diately comes to mind. In patients in a state of relapse it may be increased several times its normal value and following liver therapy it sharply decreases.[4] It is conceivable, therefore, that excessive secretion of bile pigments into the biliary tract may have produced temporary obstruction of the cystic duct with consequent damage to the gall bladder wall.

The greater damage sustained by the female gall bladder, together with the slower rate of emptying in patients of this sex, may be explained on the basis of the greater susceptibility to gall bladder disease of women who have borne children,[5] for in all but 2 of the group the gall bladder had been subjected to the double insult of the stasis of pregnancy and that of pernicious anemia.

[4] Watson, C. J., *Arch. Int. Med.*, 1931, **47**, 698.

[5] *Cf.* Gerdes, M. M., and Boyden, E. A., *Surg., Gyn., and Obstet.*, 1938, **66**, 145.

14796

Experimental Production of Negative Pressure in the Frontal Sinus.

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The clinical syndrome known as vacuum headache has long been recognized but there seems to have been no demonstration of a reduced pressure in the sinuses or of a mechanism capable of producing it. When one of us (Hilding[1]) demonstrated that negative pressure can be produced by normal ciliary action in the lower part of the respiratory tract, it was decided to determine if a similar mechanism would produce negative pressure in paranasal sinuses.

Technic. With the animal under ether anesthesia and with observance of aseptic technic two 16-guage hypodermic needles were inserted into one frontal sinus of each dog. The needles were introduced through small holes made through the scalp and bone. Each needle fitted into both the skin and the bone effectively enough to be airtight. One needle was connected to a water manometer and the other to a syringe containing the mucinous secretion to be injected. A third needle, introduced into the opposite frontal sinus and connected to another water manometer, acted as control.

The mucinous secretion was collected from the trachea of either the dogs used in these experiments or other dogs.

[1] Hilding, A. C., *Ann. Otol., Rhin., and Laryng.*, 1943, **52**, 816.

Experiment 1. A few cubic centimeters of mucus was injected into the left frontal sinus of animal 1 at 2:15 p.m. The first portion entered without resistance but soon a resistance was felt, which increased to +270 mm of water when the injection was finished and the needle closed. In two minutes the pressure had fallen to +83 mm and it passed zero and became negative between the fifth and the sixth minute. Twenty minutes later the manometer reading stood at —50 mm and it reached a maximal negativity of —59.5 mm forty-seven minutes after injection. It remained stationary for about 7 minutes and then rose to about —45 to —48 mm where it remained until 2 hours and 6 minutes after injection, when the experiment was terminated.

Experiment 2. At 9:51 a.m., 3.5 cc of mucus was injected into the left frontal sinus of animal 2. At 10:07 a.m. the manometer recorded —3 mm of water. It varied between —3 and +8 mm until 11:00 a.m. when the experiment was concluded and the sinus opened. The mucus was about gone. The ostium was unusually large and, although mucus was passing through, the ostium was not filled or occluded by the mucus.

Experiment 3. Seven cubic centimeters of foamy mucus was injected into the left frontal sinus of animal 3 at 11:06 a.m. The imme-

diate pressure recorded on the manometer was +15 mm of water. The pressure declined to zero in 5 minutes and then became negative. The negative pressure increased rapidly for 12 minutes to reach —58 mm and then more slowly for another 12 minutes to reach a maximal negativity of —66 mm. The reading remained almost stationary for 5 minutes and then changed slowly to —32 mm, where it stood when the experiment was concluded after 4 hours and 39 minutes. Blockage of the needle with blood and mucus apparently had prevented return of the pressure to zero.

Experiment 4. Five cubic centimeters of foamy mucus was injected into the left frontal sinus of animal 4 at 11:18 a.m. The manometer reading stood at zero at 11:20. Negative pressure then began to develop and increased steadily to a maximum of —38 mm of water in 18 minutes. It varied between —36 and —38 mm for 7 minutes and then changed to —34 where it stood at 11:49. The animal was decapitated at 11:50 and the needles were removed and cleaned.

The needles were reinserted and 6 cc of mucus was injected at 11:59. Immediately after injection, the manometer reading stood at zero. Negative pressure began to develop after a minute or two and reached a negativity of —16 mm thirteen minutes after injection and 22 minutes after decapitation of the animal. The readings varied during the next 20 minutes between —8 and —22 mm. When the experiment was concluded at 12:32 p.m., the pressure was —16 mm.

Experiment 5. At 10:21 a.m., 6 cc of foamy mucus was injected into the right frontal sinus of animal 5. A slight positive pressure (+10 mm of water) was recorded on the manometer immediately but it passed the zero mark and became negative during the second minute and at 10:23 the reading was —6 mm. The negative pressure increased to —28 mm during the next 6 minutes. Then a leak seemed to develop about the needle and a larger sized needle was substituted. At 10:35 the pressure was again —7 mm and negativity progressively developed to reach a maximal negativity of —36 mm 19 minutes later (10:54 a.m.).

The femoral artery was cannulated and exsanguination begun at 11:05. When respirations ceased 3 minutes later the pressure stood at —30 mm and at 11:16 at —25 mm.

The animal was decapitated at 11:18 without disturbing the needles. At 11:19 the pressure was —22 mm; then for some unknown reason the change of pressure reversed and negativity increased again to —34 mm 19 minutes after respirations had ceased (11:27). The pressure varied between —24 and —34 mm until the experiment was terminated at 11:50, 42 minutes after death of the animal and 32 minutes after decapitation.

Meanwhile 7 cc of mucus was injected into the left frontal sinus of the same head and the sinus connected with a second manometer at 11:24, six minutes after the animal had been decapitated. A pressure of +4 mm was indicated one minute later and 3 minutes later the reading was —1 mm. An increasing negative pressure developed until, 20 minutes after injection, it amounted to —43 mm. When the experiment was terminated, 26 minutes after injection of mucus (11:50), the pressure was —41 mm (Fig. 1).

Comment. A marked negative pressure was produced in 5 of 6 normal sinuses by the injection of sufficient mucus to occlude the ostium. The failure to produce negative pressure in the second experiment probably resulted from the unusually large ostium found in that sinus.

The negative pressure found in the other 5 was presumably caused by the removal of mucus through the ostium by ciliary power. While the ostium remained occluded by mucus, air could not enter to replace the mucus as the latter was removed. It seemed improbable after the first 3 experiments that another mechanism such as absorption of air from the sinuses could have caused negative pressures of such magnitude.

Experiments 4 and 5 were designed to determine with certainty whether or not the air could have been removed by absorption through the blood stream. Hence both of these animals were decapitated and the experiment was repeated on the detached heads. In the case of animal 4, the experiment was repeated in the same sinus and in the case of animal 5 in the opposite sinus. In both

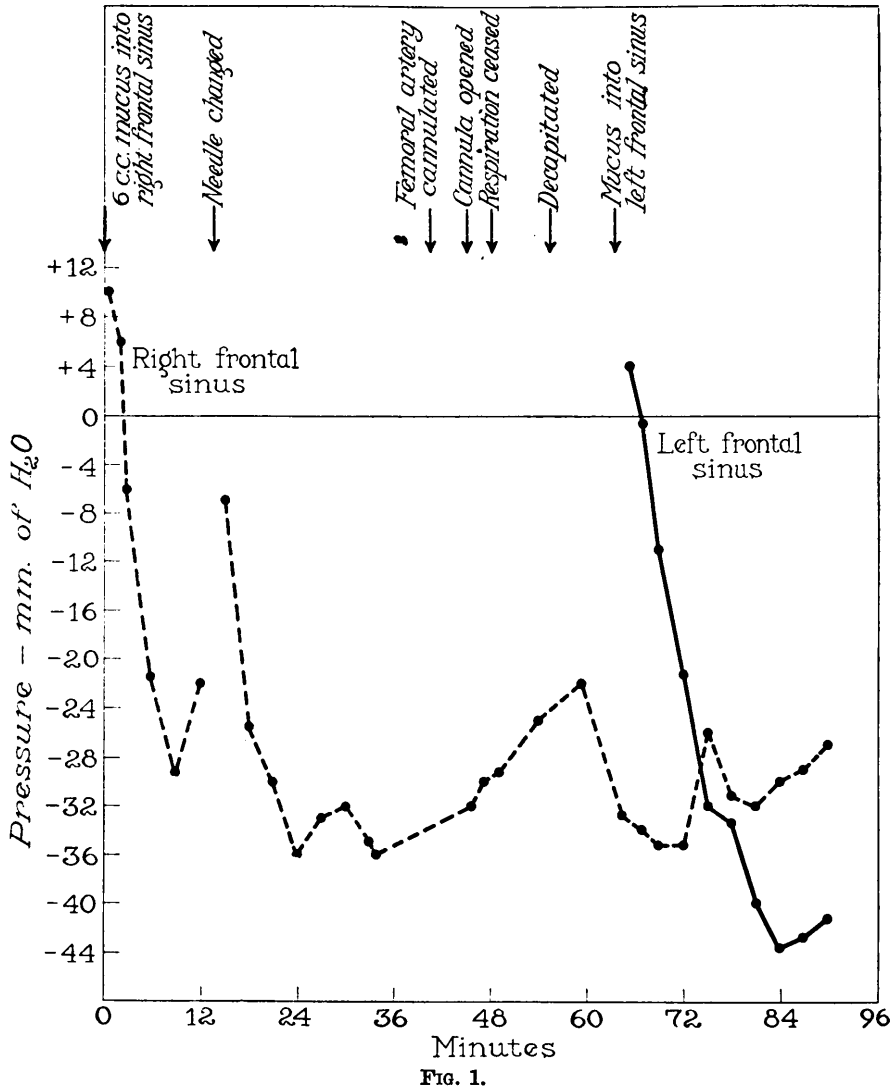

FIG. 1.

Negative pressure developed both before and after decapitation of the animal in experiment 5. Mucus was injected into the right frontal sinus and the development of negative pressure observed and recorded (dotted line above). The animal was then bled to death and decapitated without disconnecting the needles or manometer. There was some variation, as indicated. Mucus was injected into the left frontal sinus also but not until after decapitation. A greater negative pressure developed in the left sinus than in the right (solid line).

instances, there resulted negative pressure comparable to that which occurred before decapitation. In animal 4 the negative pressure after decapitation was somewhat less than before decapitation and in animal 5 somewhat greater.

Conclusions. 1. Negative pressure can be produced by ciliary activity within a normal sinus after a considerable quantity of mucinous secretion (from the same species of animal) has been injected. 2. This negative pressure occurs even after death and decapitation of the animal and is therefore not due to absorption of air by the blood stream.