Surgery of the Upper Respiratory System

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Chapter 4: Surgery of the Frontal Sinus

Frontal Sinus Anatomy

The frontal bone consists of two portions: (1) a squamous or vertical portion which forms the forehead and houses the frontal sinuses, and (2) an orbital or horizontal portion which serves as the roof of the orbital cavity and floor of the anterior cranial fossa. The nasal process of the frontal bone articulates with the two nasal bones and the ascending process of the maxilla. Along with the zygomatic bone, the frontal bone makes up the supraorbital margin. Laterally, in the temporal fossa, the frontal bone articulates with the greater wing of the sphenoid bone. Posteriorly, it articulates with the parietal bone to form the coronal suture. In the orbital cavity, the frontal bone articulates with the lacrimal, ethmoid, and sphenoid bones.

Each frontal sinus is usually somewhat pyramidal in shape and lies between the inner and outer table of the vertical portion of the frontal bone. The roof of the orbital cavity forms its base. There are usually two frontal sinuses, but there may be three or even more. If additional frontal sinuses are present, they may lie lateral or posterior to one another. Quite frequently a frontal sinus is partially subdivided by septa. These septa can be so placed as to interfere with proper drainage. The two frontal sinuses are frequently asymmetrical. In about 10% of persons, one frontal sinus does not develop above the level of the supraorbital rim. The important relations of the frontal sinus are the anterior cranial fossa and the orbit. The bony plate separating the frontal sinus from these neighbors can be quite thin and is potentially the direction for extension of disease.

Drainage from the frontal sinus into the nasal cavity is variable. In most persons the nasofrontal duct is absent and drainage takes place directly from the frontal sinus into the frontal recess of the nasal cavity. In approximately 15%, the drainage from the frontal sinuses is by way of a nasofrontal duct into the infundibulum ethmoidale. Probably the most common cause for blockage of drainage and maintenance of a chronic infection of the frontal sinus is impingement of the nasofrontal orifice in the middle meatus. This can be caused by abnormally large ethmoid cells in this region, a cystic or cellular middle turbinate, a deviated nasal septum, or a chronic edematous inflammatory process of the middle turbinate. In some persons, an anterior ethmoid cell may extend superiorly and interfere with the patency of the nasofrontal orifice or duct.

The blood supply to the frontal sinus is from the internal carotid artery by way of the supraorbital branch of the ophthalmic artery. On occasion there may be a branch of the anterior ethmoid artery supplying the frontal sinus. Externally, blood is drained from the sinus into the facial vein; posteriorly, venous drainage takes place through emissary vessels passing into the dura, and internally, by way of the orbit.
The frontal sinus is innervated by the supraorbital branch of the ophthalmic nerve. Most of the sensory nerve endings are found in the region of the nasofrontal orifice; thus an increase or decrease of intrasinus pressure can produce severe frontal pain.

**Trephination of the Frontal Sinus**

**Indications**

Most episodes of acute frontal sinusitis clear spontaneously or following local intranasal therapy (decongestant sprays), intermittent packing with 4% cocaine-impregnated cotton pledgets in the region of the middle meatus, and/or local application of heat combined with systemic treatment (antibiotics and systemic decongestants).

If pain is not present, a 10-day to 2-week period of local and systemic therapy should be prescribed. X-rays of the sinuses should be taken (upright Waters' views) at 2- to 4-week intervals until the sinuses appear normal. X-ray evidence of fluid and/or swelling of the mucosal lining of the frontal sinus is not positive indication for the trephine operation unless the patient has persistent pain.

If, on the other hand, the acute frontal sinusitis is accompanied by persistent pain in the region of the sinus and edema of the upper eyelid and there is lack of response to conservative measures, it will be necessary to obtain drainage in order to prevent complications.

In addition to its use in the treatment of acute frontal sinusitis, the trephine operation may be employed as an exploratory procedure, to determine the nature of chronic frontal-sinus disease and/or to obtain a biopsy specimen.

**Technique**

Trephination of the frontal sinus can be carried out with the patient under either local or general anesthesia. A 3/4-inch horizontal incision is made in the superomedial aspect of the orbit just below the eyebrow, through skin, subcutaneous tissue, and the periosteum over the floor of the frontal sinus. The periosteum is then elevated above and below this incision, exposing the floor of the frontal sinus. The floor, rather than the anterior wall, is penetrated, for the floor consists of laminar bone containing no marrow, whereas the bone of the anterior wall is cancellous and contains marrow. If cancellous bone becomes contaminated by the purulent secretions from the frontal sinus there is danger of complicating osteomyelitis. A curette, or, preferably, a rotating cutting bur is used to penetrate the bone and make an opening in the floor 6 to 8 mm in diameter. Material for culture is then taken.

Some idea of the status of the interior of the sinus can be obtained by direct vision and also by inspection with an instrument, such as a nasopharyngoscope, inserted into the sinus through the trephine opening. Following inspection of the sinus, a rubber or plastic drainage tube, approximately 1 inch in length, is inserted and sutured in place.

Following the release of pus, the edema of the mucous membrane in the region of the nasofrontal orifice soon subsides, and normal drainage is reestablished. Irrigation of the sinus
through the drainage tube with warm normal saline solution is of value, and should be executed at least four times a day. Specific antibiotics, prescribed according to results of sensitivity tests, may be added to the irrigation solution. In addition to local treatment the patient is given systemic antibiotics. The patency of the nasofrontal communication may be determined by inserting a dilute dye solution (methylene blue) into the sinus through the trephine tubing. If the nasofrontal orifice is patent the dye should appear in the nasal cavity almost immediately. The trephine tube is removed as soon as drainage by the natural route has been reestablished.

**Intranasal Surgery for Chronic Frontal Sinusitis**

The treatment of chronic frontal sinusitis has been a frustrating problem for the rhinologist. Antibiotics alone are often of little value but should be given during the subacute and early chronic stages, along with local and systemic nasal decongestants.

In many instances, chronic frontal sinusitis can be cured by correcting the intranasal situations which either interfere with proper drainage by way of the nasofrontal passage or initiate re-infection of the sinus. The establishment of adequate drainage with ultimate resolution of the infection can often be accomplished by an intranasal operation. A careful submucous resection of the nasal septum, removal of intranasal polyps and/or the anterior portion of the middle turbinate, and an anterior ethmoidectomy are the procedures used to reestablish this drainage. If chronic ethmoiditis seems to be the offender, a complete external ethmoidectomy is indicated.

Intranasal probing and attempted enlargement or cannulization of the nasofrontal orifice are mentioned only to be condemned. Once the virginity of the nasofrontal passage is violated, scarring and stenosis are inevitable. If conservative intranasal surgery is not successful, then radical frontal sinus surgery is indicated.

**External Surgery of the Frontal Sinus**

**Indications**

Chronic frontal sinusitis, complicated with persistent pain, external fistula, internal fistula, intracranial extension, bone necrosis, orbital complications, and/or a mucocele or pyocele, and benign and malignant tumors of the frontal sinuses are positive indications for external frontal sinus surgery.

**Various Techniques**

There are numerous external frontal sinus operations, each having many variations. Those currently popular in the USA and the anatomic changes effected by each are shown.

**Lynch Frontal Sinus Operation (1920).** In the USA, this is probably the most frequently employed procedure for the treatment of chronic frontal sinus disease. An ethmoidectomy, removal of the middle turbinate, and resection of the entire floor of the frontal sinus are included in this operation. A rubber or plastic tube is placed between the frontal sinus and the nasal cavity by way of the ethmoid labyrinth. This tube is left in place
from one to three months following the operation and, at times, requires considerable care. As a general rule, the Lynch frontal approach has been highly effective in the control of chronic frontal sinus disease; on the other hand, its failure rate is sufficient to warrant the search for a better operation. Incomplete removal of the mucous membrane of the sinus can result in mucocele and pyocele formation. A stenosis of the reconstructed nasofrontal passage may lead to recurrent chronic frontal sinusitis.

**Riedel Operation (1898).** This consists of removing the anterior wall and floor of the frontal sinus, thus offering wide exposure of the sinus. The sinus cannot be completely obliterated in many cases, especially when its anteroposterior dimensions are large. Mosher modified the Riedel operation by removing the posterior wall of the sinus also. As a general rule, the Riedel procedure is disfiguring and offers a percentage of cure no higher than that of the Lynch operation.

**Lothrop Frontal Sinus Operation (1914).** This procedure entails a unilateral or bilateral anterior ethmoidectomy and middle turbinectomy. The interfrontal septum is removed. A large opening from the frontal sinuses into the nasal cavity is made by connecting the two nasofrontal ducts and resecting a portion of the superior nasal septum. The operation may be technically difficult, but it is quite effective in a patient with bilateral frontal sinus disease and in frontal sinuses with wide anteroposterior dimensions.

**Killian Operation (1904).** This is a modification of the Riedel procedure. In the Killian operation also, an anterior ethmoidectomy and middle turbinectomy are performed. However, a bridge of bone 10 mm wide is left in place at the supraorbital rim. This functions, of course, to prevent postoperative disfigurement. This operation is attended with much less alteration of the forehead contour than is the Riedel procedure; on the other hand, the bridge prevents obliteration of the sinus. Actually, the end result of the Killian operation is quite similar to that of the Lynch operation.

**Anterior Osteoplastic Frontal Sinus Operation.** This operation, described in the late nineteenth century literature, has been revived during the past decade. In this operation an inferiorly hinged "trapdoor" of bone is fashioned from the anterior wall of the frontal sinus. This affords direct access to the entire contents of the frontal sinus and an excellent view of the nasofrontal orifice from above. The intrasinus disease can be removed with ease. Revisions of previous frontal sinus surgery can be performed. Adequate drainage from the frontal sinus to the intranasal space can be established, or the frontal sinus can be obliterated completely by the implantation of adipose tissue.

The modification of the osteoplastic adipose obliteratorive frontal sinus operation is basically similar to that outlined by Bergara and Itoiz and by Tato and associates. It has been very successful in the treatment of chronic frontal sinus disease. The advantages of this techniques are:

1. It is a direct approach. The entire sinus, including the orifice of the nasofrontal duct, can be seen. The intrafrontal disease can be eradicated entirely. The dissecting microscope may be employed, if necessary, to accomplish this task. A decision whether or not to obliterate the sinus can be made readily. For example, when revising a Lynch frontal
operation, the surgeon has the choice of revising the approach from above or obliterating the sinus with adipose tissue.

2. There is no resultant facial deformity following the operation. All other radical frontal sinus operations do, at least on occasion, produce orbital or forehead defects

3. The operation is relatively atraumatic and its morbidity is low. Postoperative care is negligible. We have found follow-up care to be unnecessary other than for the purpose of clinical research.

4. The two frontal sinuses may be operated upon simultaneously.

One hundred consecutive cases of frontal sinus disease treated by the osteoplastic approach have been reviewed. They are categorized as follows:

I. Osteoma 15
   A. Uninfected 9
   B. Infected 6

II. Trauma 2

III. Foreign body 1

IV. Chronic infection 82
   (The categories below are not mutually exclusive.)
   A. Orbital displacement 15
   B. Previous surgery 41
   C. Painless swelling 5
   D. Draining fistula 7
   E. Bilateral operation 31
   F. Brain abscess 2
   G. Allergy 21

Fifteen of the 100 patients were operated upon because of an osteoma or complications thereof. Nine of these were found to have osteoma without secondary infection. Their complaints consisted of pain in the region of the orbit and over the frontal sinus and manifestations of displacement of the orbital contents. The most common direction of extension of disease was through the floor of the frontal sinus, interfrontal septum, and posterior wall, exposing the dura. In all these patients the operation consisted of simple removal of the osteoma without disturbing normal mucous membrane. The sinus was not obliterated with adipose tissue. There have been no postoperative complications.

Six of the patients with osteoma had secondary infection. Two were referred for frontal sinus operation after excision of frontal lobe abscesses.

Two patients underwent bilateral adipose obliteration of the frontal sinuses in order to create a barrier between the nose and intracranial space following trauma to the frontal region.
One patient had pain and swelling of the right frontal region which occurred shortly after neurosurgical treatment of a berry aneurysm. X-ray examination revealed increased density in the right frontal sinus and a metallic button in the frontal bone just superior to the sinus. At surgical exploration, the sinus was found to contain a large cyst in continuity with the metallic button. The sinus membrane was thickened. The dura was exposed. Diseased tissue was removed and the sinus was obliterated. The patient has remained asymptomatic for five years.

Eighty-two of the 100 patients were operated upon because of chronic frontal sinus infection. The chief complaint of the majority of these patients was forehead pain. In 50% of them the presenting symptom was swelling in the region of the eyebrow or upper lid; 13 complained of diplopia. One half of the group had a history of a previous operation upon the frontal sinus. Five patients with painless swelling in the region of the supraorbital rim had been seen first by ophthalmologists. At operation, all 5 were found to have erosion of the sinus floor and exposure of orbital periosteum, and all but one had exposure of the anterior fossa dura.

Complications among the 100 patients were not common. Five had hematomas of the forehead which became secondarily infected. Treatment consisting of drainage and antibiotics was effective and no further complications ensued. One elderly patient developed thrombophlebitis and a nonfatal pulmonary embolism. Some of the patients complained of either hypoesthesia or hyperesthesia in the distribution of the supraorbital nerves. In 3 patients the operation failed to effect a cure; in 2 of these, the Lynch frontal sinus operation had been performed previously and in the third, failure was associated with fibrous dysplasia of the frontal bone.

A number of categories were studied in the group of 82 patients who had chronic frontal sinusitis. Fifteen of the group complained of diplopia; all but two of these had orbital and frontal pain. Nine of the 15 had erosion through the floor of the frontal sinus, and the remaining 6 had inferior convexity of the floor producing displacement of the orbital contents. Three patients had erosion of the posterior wall of the frontal sinus with exposure of the dura of the anterior fossa. A pyocele or a mucocele was found in 13, chronic inflammation in one, and hypertrophic polypoid sinusitis in another.

Forty-one patients had undergone previous surgery related to the frontal sinus exclusive of other intranasal or sinus procedures. Twenty-nine of these had had a Lynch frontal sinus operation previously; 26 of the 29 had either a mucocele or a pyocele.

Five patients were first seen by an ophthalmologist and were referred to the otolaryngologist after x rays revealed frontal sinus disease. They complained of diplopia without symptoms referable to sinus disease. One of this group had had a Lynch frontal operation previously. The other 4 gave no definite history of sinus disease. All 5 of these patients had erosion of the frontal sinus floor, and one had exposure of the anterior fossa of the dura.

Seven patients had a chronic draining fistula in the region of the eyebrow or forehead. All of these had chronic inflammatory disease of both frontal sinuses. Adipose tissue was used to obliterate the sinuses in all of the group. Antibiotics, selected according to culture and
sensitivity tests, were administered pre- and postoperatively. None of the group had postoperative complications.

The bilateral osteoplastic frontal sinus operation was performed on 31 patients. As experience and confidence in the procedure grew, there was less hesitation about operating on both sides when the x rays showed bilateral disease, even though only one side presented symptoms. The bilateral operation adds very little extra time to the procedure and sometimes provides better exposure with more working room than a unilateral bone flap would allow. The morbidity of the bilateral operation is no greater than that of the unilateral. The horizontal scar across the root of the nose is rarely objectionable and is hidden by eyeglasses. The scar is obviated in females by a coronal incision behind the hairline.

In addition to the two patients previously discussed in the osteoma group, two young women, ages 16 and 29 years, underwent frontal sinus operation following neurosurgical treatment of frontal lobe abscess. Both had a bilateral operation for chronic infection with exposed dura. In the younger patient, a large area of osteomyelitic frontal bone was resected. Both patients have done well postoperatively.

Twenty-one patients have a history of varying degrees of nasal symptoms ascribed to "allergy." This proportion is about what one might expect in any average New England population. A number had had repeated polypectomies and an ethmoidectomy. The type of sinus disease encountered and the postoperative results were no different from those in nonallergic individuals. One patient, 8 years after the osteoplastic procedure, which had followed multiple unsuccessful operations, states that the operation relieved her of a life of misery and "even cured my allergy." One wonders, in some cases, whether the "allergy" causes the sinusitis or vice versa.

Experimental evidence has shown that adipose tissue seems to be the ideal implantation substance for long-term obliteration of the frontal sinus. Adipose obliteration of the feline frontal sinus has initiated the following observations and conclusions:

1. Varying amounts of adipose tissue survive. The remaining portion is replaced by fibrous tissue to complete the obliteration.

2. Time is not a factor, for both one-week and one-year experiments showed nearly 100% survival of adipose tissue, while other experiments, such as a one-month implant, showed only 50% survival of the adipose tissue.

3. Revascularization of the adipose implant from the blood supply available in the osseous sinus wall occurs during the first few days by ingrowth of blood vessels and direct blood-vessel anastomosis.

4. Traumatized adipose implants do not survive well and are for the most part replaced by fibrous tissue.

5. Adipose tissues seems to resist infection. Clinical results demonstrate that cartilaginous adipose implants have not been affected by the presence of pathogenic organisms. None of our experimental adipose implants became infected.
6. There was complete obliteration of the frontal sinus in all experiments when adipose tissue implants were used.

7. There was no regeneration of mucous membrane. It is apparent that the rapid revascularization of the implant prevents ingrowth of mucous membrane into the frontal sinus or into the nasofrontal region.

8. The evidence obtained from the experiments as well as clinical experience strongly emphasizes the fact that the removal of both the mucosal and inner cortical linings of the frontal sinus is absolutely necessary for a successful obliteration.

**Technique of Unilateral Osteoplastic Operation**

**Preoperative Preparation.** Preoperative bacteriologic cultures from the nose should be obtained for antibiotic sensitivity tests. Cultures must be made well in advance so that appropriate antibiotic therapy may be instituted prior to surgery. Pathogenic organisms are often not found in cultures of intranasal material obtained prior to operation, and therefore it is important that additional material for culture he taken from the frontal sinus at the time of the operation.

An x-ray cutout (template) is made preoperatively from the Caldwell view of the x-rays of the sinus. This is done by placing an exposed transparent x-ray film over the Caldwell view and outlining the sinuses with a glass-marking pencil. The cutout may be made slightly smaller than the actual dimensions of the sinus to ensure that the cut will lie within the sinus limits. However, with careful cutting this is not essential. The cutout is placed in sterilizing solution prior to surgery.

The abdomen should be prepared so that an adipose autograft may be obtained from the subcutaneous layer of the left abdominal wall (a right rectus incision is avoided so that the scar will not at a later date be interpreted as one resulting from an appendectomy).

**The Operation.** The forehead and face are prepared and draped in the manner appropriate for any frontal sinus procedure. The patient lies on the table in the supine position with his head slightly raised and inclined forward. The patient's eyelids are sewed together with #5-0 dermal sutures to prevent injury to the eyes during the operation. The eyebrows are not shaved.

Procaine or Xylocaine (2%), with added epinephrine, is infiltrated along the upper margin of the eyebrow, both to reduce the amount of bleeding and to supplement the general anesthetic.

In the unilateral procedure the first incision is made along the entire length of the upper margin of the eyebrow. The incision is carried through the subcutaneous tissues and the frontalis muscle to the periosteum covering the frontal bone. It is essential not to extend the incision into the periosteum in order that the blood supply to the osteoplastic flap is preserved.
With scissors and blunt dissection a plane of cleavage is easily established between the frontalis muscle and the frontal periosteum. It is important to make this exposure wide enough so that the x-ray cutout may be applied to the periosteum to outline the periosteal incision.

The periosteal incision is made around the x-ray cutout (template). This incision should include the periosteum over the supraorbital rim medially and laterally. The periosteum along the supraorbital rim between the above incisions is not disturbed so as to ensure an adequate blood supply for the osteoplastic flap. The periosteum above the incision is then elevated a few millimeters in order to obtain adequate space for a clean bone cut.

The bone incision is made along the outline of the periosteal incision with a Stryker saw blade which has been especially designed for this purpose. The saw is slightly angulated so that it is directed towards the cavity of the frontal sinus. Beveling of this bone incision accomplishes two purposes: it ensures that the incision is within the limits of the frontal sinus and it allows for accurate replacement of the osteoplastic flap. Following the outline of the periosteal incision, the bone incision is extended so as to include the supraorbital rim medially and laterally. This step is essential to provide for a fracture which hinges the osteoplastic flap across the floor of the frontal sinus, just posterior to the supraorbital rim.

A mallet and chisel are used to inspect the completeness of the bone incision. Inspection is accomplished by inserting the chisel, tapping lightly, and prying around the entire bone incision. The chisel is then placed superiorly and, with a prying maneuver, the osteoplastic flap is elevated downward and forward.

The interior of the frontal sinus can now be inspected. A sample is taken for culture. It is at this point that the surgeon makes his final decision as to the extent of the operation. If a benign tumor, such as an osteoma, is present, it is removed and no further surgery is necessary, providing the mucous membrane lining is not diseased and the nasofrontal orifice is adequate. If the mucous membrane lining of the frontal sinus is so extensively diseased that there is no possibility of its recovery, it is removed and the surgeon should proceed with an obliteratorative procedure. The entire inner cortical bony lining of the sinus, including that on the inner aspect of the osteoplastic flap, is removed with a rotating cutting bur. This step must be systematically and carefully accomplished. The dissecting microscope may be used if necessary. The removal of the inner cortical lining is essential both to ensure a complete removal of the mucosal sinus and to establish a blood supply to nourish the adipose autograft. The removal of mucous membrane and inner cortical lining is carried up to, but not into, the nasofrontal orifice. Revascularization of the adipose implant, during the first few postoperative days, creates a barrier between the nasofrontal orifice and the sinus cavity.

Subcutaneous adipose tissue is obtained from the left abdominal wall by way of a left rectus incision. Subcutaneous catgut sutures are used to eliminate the dead space resulting from the removal of this tissue. Blood vessels are carefully ligated to prevent formation of a hematoma. A drain should remain in place for 48 hours.

The adipose tissue autograft is then fashioned so as to fill the frontal sinus completely. The osteoplastic flap is then returned to its original position. The periosteum is sutured with
#4-0 chromic catgut. The wound is then closed spontaneously with #4-0 chromic catgut sutures and the skin with #5-0 dermal sutures.

The forehead dressing consists of Telfa gauze, placed over the incision, an eye pad, fluffed 4- x 4-inch sponges and three strips of elastoplast adhesive. An elastic bandage is placed over this dressing.

The elastic bandage is removed at the end of 24 hours. The remainder of the dressing is removed at the end of 48 hours. No further postoperative care is necessary other than administration of antibiotics, if prescribed, and removal of the skin sutures on the fifth and sixth postoperative day.

**Techniques of Bilateral Osteoplastic Operation**

**Preoperative Preparation.** X rays of the sinuses are taken within a few weeks prior to the operation in order to determine the extent of disease. It is of particular interest to nose: (1) the depth of the sinuses; (2) whether or not the anterior and posterior walls are intact; and (3) if the interfrontal septum has been perforated or destroyed by disease. A pattern (template) of the outline of the frontal sinuses is obtained from the caldwell x-ray view. The template is made by placing a transparent exposed piece of x-ray film over the Caldwell view and tracing the outline of the sinus with a glass-marking pencil. The template, of course, must be sterilized prior to surgery.

A culture of the nasal cavity should be obtained at least one week before the operation. If pathogens are found, sensitivity tests should be carried out and the proper antibiotic administered during the immediate postoperative period.

If the coronal incision is to be used the patient is given a thorough shampoo with hexachlorophene solution the evening before the operation. The abdomen is shaved and prepared for the removal of the subcutaneous abdominal adipose tissue that is to be used to obliterate the frontal sinuses.

**The Operation.** Either the eyebrow or the coronal incision can be used for the bilateral osteoplastic frontal sinus operation. The eyebrow incision should be made along the entire length of the upper margin of the eyebrow and extended horizontally over the nasal process of the frontal bone. If the coronal incision is employed the hair is saturated with undiluted hexachlorophene solution, combed back, and shaved approximately 1.5 inches behind the anterior hairline. The incision is made approximately 1 inch behind the anterior hairline. Drapes are carefully sutured in place in order to maintain a sterile field during the operative procedure. The eyelids are closed with #5-0 polyethylene or silk suture material when using the eyebrow incision. This is not necessary when the coronal incision is employed. The bilateral eyebrow flap is elevated superiorly in a plane between the frontalis muscle and the peristom over the frontal bone. The coronal flap is elevated in the same plane and reflected inferiorly. Since bleeding is much more of a problem with the coronal incision, 1% Xylocaine or procaine solution, with added epinephrine, is infiltrated into the line of the incision. Hemostatic clips much facilitate the control of this bleeding. The coronal incision is reflected inferiorly over the face, exposing the supraorbital rims and the nasal process of the frontal bone.
The bilateral eyebrow flap is elevated superiorly, exposing the nasal process of the frontal bone. The coronal flap is reflected inferiorly over the face, exposing both supraorbital rims and the nasal process of the frontal bone.

The x-ray template is taken from the sterilizing solution, rinsed with saline solution, and placed over the frontal periosteum. The inferior aspect of the template is cut across horizontally at a level just above the cribriform plate. A notch placed in the superior aspect of the template indicate the midline or position of the interfrontal septum is quite helpful. The template is positioned so that it accurately approximates the supraorbital rims on each side. It is held in place by any sharp object, such as a needle or knife, by stabbing through the template, periosteum, and against the frontal bone. A #15 scalpel blade is used to incise the periosteum around the outline of the template. A horizontal incision is made in the periosteum over the nasal process of the frontal bone. It is important to include the periosteum over the supraorbital rims, both medially and laterally. Superiorly, the bone incision is made on a bevel so as to make certain that it enters the frontal sinus and to ensure an accurate reapproximation of the osteoplastic flap.

The osteoplastic flap is then elevated by prying with a chisel or an elevator at the superior aspect of the bone incision. As the flap reflects downward and forward there is a fracture across the floor of the frontal sinuses just behind the supraorbital rims where the bone is invariably quite thin. If the interfrontal septum is present, it will interfere with the elevation of the osteoplastic flap. This septum must be incised by inserting a chisel from above before attempting to elevate the flap.

After the osteoplastic flap has been reflected inferiorly, the interior of the sinuses is inspected. The diseased tissue and mucous membrane are removed from the frontal sinus and the superior margin of the nasofrontal orifice. The interfrontal septum is removed. A rotating cutting bur is then used to remove the remnants of mucous membrane and also the inner cortical lining of the sinuses. The inner cortical lining of the inner aspect of the osteoplastic flap should also be removed to ensure complete removal of the mucosal lining and to establish an adequate blood supply to nourish the adipose implant.

Subcutaneous adipose tissue is taken by way of either a vertical or a horizontal left rectus incision and fashioned so that it completely fills both frontal sinuses and obstructs the superior aspect of both nasofrontal ducts. It is not important to attempt placing adipose tissue into the nasofrontal ducts, for they will be sealed from the sinuses by revascularization of the adipose implant within a few days after the operation. The osteoplastic flap is returned to its original position, and the periosteum sutured with #4-0 chromic catgut. The coronal incision is sutured as a single layer, using #3-0 polyethylene sutures. A pressure dressing, to remain in place for 24 to 48 hours, is placed over both eyes and the forehead. Antibiotic therapy is continued for at least 7 days postoperatively.

**External Frontoethmoidectomy (Lynch Frontal Sinus) Operation**

The classical incision is made along the inferior margin of the eyebrow extending downward, half-way between the inner canthus and the anterior aspect of the nasal bones, well down onto the lateral aspect of the nose. This incision is extended through skin, subcutaneous tissue, and periosteum. Troublesome bleeding is usually encountered from the
angular vessels. Before proceeding further it is best to control all bleeding either by ligation or electrodessication.

The periosteum is elevated from the medial wall of the orbit, exposing the lacrimal crests and fossa. The lacrimal sac is displaced laterally, thus allowing exposure of the cribriform lacrimal bone and, more posteriorly, the lamina papyracea. The anterior ethmoidal artery is encountered during the elevation of the periosteum from the lamina papyracea. The bleeding from this vessel can be troublesome and is controlled by cautery and by packing for a short period. The posterior ethmoid artery, found further back along the suture line between the orbital plate of the frontal bone and the lamina papyracea, is similarly treated. Some surgeons prefer to ligate both the anterior and the posterior ethmoid arteries.

The periosteum is elevated from the floor of the frontal sinus. This elevation is most easily begun at the junction of the superior and medial orbital walls. The periosteal dissection is then carried laterally until the floor of the frontal sinus has been completely exposed.

The frontal sinus is approached by way of the ethmoid sinus. Entrance into the ethmoid sinus is accomplished by removing the lacrimal bone with a sharp curette; it is important not to disturb the underlying nasal mucous membrane anteriorly. The opening is enlarged with various-sized Kerrison forceps and rongeurs. The anterior ethmoid cells are removed with Brownie or Takahashi forceps. If a mucous membrane flap is to be used, it is fashioned at this time. A superiorly based mucosal flap, 1 to 2 cm wide and 2 to 3 cm long, is made in the upper lateral nasal wall. This flap is later turned upward for epithelialization of the reconstructed nasofrontal communication.

With Kerrison forceps, bone is removed from the upper medial orbital wall to the beginning of the osseous floor of the frontal sinus. At this point the frontal sinus cavity is encountered. The entire floor of the frontal sinus is resected. The mucous membrane lining of this sinus is removed by means of periosteal elevators, curettes, and forceps. This is often quite difficult if the sinus has lateral or superior projections and this step in the procedure represents one of the shortcomings of this approach. If the mucous membrane lining is not entirely removed, a mucocele may form at a later date.

The remainder of the anterior and posterior ethmoid cells are removed as well as the lamina papyracea and as much of the middle turbinate as is necessary to establish an adequate opening into the nasal cavity. The relative position of the cribriform plate must be kept in mind at all times. Cerebrospinal fluid leakage will not be a complication if the surgeon's work has been performed carefully. Lynch marked the position of the cribriform plate by means of a probe inserted through the nostril with its tip in contact with the roof of the olfactory slit. The anterior wall of the sphenoid is encountered at the posterior limit of the ethmoid labyrinth. If indicated, the sphenoid sinus is entered with a sharp curette. This opening is enlarged with Kerrison or Hajek forceps, and the diseased tissue is removed.

The mucous membrane flap which has been fashioned from the upper lateral nasal wall is turned upward to line the medial wall of the newly formed nasofrontal opening. This is kept in place by petrolatum gauze, a "cigarette" drain, or a rubber or plastic tube. The support for this mucosal flap is removed on the sixth postoperative day.
Other supports for maintaining the patency of the reconstructed nasofrontal passage include split-thickness skin grafts or Cargile membrane-covered tubes, uncovered plastic or rubber tubing, and tantalum foil. It is necessary that these supports remain in place from 1 to 3 months following the operation.

The success of external frontoethmoidectomy is dependent upon: (1) removal of the entire bony floor of the frontal sinus; (2) removal of the entire mucous membrane lining; (3) a complete ethmoidectomy; and (4) establishing an adequate opening into the intranasal cavity. Even after these requirements have been met, there is a significant incidence of subsequent stenosis of the nasofrontal passage, recurrent sinusitis, and mucocele formation.

**Fractures of the Frontal Sinus**

**Etiology.** The most common cause of fracture of the frontal sinus today is an automobile accident in which the victim's forehead strikes against the steering wheel or dashboard. Falls and missile injuries are also relatively common causes. A fracture into the frontal sinus may also occur during a frontal craniotomy; a bur-hole disk may enter the periphery of a frontal sinus.

**Diagnosis.** Routine x rays of the sinuses usually demonstrate fractures of the anterior and posterior walls of the frontal sinuses and any degree of displacement that may be present. Laminograms may be necessary to more clearly outline the contour of the posterior wall of the frontal sinus. The most common deformity results from posterior displacement of the anterior wall. The nasal process of the frontal bone may be posteriorly displaced. This fracture is quite frequently associated with a cerebrospinal fluid rhinorrhea, with the fluid escaping by way of the cribiform plate. Superior displacement of the floor of the frontal sinus may be associated with a fracture of a supraorbital rim. Air in the orbit is diagnostic of fracture of the floor of the frontal sinus, while air in the anterior cranial fossa behind the frontal bone signifies fracture of the posterior wall of the sinus. A degree of enophthalmos may be found to be associated with a fracture of the posterior wall.

**Complications.** The most common sequela of fracture of the frontal sinus is a mucocele or pyocele. The lesion usually does not occur for several years following the fracture. As has been mentioned, cerebrospinal fluid leakage may be associated with fracture of the posterior wall of the frontal sinus or with posterior displacement of the nasal process of the frontal bone. Secondary infection may occur with a compound fracture. Delayed secondary infection may appear with a subsequent upper respiratory infection and may extend from the frontal sinus to the extradural spaces.

**Treatment.** A history of the circumstances of the injury is most important. Immediate unconsciousness is usually the result of a concussion or intracranial hemorrhage. On the other hand, increasing unconsciousness after the injury may be the result of cerebral edema. Unconsciousness occurring days or weeks after the injury may be due to secondary infection.

Patients with simple fractures without displacement are treated expectantly. Antibiotics are administered when there is air in the orbit, or behind the posterior wall of the frontal sinus, in order to prevent any potential infection.
The patient should have carefully executed local and neurologic examinations. Neurosurgical consultation is requested when any sign of brain damage is present.

A depressed fracture of the frontal bone should be explored whether or not it is compounded. This is done to prevent deformity, to determine the presence of a hematoma, and to detect splintering of the posterior wall with a resultant laceration of the dura of the frontal lobe which may lead to cerebrospinal fluid leakage.

The depressed fracture of the frontal bone is often compounded, and thus repair can be accomplished through the wound. If this is impossible, the area is exposed by turning down a coronal flap or by making an incision along the upper margin of the eyebrow.

A trephine opening through healthy bone is useful for both inspection of the sinus and for insertion of instruments for elevation of the bony fragments. Usually the displaced fragments can be elevated through the fracture lines. A steel hook is inserted in the fracture line and turned 90 degrees for elevation in the direction of the loose fragments. The hook is then rotated to the position of its insertion and removed. If this is not possible, a small trephine opening is made at the margin of the fracture line to allow for instrument insertion. Small or soiled fragments of bone should be removed. Hooks, elevators, and chisels are the most useful instruments for repair of depressed fragments.

A cerebrospinal fluid rhinorrhea caused by laceration of the dura of the frontal lobe is positive indication for exploration of the frontal sinus. If comminution and displacement of the anterior wall of the frontal sinus is not extensive, an osteoplastic approach is ideal for management of the spinal fluid leakage. As indicated, either a unilateral or bilateral osteoplastic flap is elevated, providing an excellent view of the entire posterior wall and the site of leakage. A portion of the posterior wall in the vicinity of the dural defect is removed, and the dura is repaired by primary suture if possible. If this method of repair is not satisfactory, the entire mucosal and inner cortical lining of the frontal sinus is removed, and the sinus is obliterated with adipose tissue. The adipose tissue is placed directly against the dural defect.

A mucocele or pyocele not uncommonly follows a fracture of the frontal sinus. It may occur several months or many years following the injury. It can be treated by using the osteoplastic adipose obliteration procedure.

If secondary infection complicates a frontal sinus fracture and extends into the extradural space, the first line of therapy should be the administration of antibiotics according to culture and sensitivity tests. Surgical intervention, such as an anterior craniotomy by a neurosurgeon or a trephination of the frontal sinus by an otolaryngologist, may be necessary. As soon as the infection is under control, the sinuses should be obliterated with adipose tissue. Usually tend days to two weeks of antibiotic therapy are required prior to the osteoplastic obliteration operation.