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CHANGES IN HEMODYNAMICS, BLOOD OXYGEN SATURATION LEVEL AND CENTRAL NERVOUS SYSTEM IN RESPONSE TO POSTURAL LOADING

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Nature of functional disorders developing as a consequence of changes in blood redistribution during space flight and characters of reflextory responses associated with space flight conditions are key-questions of space physiology in our days.

During periods of adaptation to weightlessness and post-flight readaptation to the earth gravity, working capacity of space crew members often decreases in a troublesome extent. In an attempt to eliminate unfavourable factors decreasing working capacity it is necessary to develop complex non-invasive methods of investigation which can be used in the most different situations for a right assessment of health condition of astronauts /1/.

Materials and methods

Our investigations were performed in 20 healthy pilots aged 22-34 years.

Initial values were registered on a tilting table during 10 minutes. Then changes in PO_2 of capillary blood were measured by a noninvasive transcutaneous oxymetry on the skin of forehead, chest and leg in orthostatic position during 20 minutes according to the criteria of passive orthostatic test and in a Trendelenburg position of 30^o during 6 minutes according to the criteria of passive antiorthostatic test. Measurements were performed by 6 Hellige Servomed Oxymonitors. Miniaturized Transoxode electrode of the instrument with a constant heating indicated capillary blood PO_2 changes through the skin with normal blood supply. Relative changes of heating capacity needed for maintaining a constant temperature gave also an indirect information about the perfusion of the skin surfaces involved.

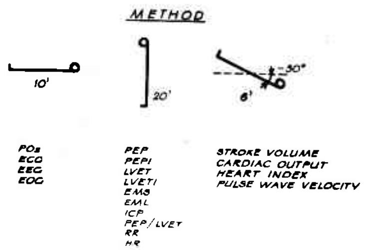
To follow cardiovascular reactions we have recorded and analysed simultaneousely electrocardiograms in 12 leads, carotis, femoralis and radialis pressure curves and their derivatives, phonocardiograms, noninvasive systolic and diastolic pressures, averaged and bip to bip pulse and respiratory rates.

In order to ascertain changes in cardiac contractility we have determined systolic part-times and their indices corrected and derivated by Blumberger and Weissler. A precise evaluation of hemodynamic changes was performed by registration of changes in stroke volume and cardiac output using a method developed by Bremser-Ranke /2-20/.

Changes in vasoregulatory functions and volume loading in systemic circulation were revealed by measuring pulse wave velocity changes in a myogenic arterial segment /left ventricle-radial artery/ and in an arterial segment of elastic type /left ventricle - femoral artery/.

In order to clarify what changes occur in the cerebral bioelectric activity in response to the changes of systemic circulation, we have recorded electroencephalograms in 12 leads during all the period of the experiments. Vestibular disorders were identified by electrooculograms in 2 leads with following analysis of nystagmoid eye movements. /Fig. 1/

Fig. 1.



Results and discussion

In orthostatic position PO_2 measured on the skin of forehead has shown a minimal decrease in the first 10 minutes. After 10 minutes it was seen a marked increase and then a repeated decrease. In antiorthostatic position a moderate increase was recorded.

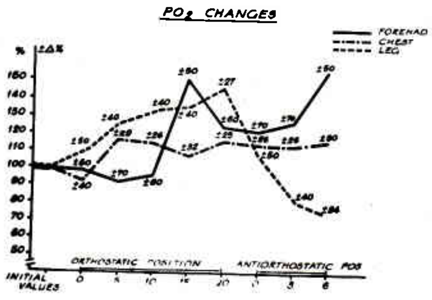


Fig. 2.

PO_2 determined on the chest has shown a minimal increase in the 5th minute, after which no changes could be observed.

PO_2 measured on the skin of the leg increased progressively in orthostatic position while in antiorthostatic position has shown a pronounced decrease /Fig. 2/.

Available materials give evidence that PO_2 values correlate well with capillary blood oxygen saturation levels /21, 22, 23, 24, 25/. As in our experiments all subjects were in similar conditions from the point of view of oxygen supply, there are grounds to believe that changes observed are related to the changed circulatory conditons. Transcutaneous oxymetry proved to be a useful method for measuring cutaneous circulation differences associated with gravitational changes resulting from different postures.

As known, activity of baroreceptros perceiving volume loading in limb circulation surpasses activity of other receptors /e.g. thermoreceptors/ regulating cutaneous circulation /26/. Thus, from our findings it can be drown conclusions about intensity of limb circulation. PO_2 values measured at the rest in the different parts of the skin were different. These variances occur presumably as a result of the different structure of the skin, of variances in thickness and fat content of subcutaneous tissues and in proximity of great veins /27/. These variances are also responsible for the individual differences seen in subjects involved. Instability of values measured on the skin of forehead speaks about the strong vasoregulation of the head which might be interpreted as a signe of redistributing process aimed to maintain the crebral blood flow at a constant level /28/. PO_2 and blood flow respectively on the opposite body end i.e. on the leg follow rather passively the distribution differences induced by changed gravity conditions. With the use of a new method, our investigations gave further evidence of regulatory function of gravity in blood distribution.

A statistical analysis of data obtained in subjects with optimal cardiorespiratory reactivity and high tolerance to overloading was performed /29, 30, 31/. On the electrocardiograms of the subjects involved no defects in excitation and conduction were observed, normal repolarization and depolarization processes were seen. Fig. 3 shows optimal pulse and respiratory reactions. In orthostatic position we have found tachycardia while in antiorthostatic position bradycardia. Respiratory rate shows a moderate decrease in orthostatic position while an increase in antiorthostatic position.

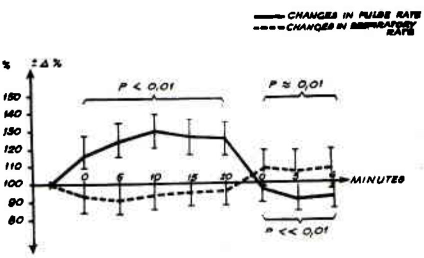


Fig. 3.

Pulse pressure values show a decrease of 30% in orthostatic position. In antiorthostatic position pulse pressure becomes normal and then increased /Fig. 4/.

On the basis of the systolic part-times, adequate contractility reactions were noted. In orthostatic position we have seen lengthening of PEP and shortening of LVET while in antiorthostatic position these parameters became normal and then presented changes in the opposite direction /Fig. 5/.

Fig. 4.

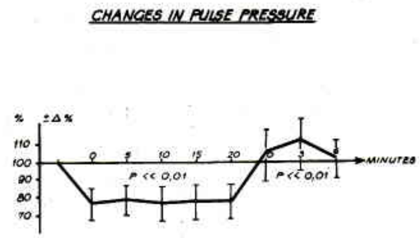
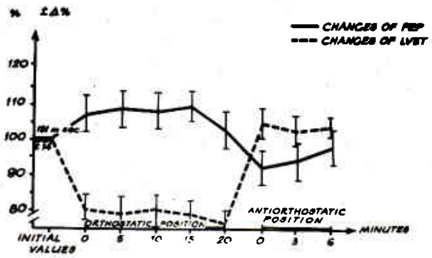
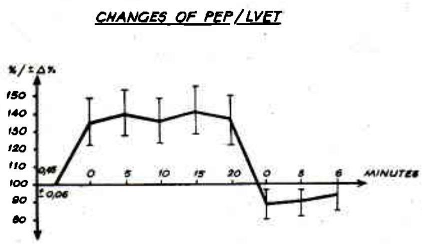


Fig. 5.



PEP/LVET ratio markedly increased and then decreased /Fig. 6/.

Fig. 6.



Values of stroke volume and cardiac output indicated a decrease of 20-40% in orthostatic positon and a trend to normalization with subsequent increase /Fig. 7/.

Remarkable changes in pulse wave velocity as a result of volume overloading could be seen first of all in elastic artery. Pulse wave velocity values measured in arteries of myogenic type gave an evidence of an adequate vasoregulation /Fig. 8/.

Fig. 7.

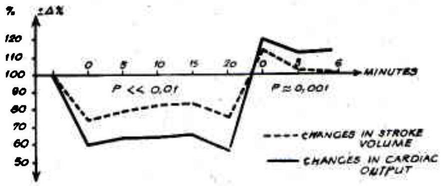
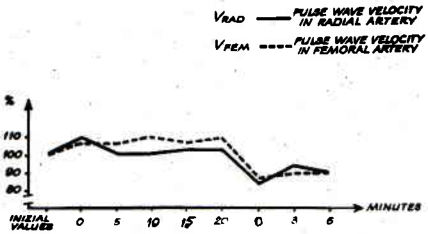
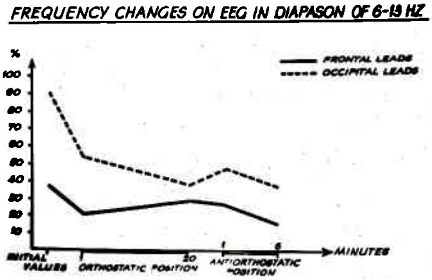


Fig. 8.



Analysis of electroencephalograms indicates changes in the cerebral bioelectric activity resulting from hemodynamic changes. A tendency to desynchronization can be seen both in orthostatic and antiorthostatic positions. This tendency is more pronounced in antiorthostatic position /Fig. 9/.

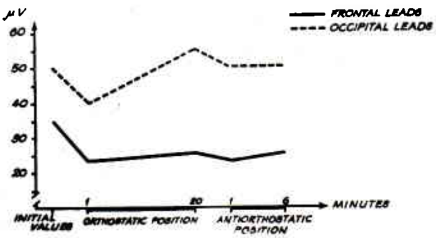
Fig. 9.



Amplitude analysis of wave frequencies of 6-13 Hz indicates that the greater changes occur during the first minute of the tilting into orthostatic position /Fig. 10/.

Fig. 10.

AMPLITUDE CHANGES ON EEG IN DIAPASON OF 6-13 HZ



On the basis of the analysis of electooculograms it can be concluded that under antiorthostatic conditions frequency of macroscopic bulbar movements increases even in healthy men with optimal reactivity and afterwards nystagmoid eye movements appear. In response to orthostatic loading no changes of this type occur. This suggests that hemodynamic changes induced by changes gravity have an effect of vestibular stimulus even in subjects without vestibular supersensitiveness.

Conclusions

1/ Our investigations give evidence that the noninvasive transcutaneous oxymetry offers objective data for estimation of changes in oxygen saturation level in different posture and contributes to a better assessment of the tolerance. Relying upon our experience noninvasive transcutaneous oxymetry seems to be an appropriate method to follow hemodynamic changes occuring in response to weightlessness on the board of a spacecraft and to evaluate effectiveness of methods for preventing unfavourable changes.

2/ On the basis of our complex investigation it can be concluded that both orthostatic and antiorthostatic loading induce substantial changes in the circulation, but from the point of view of the functional damage antiorthostatic loading represents a more serious adverse factor as it is evidenced by our electroencephalographic and electrooculographic studies. This suggests that hemodynamic changes - in addition to others - play an important role in the pathomechanism of vestibular disorders caused by weightlessness.

REFERENCES

1. V.G. Doroshev, T.V. Batenchuk-Tusko, N.A. Lapshina, Yu.A. Kukushin, N.A. Kalminova, V.N. Ragoshin: Izmenenie gemodinamiki i fazovoi struktury serdechnogo tsikla u ekipazha vtoroi ekspeditsii "Saliut-4". Kos.Biol.Aviakosm. Med. 26-30, 2. /1977/
2. Simonyi J., Porubszky I., Török E., Békés M. Magyar Belorvosi Archivum 21, 249, 1968.

3. Békés M., Lengyel M., Simonyi J. Magyar Belorvosi Archivum 21, 326, 1968.
4. Paizs Zs., Rochlitz K., Fischer J. Magyar Belorvosi Archivum 29, 21, 1976.
5. Simonyi J., Kiss É., Somogyi Gy., Romoda T. Orvosi Hetilap 109, 1191.
6. Franks B.D., Cureton T.K. Jr. Res. Quart. 39. 524, 1968.
7. Bódis L., Gaszner P., Radnai B. Orvosi Hetilap 117, 779, 1976.
8. Sutton G.C., Little D.L. Jr.Amer. J. Med. Sci. 232, 648, 1956.
9. Frank M., Kinlan N.W.B. Amer. J. Cardiol. 10, 800, 1962.
10. Apor P., Szmodics I. Orvosképzés 45, 460, 1970.
11. Weissler A.M. et al. Circulation 27, 149, 1968.
12. Weissler A.M., Harris W.S., Schönfeld C.D. Amer.J.Cardiol. 23, 577, 1969.
13. Simonyi J., Kiss É., Kenéz B. Magyar Belorvosi Archivum 21, 191, 1968.
14. Weissler A.M. et al. Amer.Heart J. 62, 367, 1961.
15. Holldack K. Dtsch. Arch.Klin.Med. 178, 71, 1951.
16. Blumberger K. Erg. inn. Med. 62, 424, 1942.
17. Neumann H., Boeder K.J. Funktionsprüfungen in der Herz-Kreislaufdiagnostik. II. Ausg. W. de Gryter Co., Berlin, 1963.
18. Rochlitz K., Pajzs Zs., Blumenfeld Gy. Cardiologica Hungarica 2, 25, 1973.
19. Reindell M., Kleipzig K.Z. Kreislaufforsch. 38, 129, 1949.
20. Rackley I.E., Craig R.J. et al. Arch.Int.Med. 121, 50, 1968.
21. Huch A., Huch R. Klinische un physiologische Aspekte der transcutanen Sauerstoffdurckmessung in der perinatalmedizin. Z. Geburtsch. Perinat. 179, 235, 1975.
22. Knote G., Bohmert H. Zur Bestimmung der Überlebensfähigkeit Nekrosegefährdeter Hautareale. Fortschritte der Medizin 95, 640, 1977.
23. Dennhardt R., Fricks M., Mahal S., Huch A., Huch R.Transcutaneous PO_2 monitoring in Anesthesia. Eur. J. Intensive care Medicine 2, 29, 1976.
24. Huch A., Huch R., Rooth B. Continous transcutaneous oxygen tension measured with heated electrode. Scand. J. Clin. Lab. Invest. 31, 269, 1973.
25. Duc G. Is transcutaneous PO_2 reliable for arterial oxygen monitoring in newborn infants? Letter to the editor. Pediatrics 55, 566, 1975.
26. Crossley R.J., Greenfield A.D., Plassaras M., Stephens G.C. The interrelation of thermoregulatory and baroreceptor reflexes in the control of the blood vessels in the human forearm. J. Physiol. 186, 628, 1966.
27. Hoch et al. Scand. J. Lab. Invest. 31, 269, 1973.
28. Abel F.L., Pierce J.H., Guntheroth W.J. Baroreceptor influence on postural changes in blood pressure and carotid blood-flow. Amer.J.Physiol., 205, 360, 1963.
29. Remes P., Hideg J., Bognár L., Gyökössy J. Fazovyi analiz serdechnogo tsikla pri izmenenii polezheniya tela kosmonavtov. Dokl. delegatsii VNR na XII Konferentsii Kosmi-

tseskoi biologii i medicine Soveta Interkosmosa, Krakow-Warsawa, 1979.
30. Gyökössy J., Remes P., Hideg J. Systolés részidők vizsgálata pozitiv intrapulmonális nyomás esetében. Honvédorvos, 29, 192-206, 1977.
31. Stafford R.W. et al /Abst./ Amer. J. Cardiol. 19, 1, 152, 1967.