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The nasal cycle in swine

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SUMMARY

The domestic pig exhibits characteristic fluctuations in nasal mucous membrane congestion and decongestion which meet the stipulated criterion for the existence of a nasal cycle. This phenomenon was documented in 6 of the 11 pigs studied. Also, unilateral sympathectomy acutely affects ipsilateral nasal resistance, but this elevated nasal resistance gradually decreases to preoperative values over several weeks. Finally, a new technique using active anterior rhinomanometry has been developed which can be applied to the study of nasal resistance changes in laboratory animals.

INTRODUCTION

Many integrated functions performed by the mammalian nose are essential to homeostatis. The control mechanisms of such nasal interactions must be delicately integrated so as to adequately meet not only the day-to-day but also the moment-to-moment demands of an ever-changing environment (Ogura et al., 1964, 1968; Whicker and Kern, 1973a). Execution of such precise regulation of nasal function is exemplified by the nasal cycle.

The alternating congestion-decongestion of the nasal turbinates in man has been known to investigators for almost a century (Kayser, 1895). The exact role, function, and control of this nasal cycle, as well as the effects of surgery and disease states on this cycle, are not known. To better comprehend the control and significance of this cycle, we investigated an experimental model.

The specific aims of this study were (1) to determine whether such a nasal cycle was present in the laboratory animal (Eccles and Maynard, 1975, 1978), (2) if such a cycle is present, to ascertain the role of the autonomic nervous system on the control mechanisms, and (3) to develop a new technique by which active anterior rhinomanometric principles (Kern, 1973) for the measurement of changes in nasal pressure and nasal air flow in the domestic pig could be simply applied.

METHODS AND MATERIALS

Eleven pigs (five males, six females) with a mean weight of 25 kg were immobilized using sodium pentobarbital. A loading dose of 10 mg/kg was given parenterally through a marginal vein of the pinna or through an antecubital vein. The intraperitoneal route is a less suitable choice because absorption rates are variable by this route. This small loading dose, along with intermittent controlled infusions of sodium pentobarbital, permitted optimal anesthesia with minimal risk of inducing lethal respiratory collapse. Under these circumstances, coughing and swallowing reflexes remained, and these reflexes protected the lower airway from

the pooling of pharyngeal and bronchial secretions that could interfere with rhinomanometric recordings. The use of anticholinergic drugs was therefore avoided.

Room temperature was constant at 21.1 °C (±1.7 °C), with humidity at approximately 30%. The pigs were supine and outstretched with the snout adequately taped (Figure 1). Because the oral cavity was totally occluded, it was assumed that tidal airflow was transnasal. Both heart and respiratory rates were monitored. During these experiments, the head was elevated 20° from the horizontal in order to reduce and "standardize" dependent turbinate congestion.

The apparatus used to measure transnasal pressure differences between the nasopharynx and anterior nares consisted of two pressure transducers to allow measurements of transnasal pressure (ΔP) and transnasal airflow ($\dot{V}$) (Figure 2). From these measurements, transnasal resistance could be calculated. Equal lengths of plastic tubing (intraluminal diameter of 2 cm) ensured a constant resistance in the system to airflow during both inspiration and expiration. The tubing was slightly narrowed at one end (silicone ring) so as to snugly fit the naris. This narrowed end carried a polythylene cannula that measured ambient pressure at the ipsilateral anterior naris. The opposite naris was fitted tightly with another cannula, cushioned by an outer seal of foam rubber, to measure nasopharyngeal pressure. Both of these leads were connected to a PM 131 pressure gauge, which measured the transnasal pressure gradient during the respiratory cycle.

A PM 270 pressure gauge was calibrated against a standard volume flow which allowed transnasal airflow ($\dot{V}$) to be measured (Figure 2). This pressure-flow rela-

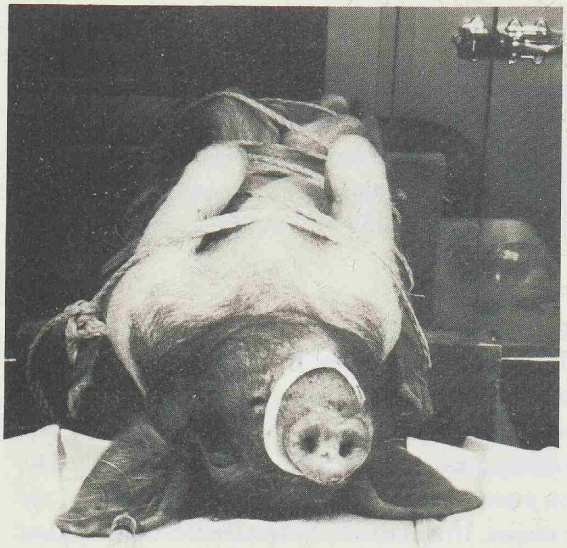


Figure 1. Supine pig, anesthetized via cannula in left pinna. Note muzzle is taped so that all tidal flow is through nares and neck is free of strapping.

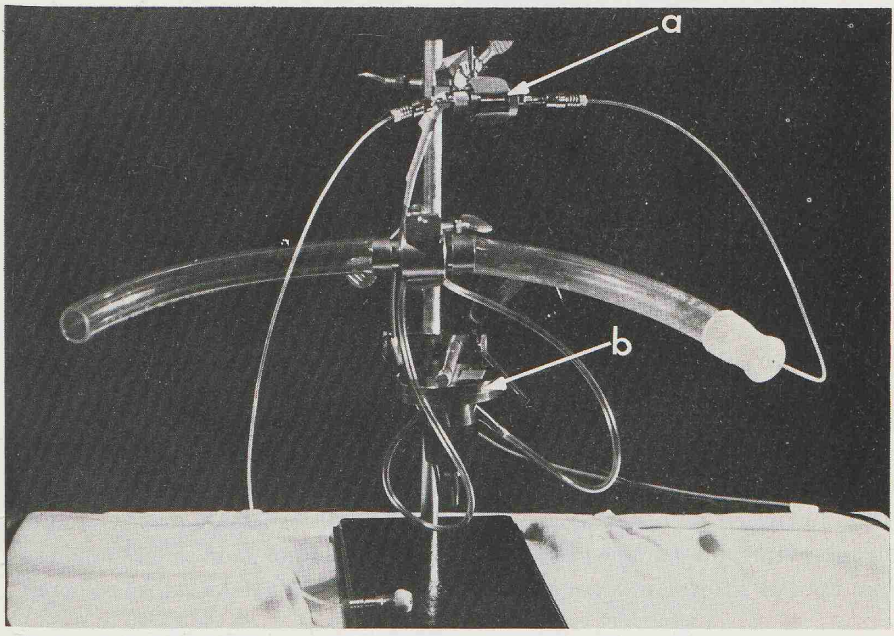


Figure 2. Original manual rhinomanometer showing two pressure transducers: (*a*) PM 131 pressure gauge used to measure transnasal pressure (ΔP) and (*b*) PM 270 pressure gauge used to determine transnasal airflow ($\dot{V}$).

tionship was determined to be constant for bidirectional flow and was linear up to flow rate of 1 liter/sec (Figure 3). A flow rate of 1 liter/sec was never exceeded in these experiments.

Signals from both gauges (PM 131 and PM 270) were amplified (Hewlett-Packard model 7414A) and written out on recording paper. When desired, these signals were led into a storage oscilloscope (type 564B).

The laboratory arrangement of the recording tubes employed during the early experiments is shown in Figure 4. Because of small variations in contact pressure between the plastic tubes (nozzles) and the pig's snout, variations in the amplitudes of flow recordings were observed. Furthermore, firm consistent manual pressure was required to ensure an adequate seal between the naris and the nozzle. These maneuvers could irritate the lightly anesthetized pig and result in head movements that could introduce pressure change artifacts.

To overcome these initial problems, a new rigid self-supported mask rhinomanometer was designed. This apparatus was comfortable for the pig and convenient for the investigator. Recordings were stable and not subject to manual pressure artifact. This mask allowed the investigator to be free so that he could manage the anesthesia and the recording apparatus while conducting the experiments.

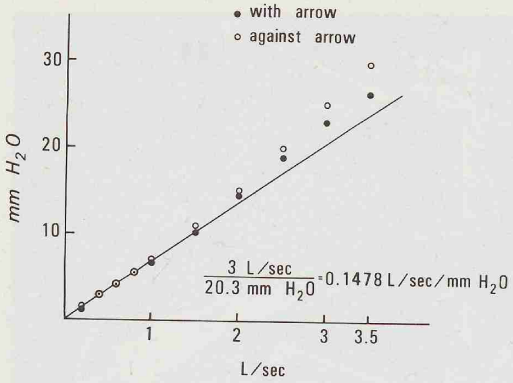


Figure 3.
Pressure-flow relationship calibration of PM 270 pressure gauge, using bidirectional airflow. Note linear relationship with bidirectional flow rates of up to 1 liter/sec.

The newly developed equipment and experimental arrangement for recording transnasal pressure (P) and transnasal flow ($\dot{V}$) fluctuations are shown in Figure 5. The mask consisted of a cylindrical rigid translucent plastic container opened at one end by a telescoping, tight-fitting, flexible rubber material that ensured an adequate seal with the taped snout. An inflatable 3-ml balloon carried one lead from the PM 131 pressure gauge, which detected contralateral transnasal pres-

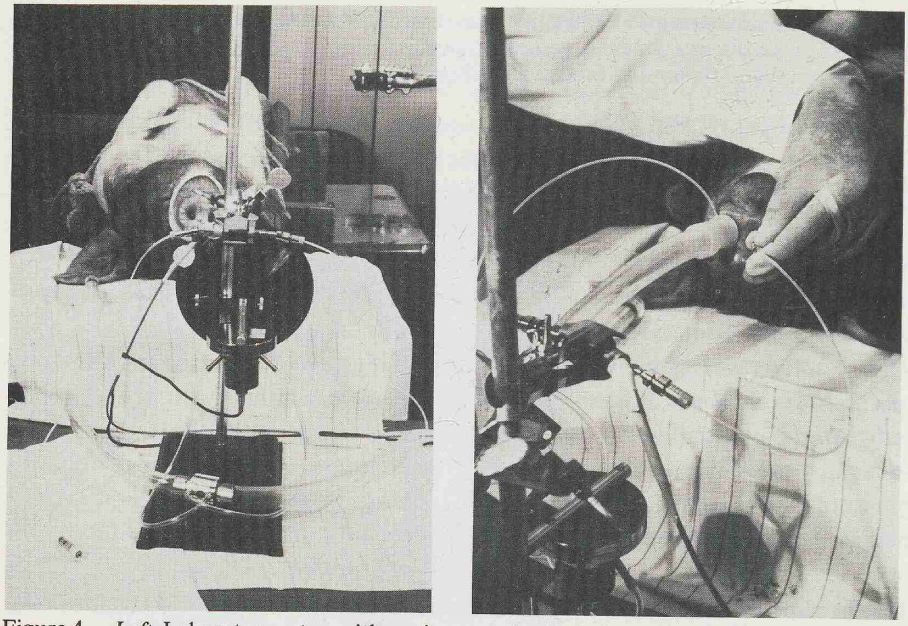


Figure 4. *Left*, Laboratory setup with supine anesthetized pig and original manual rhinomanometer ready for use. *Right*, Demonstration of original manual rhinomanometer in use. Note large-diameter Silastic tube in contact with left nostril to detect left-sided transnasal airflow ($\dot{V}$) and sponge-coated nozzle in right nostril to detect transnasal pressure (ΔP) of left nasal cavity.

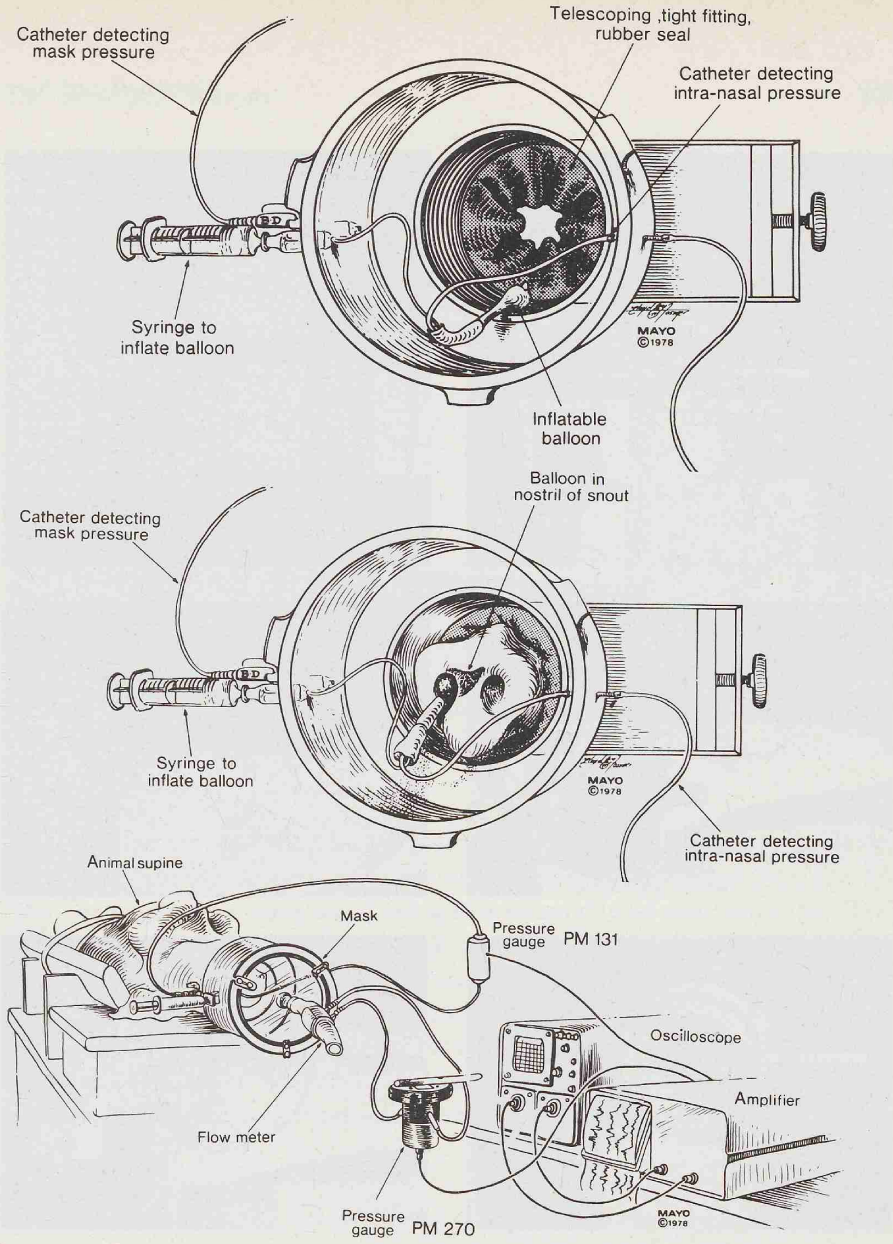


Figure 5. *Top*, Sketch of face mask (after lid removed). Note tight-fitting rubber seal for muzzle; cannula with inflatable balloon to detect intranasal pressure; cannula to detect mask pressure. The two cannulas lead to a PM 131 pressure gauge, enabling transnasal pressure (P) to be measured. *Middle*, Sketch of face mask (with lid removed) and snout in situ. Note tight seal of left nostril enables nasopharyngeal air pressure to be detected. Pressure at right anterior naris is sensed by cannula measuring mask pressure; the difference between anterior naris and nasopharyngeal pressures is ΔP. *Bottom*, Laboratory animal, face mask (with lid in situ), pressure gauges (PM 131 and PM 270), and recording equipment (Hewlett-Packard model 7414A and storage oscilloscope type 564B) set up for use. Note that device needs no manual stabilization during recordings and introduces less artifact (compare with Figure 4 *Left* and *Right*).

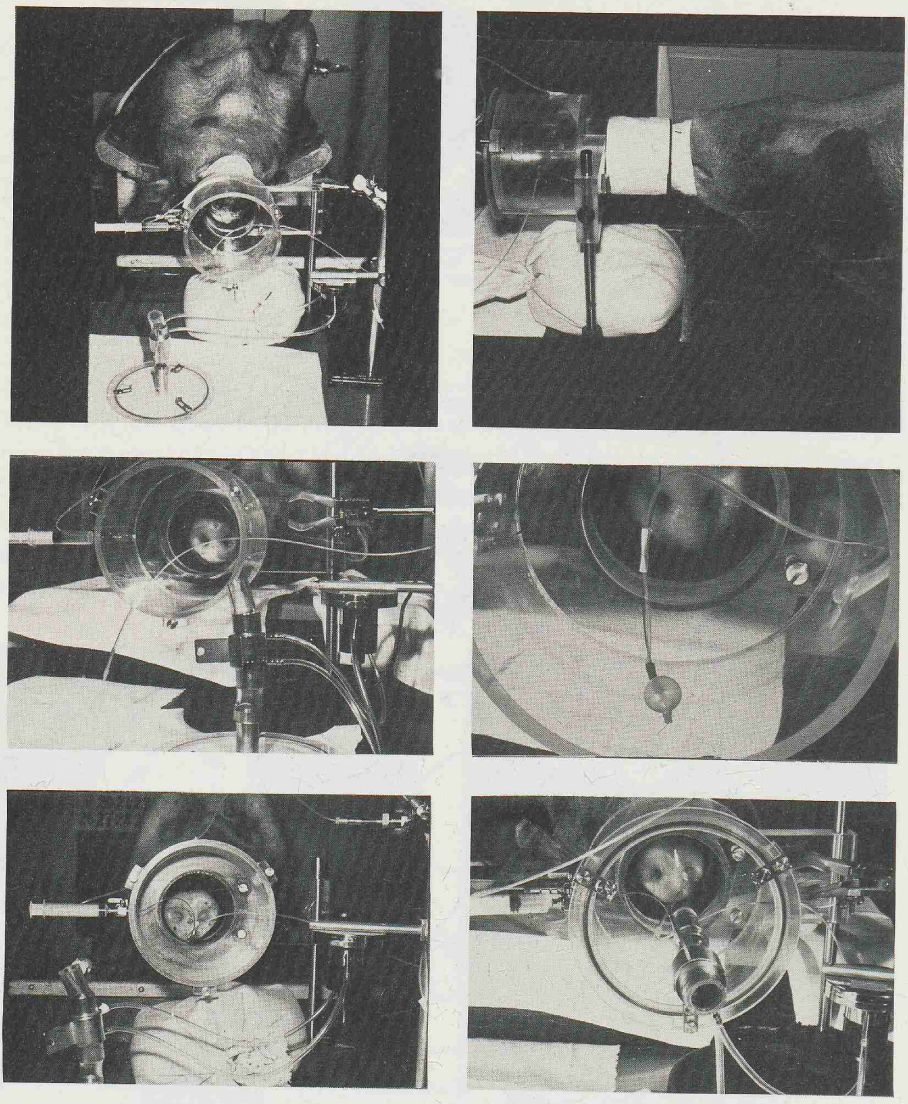


Figure 6. *Top Left*, Pig supine with face mask in situ. Note lid lying separated and connected to flowmeter. All strappings are loose. *Top right,* Lateral view of face mask in situ, fitting snugly with snout. Sandbag weights face-mask stand. *Middle Left*, Close-up of face mask in situ with lid removed. Flowmeter is attached to lid in lower right field. Note cannula with balloon (deflated) to detect intranasal pressure. *Middle Right*, Close-up of mask with snout in situ and inflated balloon carrying cannula for intranasal pressure detection. *Bottom Left*, Lid removed. Balloon inflated in right anterior naris. *Bottom Right*, Mask with lid tightly clasped, fitted, and ready for use. Note balloon with cannula in right nostril so that transnasal pressure (ΔP) for left nasal cavity can be recorded.

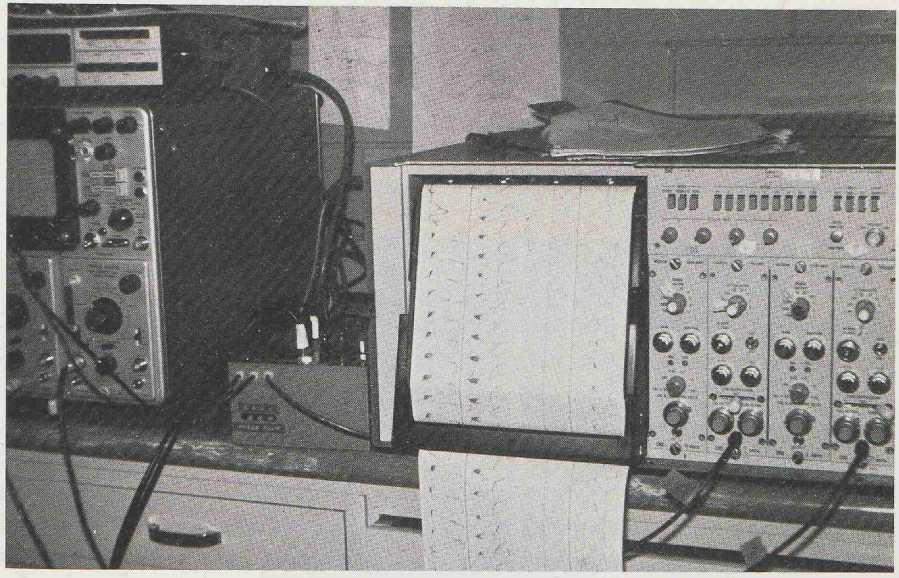


Figure 7. Hewlett-Packard model 7414A amplifier at right. Storage oscilloscope type 564B at left.

sure. The other end of the PM 131 pressure gauge detected pressure inside the mask (ambient atmospheric mask pressure).

The open end of the mask was fitted with a removable lid containing the "flowmeter" and an inlaid rubber washer (which ensured an airtight seal when clasped in place). Leads from the "flowmeter" passed to the PM 270 pressure gauge and were connected to the amplifier. The laboratory arrangement is shown in Figure 6. A recorder (Hewlett-Packard model 7414A) and storage oscilloscope (type 564B) were used (Figure 7). A sample recording of pressure (P) and airflow ($\dot{V}$) shows downward deflections as inspiratory and upward deflections as expiratory (Fig-

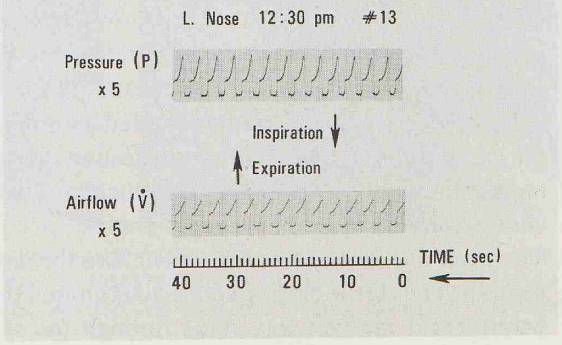


Figure 8. Sample of pressure and airflow recordings (read from right to left). Inspirations are downward deflections, and expirations are upward deflections.

Table 1. Calibration Values.

With attenuation factor	One division equals:	
	P (cm H_2O)	$\dot{V}$ (L/sec)
x 1	0.2	0.006
x 2	0.4	0.012
x 5	1.0	0.03
x10	2.0	0.06
x20	4.0	0.12

ure 8). Attenuations are marked so that accurate calculations can be made. Actual pressure and airflow values may be quantitated from the graph recordings, by using Table 1.

By this active anterior rhinomanometric technique, unilateral nasal resistance (Rn) was calculated in centimeters of water per liter per second (cm H_2O/L/sec) from the formula $Rn = P/\dot{V}$. Pressure was measured in centimeters of water, while airflow was measured in liters per second. Airflow ($\dot{V}$) was measured at a fixed pressure of 4 cm of water during inspiration. The use of a fixed pressure point for measuring airflow allowed valid inter-pig comparisons as well as intra-pig comparisons after various surgical manipulations.

Recordings were obtained at intervals of 10 to 15 minutes for periods of 3 to 5 hours. Morning and afternoon studies were obtained to determine the presence of any circadian rhythmic changes.

SURGICAL PROCEDURE

The pigs were anesthetized using sodium pentobarbital as previously described. With the aid of a laryngoscope, the vocal cords were visualized and sprayed with 2 ml of 4% lidocaine solution. The trachea was intubated. The pigs were given intramuscularly 0.4 mg of atropine and 600,000 units of aqueous penicillin G. Oxygen was supplied continuously via a respirator through the endotracheal tube, while intermittent infusions of sodium pentobarbital maintained satisfactory anesthesia.

Studies were performed in 11 pigs before and after unilateral excision of the cervical sympathetic trunk. (The nonoperated side served as the control.) By direct measurement of transnasal pressure and transnasal airflow, nasal resistance was calculated. These experiments provided information concerning the naturally occuring patterns of alternating congestion-decongestion of the nasal mucous membranes and documented the influence of the autonomic (sympathetic) nervous system on these physiologic events.

The neck was shaved from the clavicle to the jaw and cleansed with thimerosal solution, and sterile drapes were placed around the operative field. A 10-cm right paratracheal incision was made through the skin to the sternocleidomastoid

muscle (Figure 9). The muscle was retracted anteriorly; the carotid sheath and its contents, including the carotid artery and internal jugular vein, were exposed; and both the posteromedially placed vagosympathetic trunk and the sympathetic component were isolated (Figure 10). The sympathetic component, which was detected as a separate distinct bundle in this common trunk, was somewhat gray and had a finer diameter when compared with the large white vagus nerve. A 3-

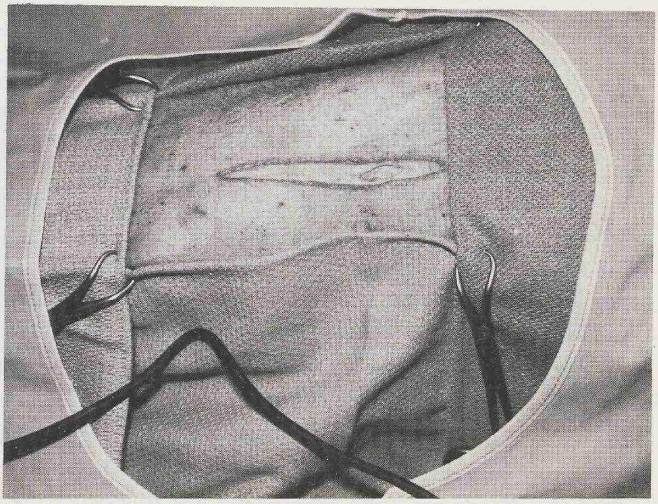


Figure 9.
Sterile operative field with right paratracheal incision made through skin (head is at right).

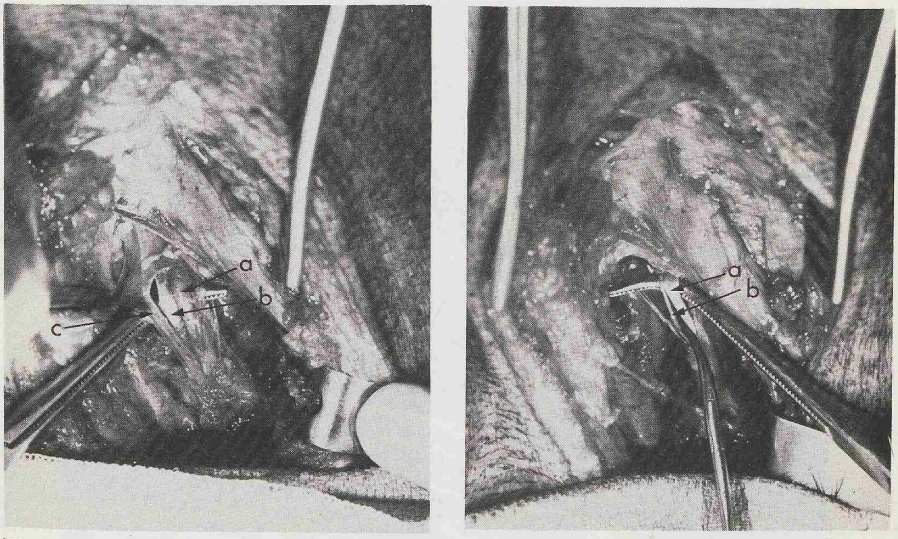


Figure 10. *Left*, Sternocleidomastoid muscle retracted anteromedially and carotid sheath contents exposed: (*a*) carotid artery, (*b*) vagosympathetic trunk, and (*c*) internal jugular vein. *Right*, Vagosympathetic trunk, isolated and dissected to show (*a*) vagus nerve and (*b*) sympathetic component.

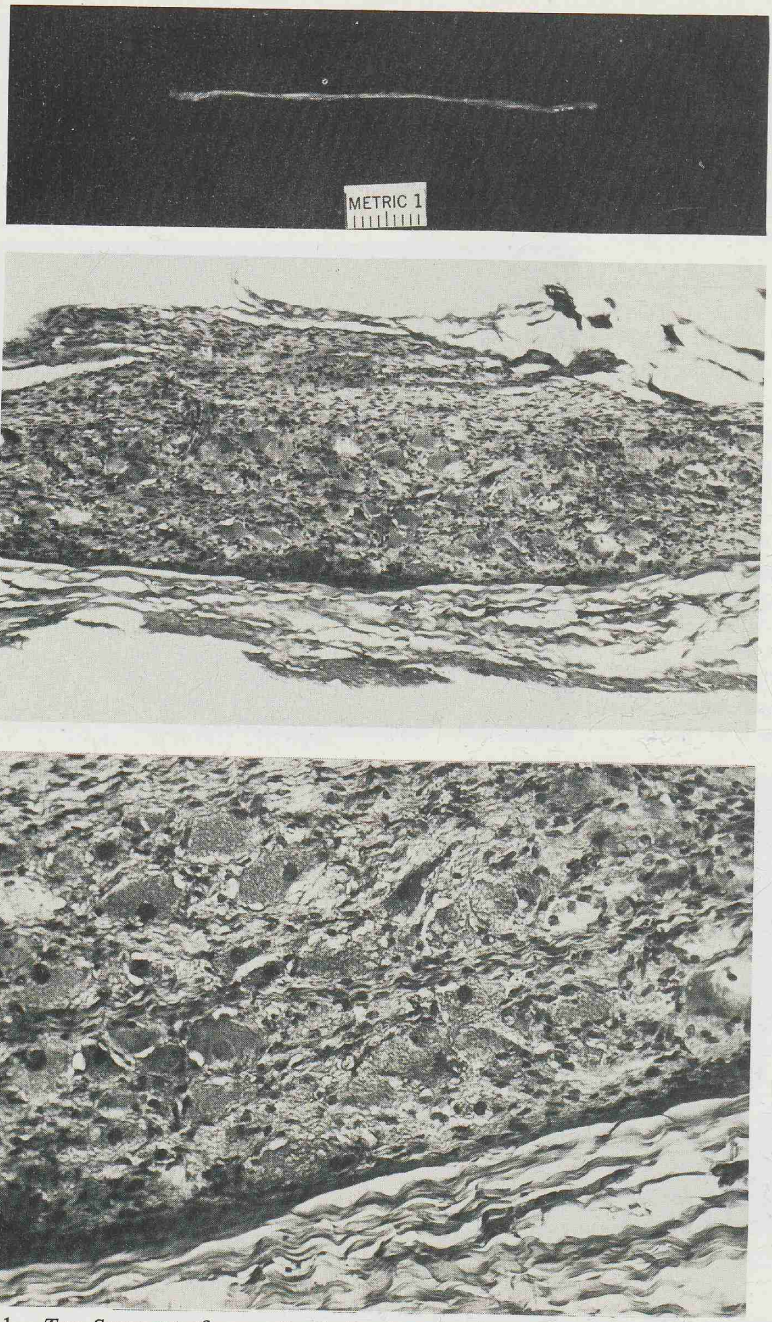


Figure 11. *Top,* Segment of sympathetic trunk excised. *Middle,* Section of sympathetic trunk showing large ganglion cells with prominent nucleoli and abundant granular cytoplasm. (Hematoxylin and eosin; × 100). *Bottom,* Higher magnification of *Middle* (× 250).

cm to 4-cm segment of sympathetic trunk was excised for histologic examination (Figure 11). The remainder of the carotid sheath was left undisturbed in order to avoid interference with septoturbinate vascular perfusion. Hemostasis was achieved by electrocoagulation, and the wound was closed in layers.
When respiratory efforts were spontaneous and regular, the use of oxygen was discontinued and the pig extubated. Usually, postoperative recovery was uneventful.

RESULTS

Of the 11 pigs included in the study, a definite nasal cycle was detected in 6 (Table 2) on the basis of criteria of a difference of 20% or greater in nasal resistance between the two sides of the nose for at least two consecutive calculations. This rhinomanometric criteria for the presence of a nasal cycle has been described and discussed in the literature (Hasegawa and Kern, 1977) and found to be satisfactory in defining cycling patterns in humans. The frequency of cycling found ranged from 0.20 to 0.50 cycle/hr, with the mean rate being 0.33 (Table 2). These frequencies are simular to the frequencies found in humans (Cannon and Rosenblueth, 1949). A nasal cycle was seen in six pigs (Figure 12). Five pigs did not demonstrate a nasal cycle before unilateral cervical sympathectomy (Figure 13). Unilateral cervical sympathectomy invariably disrupted the nasal cycle and produced a greatly elevated nasal resistance on the homolateral side. Contralateral nasal resistance was not altered in any pig (Figure 14). One pig (no. 4) demonstrated an interesting series of events in which preoperatively there was a nasal cycle (Figure 15 *upper left*), but after sympathectomy, the nasal resistance was elevated on the right (operated) side (Figure 15 *upper right*). The elevated ipsi-

Table 2. Frequency of cycling in presympathectomized pigs.

Animal no.	Code no.	Recording time (hr)	No. of cylces	Cycles/hr
1	1B	4.92	1	0.20
2	2B	4.00	2	0.50
3	4B	4.23	1	0.24
4	5A	5.63	2	0.35
4	5B1	4.95	2	0.40
4	5B2	3.03	1	0.33
5	6B	4.13	None	None
6	7A	4.65	None	None
7	8B	3.12	None	None
8	9A	3.75	None	None
9	10B	3.08	1	0.32
10	11B	3.03	2	0.66
11	12A	3.08	None	None
$\bar{x}$		3.89		0.33

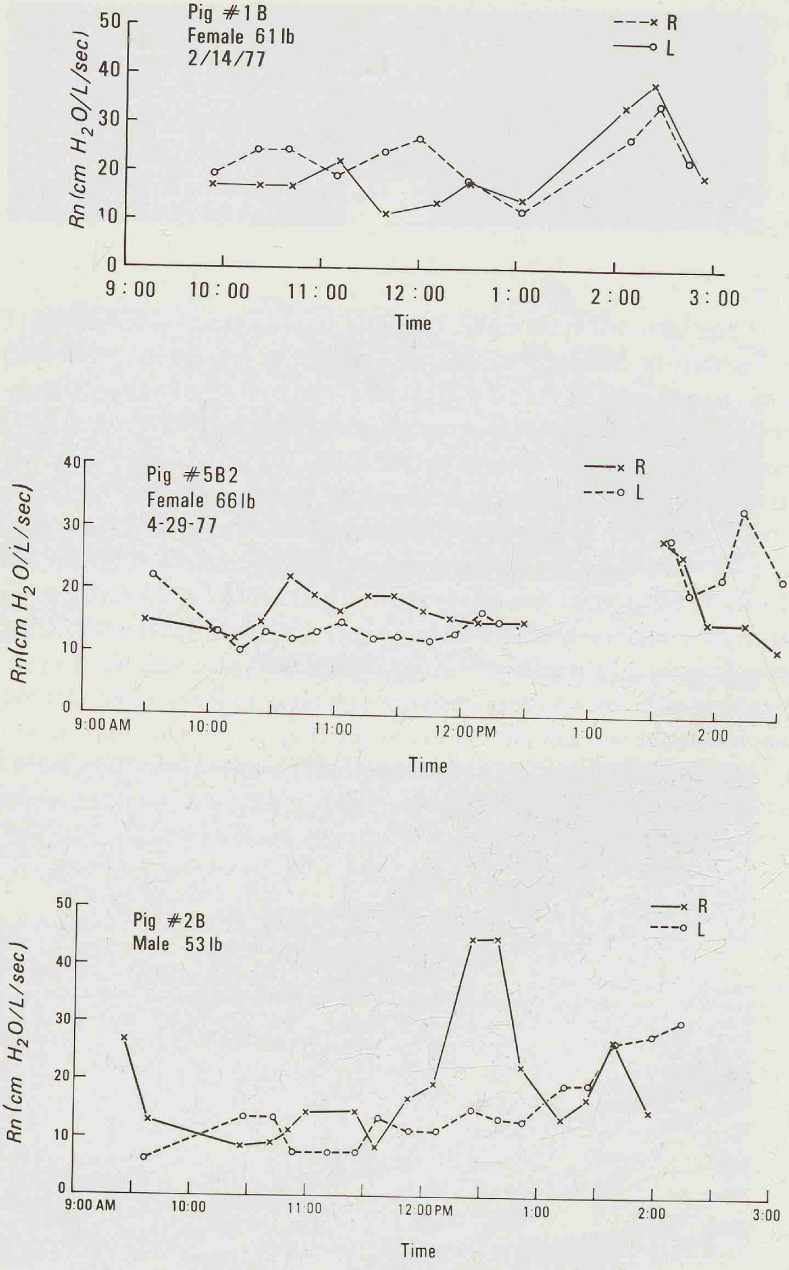
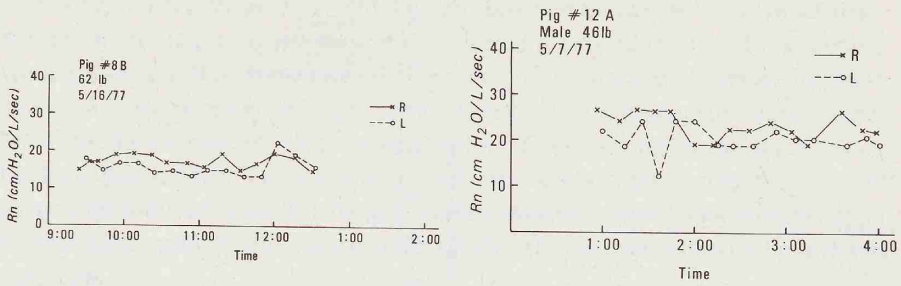


Figure 12. *Top,* Cycling at 12:30 p.m. *Middle,* Cycling pattern. (Break in recordings was taken in an attempt to obtain roentgenographs of congested turbinates at this stage of cycle.) *Bottom,* Cycling pattern changes occured at 10:45 a.m. and 1:10 p.m.



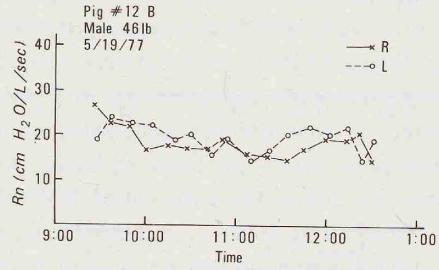
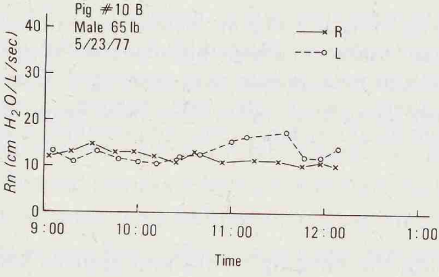


Figure 13. *Left,* No cycling pattern. (Note differences in resistance between right and left nose are less than 20% after the increase in left nasal resistance at 12:00 noon.) *Right,* No nasal cycle. *Lower,* Twelve days later. Same pig as in *Right* again failed to show a cycling pattern.



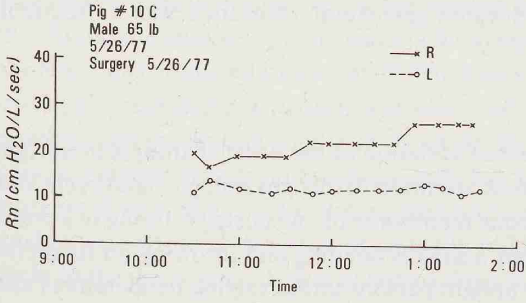


Figure 14. *Upper,* Cycling at 10:30 a.m. (prior to sympathectomy). *Lower,* Same pig 3 days after right sympathectomy. Note elevation of right nasal resistance, unchanged left nasal resistance, and absent nasal cycling pattern.

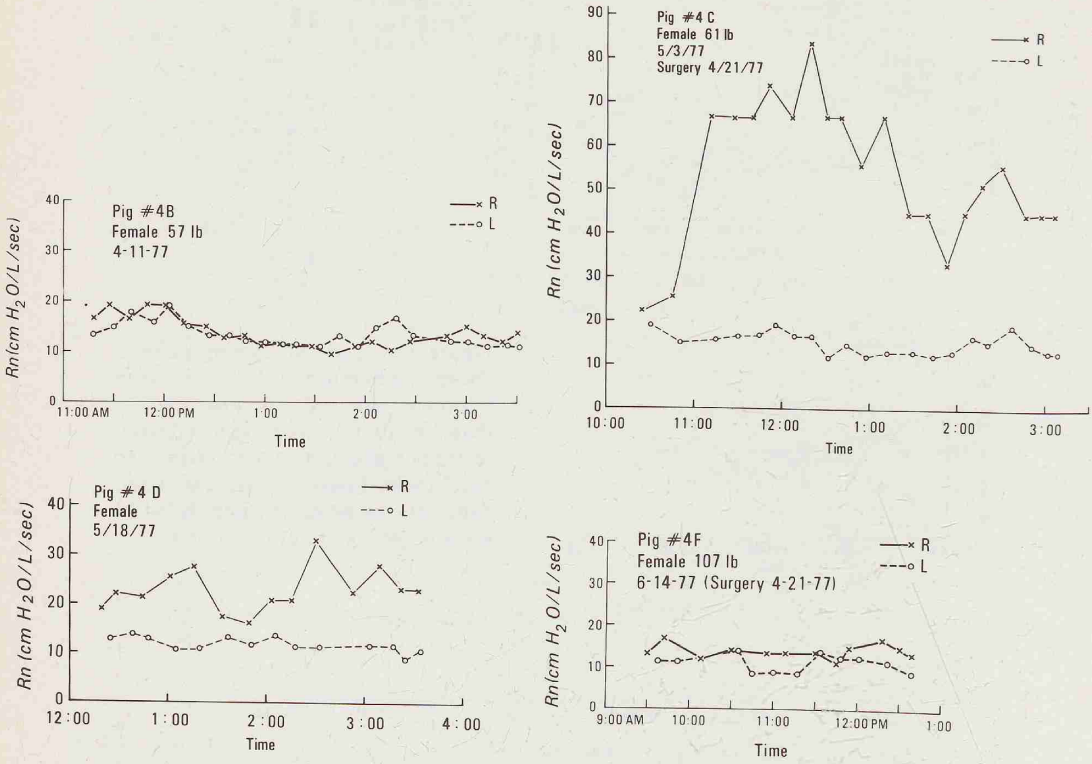


Figure 15. *Upper Left,* Note cycling pattern occuring at 2:30 p.m. (before sympathectomy). *Upper Right,* Large elevation in right nasal resistance in same pig after right sympathectomy was performed 2 weeks previously. Left nasal resistance is unchanged. *Lower Left,* Same pig. Note lowering of right nasal resistance 4 weeks after sympathectomy. *Lower Right,* Seven weeks after sympathectomy.Right nasal resistance returned to preoperative levels; however, no cycling pattern.

lateral resistance eventually waned during the ensuing weeks and approached presympathectomized levels.in less than 2 months (Figure 15 *lower left* and *right*). This postoperative waning of elevated ipsilateral resistance was a frequent finding.

DISCUSSION

In 1895, Kayser observed a patterned variation of the nasal chambers in upright normal persons. Lillie, in 1923, drew attention to this physiologic nasal cycle and remarked that ". . . while the mucous membrane of one nostril is filling to a point approaching obstruction, the other nostril is opening and throwing off its secretion . . .". In a further study of 60 upright persons under varying temperatures and

humidity, Heetderks, in 1927, found by direct observation that this distinct alternating physiologic congestion and decongestion existed in 80% of his random study group. He determined that the duration of this nasal cycle varied between 30 minutes and 4 hours and had a mean duration of 2½ hours. Heetderks postulated that the purpose of this cycle was twofold. First, the inspired air was warmed by the congested turbinates acting as a radiator of heat, and second, the inspired air was humidified using discharged seromucous secretions. The abundance of secretions seemed to bear a close direct relationship to congestion of the turbinal sinusoids.

Using objective anterior rhinomanometric techniques, Stoksted in 1952 demonstrated variations of the nasal cycle in pathologic rhinologic conditions. He recorded a characteristic complete absence of any regular cycle in "vasomotor rhinitis". A low-amplitude rhinomanometric curve and a diminished cycle were demonstrated in a patient with "atrophic rhinitis", whereas an elevated curve of increased pressure was found in genuine "hypertrophic rhinitis".

In 1970, Principato and Ozenberger, using the active posterior rhinomanometric mask technique, revealed an almost clocklike nature of the rhythm of the nasal cycle in humans. Although they did not note the number of subjects studied, they observed that mucosal turgescence could be temporarily obviated by topical vasoconstrictor agents. They also discovered that the cycling of the human nasal chambers could be resumed in its respective phases when the local effects of these agents were dissipated. Moreover, they observed that the local factors altering the state of the cavernous tissues in one nasal chamber did not modify or affect the behavior of the contralateral side.

An additional interesting observation made by Stoksted and Principato and Ozenberger was that, although the turbinates fluctuated independently and out of phase with each other, producing increases and decreases in ipsilateral uninasal resistance, the total (binasal) resistance remained relatively constant, with the total (binasal) resistance remaining less than that on either of the two individual sides. This finding also has been confirmed in 50 human subjects by Hasegawa and Kern (1977), who used an active posterior rhinomanometric mask technique.

Regulatory control of this cycling pattern has been believed to be mediated via the autonomic nervous system, namely the sympathetic out-flow. The supportive evidence was produced by a study in which complete bilateral elimination of the turbinate engorgement pattern was observed when human subjects were exposed to carbon dioxide (Ogura et al., 1964). This concept of the influence of the central nervous system on the nasal cycle has suggestive support from previous workers (Ogura et al., 1964; Principato and Ozenberger, 1970). Notable was an analogous rhythmic sequence of caudally migrating motor complexes that recycle in the upper small bowel of fasting dogs, lasting from 4.8 to 7.0 minutes. As

one cycle terminates in the ileum, another begins in the duodenum or upper jejunum (Szurszewski, 1969). Again, control is via the autonomic nervous system. In addition to evidence of an upper to lower airway reflex mechanism (James and Daly, 1969; Allison, 1977; Wicker et al., 1973b, 1978) data on nasal vascular control through the autonomic nervous system have been obtained from experiments in humans (Hasegawa et al., 1978, 1979; McCaffrey and Kern, 1979a) and dogs (McCaffrey and Kern, 1979b). The mounting weight of these studies lends credence to the idea that nasal physiologic mechanisms are interconnected with certain central and peripheral physiologic events. Ogura et al., in 1968, showed that pulmonary resistance changes occur with various degrees of nasal obstruction. In another study, in 1964, they postulated the existance of a reflex mechanism between the nose and bronchomotor tone which affects the aerodynamics of the respiratory system. Wyllie et al. (1976) demonstrated changes (increased pulmonary resistance) secondary to artificial nasal airway obstruction in man. These changes were reversed when the obstruction was removed. As far back as the early part of this century, Šercer (1930) observed the corresponding ipsilateral expansion of the thorax when blowing air into one nostril of laryngectomized patients. This response was absent when the nose was anesthetized. It was believed that the trigeminal, vagal, and phrenic nerves were involved in this phenomenon.

Whicker et al. (1978), in a convincing series of well-controlled experiments in dogs, clearly showed that a "nasorespiratory reflex" was present but that it was *not* mediated through changes in bronchomotor tone. There is no doubt that upper and lower airway interdependence exists, but the exact mechanisms are still not well worked out. These findings have enormous implications on the final respiratory pathway and pulmonary alveolar gas exchange.

In 1975, Eccles and Maynard described the presence of a nasal cycle in large immobilized pigs. Unfortunately, the methods were not detailed. Before this work, a nasal cycle had not been known in any other species other than humans; preliminary work in dogs, cats, rabbits, and rats was unsuccessful (Eccles and Maynard, 1975). Recently, in 1976, Grote et al. demonstrated cyclic changes in nasal patency in rats using the Zwaardemaker mirror technique. Now, because of this current work, a new method for active anterior rhinomanometry in the laboratory animal is firmly established. This rhinomanometric technique has substantiated the existence of a nasal cycle in the porcine preparation.

Experiments performed in cats show that involuntary physiologic changes in nasal resistance are mediated via alteration of blood flow to nasal mucous membrane arterioles and sinusoids (Malm, 1973). Such vasomotor changes occur through the interplay of bilateral parasympathetic outflow via sphenopalatine ganglion efferents on one hand and of sympathetic tone via the bilateral cervical sympathetic trunks and deep petrosal nerves on the other (Malcomson, 1959; Malm,

1973). Elimination of vascoconstrictor sympathetic tone via unilateral cervical sympathectomy should result in increased ipsilateral mucosal turgescence and concomitant elevated nasal resistance. Ipsilateral rhinorrhea accompanied by Horner's syndrome also would be evidence of sympathetic tone loss and disruption of normal autonomic interplay. Thus, such disruption should interfere with any normal cycling patterns of nasal mucous membranes that previously existed. In comparing cyclical patterns repeated the next day or even 1 week later in the same animal, variations in resistance were frequent. This variation is similar to that noted, in humans (Hasegawa and Kern, 1977). In fact, one animal may exhibit nasal cycling on one day and not on another. In addition, elevated nasal resistances may fluctuate from day to day and from side to side (Figure 16). These findings contrast with the regular, clocklike patterning of the nasal cycle described by Principato and Ozenberger. Instead, they highlighted the many and variable influences of environment and physiologic bodily changes (hormonal, metabolic, positional, P_{CO_2}, age, and so forth) on nasal mucosal congestion and decongestion (Taylor, 1973).

The mean total nasal resistance throughout a recording session is less than either one of the individual (right of left) sides (Figure 17). Because the nasal passages are simply parallel resistors, the total nasal resistance (*Rn*) may be determined from the formula:

$$\text{Total } Rn = \frac{\text{product } (Rn \text{ left} \times Rn \text{ right})}{\text{sum } (Rn \text{ left} + Rn \text{ right})}$$

These findings help support the theory that, although each nasal cavity has individual and separate autonomic innervation and although one nasal chamber seems to "rest" while the other "works", there is integration and coordination at a central level so that the total resistance of the nose remains relatively constant. At the same time, the nasal resistance and resulting transnasal pressure gradients needed for respiratory airflow and eventual alveolar ventilation are provided. This total nasal resistance is less than that of each individual side.

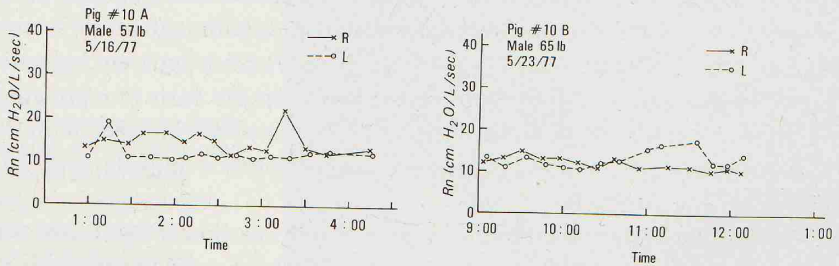


Figure 16. *Left,* No cycling pattern. However, right nasal resistance predominates. *Right,* Same pig, showing cycling pattern 1 week later. Right nasal resistance no longer predominates.

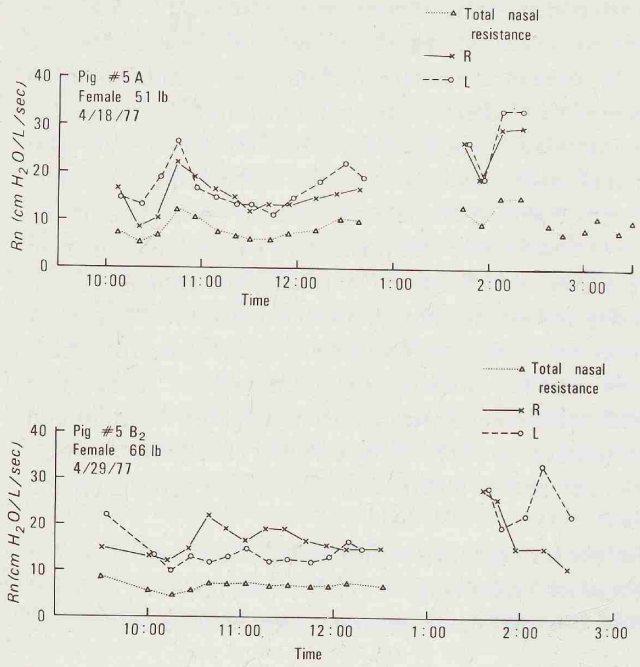


Figure 17.
Upper, Nasal cycling. Calculated total nasal resistance is less than either side.
Lower, Same pig. Total nasal resistance is relatively constant.

The effects of surgery (unilateral cervical sympathectomy) were manifested clinically as well as rhinomanometrically. A profuse ipsilateral foamy rhinorrhea, along with significant ipsilateral ptosis and enlargement of the medial canthal caruncle, were clinically apparent (Figure 18). The intensity of the rhinorrhea diminished over ensuing weeks.

Rhinomanometrically, cycling was absent in all pigs with pronounced elevation of ipsilateral nasal resistance after cervical sympathectomy. Contralateral nasal resistance was not affected. The effects of unilateral cervical sympathectomy were mirrored rhinomanometrically as elevated resistances that gradually waned after several weeks and approached preoperative levels (although ptosis seemed to persist) (Figure 15 *lower left* and *right* and Figure 19). Such apparent reduction in sympatholytic effect is unlikely to be explained on the basis of regrowth of nerve fibers, because a long nerve segment (3 to 4 cm) was resected. With this great gap between proximal and distal segments, regrowth is unlikely, especially after only several weeks.

Another considerations is the eventual regaining and exertion of significant sympathetic tone via minor, residual pathways that might have escaped nerve section. One of these pathways may be via the external carotid and maxillary arterial systems (Malcomson, 1959; Jackson and Rooker, 1971; Malm, 1973). However, radi-

cal sectioning of the cervical sympathetic trunk and its ramifications about the carotid artery makes this route improbable. Similarly, a coursing of sympathetic fibers to the nose along the ethmoidal nerve is unlikely, because these axons originate with the cervical sympathetic trunk and travel via the pericarotid plexus (Malcomson, 1959). However, in his experiments with cats, Malm (1973) found that, when the sympathetic nerve was stimulated on one side, contralateral nasal

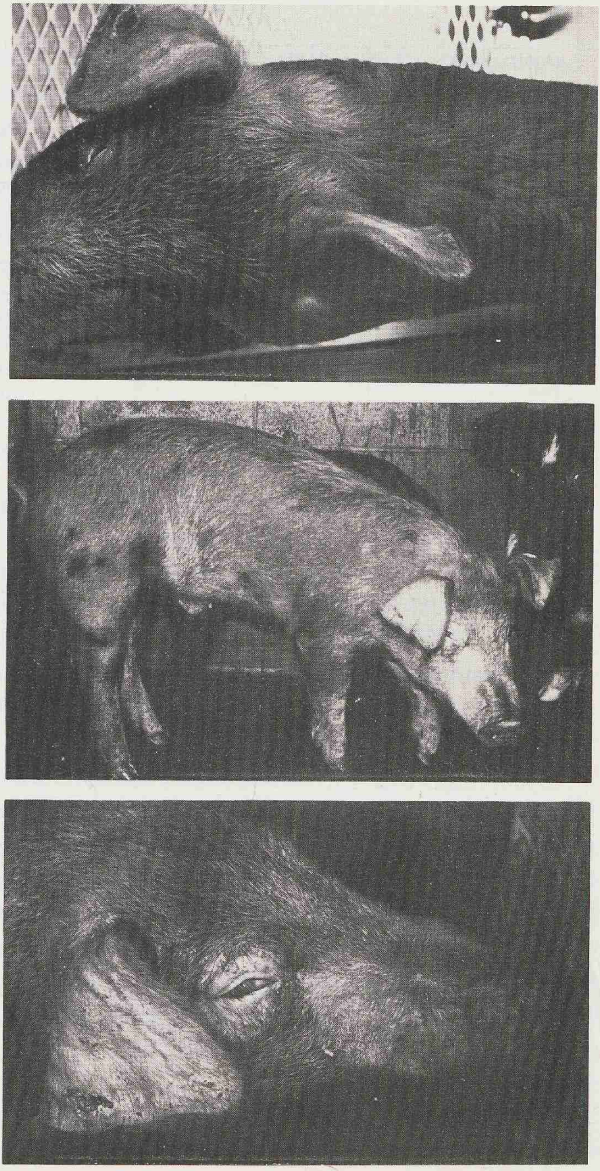


Figure 18.
Top, After sympathectomy, showing severe ptosis on operated side (right). *Middle,* Several months after sympathectomy, with persistent ptosis on operated side (right). *Bottom,* Close-up of right side of face.

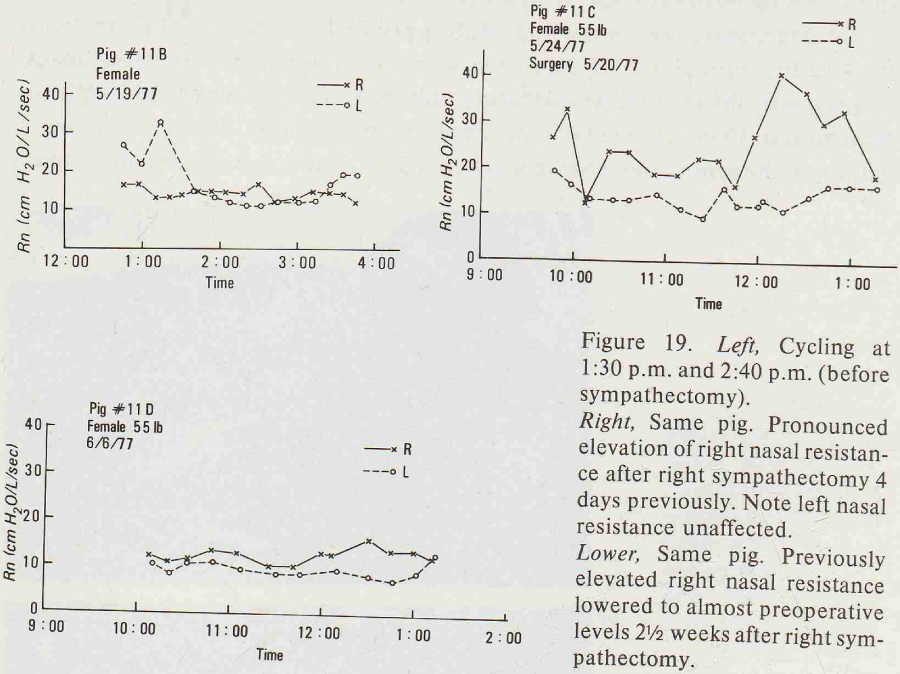


Figure 19. *Left,* Cycling at 1:30 p.m. and 2:40 p.m. (before sympathectomy).
Right, Same pig. Pronounced elevation of right nasal resistance after right sympathectomy 4 days previously. Note left nasal resistance unaffected.
Lower, Same pig. Previously elevated right nasal resistance lowered to almost preoperative levels 2½ weeks after right sympathectomy.

patency increased. This raises the possibility of sympathetic fibers crossing the midline from the opposite intact cervical trunk.

A more likely explanation of postsympathectomy variations in resistance could be derived from Cannon's law of denervation or denervation hypersensitivity (Cannon and Rosenblueth, 1949; Malm, 1974). This law contends that the catecholamine receptor sites become sensitized to circulating neurotransmitters (epinephrine, norepinephrine) in the presence of degenerating sympathetic nerve fibers.

With the establishment of a method of closely monitoring the nasal cycle in the laboratory animal, further studies to assess changes in altered physiologic and disease states (for example, pregnancy, vasomotor rhinopathy, acute and chronic rhinitis), as well as changes resulting from surgery and positional turbinate congestion, might later follow. Additionally, it would be of interest to measure blood gases (particularly P_{CO_2}) at various intervals throughout the cycle recordings, because of the sympathomimetic effects of carbon dioxide on turbinal congestion, even though such influence would be bilateral (Ogura et al., 1964).

CONCLUSIONS

The domestic pig exhibits characteristic fluctuations in nasal mucous membrane congestion and decongestion which meet the stipulated criterion for the exist-

ence of a nasal cycle. This phenomenon was documented in 6 of the 11 pigs studied. Also, unilateral sympathectomy acutely affects ipsilateral nasal resistance, but this elevated nasal resistance gradually decreases to preoperative values over several weeks. Finally, a new technique using active anterior rhinomanometry has been developed that can be applied to the study of nasal resistance changes in laboratory animals.

RÉSUMÉ

Le porc domestique présente des fluctuations caractéristiques de congestion et de décongestion de la muqueuse nasale, ce qui répond au critère stipulé pour l'existence d'un cycle nasal.

Ce phénomène a été documenté chez 6 porcs d'un total de 11 porcs étudiés. Une sympathectomie unilatérale aussi agit vivement sur la résistance nasale ipsilatérale, mais cette résistance nasale élevée diminue graduellement aux valeurs préopératives, au cours de quelques semaines.

Finalement une technique nouvelle a été développée utilisant la rhinomanométrie antérieure active; cette technique peut être appliquée à l'étude des changements de résistance nasale chez les animaux d'expérience.

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