Effektiveness of CPAP versus High-Frequency Jet Ventilation by Noso-Oral Mask (HFJV-M) in treatment of Pulmonary Edema.

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Summary

Goal of the study: In the retrospective study, the authors were comparing the effectiveness of continuous positive airway pressusre (CPAP) and high-frequency jet ventilation by mask (HFJV-M) in the treatment of cardiogenic pulmonary edema.
Type of the study: retrospective
Name and address of the workstation: Anaesthesiology and intensive care unit, hospital NsP Vranov n/T., Slovakia

Material and methodology: There were 196 patients hospitalized with some form of cardiogenic pulmonary edema (PE). The patients were sorted into three groups according to the severity of PE. With a comparable pharmacotherapie and comparable mean airways pressure and FiO2, the authors were comparing the effectiveness (CPAP in 64 patients and HFJV-M in 101 patients) on the speed of decrease of ventilatory frequency, oxygenation, acidobasic balance, as well as duration of essential ventilatory support and duration of hospitalization in AICU. The results were evaluated by non-paired Student's t-test. The methodology of ALV using HFJV-M was approved for a clinical use in the year 1989 by the professional and ethical committee of Ministry of health of Slovak Republic.

Results: In the lighter forms of PE that were titled as the 1st phase of PE, there wasn't found the statistically significant difference in the evaluated parameters in application of CPAP or HFJV-M. In the heavier forms characterized as the 2nd and the 3rd phases of PE, there were proven the statistically significant differences in the speed of decrease in spontaneous breathing frequencies from the values of 25 – 33 b/min to 18 – 22 b/min ($p<0,01$) in the first 3 hours of ventilatory support in favour of HFJV-M group. Similarly, the statistically signigicent difference was discovered in the speed of adjustment of PaO2, pH and index PaO2/FiO2 ($p<0,01$) mostly during the first 2 hours of therapie in favour of HFJV-M group. Comparing the average duration of essential ventilatory support (CPAP vs. HFJV-M: 10,9 vs. 6,8 hours) and average duration of hospitalization (CPAP vs. HFJV-M: 2,7 vs. 2,0 days), there were discovered the statistically significant differences ($p<0,01$, resp. $p<0,05$). From the patients included in the study, it was necessary to intubate and ventilate by the conventional methods of ventilation only 6,6%.

Conclusion: After the statistical analysis of the monitored parameters (oxygenation, ABR, duration of ventilatory support, duration of hospitalization, necessity to intubate), the authors have discovered that the ventilatory support by HFJV-M was in comparison to CPAP statistically signigicantly more effective already in the first 2-5 hours of therapie and that by the application of HFJV-M, the essential duration of ventilatory support as well as duration of hospitalization in AICU is shortened whereas the necessity of intubation was decreased to 6,6% of patients.

Key search words: non-invasive ventilation, continuous positive airway pressusre (CPAP), high-frequency jet ventilation (HFJV), pulmonary edema

Introduction

Pulmonary edema (PE) is a clinical syndrome characterized by pathological accumulation of liquids and solutes in the extra-vascular space and lung tissue.

Blood pressure is increased in the lung microcirculation that furthermore leads to the state of hypoxia caused by vasoconstriction /Eulerov-Liljestrandov reflex/, that further leads to significantly stepped-up lung capillary hypertension. PE caused in the way of deepened hypoxia is potenting the creation of itself. /4, 8/

As a cause of depletion of water element from intravascular space, further if patient is a hypertonic, leads to increased blood viscosity, that further increases afterload and so the demands on myocard performance. From the point of view of ventilation effectiveness, lung failure develops along the continuous increase of airways resistance and decrease of lung compliance along the worsening of difusion of gases through Alveolar Capillary Membrane (AKM). Elevated demands for ventilation increase the ventilation work which becomes ineffective. The resalt is deepened PE, development of tissue hypoxia, anaerobic metabolism followed by cell death and hence death of the individual. /5/

Early and efficient therapeutic intervention in the phase of interstitial or early stage of alveolar edema can prevent irreversible processes and has a better prognosis for treatment compared to the intensive treatment of developed pulmonary-edema.

The main goal is to maintain the tissue oxygenation , to optimalize preload, afterload, blood viscosity and contractility of myocard. From the point of view of ventilation, it is essential to improve the gas exchange in lungs itself as well as the transport of gases on AKM and decrease the anyway extremely intensive ventilation work.

The „classical therapy“, i.e. pharmacotherapie with the application of oxygen via noso-oral mask in the harder forms of PE will often fail. In the general practice, the methods of non-invasive ventilatory support are applied. /5, 6, 7/

The representative of classical non-invasive ventilatory support was until recently the application of continuous positive airway pressure (CPAP) by noso-oral mask, „helm“ or nosal mask /5, 9, 10/ that has been replaced in the recent years at our clinical workstation by high-frequency jet ventilation by noso-oral mask (HFJV-M). /11,12,13,14/

The aim of this retrospective study was evaluate and compare the effectiveness of application of CPAP versus HFJV-M in the treatment of cardiongenic pulmonary edema.

Advantages of HFJV-M.

The use of ventilatory support allows to unload patient so, that the appliance overtakes the part of breathing work, respectfully significantly decreases the breathing work of patient. In case of CPAP, in compare, expiratory breathing work can even increase.

The arosen inadvertent positive end expiratory pressure (PEEPi) prevents the collapse of alveoli, that leads to the „stabilization of geometry“ of alveoli and helps to improve the transportation of gases through AKM. The resulting effects are the improved ventilatory-perfusion ratios. The application of HFJV in many cases by-passes the necessity of intubation and thus anaesthesia and muscle relaxation with its cardio-depressive effects on an already deeply afflicted patient. HFJV allows the cooperation with patient, as it non-interferes with spontaneous breathing activity. The avoidance of intubation also decreases the risk of colonisation and infection of breathing apparatus. /1, 15/

Disadvantages of HFJV-M

The contraindications of the use of HFJV are obstructive lung deceases. Especially important is to distinguish the cardiac failure from the attack of bronchial asthma. HFJV-M is contraidicated in severe asthmatic status.

The basic clinical prerequisites for indication of low-invasive ventilatory methods (CPAP, HFJV-M, etc.) applied via face mask are:

- patients are conscious, able to hold their airways transitional
- the presence of intact upper airways protective reflexes
- non-presence of an obstructive lung disease
- non-injured facial part of skull (the issues with sealing of mask on patient’s face e.g. anodontia, moustache, deformations, etc.)

Material and Methods

In the term of 19 years, we have applied the invasive as well as low-invasive artificial lung ventilation (ALV) to more than 800 patients with pulmonary edema of cardiac and non-cardiac origin. In the retrospective study, we have evaluated 196 patients with some form of cardiogenic PE for the treatment of which we have used CPAP or HFJV-M methods. According to immediate possibilities for the patients, the basic vital signs, CVP, mechanical properties of their respiratory sytem (Dynavent 888 by Medinvex), SpO2 by saturation monitor (Pace-Tech and Datex-Ohmeda) were monitored. Blood gases and pH were measured by ABL 330 (Radiometer). Respiratory volumes were measured by a ventilometer (Medi) or electronic monitor Dynavent 888 (Medinvex).

Airway pressure and pressure in ventilatory circuit was measured by the electronic pressure monitor MLT 01 (Chirana). The patients in the CPAP group were ventilated by the ventilator Chirolog

-SV-ALFA (Chirana), or medical equipment for CPAP and high-frequency jet ventilators Paravent M, PA, PAT (Medinvex – Kalas). HFJV was applied through the multi-nozzle jet injector (MNJI no.10), using ventilation frequency 120 c/min. and driving pressure Pin = – 190 kPa. FiO_2 = 0,55. The methodology of ALV using HFJV-M was approved in the year 1989 by the professional and ethical committee of Ministry of health of Slovak Republic and was granted a license for a new therapeutic method. /11/

The patients were mainly applied, before admitted to the unit, the O2 therapie /FiO_2 = 0,4- 0,6 /. After the admittance to the unit and the evaluation of state severity, the patients were immediately attached to CPAP, HFJV-M or intubated and connected to the conventional ventilator.

The patients transported by emergency medical systems (EMS) were applied oxygenotherapie, or in the recent years, some were applied even ventilatory support by HFJV-M. According to the patients‘ status, the patients were sorted into four groups of severity of lung edema (PE phase 1 – 4). Tab. No.1

Patient was included into the respective group if at least 60% of criteria (minimum 11) mentioned in the table were within the respective ranges, or symptoms. We have statistically evaluated 196 patients ranked in the PE phases 1 – 3 to whom CPAP or HFJV-M was applied. The patients in the 4th phase were mostly intubated and thus were not evaluated in the study. The demographic data and basic diagnosis of the patients are mentioned in the tab. no. 2 and 3. The distribution into the groups based on the applied ALV is shown in tab. no. 4.

The characteristics of pharmacotherapie is shown in tab. no. 5. In the both groups we have applied the comparable FiO_2 = 0,5 – 0,6 during the first 4-6 hours of the treatment. Later, FiO_2 was adjusted based on the results of blood gases. The patients were disconnected from CPAP, resp. HFJV-M after the improvement of physical findings on lungs, stabilization of circulation and reaching PaO_2 > 10 kPa, $PaCO_2$ < 6 kPa, f - breathing < 22 b/min, if the status wasn’t deteriorating after 20 minutes of spontaneous ventilation with FiO_2 <0,4.

The results were compared by non-paired Student‘s t-test.

The results

We were comparing the average mean airways pressure (in mask) in the application of HFJV-M and CPAP during the whole phase of ALV application. We haven’t discovered any statistically significant differences. Tab. no. 6

We have compared the average essential time of ALV in the application of CPAP and HFJV-M according to the respective phases of PE (phases 1 – 3). In the patients‘ group in the 1st phase we haven’t discovered any statistically signicicant difference in compare to the patients in the groups in the phases no.2 and 3, where the lasting of ALV in the group of HFJV-M was statistically significantly shorter than in the group of CPAP. Tab. no.7

Comparing the dynamics of improvement of PaO_2 and index PaO_2/FiO_2 we have discovered that in the group characterized by the 1st phase of PE there wasn’t any statistically significant difference between the application of ALV by CPAP versus HFJV-M. Graph no.1
In comparison, in 2nd and 3rd phases of PE there was a statistically significant difference in the speed of adjusting of oxygenation in the application of HFJV-M in compare to the group ventilated by CPAP. Graph no.2 and 3

Comparing the speed of changes in $PaCO_2$ we haven’t found the statistically significant difference even though in the group of HFJV-M the $PaCO_2$ levels were lower. Comparing the speed of pH adjustment, the normalization of pH was statistically significantly faster in the group of HFJV-M during the first 4 hours of ALV. Graph no.4

Comparing the changes of respiratory frequencies in spontaneous breathing of the patients in the 1st phase of PE we haven’t found statistically significant difference. In comparison to the patients in 2nd and 3rd phases of PE, in the patients ventilated by HFJV-M we have discovered the statistically significant decrease in respiratory frequencies in spontaneous breathing in the first 3 hours of ALV compared to the group ventilated by CPAP. Graph no.5

We were comparing the effectiveness / ineffectiveness of application of CPAP and HFJV-M in therapie of PE. In the study, we were evaluating the number of patients, that due to the non-improvement or the deterioration of their status needed to be changed the method of ventilation from CPAP to HFJV-M or CMV, or from HFJV-M to CMV. Tab. no.8

From the results in the table no.8 it is apparent that 17% of the patients from the CPAP group had to be transfered to the different means of ALV, usually to HFJV-M. For 6,8% of the patients from the HFJV-M group it was necessary to intubate or ventilate by CMV. From all of the study-evaluated patients it was necessary to intubate 13 patients due to the ineffectiveness of ventilatory support, that was 6,6%. From the monitored group of 196 patients in Anaesthsiology and Intensive Care Unit (AICU), 9 patients (4,6%) have exited mostly from the group hospitalized due to PE caused by left ventricular failure in AMI (acute myocard infarction) We have evaluated the duration of patients‘

hospitalization in AICU according to the used method of ALV in the individual phases of PE. We haven't discovered the statistically significent difference in the patients in the 1st phase of PE. On the contrary, we have discovered the statistically significent difference in the duration of hospitalization in AICU of the patients in 2nd and 3rd phases of PE. The duration of hospitalization in relation to ALV was shorter in the HFJV-M group than in the CPAP group. Tab. no.9

Discussion

The method of the choice in treatment of PE used to be phlebothomie with the extraction of cca 500 ml of blood. The method was replaced by alternation of turnikets in legs (limbs) – non-blood venesection, at some cases the plazmapheresis was used to decrease the preload. These methods were replaced by the more intensive use of intravenous nitrates at the expense of diuretics. Through the development went also the methods of oxygenotherapie and ventilation. The aim is the fastest possible renewal of oxygenation, that shall avert the deterioration of patient's status, that could lead to the need of intubation. The current trend is to utilize the earliest possible low-invasive methods and techniques of ventilation (NIV). /1, 7, 10/

There were numerous studies published in the recent years that were comparing the results of PE therapie that we were comparing only the applications of oxygenotherapie and pharmacotherapie with CPAP, whereas the results are testify expressly in favour of application of CPAP, mostly by mask. /3, 6, 7, 10/

Despite the fact that the application of CPAP leads to the faster dynamics of improvements in ventilatory and oxygenation parameters, the actual CPAP does not decrease the ventilation work, on the contrary it can increase the exspiratory ventilation work /13/. With the development of low-invasive ventilatory methods (NIV) such as BiPAP, PSV, HFJV (Bilevel ventilation, Pressure support ventilation, High frequency jet ventilation) that are applied by face or nosal mask, use of these methods in the treatment of PE is proving to bring a considerable contribution from the point of view that the part of ventilatory work is overtaken by ventilator. Similar to our study, the other authors document a considerably faster normalization of frequencies of spontaneous breathing and breathing volume. /1, 3, 9, 10/

Comparing the effectiveness of ventilatory support inbetween CPAP and BiPAP /9, 10/, CPAP and PSV /9, 10/, CPAP and transtracheal HFJV /3, 14/, it was proven that the application of non-invasive ventilatory support leads to the significantly faster restitution of oxygenation, improvement of elimination of CO_2, as well as faster decrease of ventilatory work. Despite that we haven't discovered statistically significant difference in the speed of decrease of $PaCO_2$, some authors in studies comparing CPAP versus NIV also document a faster elimination of CO_2 in the application of NIV. /7/ Similar to our study, most of authors have proven the significant decrease in the necessity of

intubation as much as 90%, as well as shortening of hospitalization stay in AICU and shortening of essential time of ventilatory support in the application of NIV in compare to CPAP. /7/

The utilization of NIV in pre-hospitalization care means a big time savings, prevention of deepening of PE and patient is admitted to hospital in a considerably better status. The exceptions are of course the statuses of hard deficit of contractil myocard muslce in AMI where mortality is high.
The majority of authors emphsise the importance of adequate pharmacotherapie that is dependent on the cause of PE. In general, however, prevailing is a trend with emphasis on transfer from diuretics towards the higher use of vasodilators (mainly nitrates) in combination with NIV methods of ventilation. /2/

Conclusion

In the treatment of PE we were trying to use the least invasive ventilatory methods from which we were comparing the effectiveness between the use of CPAP and HFJV-M applied by face mask. In the group of patients hospitalized in AICU with pulmonary edema caused by circulation diseases, we have proven that with the comparable parameters of FiO_2 and mean pressure in airways it leads to a statistically significantly faster readjustment of oxygenation, pH, faster decrease of ventilatory work in the application of HFJV-M than in the group of patient ventilated by CPAP. Comparing the groups ventilated by HFJV-M in compare to CPAP, it happens that the duration of essential ALV and also hospitalization stay in AICU is statistically significantly shorter. Only in 6,6% of the patients we had to apply the intubation and ALV by some of the classical methods such as CMV or PCV.

Based on the discovered results we can conclude that HFJV-M as a method of ventilatory support in PE is more effective than CPAP. HFJV-M is very well tolerated by patients that are conscious and are able to accept the necessary cooperation.

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Tab.no.1.
Our distribution of pulmonary edema into 4 phases according to clinical, biochemical and monitored parameters during the admittance of patient to the unit

Cause / result	***1st phase***	***2nd phase***	***3rd phase***	***4th phase***
Dyspnoe	+	++	+++	++++
Tachypnoe (b/min)	>20	21 -30	>30	>45 *
Hyperventilation (MV l/min)	<12	13 -18	>18	>25 * <6
Crops	+	+ +	++++	+++++
Bronchospazm	+	+	++	+/- *
Conscious, as far as agitated	+++	+++	++	+/--- *
Cyanosis	+/-	+	++	++++
Tachycardia (p/min)	<99	100 -120	>120	<60* >140
Blood pressure (Mean in mmHg)	<90	91 -110	>110	>140 * <70
CVP (cmH2O)	<10	11 -18	> 19	>25 *
Index PaO_2/FiO_2 (kPa/non-dim.var.)(FiO_2=0,5)	40-60	25-39	15-24	<15
SpO_2 (SO_2) (%) in inhalation O_2 (FiO_2=0,5)	89-94	85-88	80-84	<80
$PaCO_2$(kPa)	3-4	4,1-5,5	5,6-6,8	>6,8
pH	7,32-7,4	7,25-7,32	7,1-7,24	<7,1
RTG diagnosis on lungs	+/-	+	+++	++++
Lungs compliance (C_L)	-	--	--	---
Edema liquid in airways (ET cannula)	-	+/-	++	+++
Edema liquid in mouth	-	-	+	+++

+ symptom present (+++significant)
- symptom not present (decrease of figure)
*** symptom is unstable +/-**

Tab.no.2
Demographic data of patients (average / SD)

Gender	**No. of pacients**	**Age (yrs.)**	**Hight (cm)**	**Weight (kg)**
Males	96	62±8	174±13	88±9
Females	100	64±8	159±12	67±8
Total	196			

Tab.no.3
Underlying cause / diagnosis of admitted patients

Diagnisis	**No. of pac.**	**%**
I.M.-heart stroke with LVHF	16	8,2
Myocard ischemy + M.hyperton. with LVHF	128	65,3
Crisis hypertonica with LVHF	52	26,5
TOTAL	196	100

Tab.no.4
Distribution of patient according to applied ALV and severety (phase) of pulmonary edema

Group accord. To ALV	Gender	No. of patients	1st phase	2nd phase	3rd phase	4th phase
CPAP	Male	29	8	11	10	0
	Female	35	7	20	8	0
CPAP -total		**64**	**15**	**31**	**18**	**0**
HFJV-M						
	Male	77	4	43	30	0
	Female	55	4	27	24	0
HFJV-M total		**132**	**8**	**70**	**54**	**0**
TOTAL all		**196**	**23**	**101**	**72**	**0**

Tab.no.5
Used drugs

Drug/treatment procedure	% of patients to whom drugs were applied in CPAP group	% of patients to whom drugs were applied in HFJV-M group
Opiates	92,1	94,2
Light sedatives	88,1	85,3
Corticosteroids	65	51,3
Cardiotonics	34	33,2
Bronchodilatational therapy	77,5	79,8
Alpha-lytics, nitrates	77,9	88,1
Beta – mimetics	32,1	44,2
Beta lytics	4,8	2,9
Hypotensives other that nitrates	12,2	16,7
Diuretics	48,6	40,4
Antidysrhytmics	12,6	11,0
Colloids	37,7	52,8
Crystalloids	100	100
NaHCO3	10,7	12,6
Thrombolysis	3,7	3,3

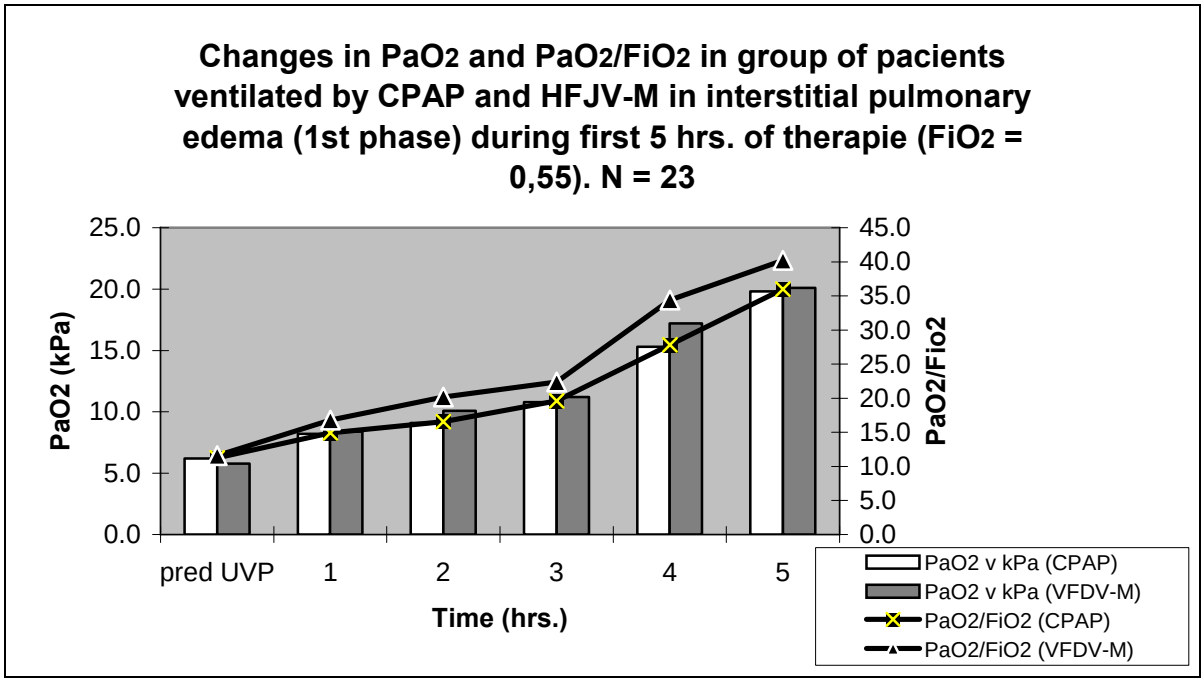
Tab.no.6
Mean airway pressure (M / SD) in group CPAP and HFJV-M during ALV.

Group	1st phase	2nd phase	3rd phase
	Mean pressure in mask (kPa)	**Mean pressure in mask (kPa)**	**Mean pressure in mask (kPa)**
CPAP	0,7±0,15	1,1±0,3	1,5±0,5
HFJV-M	0,8±0,2	1,2±0,5	1,6±0,8
p< (t-test)	NS	NS	NS

Tab.no.7
Duration (mean / SD) ALV in individual phases of PE

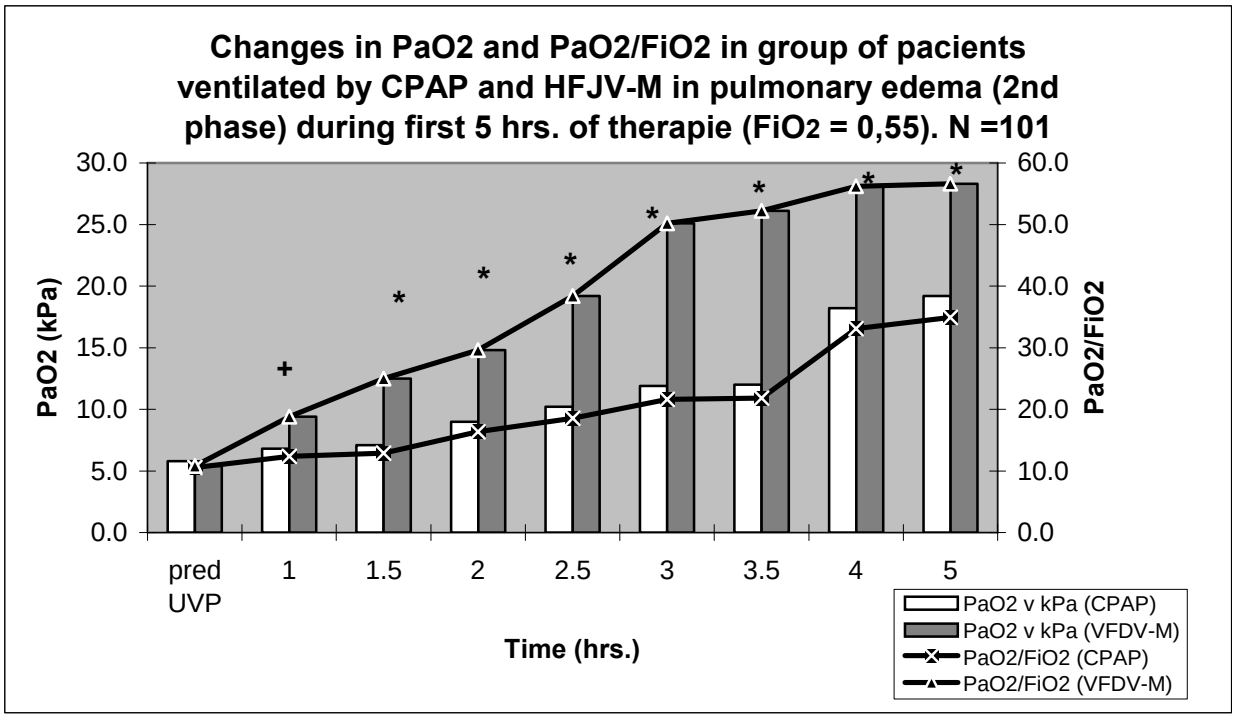
Group	1st phase	2nd phase	3rd phase
	Avg. duration ALV (hrs.)	Avg. duration ALV (hrs.)	Avg. duration ALV (hrs.)
CPAP	4,8±1,1	9,8±2,8	19±6,5
HFJV-M	4,7±1,4	5,1±2,5	10±4,8
p<(t-test)	NS	0,01	0,05

Graph.no.1



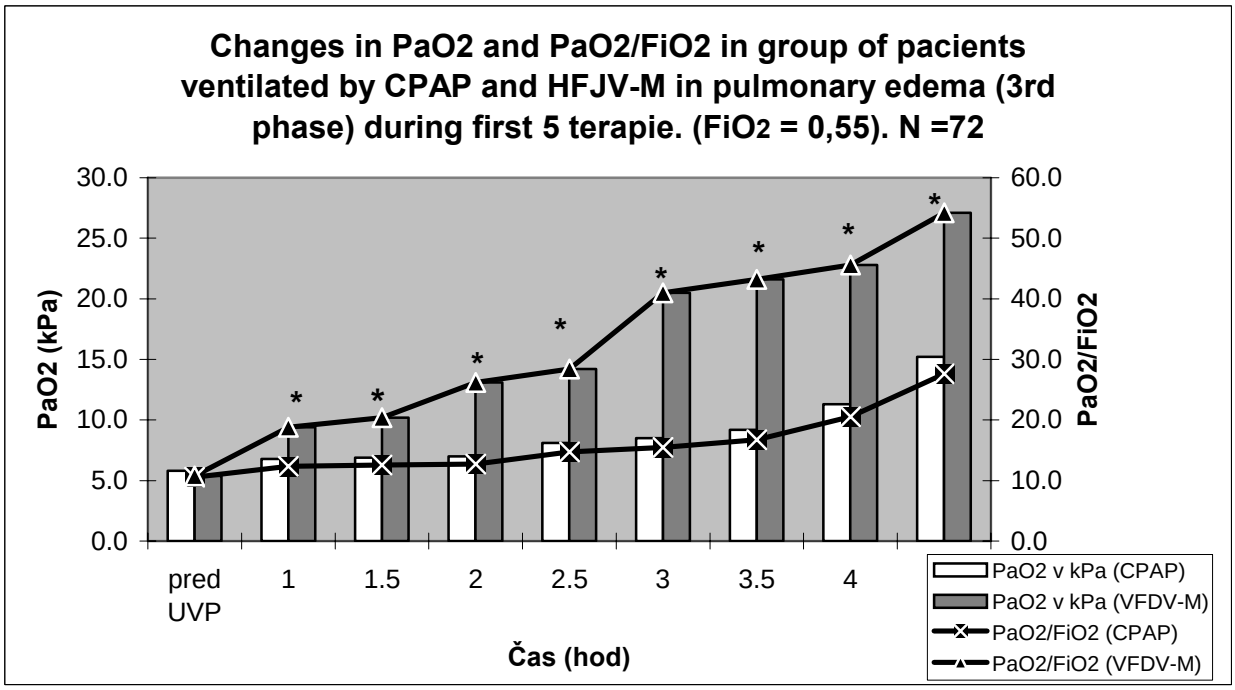
Statistically significant difference by Student's non-paired t-test not found (NS)

Graph.no.2



+ Statistically significant difference by Student's non-paired t-test p<0.05
* Statistically significant difference by Student's non-paired t-test p< 0.01

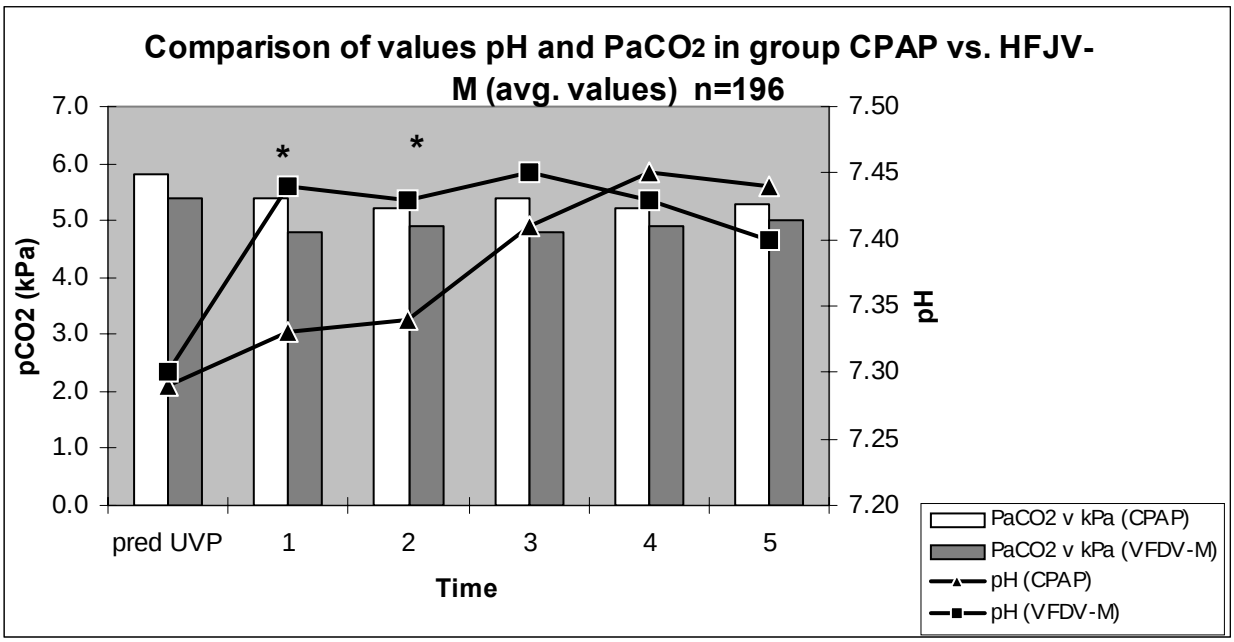
Graph.no.3



*

Statistically significant difference by Student's non-paired t-test p< 0.05

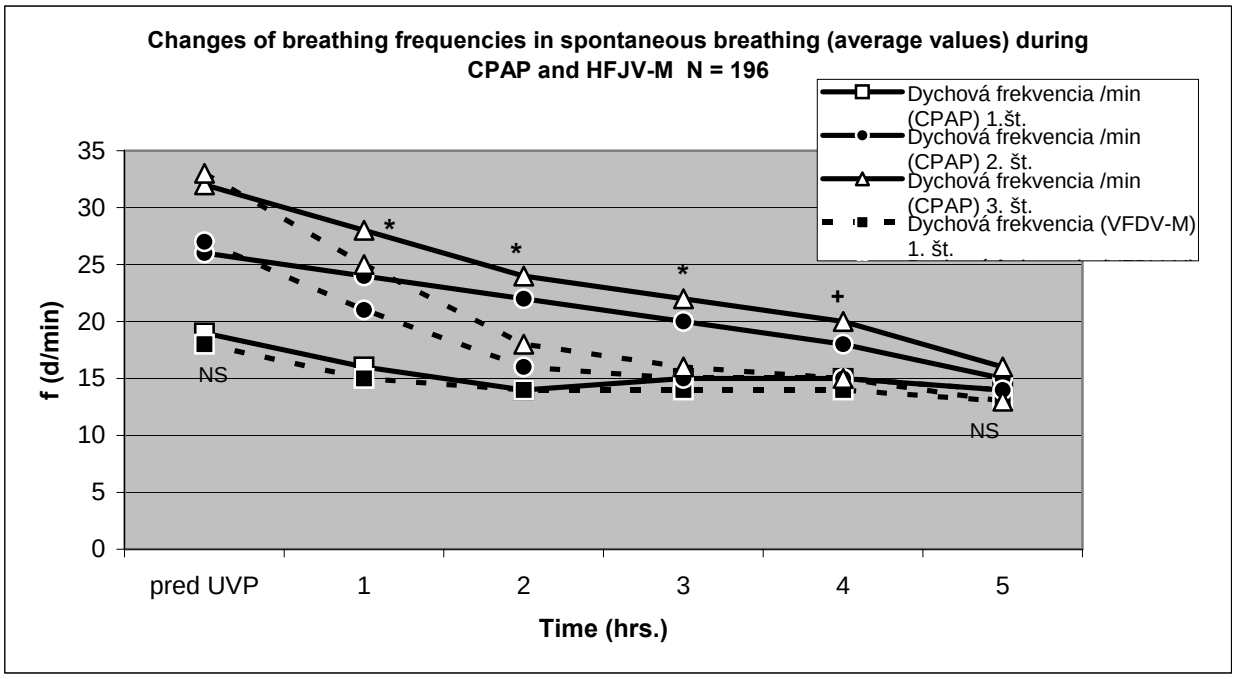
Graph.no.4



*

Statistically significant difference of pH by Student's non-paired t-test p< 0.05

Graph.no.5



***** Statistically significant difference by Student's non-paired t-test p< 0.05 in groups of 2nd and 3rd phases of PE

NS – non-significant difference in the group of 1st phase of PE

Tab.no.8
Comparison of ineffectiveness (effectiveness) CPAP and HFJV-M .

Group accord. to type of ALV	1st phase	2nd phase	3rd phase	Pac. total	% ineffectiveness
CPAP not successful	2	4	5	11	**17**
HFJV-M not successful	0	4	5	9	**6,8**
TOTAL not successful	**2**	**8**	**10**	**20**	**10,2**

Tab.no.9
Comparison of duration of patients‘ hospitalization in AICU (maen / SD).

Group	1st phase	2nd phase	3rd phase
	Avg. duration of hospitalization in AICU (days)	**Avg. duration of hospitalization in AICU (days)**	**Avg. duration of hospitalization in AICU (days)**
CPAP	1,6±0,5	2,8±1,5	3,9±1,4
HFJV-M	1,5±0,5	1,9±1,1	2,7±1,2
p<	NS	0,01	0,05