exposure may be obtained more easily and entirely adequately through a high posterolateral thoracotomy.

Division of the azygous vein and longitudinal opening of the mediastinal pleura permits access to the trachea in mid- and lower thoracic extent. The superior vena cava is gently retracted medially. The initial dissection is rapidly but gently accomplished to expose the airway below the level of obstruction. Once this is done the dissection may proceed with complete safety since an airway may be established below the obstruction at any time, should ventilation become difficult. Such control is easily accomplished, except when reexploring the mediastinum after extensive prior operation has been attempted. We have, therefore, preferred not to use technics for by-passing the right heart.

The lung is fully mobilized from all parietal pleural adhesions and the inferior pulmonary ligament is divided. The pulmonary artery and veins are cleanly dissected, dividing the pulmonary plexus and hilar connective tissue. Bronchial blood supply is preserved, if possible. Dissection may be carried down along the left main bronchus beneath the aortic arch. The hilar

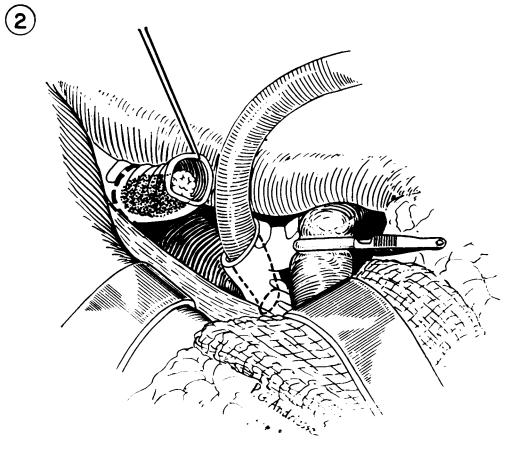


FIG. 3. (2) Trachea is divided below the lesion. Endotracheal tube lies across the operative field and in the left main bronchus. Right pulmonary artery is temporarily clamped.

vessels are freed from the pericardium if greater length is needed. Dissection of the mediastinum is best completed prior to opening the trachea. Mobilization of the middle and upper thoracic trachea is now done to the extent required. Extensive proximal dissection is not often needed since greatest length is obtained by advancing lower trachea or carina rather than by pulling down the upper trachea.

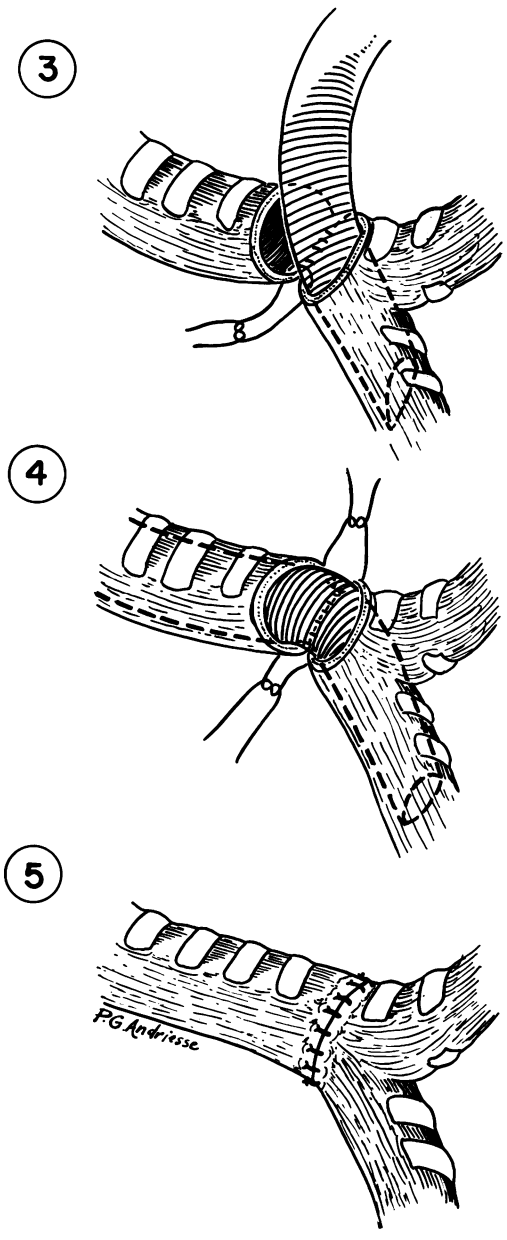


FIG. 3. (3) Anterior layer of anastomosis is completed. (4) An endotracheal tube has been passed from above into the left main bronchus. Posterior sutures are now placed. (5) Completed anastomosis. Both lungs are now ventilated. The clamp on the pulmonary artery is removed.

Precise localization of the upper border of a tumor is possible preoperatively by bronchoscopy. The lower extent may be defined by x-ray technics, including laminography. If a high degree of obstruction exists it is inadvisable to perform bronchoscopic manipulation, such as biopsy, or to use contrast medium—unless with extreme caution. The inferior limit of tumor may be defined during operation by direct palpation through the soft posterior tracheobronchial wall.

Following placement of traction sutures in the trachea or bronchus, below the level of expected transection, the trachea (or left main bronchus) is opened horizontally below the lesion, on the wall opposite to the base of the tumor. If the margin at this exploratory level appears to be too small, final transection is done more distally. If the transection is in the last 2 cm. of trachea or if the lesion necessitates carinal removal, the left main bronchus is then directly intubated with a Tovell tube which crosses the operative field (Fig. 3). The endotracheal tube is linked with sterile connecting tubes to the anesthetist's field. He now disconnects his anesthetic mixture from the translaryngeal tube to the transthoracic tube. At this point, temporary clamping of the right pulmonary artery avoids the relative unsaturation which may result from continued perfusion of a nonventilated right lung.[7, 18] In midtracheal lesions the anesthetic tube is placed in the lower tracheal segment instead of in the left main bronchus.

After placement of traction sutures above the level of anticipated proximal tracheal transection, the diseased segment is excised. Ease of approximation is tested, using the traction sutures to draw the tracheal

ends together. During approximation, the nonaerated right lung should be either gently supported by the assistant's hand or floated in saline in the thoracic cavity, to eliminate the weight of the lung from this determination of the tentative force necessary for approximation. Direct measurement of the force required for approximation may be made; at present, this is of investigative importance only, since baseline information is limited. If tension is satisfactory, anastomotic sutures are placed in the anterior tracheal wall (Fig. 3). We have used 4–0 nonabsorbable, minimally reactive sutures (Mersilene or Dacron). The flexible Tovell tube permits easy placement of these sutures. After most of these sutures are tied, the Tovell tube is withdrawn. The long endotracheal tube which has been lying in the proximal trachea is now intro-

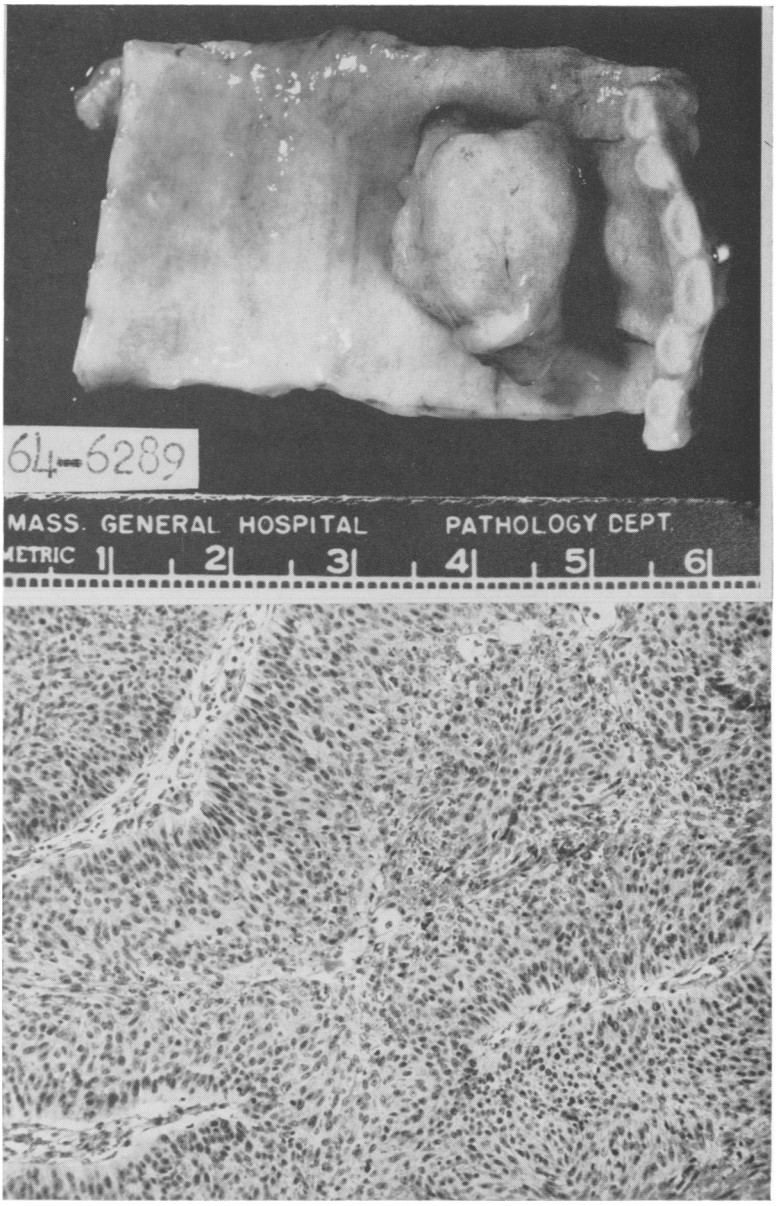


FIG. 4. A) Gross specimen, Case 3. B) Photomicrograph, Case 3. (H&E × 170.) Squamous carcinoma of trachea.

duced past the line of anastomosis into the left main bronchus and anesthesia so continued. The remaining, more laterally placed, anterior wall sutures are tied and the anastomosis completed. A single layer of sutures is used. These are placed directly through the cartilage and mucosa with care taken to obtain accurate approximation. The tube is next withdrawn to a point in the trachea proximal to the anastomosis and the right pulmonary artery unclamped. The suture line is buttressed with a pedicled pleural flap.

If the left main bronchus must be detached (as in Case 1), it is implanted into an ovoid opening excised from the lateral surface of trachea or bronchus intermedius. In such a case, the right main bronchus is first sutured to the trachea at leisure while ventilation is maintained through the left main bronchus. Anastomosis of the left main bronchus is then accomplished by the technic described, completing the anterior row initially, then removing the tube from the left main bronchus. If it is not possible with ease to advance the upper tube past a partially completed left main bronchial anastomosis, both lungs may be ventilated through the endotracheal tube. The small defect which remains to be sutured in the posterior portion of this final anastomosis is closed by the placement of a few sutures, with intermittent finger occlusion.

Cervical Trachea

Although the majority of tracheal tumors occur intrathoracically, an occasional primary tumor and some otherwise resectable cancers of the thyroid involve the cervical segment only. Benign stenosis is more common at this level. Extensive mediastinal dissection merely to obtain length for primary cervical anastomosis is not desirable and, sometimes, not permitted by vascular pattern. The urgency for immediately airtight, unstaged tracheal reconstruction, which is insistent in the thorax, does not exist in the neck. A method of reconstruction is also required if devolvement of the cervical segment is necessary to accomplish primary intrathoracic suture after unusually wide resection of mediastinal trachea.

Laboratory Studies

In experimental studies a method was devised for reconstruction of the cervical trachea, following circumferential resection, by infolding a full-thickness, bilaterally pedicled flap of cervical skin and attached platysma, held in tubular form by discontinuous plastic rings completely buried between the undersurface of dermis and platysma.[9] This phase of reconstruction is accomplished at the time of initial tracheal resection, completing the proximal and distal tracheocutaneous anastomoses. After an appropriate interval to permit acquisition of new blood supply, the anterior longitudinal cleft so created is closed in a simple second stage.

In a series of 18 dogs, detailed in another report,[9] followed for varying periods up to 8 months, the reconstruction generally healed well; there was no loss of luminal diameter and no stenosis of anastomoses. The polypropylene plastic rings were well tolerated. Hairy growth, a manageable problem in man, presented difficulties in experimental animals.

The use of full-thickness skin minimizes cicatricial contraction and eliminates anastomotic narrowing. With excellent blood supply from two pedicles, primary healing occurs dependably. Discontinuous rings provide minimal foreign material, well tolerated by the surrounding tissues. If one ring becomes involved by infection, the entire prosthetic support does not become involved. A desirable, small amount of flexibility is also obtained. Lack of contact with surface minimizes infection. A complete epithelial surface is supplied at the outset, reducing infection, secretions and crusting. Staging is minimized.

Clinical Application

This method of reconstruction of cervical trachea is illustrated by its application to the clinical problem of a 68-year-old man suffering from increasing obstruction of the upper trachea due to invasive growth of a carcinoma of the thyroid.

Case 5 (MGH 712591). A 68-year-old man was admitted with stridor, increasing dyspnea, hoarseness and hemoptysis. An irregular tumor was palpable in the left lobe of his thyroid. The left vocal cord was paralyzed. Laminograms showed invasion of the tracheal lumen beginning 1 cm. below the true vocal cord (Fig. 5). No pulmonary or osseous metastases were evident. Endoscopy showed an irregular, easily bleeding tumor occluding over two thirds of his tracheal lumen. Radioiodine scan showed uptake only on the grossly uninvolved side.

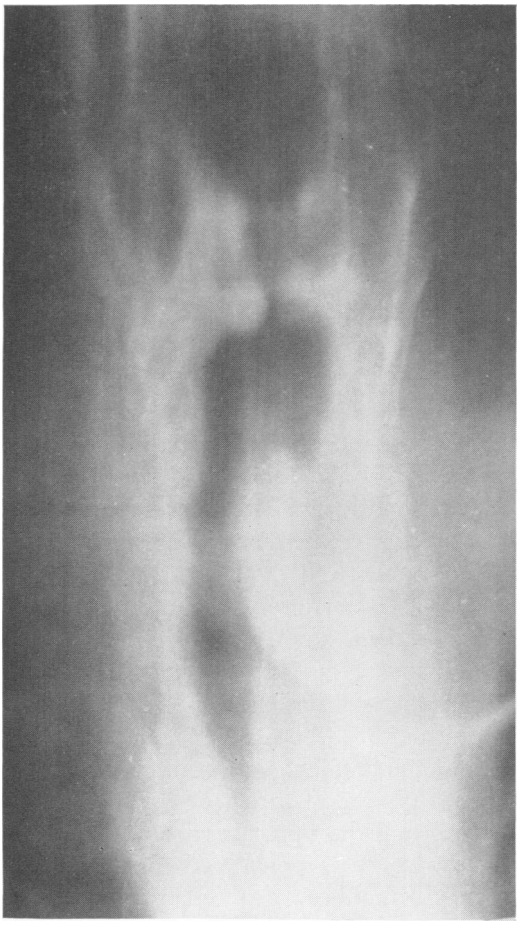


FIG. 5. Case 5. Preoperative laminogram showing invasive lesion partly obstructing the trachea below the level of the vocal cords.

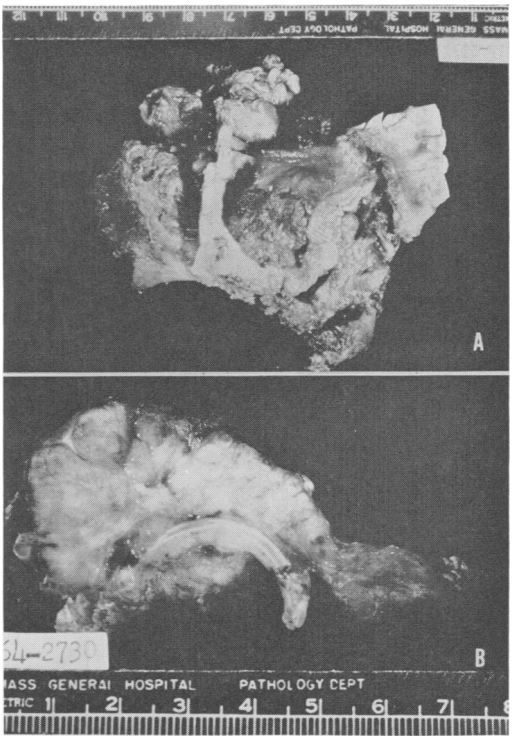


FIG. 6. Case 5. A) Longitudinal view of opened trachea showing invasive lesion. B) Cross sectional view shows the extensive involvement which prohibited lateral resection of tracheal wall.

On March 7, 1964 total thyroidectomy was performed, excising the trachea in continuity, from just below the cricoid cartilage on the right but including the cricoid on the left, for a distance of six rings. The strap muscles, the involved Delphian nodes and involved superior mediastinal nodes were excised in continuity. Tumor occupied over one half the circumference of tracheal wall so that partial tracheal excision was not possible (Fig. 6a, b). The tumor was primarily papillary adenocarcinoma (Fig. 6c), but with variable histologic pattern, containing areas of follicular differentiation and undifferentiated areas. The functioning right recurrent nerve and the right parathyroid glands were preserved. Esophagus was uninvolved. A first-stage tracheal reconstruction was then fashioned as detailed below. Because the mediastinal trachea was unnecessarily mobilized by finger dissection down to the carina, 0.5 cm. of trachea at the distal tracheocutaneous anastomosis was devitalized, necessitating later revision of this anastomosis with consequent delay in the

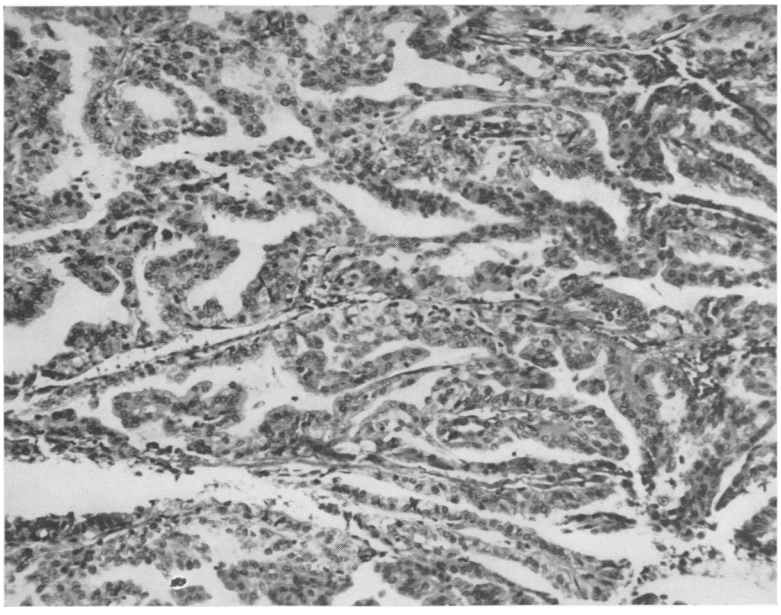


FIG. 6. C) Photomicrograph (H&E ×170). Papillary adenocarcinoma of thyroid.

second stage. The upper anastomosis healed completely. On June 27, 1964 the anterior tracheostomy slit was closed. The patient has remained well, breathes easily and coughs up a small amount of yellowish sputum daily. His "trachea" has lateral rigidity with slight flexibility similar to the normal (Fig. 7a, b). There has been no erosion of plastic rings. Bronchoscopy in September, 1964 showed an excellent lumen with a moist, clean epithelial surface without anastomotic narrowing. Chest x-ray film remains clear. He is maintained on sodium l-thyroxine.

Operative Technic

If tracheal resection is considered likely, a collar incision is made somewhat lower than usual to place it in the most advantageous location and, also, to utilize, in a hirsute male, the maximal length of relatively hairless skin which lies between the bottom of the beard line and the upper chest hair. After resection of the trachea the reconstruction is commenced by making a second incision through skin and platysma above and parallel to the first incision (Fig. 8). The bases of this bipedicled flap are flared slightly for better blood supply. Distance between incisions at their central point depends in part on the length of tracheal replacement required; this remains relatively short since the total length of cervical trachea, even with some cervical extension, is usually under eight rings. Anesthesia is maintained easily using a flexible Tovell tube inserted into the distal trachea across the operative field.

Supporting plastic rings (Fig. 10a) are introduced into the flap, using specially made needles (Fig. 10b) which pass through lateral slits in the skin flap, between the undersurface of dermis and the platysma—drawing the rings behind them. The necessary battery of rings is introduced concurrently (Fig. 8). Rings are spaced at 1-cm. intervals. The needles are withdrawn through second slits on the opposite side of the flap, holding sutures are cut and the rings then remain in place, buried within the flap in separate noncommunicating channels. Anastomosis between uppermost trachea (or the lower larynx) and the upper border of the evolving skin tube is performed in two layers. A small number of interrupted chromic catgut supporting sutures is used between the outer tracheal or laryngeal connective tissue layers and the platysma of the skin

tube. An inner layer of nonabsorbable sutures is placed between the full thickness of tracheal wall and the full thickness of skin. Accurate epithelial to epithelial approximation is made. Since the anastomosis is completed circumferentially, it is commenced posteriorly and carried in alternation around right and left circumferences. In the posterior half the outer layer of sutures is placed initially and in the anterior half the inner layer is more easily placed first. The inferior anastomosis is performed in the same way. After completion of the posterior half, the Tovell tube is removed and a translaryngeal endotracheal tube is passed from above, across the interposed cutaneous segment. This stage is completed by closing the lateral portions of both transverse incisions after insertion of suction catheters beneath the flaps. No tracheostomy tube is required postoperatively. Suction may be done easily through the stoma. The patient may speak by occluding the stoma. If excessive hairs are present in the flap, these may be removed by electrolysis in the interim preceding closure of the tracheostomy.

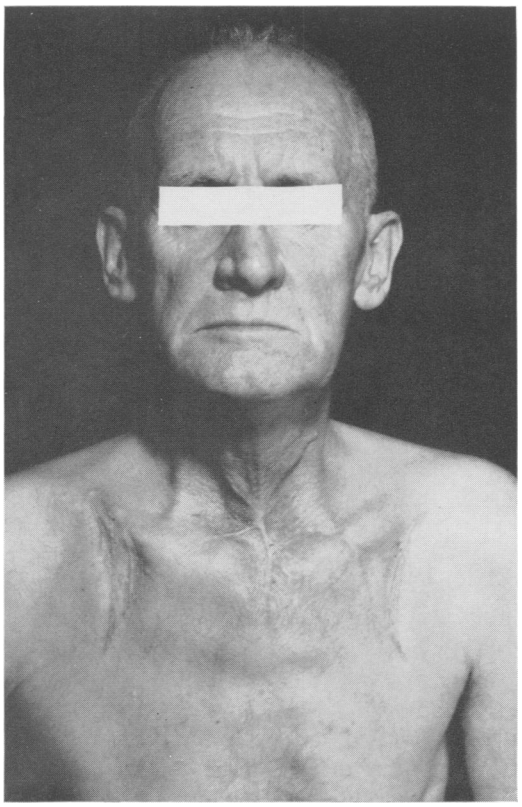


FIG. 7. Case 5. A) The operative sites.

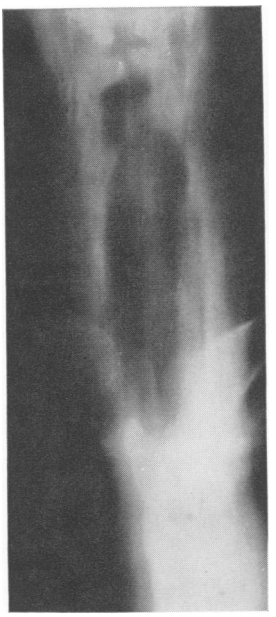


FIG. 7. B) Postoperative laminogram to show the present upper airway.

After acquisition of adequate blood supply, the tracheostomy is closed by circumcising the skin and platysma at a wide enough distance from the stoma to provide adequate tissue for infolding (Fig. 8). Additional segments of plastic rings may be introduced for added anterior support (Fig. 9). If closure had been done earlier in the case cited, added segments would not have been required. Closure of the reconstruction is done with a meticulously placed subcuticular chromic catgut suture, thus minimizing intratracheal crusting during healing of the inner incision. Closure of platysma is performed over the rings. Lateral skin flaps are now widely mobilized so that full thickness closure may be made over the reconstruction. Relaxing incisions, surfaced with skin grafts, are placed laterally over the clavicles to eliminate tension and to avoid placing a skin graft over

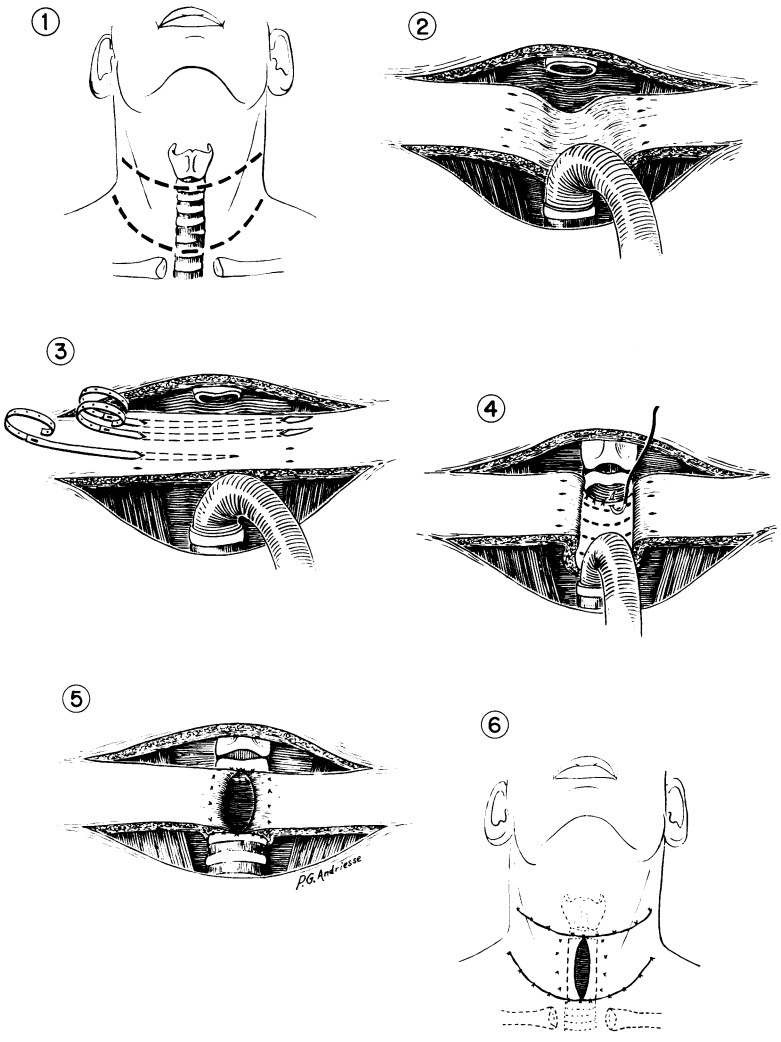


FIG. 8. Cervical tracheal reconstruction. Operative Technic. Stage I: (1) The incisions create a bilaterally pedicled flap of skin and platysma. (2) The trachea has been resected, the distal end intubated and the flap lies in the tracheal bed. (3) The ring-carrying needles are being inserted in the flap concurrently, through small lateral slits. (4) After placement of the rings between dermis and platysma, the outer layer of sutures has been inserted to form the posterior portion of the upper anastomosis and the posterior inner layer is being completed. The outer layer joins outer tracheal wall and platysma, the inner joins trachea and skin. (5) The upper and lower anastomoses have been completed, creating a longitudinal stoma. (6) Completion of the first stage by closure of the transverse incisions.

the reconstruction itself. Tracheostomy is undesirable and unnecessary.

Discussion

Despite agreement on theoretical and experimental grounds that end-to-end suture is the preferred method of reconstruction for the intrathoracic trachea following resection, its feasibility has not been widely examined in man.[8, 19] Since the problem is primarily an anatomic one, measurements in experimental animals have little applicability. Our systematic studies in man supported and extended the very pertinent observations made by Michelson, Solomon, Maun and Ramirez [14] in eight cadavers. Ferguson, Wild and Wangensteen [6] earlier suggested such a possibility on the basis of experiments in dogs and measurements of elasticity in ten human tracheas. Limited circumferential tracheal resection with primary anastomosis has been accomplished clinically,[11, 15, 21] often without confidence in the possibility of extending the resection, if need had arisen. Macmanus and McCormick [12] emphasized the importance of tracheal mobilization in a 3-cm. sleeve resection. Juvenelle and Citret [10] proposed re-

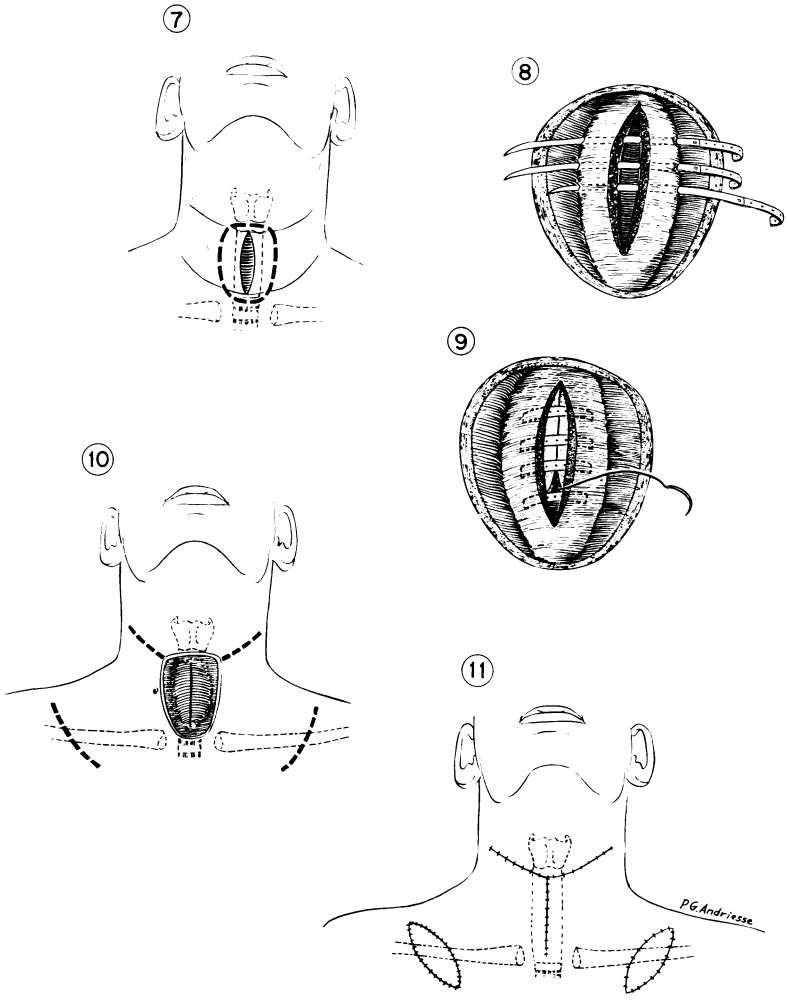


FIG. 8. Stage II. (7) The stoma is circumcised through skin and platysma. (8) The skin and platysma within the circular incision have been infolded. Additional segments of plastic rings are being added between dermis and platysma to supply more anterior support. (9) The internal skin tube is completed with a continuous subcuticular suture. (10) Platysma has been sutured over the rings. (11) Relaxation to permit midline closure of lateral platysma and skin over the reconstruction is permitted by incisions laterally over the clavicles. The resulting defects are surfaced with split thickness grafts. No tracheostomy tube is required.

implantation of the main bronchi in experimental work to facilitate resection of the lower trachea. Barclay, McSwan and Welsh [2] performed extended resections in two patients by wide mobilization and reimplantation of the left main bronchus. A similar unsuccessful attempt has also been reported.[1] Mathey, Binet, Galey, Evrard, Lemoine and Denis [13] recently emphasized the desirability of annular resection and primary anastomosis for tracheal lesions.

The present approach removes the surgeon's inhibition to perform adequate tracheal resection by supplying him with confidence that reconstruction may be made safely over a wide anatomic gap. For this reason the concept of devolvement of a cervical tracheal segment into the mediastinum has importance, although it is not often likely to be needed. Approach to any tracheal reconstructive surgery must be unhurried.[7] The anesthetic technics described supply such a setting without the added complexity of partial cardiopulmonary bypass. Advances in combined therapy of primary carcinoma of the lung and esophagus may eventually justify application of these technics in those diseases.

The many methods which have been designed for cervical tracheal reconstruc-

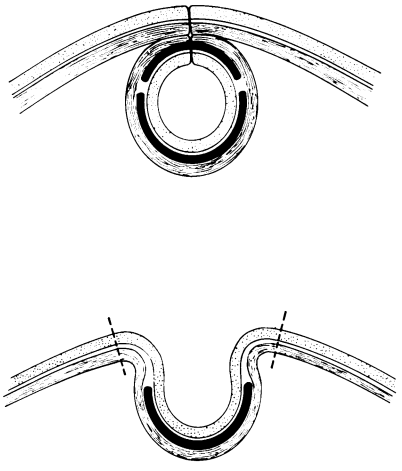


FIG. 9. Diagram of reconstruction in cross section. The lightly stippled area represents the skin. The lined area is the attached platysma. Plastic rings are solid black and lie between the two layers. The tube is infolded at the first stage, above. The dotted lines show the incisions for closure at the second stage. The surface skin is closed over to complete the reconstruction, below. At the time of closure additional anterior supports were inserted in this case.

tion will not be reviewed in this report. Their complexity is varied, as is their success.[5, 17] The present method is proposed as a simple and reproduceable one with advantages of early completion of the reconstruction and of biologic dependability. Requirements for prompt healing are met by the use of autogenous full thickness tissues, assurance of good blood supply, implantation of a minimum amount of foreign material—which is wholly buried —and avoidance of stents or tubes. Particularly in the case of secondary tumors, the method will have to be used judiciously, with full appreciation of the biologic behavior of the primary tumor and the determinable extent of the disease at the time of proposed operation. The method is also applicable to stenotic lesions. Until the method has been used in many instances and long-term results observed it must be considered to be a trial procedure despite experimental and early clinical success.

At least a bridge of respiratory epithelium often has been thought to be essential for successful functioning of any tracheal reconstruction.[3] Its absence in the upper trachea in the case described has presented no problem to date. Secretions are cleared up to the point of the new squamous segment in part by the action of the ciliated epithelium of the lower trachea and bronchus. A normal cough carries these secretions the rest of the way to expulsion. No undue secretions appear to arise from desquamation. These findings were anticipated from past evidence: adequate clearing across skin tubes and prosthetic tubes in experimental tracheal replacement in animals, occasional success of solid prostheses in the human trachea, circumferential application of split skin grafts in tracheal reconstruction in man, clearance across complexes of plastic mesh and slowly healing granulations, and the ease with which patients with extensive squamous metaplasia clear their tracheas by coughing.

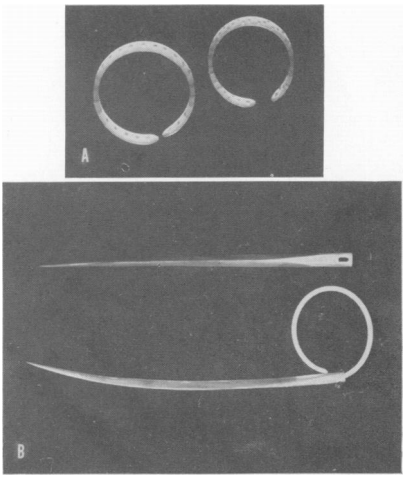


FIG. 10. A) Prosthetic plastic rings (polypropylene). The perforations permit suturing and tissue ingrowth. B) Needles for introduction of rings between dermis and platysma. The tip of the ring is held in the slotted hilt of the needle with a suture.

Summary

A practical and comprehensive system allowing extensive circumferential tracheal resection and reconstruction at any level is presented. In the *mediastinum* repair is accomplished by the ideal method of end-to-end anastomosis, made possible by wide anatomic mobilization—thus avoiding the hazards of intrathoracic prostheses. In the *neck*, a full-thickness tube of autogenous skin, supported by buried plastic rings, is simply constructed in two stages—affording prompt healing, lack of stenosis and good function despite absence of respiratory epithelium. Laboratory studies and clinical applications are described.

Acknowledgment

The experimental work briefly described was accomplished with the collaboration of Dr. Ellen F. Dignan and Dr. Tsuyoshi Miura. Some of the laboratory studies have been reported and some will be detailed elsewhere. Clinical anesthesia was planned and managed by Dr. Henrik H. Bendixen. Case 2 was operated upon with Dr. Thomas Gephart and Case 3 with Dr. James M. Shannon. The plastic rings were fabricated by Mr. Carl Hewson, Brunswick Manufacturing Co., Inc., and the needles by Mr. Carl Althausen, Massachusetts General Hospital Instrument Shop.

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Discussion

Dr. James R. Cantrell (Seattle): I am certain that all of us are aware of the availability of additional tracheal length following mobilization in the mediastinum. The re-implantation of the bronchus is quite a feasible procedure, and one which will greatly enhance the ability to repair such defects.

However, one must be aware of the fact that to a considerable extent the ability to mobilize the trachea depends upon its inherent elasticity. In younger individuals this elasticity is really quite remarkable but, with increasing age, this elasticity becomes quite strikingly diminished. In a series of cadavers in which we removed the trachea and attempted to determine the length of trachea which