The ingenuity of the chest specialist may be taxed to the limit in the management of intractable asthma. Attacks can be frightening and cruel. Responses to therapy are often unpredictable. Underlying factors influencing the intense and generalized bronchospasm are complex. They include: allergy, emotional disturbances, disharmony of sympathetic and parasympathetic nerve control, infection, mucosal thickening and problems of secretion elimination. Although asthma is considered to be a medical disease, irreversible structural changes in the bronchial system may exist. The presence of such mechanical problems should be determined and consideration given to their correction. It is the purpose of this paper to relate some experiences in the search for and the treatment of structural abnormalities which act as “trigger mechanisms.”

**Historical**

The interest of thoracic surgeons in the serious plight of the asthmatic was first kindled by the physiologic work on the nerve control of the lung. More than 100 years ago, Williams\(^1\) investigated the influence of the vagus nerve on bronchial caliber. However, it was the monumental works of Dixon and Brodie\(^2\) and Dixon and Ransoms\(^3\) which established the facts that: (1) the preponderance of constrictor fibers are found in the vagus; (2) the preponderance of dilator fibers are in the sympathetic (T1-T2-T3); (3) both systems carry both types of fibers; and (4) fibers cross from right to left and vice versa. Kummel\(^4\) in 1923 was the first to treat asthma by the removal of the stellate ganglia. Since then, there have been many attempts to relieve bronchospasm by interrupting the nerve supply to the lung.** In 1950, at the meeting of the American Association for Thoracic Surgery, three presentations on denervation for asthma were given. Klassen\(^5\) reported on results of vagal section. Abbott\(^6\) combined upper thoracic sympathectomy and plexectomy. Blades\(^7\) emphasized the importance of a complete plexectomy.

In the past, the attention of most surgeons centered on interventions which interrupted the efferent or afferent nerve pathways to the lung. Structural abnormalities were not hunted for and corrected, if present.

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**In a recent paper, the author included a more detailed historical account of surgical procedures which have been carried out in asthmatic subjects.*
Overlooked "triggers" quite possibly contributed to disappointing lasting results of denervation alone. However, it has been recognized that disturbances in one area of the bronchial system may act as a "trigger" to set off general bronchospasm. Abbott advised that destroyed segments be removed at the time the lung was being denervated. In 1952, Overholt, Walker and Woods called attention to hidden bronchiectasis in the asthmatic.

**Selection of Cases**

Intractable cases of asthma should have the benefit of a thorough investigation, particularly (1) those whose illness was initiated by an attack of pneumonia; (2) those who develop frequent colds which settle down in the chest; (3) those who have productive cough; (4) those who have a unilateral wheeze; (5) those who have chest discomfort or pain; and (6) those in whom there is systemic evidence of a focal infection, such as arthritis.

Whether or not patients who demonstrate no structural abnormality of the bronchial system be explored depends upon the degree of disability and the burden of the medical regime. At times, subjective or objective signs are present which attract attention to one side or the other. It may be a unilateral wheeze or localized discomfort or pain. Patients show an uncanny ability to lateralize their difficulty. With or without bronchographic

![FIGURE 1: Bronchial compression by enlarged lymph nodes is a common trigger mechanism in asthma. (a) Relation of normal lymph nodes. (b) Partial occlusion. (c) Complete occlusion. (d) Perforating calcific node with spicule.](image)
indication of abnormality, there may be strong presumptive evidence of mechanical difficulty which may be discovered at exploration and can be corrected forthwith.

**Bronchography Safe and Essential**

Although routine chest films are indicated in all individuals, normal lung fields will be found in most asthmatics. Visualization with contrast media is necessary if the presence, nature and extent of a structural abnormality in the bronchial system are to be determined. Since asthma has been considered by many to contraindicate bronchography, it seemed important to set forth a plan of management which minimizes risk:

1. *Preparation*—Patients are hospitalized for intensive medical management which usually includes intravenous aminophyllin drip, intermittent positive pressure breathing, aerosols and specific antibiotics, if indicated. Bronchography is deferred until maximum improvement of bronchospasm is effected.

2. *Technique*—This should be simple and free of all instrumentation save a single catheter. Preliminary sedation with a barbiturate and atropine protects against topical anesthetic reactions.* After spraying the pharynx with the anesthetic solution, a catheter is passed via the nose into the posterior pharynx. With the tongue held forward, the patient is asked to cough and, as the epiglottis rises with the blast of air, the tube is given a quick thrust. Its tip passes into the trachea, and the distal end is fastened to the nose and forehead with adhesive tape. The trachea and bronchi are anesthetized by dripping the anesthetic solution through the catheter. With the patient under the fluoroscope, the contrast media is then instilled. The catheter is left in place until the films are developed and studied. If any area has been inadequately filled, the specific region under question is re-injected.

*An anesthetist accompanies the surgeon and patient to the x-ray department. Equipment for emergency intubation, oxygenation and control of respiration is always in readiness.

**FIGURE 2:** (a) A dilated bronchus acts as a collecting reservoir of liquid material. (b) Altered position of reservoir causes flooding of other bronchi. Such irritation and blockage induce bronchospasm.
3. Interpretation—Structural abnormality is clearly indicated if saccular or tubular dilatation, incomplete stenosis, distortion, crowding or abnormal spread of branches are found. Evidence of non- or mal-function, without ectasia, is frequently less clear-cut. A segmental or subsegmental branch may fill and be of normal diameter, but be barren of finer branches. This lack of bronchiolar filling gives a "dead branch" effect in contrast to normal segments which show all the twigs. In delayed filling, functioning segments permit the media to pass on out into alveoli to produce "foliage." The barren or "dead-branch" segment never shows alveolarization in late films. Complete lack of filling of a segment means one of four things: (a) technical failure; (b) localized bronchospasm; (c) mucous plug; or (d) structural abnormality. Careful preparation, unhurried instillation with proper positioning and serial films will greatly reduce the likelihood of the first three possibilities. If conditions are right and a re-injection of a nonfilling segment again fails, the presence of an organic obstruction should be seriously considered.

What is Accomplished at Exploration

The study of the integrity and behavior of all segments is the first accomplishment of exploration. Proper examination requires an adequate exposure of a completely mobilized lung. It should be carefully inspected and palpated and its response to alterations in intrabronchial pressure tested. Variations in pigmentation are noted. In adults, the lymphatics will be laden with carbon particles in the segments which have been capable of ventilation. Nonfunctioning segments are usually devoid of pigment. The majority of the unpigmented areas trap air and remain inflated during the period of manipulation. Occasionally, an indurated,
contracted, atelectatic segment will be found which is free of pigment. Such a segment probably has been defunctionalized since childhood.

Variations in segmental density can be determined quite accurately by palpation. Bronchiectatic segments in which there has been chronic infection may show areas of contraction, thickening or nodulation. Enlarged lymph nodes and calcific deposits can be removed. The mediastinal pleura should be opened to facilitate inspection and palpation of that area. The esophagus is inspected and palpated under the azygos vein on the right or under the aorta on the left. Fibrotic, calcific or enlarged lymph nodes wedged between the esophagus and major bronchi are removed.

The compliance of the lung to pressure changes in the closed anesthetic system is the most important of all observations the surgeon makes. When the bronchi are in spasm, the lung builds up a volume greater than that of the hemithorax. It bulges out beyond the limits of the retracted chest wall, even though pressure is not maintained within the anesthetic system.*

*It is important that the anesthetist aspirate bronchial secretions and that the intratracheal tube be in satisfactory position. A bronchodilator drug, given intravenously, may temporarily release the spasm.

FIGURE 4: Adhesions may be situated so that movements of diaphragm or rib cage result in distortion or abnormal stress of bronchi. (a) Normal expiration. (b) Normal inspiration. (c) Anchorage of lung by adhesions during expiration. (d) Same during inspiration with abnormal stress on lung and its root. Note diminished caliber of bronchi in spasm.
FIGURE 6: Right lateral bronchogram in severe asthmatic in whom enlarged nodes partially constricted middle-lobes bronchi. Attacks of asthma ceased after these nodes were removed. Note satisfactory delineation of all segments except the right middle lobe and the anterior basal segment. These trigger mechanisms were removed. The patient has been free of asthma for the past seven years.

FIGURE 7: Same case as Figure 6 after intensive medical preparation. Only some of major bronchi are outlined.
This situation provides an opportunity to test the effect of denervation. The vagus nerve is in full view and all branches entering the hilum can be readily divided, care being taken, if working on the left side, to avoid the recurrent nerve. Loose areolar tissue around the great vessels and major bronchi is divided and these structures virtually cleaned so they stand out separately. Major bronchial arteries are ligated and divided. In some cases, the healthy segments will immediately and uniformly deflate. In most, there will still be evidence of delayed or incomplete deflation and greater-than-normal pressure will be required to re-inflate. Diseased and functionless segments, obviously, are not influenced by the denervation. The next step is to interrupt the parasympathetic pathways. This also is easily accomplished as the sympathetic chain is in full view. The upper ganglia (T1-5) and the connecting trunk are removed. It is not necessary to disturb the stellate ganglia, thus avoiding a Horner's Syndrome. Following the double denervation, there is usually a dramatic change in the behavior of the lung. Healthy segments then readily comply to pressure variations as found in non-asthmatic individuals.

The final accomplishment of the exploration is concerned with the necessity for and extent of tissue excision. All bronchiectatic segments which are dependent and which act as collecting reservoirs or serve as a site for inflammation should be removed. The necessity for resection of such reservoirs is usually determined in advance by bronchography. The precise extent of structural abnormality and the number of functionless segments is settled at the time of exploration. Cystic areas which trap air and do not ventilate are not only useless, but interfere with the function of healthy segments. They either compress or trigger off spasm in adjoining segments.

In general, then, the surgeon inspects and overhauls the defective or abnormally functioning ventilatory organ. He liberates abnormally anchored segments, divides adhesions or bands, decorticates constricted segments, removes enlarged nodes or destroyed segments, denervates a spastic lung and works with it until all healthy segments are functioning properly.

Benefits

The value of exploration and the elimination of "trigger mechanisms" can best be told by summarizing the history of three illustrative cases and reporting on long-term follow-up studies. The first individual case report will indicate the severity and disabling nature of the disease for which bilateral surgery was required. In the second case, the "trigger" was abolished without sacrificing any pulmonary tissue. In the third, an unsuspected "trigger" was discovered at exploration and easily corrected.

Case Reports

Case 1: Mrs. H. B. This 33 year old married mother had been tortured by sudden, severe, long-standing attacks of status asthmaticus for 2½ years. These facts were in the medical record:
1. She had been under the care of eight different doctors, two eminent allergists and a hematologist.
2. There had been repeated admissions to hospitals in New York City and Boston during periods of a few days to several weeks. She was thoroughly studied from an
allergic standpoint and treated by desensitization, courses of antibiotics and prolonged steroid therapy. A muscle biopsy revealed periarteritis nodosa.

3. Upon 12 occasions, her husband had been summoned to the hospital and told that she was moribund and not expected to live through the night.

4. Her annual drug bill averaged $1600—not including those used during hospitalization periods.

On April 8, 1958, the right middle and lower lobes which were extensively involved with bronchiectasis were removed. The upper lobes inflated and deflated normally; therefore, a denervation of that lobe was considered unnecessary. She was discharged on the 15th post-operative day as improved. Wheezing was then limited to the unoperated (left) side. In May, 1952, she was rehospitalized for 19 days. She was in status asthmaticus, and a bronchoscopic aspiration was carried out under ether anesthesia.

On December 31, 1952, the left chest was explored, and the anteromedial basal segments of the lower lobe plus the lingula were resected. The remaining segments “trapped air” so a neurectomy and upper sympathectomy were done. She was discharged on the 13th post-operative day as considerably improved.

Follow-up—She has remained under medical supervision during the intervening 5½ years. There has been no serious episode requiring hospitalization. Her physician, Dr. Jerome Leff of Springfield, Massachusetts, writes: “Aside from her dependence upon a systematic schedule of ACTH, 80 units every 10-14 days, she seems in excellent physical health. She now weighs 103 pounds as against the 85 pounds she weighed when you operated upon her. She is active in professional modeling and off television and is in addition a typical young housewife and mother who cares for a home, two young sons and a husband.”

Case 2: Miss M. C. B. Age 45. Teacher. For six years, the patient had been having cough and wheezing. She had been treated with ACTH, KI and Tredal. She was studied in a university hospital a year previously for extreme shortness of breath. She was treated with nasal oxygen and intravenous medication of aminophyllin and hydrocortisone. She produced a glary mucus which she thought came from the right side. Occasionally, she experienced soreness in the right lower anterior chest. She had been tested for numerous allergies and none was found. She had never smoked. X-ray film was negative except for several small calcified areas in the right hilar region. The bronchial pattern was normal except for absence of bronchiolar filling of the two segments of the right middle lobe.

At exploration on November 27, 1957, the upper and middle lobes “trapped air.” Pigmentation was evenly distributed. Calcified lymph nodes were found medial to the intermediate bronchus and were impinged between the take-off of the middle lobe and the anterior basal segmental bronchi. Vagal nerve branches were divided and all hilar and infracarinal nodes were excised, and an upper sympathectomy carried out. Then all segments inflated and deflated without undue delay. No resection was required.

Follow-up—In May, 1958, she reported continued progress with improved breathing, freedom from cough and wheeze, and she was carrying a full schedule.

Case 3: Mrs. A. S. Age 53. This lady’s presenting symptom was intermittent pain in the right lower anterior chest of three years’ duration. She had been treated medically for duodenal ulcer, and the gall bladder had been removed. She had also been under treatment for asthma for a 14-year period in three leading Boston hospitals. She was referred for surgery because X-ray films revealed a rounded mass in the right lower anterior chest, thought to be either a tumor or a diaphragmatic hernia through the foramen of Morgagni. The area of density so clearly called for exploration that bronchography was deemed unnecessary. Upon surgical exploration on April 17, 1958, the mass proved to be a localized eventration of the diaphragm for which no correction was necessary. Unexpectedly, a small, indurated, airless middle lobe was found. There were no adhesions. The other two lobes were normal. Right middle lobectomy was performed. The pain, cough, wheezing and dyspnea were relieved.

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immediately. She was discharged on the 13th post-operative day. She has remained well and states that now for the first time in many years she appreciates the meaning of the term, "good health."

**Long-Term Results**

In a previous report,* the late results on 43 long-term surviving severe asthmatics treated surgically between the years 1945 and 1956, were given.* This report was concerned principally with an appraisal of vagal and sympathetic denervation either with or without excision of pulmonary tissue. There were 12 patients treated by denervation alone and re-appraised. Some degree of improvement was noted in 10 (Table I).

In appraising benefits, patients were re-examined and statements from both patients and their physicians were solicited. Improvement was undisputed or their condition was classified as the same. In the tabulation of the degree of benefit, it seemed expedient to group them, as follows:

1. Improved patients who required medication, but in reduced amounts. The majority in this group required some medical supervision.
2. Considerably improved patients who, on occasions, may medicate themselves. They rarely called upon a physician.
3. Those in whom asthmatic seizures have been eliminated. They enthusiastically reported that they were well.

Results were better in those in whom functionless segments were found and removed (Table II). There were 31 patients followed for periods of 18 months to 12 years.** All were improved to some degree, and three fourths of them significantly, as 25 of the 31 fall into Group 2 or 3. One half of the entire number treated were considered to be well and completely free of asthma.

**SUMMARY**

1. Intractable asthma may be perpetuated by structural abnormalities in broncho-pulmonary segments which act as "trigger mechanisms."
2. Bronchography, if carefully done, is safe and often productive of useful circumstantial information necessary for successful management.
3. Surgical exploration permits direct inspection of the lung and testing of segments as to inflow and egress of air. Mechanical defects can be corrected forthwith and sympathetic, parasympathetic or both denervations carried out simultaneously.

*During this same period, 287 non-surgical cases of asthma were examined. The series of surgically treated asthmatics comprised 15 per cent of this number. Also, 1292 cases of bronchiectasis were seen. The patients having both bronchiectasis and surgically treated asthma represented 4 per cent of the total number of bronchiectasis cases seen in the 11-year period.

**There was no hospital death among the patients treated by resection plus denervation.
RESUMEN

1. El asma intractable puede ser perpetuada por anormalidades estructurales en los segmentos broncopulmonares que actúan como mecanismos desencadenantes.

2. La broncografía si se hace con cuidado, es segura y a menudo capaz de dar información circunstancial necesaria para un tratamiento con éxito.

3. La exploración quirúrgica permite la inspección directa del pulmón y probar los segmentos en cuanto al ingreso y egreso de aire. Los defectos mecánicos pueden ser corregidos, las denervaciones simpática, parasimpática o ambas, llevarse a cabo simultáneamente.

ZUSAMMENFASSUNG

1. Ein unbeinflussbares Asthma kann verewigen als Ausdruck struktureller Abnormalitäten in bronchopulmonalen Segmenten, die die Rolle von “Auslös-Mechanismen” spielen.

2. Eine sorgfältig vorgenommene Bronchographie ist ungefährlich und oft von Wert als nützliche und eingehende Information, die notwendig ist für eine erfolgreiche Behandlung.


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