

Acute High Altitude Pulmonary and Cerebral Oedema

Scientific analysis from the perspective of New Paradigms derived from the interpretation of the Respiratory Pulse and correlated parameters.

Abstract

Alveolar capillary blood hypertension versus low alveolar air tension is the cause of acute pulmonary oedema.

Natural adaptation and distribution of species on the surface of the Earth is relative to Altitude. *The mass per volume unit of the atmospheric air is the determinant physical factor* and, the *Lung in its thoracic ensemble* achieves this task, integrating and balancing blood and air circulations. Consequently, *Man has a limit for his safe displacement in altitude*, the boundaries of which are roughly limited between sea level and about three thousand meters.

Cyclic contraction of the muscles of the lobular bronchioles produces two simultaneous main mechanical effects:

1. Decreases the pleural lumen, *to open way* for alveolar-capillary blood circulation. **Flood-gate action.**
2. Decreases the bronchiolar capacity, increasing the mass per volume unit of the contained air, thus *increasing its molecular expansive forces*. **Pump action.**

The following muscle relaxation also enables two simultaneous main mechanical effects:

1. Allows the *molecular expansion of the previously pressurized air*, for its displacement towards the alveoli, expanding them, in balance with the circulating capillary blood, for gas exchange, while also displacing the oxygenated blood towards the pulmonary veins. **Complementary pump and Press actions.**
2. Elastic retraction of the lobular structure follows, impelling the used air towards the extra-pulmonary airways. **Pneumatic Pump action.**

Muscles contraction of the *lobar bronchi* accomplish a similar mechanical role to that of the *lobular bronchioles*, for air intake and distribution among the lobules, and pulmonary blood balanced circulation, as well as for abdominal press action, also evoking, reflex via, *costal expansion for floodgate action* to balance abdominal-thoracic and cranial blood circulation towards the right ventricle.

Failure of these extra-pulmonary mechanical effects causes visceral oedema

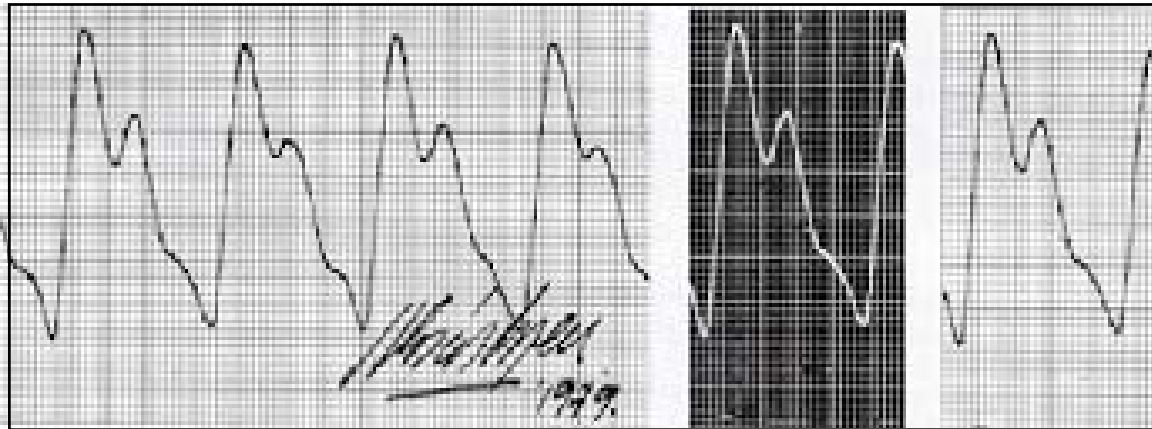


Fig 1 Pressure time graph of the Resultant of the lung's dynamics in its pleural surface The Respiratory Pulse. Note the maximal inflexion, which clinically coincides with each autonomic Inspiration of the animal; also note the series of minor inflexions, which coincides with arterial pulses. (Taken from "Fisiodinámica del Hombre en el Mundo" (1) this is unequivocal proof of the Lung being a mechanically active organ, under autonomic control.

New Paradigms

The Respiratory Pulse

The Respiratory Pulse is the Resultant, on the pulmonary surface, in the pleural space, of the cyclic autonomic dynamics of the Lung in its thoracic ensemble, to which it automatically integrates, via reflex, from the very moment of birth, by means of the visceral-somatic Pulmo-Diaphragmatic or Vago-Phrenic reflex. This autonomic dynamics is the organic process for the newborn integration and adaptation with the Atmosphere of its environment.

Human specie's adaptation level is comprised between sea level and about 3000 to 3500 meters; farther on, pulmonary functional insufficiency shall manifest as the known Acute High Altitude Sickness and Visceral oedema, for which I propose the name *Syndrome of Acute Pulmonary Insufficiency at High Altitude*.

The Lung

The Lung is an organ with a complex autonomic mechanical activity, performed by two kinds of integrated dynamic cycles, accomplished by specific structures.

One of these kinds of cycles, is carried out by the *lobar bronchi* under command of the Vagus nerve, for *renovation of volume masses of air*, simultaneously achieving integration of the individuals with the Atmosphere, at the geographical level of the species genetically programmed adaptation, while also performing *pulmo-cardio-circulatory integration and balance*, for gas exchange at the alveolar-capillary units, this latter by means of the other kind of dynamic cycles, performed by the *lobular bronchioles* under Sympathetic command.

The Primary role of the Lung is integration and balance of Organic Dynamics and Universal Dynamics, by means of the Atmosphere, at the very moment of birth and, its cyclic reaffirmation throughout Life.

Therefore, being born means the self balanced dynamic integration of the Foetus with the Atmosphere.

The mass per volume unit of the air is the physico-mathematical natural factor enabling that integration.

The Living Being in the Atmosphere of the Earth

Living Beings, humans as a prototype, defined from the perspective of Mechanics, are structural, functionally integrated models of *Mechanics of Fluids*, both liquids and gases, balanced in themselves

as with the Atmosphere at the genetic adaptation level of the species and individuals, to enable renovation and distribution of similar masses of air among the alveoli, to accomplish gas exchange with the blood and homogeneous distribution of oxygenated blood among the tissues.

This integrated dynamic balance of the whole Organic System of Fluids is the role of the Respiratory Apparatus, accomplished under active command of the Lung and the Central Nervous System's rhythm and force control.

Air *mass* per volume unit is the physico-mathematical factor determining the distribution of species and individuals at different levels of the Atmosphere, regulated by the Lung, in accordance with the Inertial Principle $F = m \cdot a$, and the balance programmed in their genes.

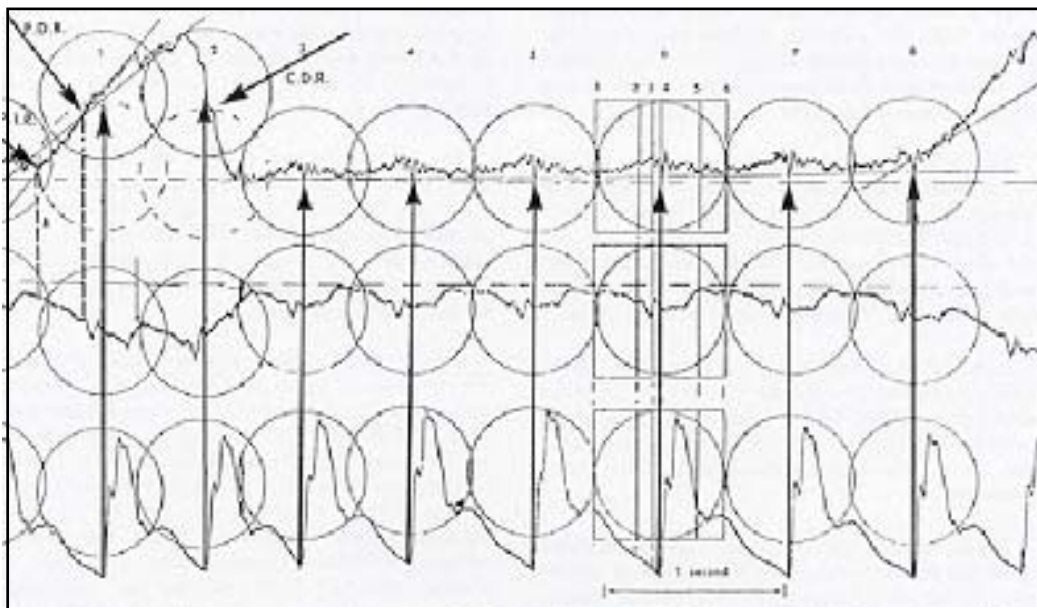


Fig 2. Simultaneous graphs of three main parameters. From top to bottoms: 1. Respiratory Pulse: 2. Intra-pleural sub-atmospheric pressure 3. Abdominal aortic pulses. The circles defines each lobular alveolo-capillary cycle and the correspondences with the others parameters. The arrows mark the coincident inflexion of capillary and arterial pulses. (Taken from "The New Theory of Respiratory Dynamics")²

Acute High Altitude Pulmonary, Cerebral and General Visceral Oedema

Introductory Remarks

Mass of atmospheric Air per Volume Unit is The Physic Natural Factor that Determines Adaptation and Balance of our Organisms With the Atmosphere.

The smooth muscles of the intrapulmonary airways, under control of the Vagus and Sympathetic nerves, when decreases their capacities, under control of the Vagus and Sympathetic nerves proportionally increase the expansive molecular force of the contained air, condition for its cyclic displacement and distension of the structures, in balance of forces.

Visceral-Somatic Functional Organic Integration

We can observe, by comparative analysis of the simultaneous graphs of the *Respiratory Pulse and Pleural Pressure Variations* (fig.2) that the starting point of the Respiratory Pulse's ascending slope and the following inflexions are simultaneous with the pleural pressure descent, which evidences a common primary cause and sequence in the performance of these mechanical phenomena.

I have demonstrated, in this sense, that the cyclic mechanical process leading to the Respiratory Function starts by the Vagus discharge to produce pulmonary broncho-constriction and, according to the bronchial structure and distribution of its muscular fibres as geodesic networks and sphincters, as described by Miller, determines a simultaneous decrease in diameter and length of the airways, decreasing their capacities and simultaneously pro-

ducing retraction of the pulmonary structure, this latter with two simultaneous effects:

1. Increase in the pleural lumen and proportional decrease in pressure of its content, which behaves like gases

This fact allowed me to conclude that the pleural space is filled with *vapour of the pleural liquid*; which remains not saturated and, all this must lead us to infer that there is a narrow cause effect relationship between these two kinds of mechanical phenomena, and that they must be necessary for specific and complementary tasks.

2. The sudden traction of the Diaphragm to evoke its reflex contraction and functional somatic integration.

Diaphragm-Intercostals-abdominal muscles belt under Pulmonary-Diaphragmatic, Vagus-Phrenic reflex command, regulates intrapulmonary gas expansion and the blood circulation balance between abdominal and thoracic cavities Mechanical effects derived from the dynamics of the pulmonary lobes:

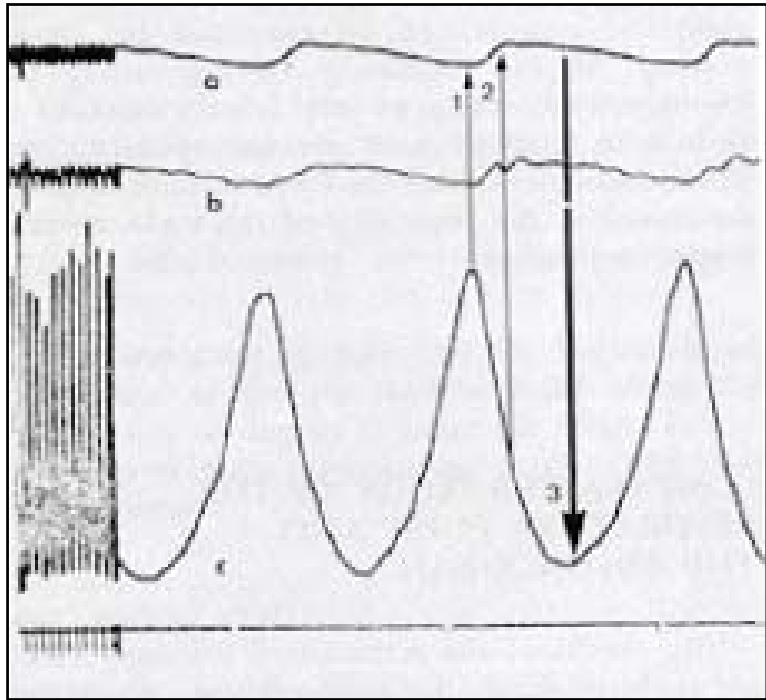


Fig 3 shows the correlation between the Respiratory Pulse graphs and the thorax expansion-retraction as graphed in the Pneumogram. (Taken from *The New Theory of Respiratory Dynamics*)² a) Pulmo-costal pulse b) Pulmo-diaphragmatic pulse. c) Pneumogram. Arrow 1 shows the transitional point between two successive Respiratory Pulses, coincident with the beginning of the pneumogram descent. Arrow 2 shows the top of the ascending slope of the pulses. The period 1-2 corresponds to bronchoconstriction and the first part of the pneumogram descent. Arrow 3 marks the lower point of the pneumogram, the maximal thorax retraction, which coincides with the beginning of the molecular expansion of the gases in the air and also with the beginning of the Lung's elastic retraction and the relaxation of the Diaphragm, conditions to start thorax expansion, show in the pneumogram.

Mechanical effects derived from the dynamics of the pulmonary lobes:

Primary role of the Lung as a thoracic-abdominal press, as well as in a reflex derived abdominal muscles press and costal wall floodgate actions. We must remember that the Phrenic nerve innervates the Diaphragm's central part, while its peripheral zone is innervated by the four or five lower intercostals nerves, the same that innervate the muscles of the corresponding intercostals spaces, and the anterolateral muscles of the abdomen.

We can infer, from these anatomical features, the chain of potential mechanical effects derived from stimulation of these nerves and also to under-

stand the reasons for the functional structure of this somatic muscular belt between the abdomen and the thorax, which behaves as a simultaneous and complementary abdominal press and costal wall floodgate.

This muscular belt, (Diaphragm, abdominal and low-intercostals muscles), coordinated by the lobar bronchi muscular contraction, via reflex, constitute the main central *engine* for balancing the general and pulmonary blood circulation, coordinated by Vagus nerve discharges, which while producing contraction-retrac

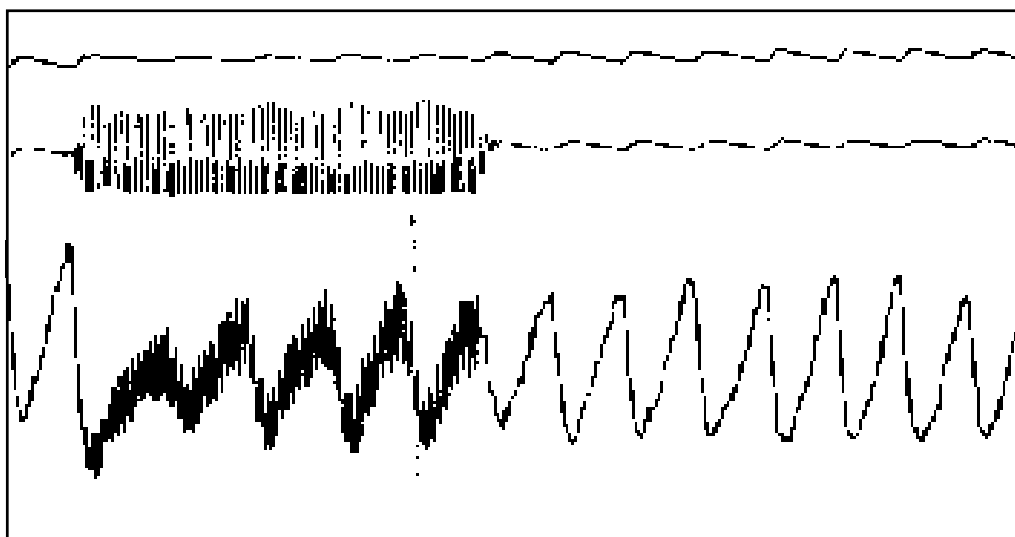


Fig. 4. Phrenic nerve stimulation after sectioning of the trachea and division of the right Vagus nerve. From top to bottom: 1. Pulmo-costal Respiratory Pulse. 2. Pulmo-diaphragmatic Respiratory Pulse. 3. Pneumogram. The pulmo-diaphragmatic pulse contrast greatly since the detector balloon is in direct contact with the Diaphragm and detects the effects of its contraction. The pneumogram contour is no longer a continuous line since it shows a series of small up and down displacements (jagged aspect) translating the effects of the artificial contractions of the Diaphragm. This is proof of the narrow relationship of the intercostals innervated muscles with the Diaphragm contraction to integrate the diaphragmatic thoracic-abdominal belt as press and floodgate balanced effects on liquid circulation.

tion of the bronchial muscles, simultaneously pull from the Diaphragm, stimulating the Phrenic nerve to start the chain of reflexes.

This visceral-somatic integration plays a very important role in balancing venous blood circulation towards the abdomen and thorax, in normal

conditions, which is distorted when the mass of air per volume unit is inferior to that of the adaptation limit of the human species and individuals, which demands maximal Vagus nerve discharges, thus producing maximal bronchoconstriction with low pulmonary expansion and derived unbalance in mechanical effects, as is the case at High Altitude.

Concurrent factors in the generation of acute high altitude pulmonary, cerebral and in general visceral oedema

The atmospheric air mass per volume unit lowers progressively during the ascent. Consequently, cyclic bronchoconstriction increases to balance the necessary air mass per volume unit into the airways and alveoli. Meanwhile, the pulmo-diaphragmatic reflex increases in intensity, with consequent effects:

This balancing of cause-effects progressively augments in proportion to the nervous discharges up to their maximal, which then makes the alveolar capillary balance impossible. This is the absolute limit of the species adaptation to the Atmosphere. Farther on the unbalance becomes evident.

Organic procedure:

Lobar autonomic mechanical effects under the Vagus nerve control.

The lobar bronchi muscular contraction, when retracting the structure of the Lung, pulls from the Diaphragm with two simultaneous effects:

1. Mechanically stimulating the Phrenic nerve, causing, by means of *Vagus-Phrenic reflex*, the contraction of the Diaphragm's central part, which when flattening its dome decreases the resistance to the expansive force of the intrapulmonary gases (air), causing expansion of the Lung towards the potential abdominal capacity, working as a press. This press action displaces the abdominal fluid streams towards the Pelvis, while also helping the upper and cranial venous circulation.

2. When the Diaphragm's central part contracts, its radial fibres pull from those in its periphery, stimulating their innervations, to evoke simultaneous contraction of the muscles innervated by the four or five lower intercostals nerves, so that all the muscles under common intercostals innervations simultaneously contract once the diaphragmatic central part begins relaxation. This complex process also evokes two simultaneous main effects:

- 2.1 Abdominal press action, by contraction of the abdominal flat muscles. This action favours cir-

ulation of blood and other abdominal fluids towards the right ventricle.

- 2.2 Floodgate action, by contraction of the named intercostals muscles, which expand the base of the costal wall, thus widening the Mediastinum and pericardial space, to widen the way for the blood stream displaced towards the right ventricle.

Note that this physiological process of Mechanics of Fluids is the sequence of facts derived from the primary Pulmo-Diaphragmatic Reflex, which responds to Vagus nerve discharges and, its reason for being is to balance the fluids circulation in the abdomen, as well as between the abdominal cavity and the Thorax and Head, while also balancing Pulmonary and cardiac reception of blood and its pressures.

If the Lung does not expand well, because of insufficient air mass, the described press action towards the abdomen will also be insufficient, disturbing the normal venous blood return and, the simultaneous intercostals contraction widen the way for blood circulation towards the right ventricle, with consequent blood re-distribution and visceral flooding, with consequent pulmonary and cerebral congestion and oedema.

The above named processes lead to hypoxemia, cellular hypoxia, decreased diuresis, and acid-basic unbalance, aggravating these pure physical consequences.

The living organism is a complex System of Fluid's Mechanics, dynamically integrated and cyclically balanced, both in itself as with the Atmosphere.

The Lung is the "integrator" and balancing organ, thus identifying it as the organ with the widest and most important mechanical activity, under complementary coordination of the autonomic nerve system.

The Lung achieves this balanced organic integration, with complementary reflex mechanical actions by the thoracic-abdominal somatic belt, via Vagus-Phrenic reflex.

Mechanical effects derived from the Lobular-alveolar-capillary dynamics:

Lobular-Alveolar-capillary floodgate and press effects.

The muscular contraction of the lobular bronchioles generates similar effects to that of the muscle contraction of the *lobar bronchi*.

Therefore, when decreasing the diameters and length of their ways, there is a simultaneous increase in the contained air pressure, as far as the alveoli, simultaneously increasing the *pleural lumen* in each and every lobular sector, leading to two complementary effects:

1. *Floodgate action* at the alveolar-capillary level, opening ways for pulmonary blood circulation throughout the alveolar capillaries.

2. *Press action*. When the bronchiolar muscles start relaxation, the molecular expansion of the intra-alveolar gases, working as a press, enables Oxygen diffusion and gas exchange, also displacing the oxygenated blood towards the pulmonary veins and, the remaining alveolar gases towards the respective bronchioles and bronchi, aided by elastic retraction of the now relaxed structure.

If the muscular contraction of the lobular bronchioles increases, to balance the contained low mass of air per volume unit, it also increases their retraction, widening the pleural lumen, therefore *increasing the arrival of an increased volume of blood*.

Furthermore, as the air mass per volume unit is lowered, the alveolar gas expansion is also lowered along with the generated pressure, consequently, the alveolar press action is insufficient and blood is retained, with pulmonary hypertension and flooding.

If the molecular expansive force of the alveolar air is insufficient, neither the alveolar distension will be big enough to balance gas exchange with the blood, nor the alveolar-capillary press action will be strong enough, disrupting blood circulation forwards, with alveolar-capillary hypertension, also adding a factor for retrograde effects towards the pulmonary artery and the Heart, becoming yet another factor to increase pressure in the pulmonary artery.

The course of these phenomena leads to pulmonary oedema for simple physical reasons, similar to any acute oedema. These factors also proportionally decrease the volume of oxygenated blood that must arrive into the left auricle.

Analytical Review of cardiac catheterisation and Necropsies

Cardiac catheterisation during acute pulmonary oedema has been reported, revealing pulmonary hypertension, arterial unsaturation and a normal left atrial pressure⁶.

These signs have a common cause: The pulmonary autonomic dynamics at high altitudes as manifest at the two levels or sectors of the whole circuit of fluids circulation:

1. At the alveolar-capillary level, under Sympathetic control.
2. At the Diaphragm-intercostals-abdominal belt level, under control of the autonomic Vagus-Phrenic nerves reflex and the following somatosomatic reflexes, as described by me elsewhere.

The produced effects are:

Widening of the pleural lumen, working as a floodgate, increasing the blood stream as far as the alveolo-capillary units, retained here due to the low press effect caused by low molecular expansion of the intra alveolar gases. For the same reason, the venous stream decreases and the pressure in the left auricle is low.

This Dynamics at the lobar bronchi and the lobular bronchiolar level obeys the same natural conception programmed in the genes: Contraction of the Reissessen' muscle, producing four simultaneous effects:

1. Abdominal press, under Vagus command working at the lobar bronchi
2. Alveolar press, under Sympathetic command, for two simultaneous effects:

2.1 Oxygen diffusion balance

2.2 Displacing the oxygenated blood towards the left auricle.

Consequently, when the air mass at the lobular level is insufficient, Oxygen diffusion will also be insufficient, causing blood Oxygen unsaturation and low pressure in the left auricle.

The simultaneous lobular retraction leads to widening of the pleural lumen with floodgate effect, increasing the blood stream and, as the press effect is low, blood is retained with the consequent pressure increase. These are the cardinal signs of Acute High Altitude Sickness as is believed, characterising the first step of the sickness.

If the patient is not removed from the high Altitude, the Central Nervous System increases its intensity of discharges and rhythm, with negative effects because of the insufficiency of the alveolar molecular mass, even with maximal nerve discharges and the blood stream is retained, causing generalised visceral flood and oedema, best noticed in the Lung and cerebrum due to their obvious clinical manifestation. A vicious circle is established, with irreversible damage leading to death.

There is only one cause:

The low mass per volume unit of the atmosphere in altitudes above the upper limit of the natural adaptation of the human specie and individuals. Consequently, specific treatment is immediate descent to lower levels.

Necropsy findings:

The macroscopic findings were characteristic of pulmonary oedema.

“All viscera were congested. The right side of the heart was distended with blood and the left side was empty. There was no cardiac enlargement. The large blood vessels were normal. In a fulminating case there was 400 ml. Bloodstained effusion in each pleural cavity”⁶

Microscopically, “enormous distension of blood vessels down to the capillaries, sludging of red

blood cells and perivascular seepage of blood (haemorrhage) were noted in all the organs.

In the brain, this resulted in characteristic ring and ball (haemorrhages). The liver showed focal areas of necrosis. The suprarenal showed stress effects... Congestion of the lungs were severe in the pulmonary arterial as well as in the pulmonary venous systems. The alveolar capillary distension led to the thickening of the alveolar walls. There was sludging of the red cells with perivascular haemorrhage in almost all the vessels”⁷

Conclusions

Low Air Mass per volume unit at High Altitude is the Cause of Acute Mountain Sickness, the progress of which leads to visceral oedema and death.

The whole progress of the signs and symptoms of Acute High Altitude Sickness is an open book showing the dynamic and anatomopathological consequences in the Organic-Natural sequence of actions and reactions, leading to integral dynamic balance of the organic fluids circulation, while at the same time also integrating with Universal Dynamics, mediated by the Earth's Atmosphere.

In our case in study, the accelerated mass is that of the mixture of gases of the air and, the final working force at the alveolar level is the expansive molecular force of the contained gases; this is the physic-natural factor determining organic-physical integration and balance for Life on Earth.

In Synthesis, the most determining factor of organic failure at high altitude is the low mass per volume unit of the air, which does not satisfy the autonomic programmed results, according to the Inertial Equation $F = m \cdot a$

The known anoxic phenomenon is a consequence that can add secondary effects to the mechanical problem, but it is never the causal factor.

Prevention and treatment of Acute High Altitude Sickness must be focused on solving the evident causal factor present at high altitudes: Low mass of air per volume unit.

Therefore, the prudent way to act must be not to surpass the physiological limit of the human specie's adaptation without the right equipment.

The rational method to be applied must be immediate descent to the adaptation levels of the individual, which, could be appreciated between sea level and about 3000-3500 meters high, for our specie.

Workers and mountaineers must be provided with chambers of pressurised air. Additional supply of Oxygen is not necessary.

Any sign of transitorily adaptation of an individual to high altitude can lead to dangerous interpretation since this sickness represents a real organic emergency of not ease evaluation and we now know the pathogenesis in progress.

This study also is, in itself, a proof of the features and interpretations of the Author's *New Theory of Respiratory Dynamics*² so complex and determinant for Life in the Earth.

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On behalf of a World free from Pulmonary Emphysema

The study, discussion and practical application of my discovery of the causal agent and pathogenesis of Pulmonary Emphysema and, as a consequence, the real possibility of its total prevention, or early effective or late palliative treatment, must take prominence among the policies in defence of the Human Right to Life and Health, which must lead, in this context, to the eradication of the habit of Smoking

The undersigned, Américo González-Bogen, M.D. Prof ®. President of the scientific, private, non-profit Foundation “The Respiratory Pulse” (NGO). Author of the contributions to scientific knowledge based on the discovery and interpretation of the autonomic pulmonary mechanics, applying these to the interpretation of the Aetiology and pathogenesis of *Pulmonary Emphysema* (fourth cause of death according to known statistics) has proved that *tobacco Nicotine* is the causal drug for this sickness and its pathogenesis is due to its adrenergic-positive effect on the finest structures of the Lung, that is to say, on the bronchioles up to the alveoli, which are innervated by fibres of Sympathetic nerves that increases the frequency and contracting force of their smooth muscles, causing the structural damage well known in Anatomical pathology, such as: progressive distension, loss of elasticity, and finally irreversible mechanical destruction.

Consequently, *the habit of smoking, without doubt, is not only a “risk factor” as is believed, but the transportation media of the successive doses of Nicotine* which, with their repeated action over years causes irreversible damage, with the aggravating fact that the Nicotine in suspension in tobacco smoke produces similar damage in the well-named “passive smokers”

The only effective treatment of Pulmonary Emphysema is an early curtailment to the destructive process by not smoking and avoiding contaminated environments.

I suggest all this as a provisional measure to be applied until that moment in which radical measures, under Ethical, Juridical, Humanitarian, Scientific and Social understanding that *Created Life in Health, in its dynamic integration with the Natural Atmosphere* becomes the Human Natural Right of excellence, which must be the *First Constitutional Right*

Acquired rights, under any concept, that threaten Life and Natural Health, able to be proven with the new advances in scientific knowledge, must be invalidated by force of Law

Pulmonary Emphysema can be eradicated from the Earth in a mere two or three decades, if appropriate and continued measures are taken in due time