



## Amelioration of Sleep by Expansion of the Nasal Cavity: A Role of the Nose

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### Abstract

In the Background, characteristics of homo sapiens were described. The structural weak point is the neck. Homo sapiens are born with the tongue and the epiglottis and larynx deviated upward and forward. The state of that was exactly ankyloglossia with deviation of the epiglottis and larynx (ADEL). ADEL inhibits respiration. For correction of ADEL, both correction of the glosso-larynx (CGL) and the expansion of the vestibular oris (EVO) were done. In this study total of 334 cases with complaints of sleep disorders were studied. Nasal patency and changes in sleep were measured by acoustic rhinometry and by questionnaires before and one month after CGL and EVO.

Average patency of the nasal valve area before and one month after were 1.3 cm<sup>2</sup> and 1.4 cm<sup>2</sup>, respectively, and of the piriform area were 1.7 cm<sup>2</sup> and 2.9 cm<sup>2</sup>, respectively. Nasal volume for these time periods was 17.6 cm<sup>3</sup> and 19.8 cm<sup>3</sup>, respectively. The volume and area of the nasal cavity was augmented. Questionnaires showed much amelioration of sleep after CGL and EVO, indicating that the increase in nasal patency resulted in good sleep. Results indicated that one role of the nose is cooling of the brain. The facial cranium consists a heat exchange system for the brain.

**Keywords:** Ankyloglossia with deviation of the epiglottis and larynx (ADEL); Nose; Negus V; sleep; REM; Homo sapiens; Evolution; Brain

### Introduction

It has been only 200,000 years since we, homo sapiens, emerged in this world. Homo sapiens not only surpassed the other homo species, but also completely devoured the large animal species on the earth. They spread to every corner of the earth. The important characteristic of homo sapiens is that the foramen magnum is at the center of the cranial base compared to the other homo species and animals. This enables homo sapiens to stand straight and observe objects straight ahead from higher levels. They can sweat and cool their bodies. These were great advantages for hunting. They could form words and communicate with each other. Their thoughts and arts were transmitted to and accumulated by subsequent generations. Homo sapiens proliferated greatly on the earth.

Homo sapiens breathe through the nose and talk and consume foods by mouth while they stand straight and observe objects by their eyes. Their respiratory and phonatory systems as well as the nutritional passage meet at the neck. The neck is the weak point of homo sapiens [1-9]. In the 17<sup>th</sup> century, in Italy almost all babies underwent frenotomy at their baptism whether or not the lingual frenum was present as ankyloglossia (Hieronymus, 1537-1619). Till the early 20<sup>th</sup> century, frenotomy was performed on all babies as an important part of childcare. Ankyloglossia is accompanied by deviation of the epiglottis and larynx. This condition was named ankyloglossia with deviation of the epiglottis and larynx (ADEL). Studies of ADEL have continued for over 30 years by Mukai "et al." [10-14]. At a health check-up of 4-month-old babies at Hodogaya and Asahi wards in Yokohama in 1992, ankyloglossia was observed in 96% [15]. A developmental check-up of 5- and 6-year-old children in a kindergarten in Kobe in 2000 revealed severe (36%), moderate (38%) and mild (26%) ankyloglossia in 92 children [16]. The high rate of observation of ankyloglossia by our research in Japan and that frenotomy was performed for all babies in Europe mean that ADEL is common in humans. That is, homo sapiens are born with their foramen magnum at the center of the cranial base and the tongue and the epiglottis and larynx are deviated upward and forward. The symptoms in babies with ADEL are a colicky cry, shallow sleep, snoring, cold extremities, swollen abdomen and umbilicus, frowned facial expression, etc. [17-21]. These babies were found to have breastfeeding difficulties and to hurt their mothers' breasts by suckling [22]. Sleep and various physico-mental problems were observed in children and adults with ADEL [23]. The state of ADEL inhibits respiration [16,24]. The Correction of the Glosso-Larynx (CGL) and the

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expansion of the vestibular oris (EVO) were established for ADEL. In CGL several bundles of genioglossus muscles are cut. The tongue goes back and downward and as a result the epiglottis and larynx move back and downward, too. Respiratory rate was increased from 16.7 to 20.8 after CGL. Increases in VC from 93% to 107% and FEV<sub>1.0%</sub> from 60.6% to 66.7% were observed after CGL in adults. Expansions of the hypopharynx, larynx and trachea were also observed after CGL [12,25,26].

In the EVO the depressor septi-nasi (DSN) muscles are ablated from the maxillary bone. This releases the inhibitory strength of the DSN muscles to the facial muscles and to the maxillary bone. Height of the nose and widths of nostrils and lips are increased after EVO. Decreases in nasal airway resistance and increases in nasal airflow were observed after EVO [27-30].

### Aim of the present study

Volume of the nasal cavities and areas of the nasal valve and of the nasal piriform cavities were measured before and after CGL and EVO by acoustic rhinometry in patients who complained of sleep disorders. At the same time, complaints of sleep problems were surveyed by a questionnaire. Functions of the nose are reconsidered from the viewpoint of physiology of sleep and the cranio-facial anatomy by the results.

## Cases and Methods

### Cases

Studied were 334 cases (male 159, female 175). From 25/July 2013 to 10/Dec. 2015, they received CGL and EVO for complaints of sleep disorders. Their average age was 42.1 y (SD  $\pm$  14.3 y; range 13 to 77 y; males 41.3 y; females 42.8 y). There was no statistical difference between the average age of males and females.

### Methods

**Acoustic rhinometry:** An acoustic rhinometer (GM Instruments, Ltd., Ashgrove, UK) was employed to measure volume and area of the nasal cavity. The results of the measurements are expressed as both curved lines and numerals. Numerals were employed in this study; that is, the area of nasal valve region is indicated by Min 1 (cm<sup>2</sup>) and the narrow place of the nasal piriform area that is 5 cm inside the nose and is surrounded by the frontal margin of the inferior concha and nasal septum is indicated by Min 2 (cm<sup>2</sup>). Volume from the margin of the nostril to 5 cm inside the nose indicates Vol<sub>0-5</sub> (cm<sup>3</sup>) and from the nasal valve to 5 cm indicates Vol<sub>2-5</sub> (cm<sup>3</sup>). Changes in Min 1, Min 2, Vol<sub>0-5</sub>, and Vol<sub>2-5</sub> were measured before and one month after EVO and CGL.

**Conditions of measurements:** The patency of the nose changes according to conditions of nasal mucous membranes. Such changes are caused by rhinitis, allergy, humidity and temperature. These conditions can change according to the day and time [31,32]. To avoid the influences of mucous membranes, nasal decongestants (tramazoline hydrochloride; 0.118% AFP) were sprayed into both nasal cavities 30 minutes before each measurement. Results of right and left nasal cavities are shown both separately and added together. The latter were employed in this study.

### Questionnaires on sleep

Questionnaires were conducted twice: before the operation and one month after the operation.

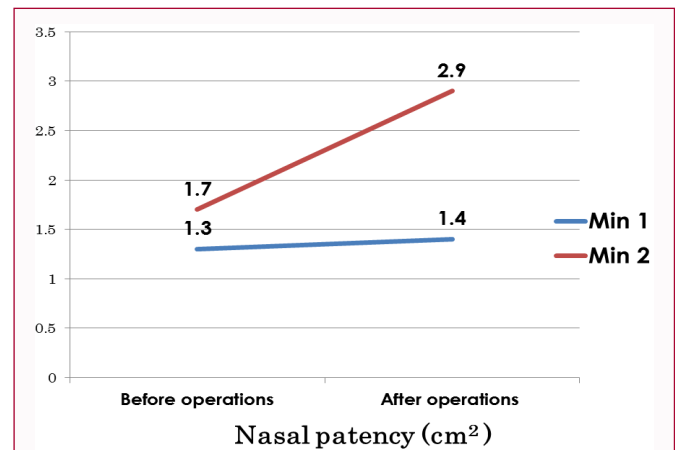


Figure 1: Nasal patency before and after operations ( $p < 0.001$ ).

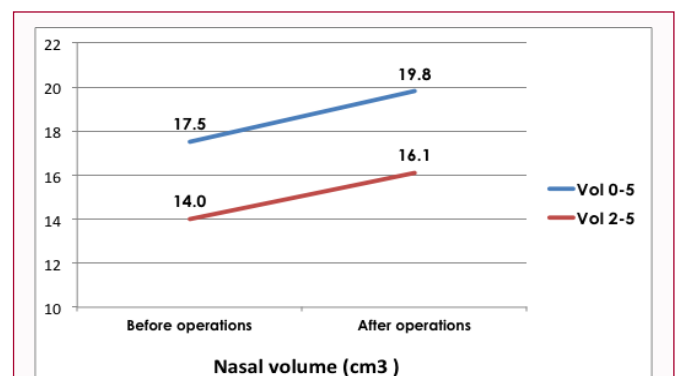


Figure 2: Nasal volume (cm<sup>3</sup>) before and after operations ( $p < 0.001$ ).

### Questionnaire before operation

- Can you fall asleep swiftly?
- Are you a snorer?
- Do you have sleep apnea?
- Do you wake up not less than twice nightly?
- Do you have daytime somnolence?
- Don't feel having slept soundly?
- Do you feel refreshed when you wake up?
- Are you fatigable?
- Do you feel sleepy while driving?
- The rate of "yes" answers was counted.

### One month after operation

The above questionnaires were administered one month after the surgery. Responses were examined to indicate whether the operations brought about "remarkable amelioration", "amelioration", "no change" or "worsen". This study was done with the consent of the patients after a full explanation of the aim of the research was provided.

## Results

### Acoustic rhinometry

**Nasal patency (Figure 1):** Average patency of the nasal valve area (Min 1) before and after operations was 1.3 cm<sup>2</sup> and 1.4 cm<sup>2</sup>,

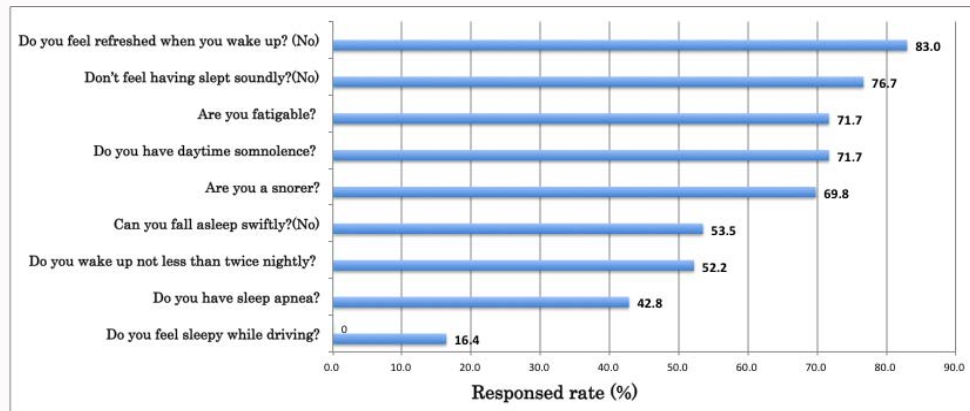


Figure 3: Rate of responses to the questionnaires.

respectively. That of Min 2 was 1.7 cm<sup>2</sup> and 2.9 cm<sup>2</sup>, respectively. These areas of the nose differed significantly between before and after operations (p<0.001).

**Nasal volume (Figure 2):** Average volume of Vol<sub>0.5</sub> before and after operation was 17.6 cm<sup>3</sup> and 19.8 cm<sup>3</sup>, respectively and the average volume of Vol<sub>2.5</sub> before and after operation was 14.1 cm<sup>3</sup> and 16.1 cm<sup>3</sup>, respectively. There were significant differences between before and after operations (p<0.001).

**Questionnaires on sleep**

The rate of “yes” answers were as follows in the order of the highest to the lowest rates (%) (Figure 3)

- Do you feel refreshed when you wake up? (83.0%).
- Don't feel having slept soundly? (No) (76.7%).
- Are you fatigable? (71.7%).
- Do you have daytime somnolence? (71.7%).
- Are you a snorer? (69.8).
- Can you fall asleep swiftly? (No) (53.5%).
- Do you wake up not less than twice nightly? (52.2%).
- Do you have sleep apnea? (42.8%).
- Do you feel sleepy while driving? (16.4%).

**Questionnaires one month after operations**

The answer of “remarkable amelioration” or “ameliorated” was counted as “amelioration”. When it was “not changed” it was counted as “unchanged”. When the answer was “worsen” it was counted as “worse”. The rate of answers for each question was counted.

Amelioration rate (%) for each question as follows in the order of higher to lower rates (Figure 4).

- Can you fall asleep swiftly? (83.5%).
- Do you feel sleepy while driving? (81.3%).
- Are you fatigable? (79.8%)
- Do you have daytime somnolence? (79.8%).
- Don't feel having slept soundly? (79.5%)
- Do you feel refreshed when you wake up? (73.5%).

- Do you wake up not less than twice nightly? (71.1%).
- Are you a snorer? (63.1)
- Do you have sleep apnea? (60.3%).

**Discussion**

Average patencies of the nasal valve area before and after the operations were 1.3 cm<sup>2</sup> and 1.4 cm<sup>2</sup>, respectively. Areas that were surrounded by the nasal septum and the margins of conchae were 1.7 cm<sup>2</sup> and 2.9 cm<sup>2</sup>, respectively. Expansion at the margin of the conchae was wider than that of the nasal valve area. Volume of expansion of the nose from before and after the operations was from 17.5 cm<sup>3</sup> to 19.8 cm<sup>3</sup>. These results indicate that the nasal cavities as well as maxillary bone widened after these surgeries. The results of this study also proved that ADEL inhibits growth of the maxillary bone.

It is also proof that the increase in nasal airflow and decrease in nasal airflow resistance were observed by expansion of the vestibular oris (EVO) [27-30]. Velocity of the airflow of the two narrow spaces in the nose can be compared by results of this study. The narrowest place in the nose is at the nostril, nasal valve Min 1. Next to it is the place Min 2 that is surrounded by the nasal septum and margins of the nasal conchae.

Suppose the velocity in a tube is simply proportional to its dimensions. Suppose v1 is the velocity of Min 1 and that of v2 is Min2. Width of Min1 is 1.4 cm<sup>2</sup> and that of Min2 is 2.9 cm<sup>2</sup> by this study.

$$\text{Min 1} \times v1 = \text{Min 2} \times v2$$

$$v2 = 1.4/2.9 \times v1 = 0.48 \times v1$$

The relative velocity of the ventral margin of the nasal piriform area is 0.48 times that of the nasal valve area. The relative velocity in the piriform area of the nose is reduced to less than half.

From the margin of the piriform area, the nasal cavities open wider and are separated by conchae. From there the inhaled airstream changes turbulence and direction. Inhaled air passes swirling presto (t=200) through the nostril to lento (t=96) into the nasal turbinated area. Cleansing, warming and humidification as well as heat exchange might take place effectively in this turbinate area. Then swirling air changes directions passing from the choanae to the larynx and trachea. Air stream at expiration flows in the reverse order. Nasal cavities as well as paranasal sinuses are covered with nasal mucous membranes. The density of vessels in this mucous membrane is very

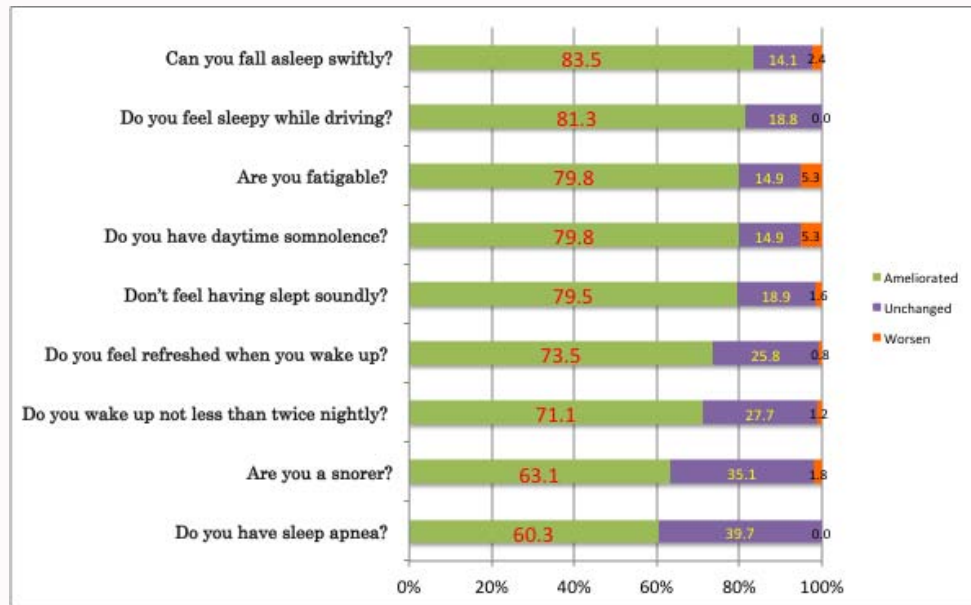


Figure 4: Rate of amelioration of complaints.

high. It was observed in a dog that from 70% to 80% of membranes involved a rete of vessels (Adams 1983) [32-35]. Heat from both inhaled as well as exhaled air in the nose transmits promptly to nasal mucous membranes. The heat then spreads to the neighboring paranasal sinus bones rapidly by the extended nasal mucous membranes. Good sleep has rhythms [33-35]. Before a healthy person falls asleep, the skin temperature rises and heat radiation starts. Then the deep body temperature and brain temperature begin to fall. After slow wave sleep, REM sleep appears. At this time temperature of the brain has already fallen. Dreams occur during REM sleep. During this time rearrangements of the brain circuits start briskly and the brain is refreshed by these rearrangements. Dreams during REM sleep are not remembered completely. This state is the deepest condition of sleep [33-35]. The remarkable ameliorations of sleep observed after operations. The most prominent amelioration revealed by the questionnaire was that the responders could get to sleep swiftly (83.5%) after the operations. It is thought that the increased nasal airflow decreased the brain temperature earlier than before operations and allowed patients to fall asleep swiftly. Also “refreshed when awake (73.5%)” suggests that patients go into REM sleep sufficiently. Heat exchange in the nasal cavities was accelerated after operations. In summary, the operations made possible good sleep.

The structure of nasal cavities is totally different from those of the snout, muzzle and trunk [36]. These animals have well branched maxillo-turbinal noses and ethmo-turbinal paranasal sinuses. The maxillo-turbinal is the area mainly concern with air conditioning, while the ethmo-turbinals serve the function of olfaction. On the contrary Man has flat turbinals nose and with empty paranasal sinuses. In Man it is enough to humidify, cleanse and warm of inspiratory air to the alveoli by the trachea, bronchi and bronchioli [36]. Sir Victor Negus said that “ the higher Apes and Man have a large cavity with no contained ethmo-turbinals, so it is impossible to explain why these sinuses, should appear in higher members, whose olfactory area is very restricted and whose sense of smell is feeble” [36]. His view from the olfaction and humidification of the nose like Dog and Cat, Man’s nose is no more the nose. But these changes indicate that the role of the human nose is evolved in the other functions.

Cranial bones are divided into two, the brain cranium and facial cranium [37]. At the center of the facial cranium beneath the brain is the nose, which consists of a piriform aperture and is divided into two by the nasal septum. On both sides of the piriform aperture the lower, middle and upper nasal conchae bones protrude. These make each meatus. The orbital cavities and maxillary bones with maxillary sinuses are at the same level as the nose. Between the orbital cavities and the piriform aperture the ethmoid cellulae or bones develop. The frontal sinuses develop over the nasal cavities. Above and back of the nasal cavities are sphenoid bones with relatively large sinuses. Ostia of these paranasal sinuses open to the middle meatus. In the upper part of the sphenoid bones, cavernous sinus veins surround the sella turcica. This constitutes the lateral border of the sella turcica and contains the oculomotor, trochlear, ophthalmic, and abducens nerves [38]. The path of the veins and position of the sinuses suggest that hypothalamus and cranial nerves need heat exchanges. The paranasal sinuses develop well around the orbits and optic nerves. The olfactory senses are at the top of the nasal cavity. In man the mucosa of olfactory region no cilia are present [36]. The cochlea and vestibular nerves occupy a large volume in the temporal bones. Exits of the temporal bones open to the choanae as ostium of the Eustachian tubes. In addition, conchae of the ear might be concerned with heat exchanges with mucous membranes and the venous rete of the temporal bones. Nasal cavities exist as a heat exchange system via those mucous membranes of facial cavernous bones and veins. The brain is contained under the frontal, parietal and occipital bones. The venae diplocae spread in these bones. Heat exchanges in the brain might be conducted by venae diplocae of these bones. Both mucous membranes of the inferior conchae swell and shrink alternatively within a day, a movement known as the nasal cycle (Kayser 1895) [39,40]. The mucous membranes of the ethmoid are also linked to the nasal cycle. It is thought that the nasal cycle of mucous membranes and the rete might be common to all cavities of facial cranial bones. Moreover, these movements have circadian rhythm (Block “et al.”. 1980) [40]. Radiation of heat as seen in the skin and conchae of the ears at the beginning of sleep and the erection of the penis during REM sleep are concerned with sleep [33-35]. Heat exchange might



be associated with a rhythm that is controlled by the center of the brain. This study shows that the role of the human nose is to refresh the brain by sleep with effective cooling. The facial cranium might be an effective heat exchange system with the nose at the center. This effective heat exchange system makes possible good sleep and refreshment of the brain in humans. Consciousness by eyesight and hearing instead of smelling might evolutionally be changed the anatomical simplicity of the noses and paranasals of Apes and Man. It was reported by a researcher of the Monkey Research Center of Kyoto University that Chimpanzee, Gorilla, Orangutan and Bonobo make their beds every day. He tried to sleep in a chimpanzee's bed. It was very nicely arranged and he slept well within it. He concluded that Apes enjoy sleeping [41].

## Conclusion

- The ADEL inhibits growth of both maxillary and mandibular bones.
- CGL and EVO accelerate respirations, nasal airflow and sleep.
- The role of the human nose is thought to refresh the brain by sleep with effective cooling.
- The facial cranium might be consisted of a heat exchange system for the brain by respiration.
- The noses of Ape and Man might be evolved from olfaction to cooling of the brain systems.

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