High frequency jet ventilation via facial mask: an unusual method of noninvasive ventilation

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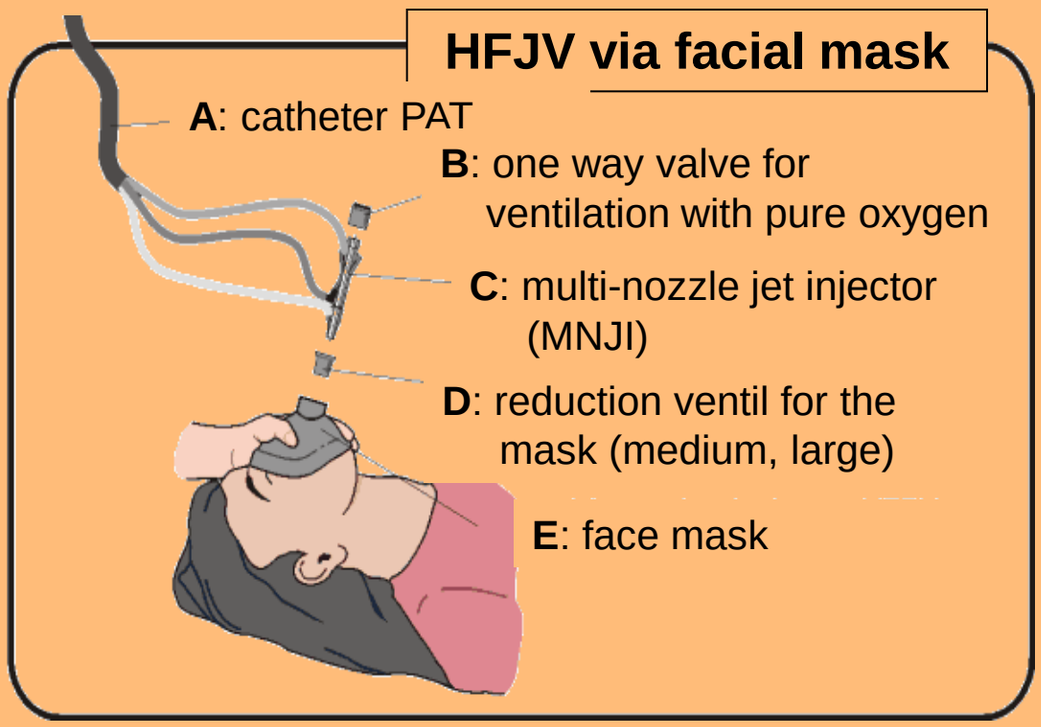
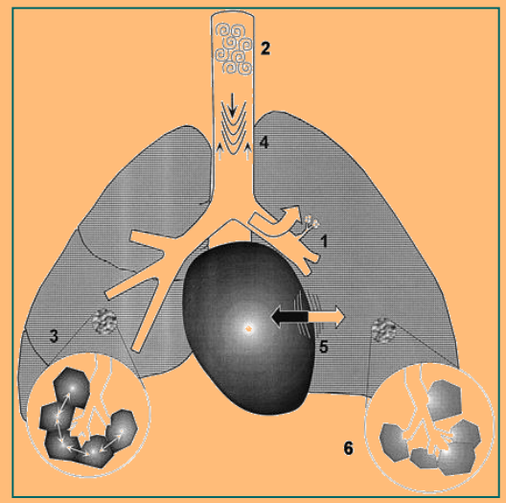
Basic principles of HFJV ventilation via facial mask

PARAVENT PAT

Paravent PAT is pneumatically controlled high frequency jet ventilator with frequency 120 cycles/minute, changeable time ratio Ti/Te (1:2, 1:1, 2:1) and adjustable insuflation pressure (0-400 kPa) which is monitored on the front panel. The source of pressure is pressed pure oxygen. The insuflation pressure changes in one of the jets of multi-nozzle jet injector (MNJI) to ventilating pressure (2,5 – 5 kPa) levelled according to chosen jet in MNJI. Tidal volume is then result of insufflation pressure, the diameter of MNJI and used jet. Fraction of inspired oxygen (FiO_2) depends on the amount of subjoin athmospheric air. Each MNJI is equipped with 3 inspiration and 1 expiration jets, and measuring connector. Expiration is passive, over pressure in airways opens expiratory valve.
Using one way valve allows ventilation with 95% oxygen when needed.



Proposed mechanisms of gas transport during HFV:
1: direct bulk flow
2: longitudinal (Taylor) dispersion
3: pendeluft
4: asymetric velocity profiles
5: cardiogenic mixing
6: molecular diffusion



Adapted from Krishnan J.A., Brower R.G.: High-Frequency Ventilation for Acute Lung Injury and ARDS. Chest. 2000; 118: 795-807

Aim of the study:

To prove the effectiveness of high frequency jet ventilation (HFJV) applied via facial mask as an unusual technique of noninvasive ventilatory support (NIV) in patients with respiratory failure.

Matherial and methods:

Retrospective analysis of results of treatment patients with respiratory failure due to acute exacerbation of COPD (AE COPD) who meet the criteria for initiation of NIV used at our Intensive Care Unit (ICU).
These patients we randomly divided into 2 groups:

GROUP I.: NIV applied HFJV with PARAVENT PAT machine (ELMET, Czech Republic), frequency 120 cycles/minute, Ti:Te 1:1, FiO_2 0,65, inspiratory positive airway pressure (IPAP) 2,5 kPa, application 20 minutes each hour

GROUP II.: NIV applied BiPAP with BiPAP RESPIRONICS S/T - D 30 (RESPIRONICS, Germany), with median IPAP 1,1 kPa, FiO_2 0,35, 30 minutes each hour, spontaneous mode

Criteria for initiation NIV:

A: clinical

- progressive dyspnoea
- respiratory distress
- tachypnoea (BF > 24 breathes/minute)
- use of accessory ventilatory muscles
- paradox movement of abdomen
- cooperative patient

B: laboratory

- pH 7,30 – 7,35
- $paCO_2$ 6,0 – 10,0 kPa
- paO_2/FiO_2 < 200

During the ventilation we monitored:

- ❖ vital functions:
  heart rate - HR,
  breathing frequency - BF
- ❖ feeling of dyspnoea
  (Borg scale)
- ❖ parameters of acidobasis
  (pH, paO_2, $paCO_2$)
- ❖ index of oxygenation
  paO_2/FiO_2

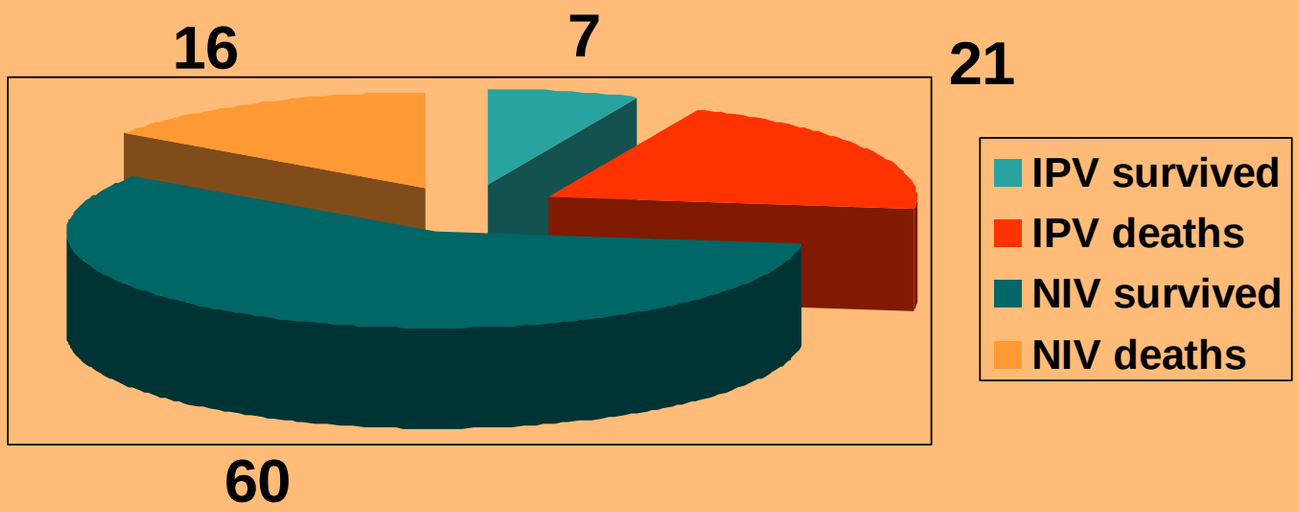
- ➢ at the admission of patients to our ICU
- ➢ 2 hours after begining of application of NIV
- ➢ the 2^{nd}, 4^{th}, 6^{th} day
- ➢ at discharge

We made statistical analysis using Student T-test for comparing the results of treatment patients with both methods of NIV.

Statistical significance – **p** – appointed as:
- low level of significance for 0,001 ≤ p ≤ 0,05 (*)
- medium level of significance for 0,000 5 ≤ p ≤ 0,001 (**)
- high level of significance for p ≤ 0,000 5 (***)

Results:

- between April and December 2004 we treated 87 pts in our ICU
- 46 pts of all (53%) suffered from respiratory failure due to AE COPD
- NIV we applied in 76 pts with mortality 21%
- invasive pulmonary ventilation (IPV) was applied in 28 pts with mortality 75% (25% of 28 pts because of failure of NIV, rest from other reasons)



- characteristics of the groups of pts chosen for the analysis: Table 1
- changes in monitored parameters for Group I. and Group II. when comparing to admission value: Tables 2 – 6 and Graphs 1, 3, 5, 7, 9
- percentual changes in monitored parameters for Group I. and Group II. when comparing to admission value : Tables 2 – 6, Graphs 2, 4, 6, 8, 10
- statistical significance – **p** – between monitored parameters in the given moment for both groups: Table 1-10

Characteristic of group of patients at admission

Table 1

	whole group	GROUP I.	GROUP II.	statistical significance (p) between Group I. and Group II.
total number of patients (pts)	40	20	20	
number of women / numbar of men	19/21	10/10	9/11	
age (mean years ± SD)	71,78 ± 9,03	69,80 ± 10,28	73,75 ± 7,03	NS
number of pts on LTOT	16	4	12	0,004527
BMI (mean value ± SD)	29,06 ± 8,75	29,41 ± 9,27	28,70 ± 8,41	NS
days of application of NIV (mean days ± SD)	7,18 ± 3,58	5,30 ± 2,08	9,05 ± 3,82	0,000290
days of hospitalisation (mean days ± SD)	14,68 ± 5,22	12,25 ± 5,14	17,10 ± 4,13	0,001115
FEV1 % PV (mean value ± SD)	37,57 ± 13,62	36,93 ± 11,74	38,20 ± 15,56	NS
FEV1/FVC % (mean value ± SD)	52,44 ± 15,96	50,09 ± 15,32	54,79 ± 16,62	NS
GOLD III. (number of pts)	20	13	7	0,030001
GOLD IV. (number of pts)	20	7	13	0,030001
dyspnoea (Borg scale) (mean value ± SD)	8,32 ± 1,44	7,85 ± 1,72	8,80 ± 0,89	NS
HR (mean value ± SD)	95,08 ± 19,19	93,00 ± 19,83	97,15 ± 18,80	NS
BF (mean value ± SD)	23,23 ± 3,00	22,8 ± 3,50	23,65 ± 2,41	NS

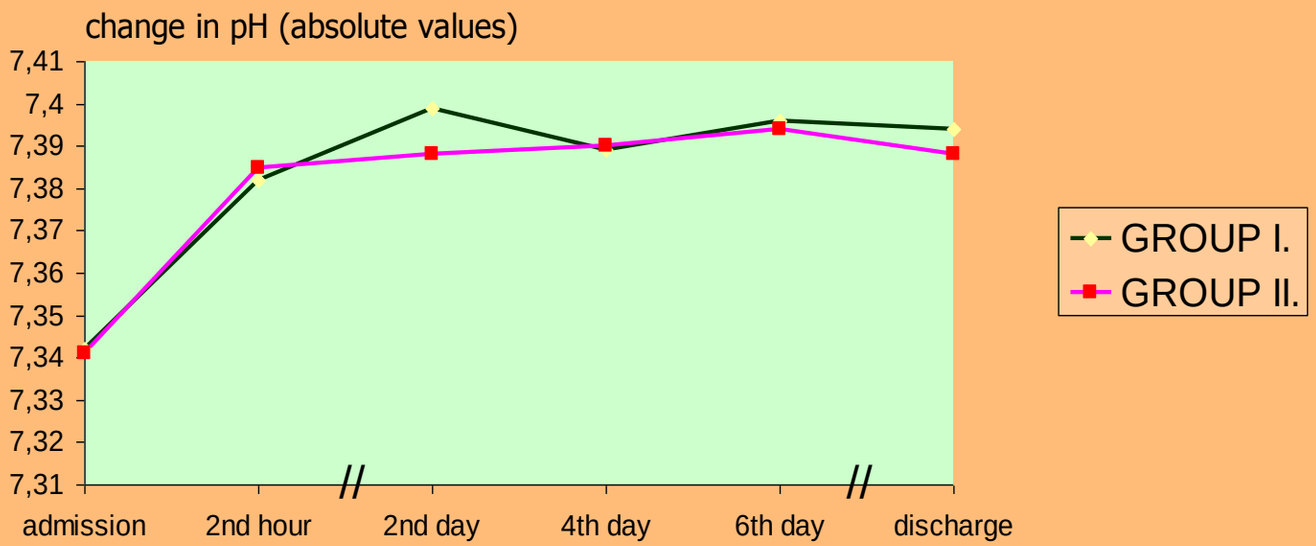
Changes in pH

Table 2

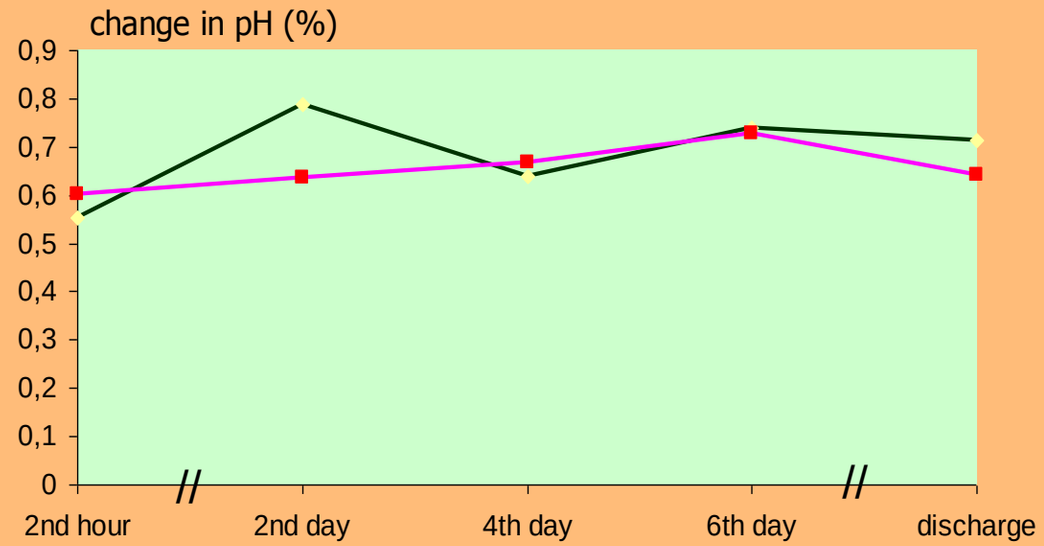
	admission value	2nd hour	2nd day	4th day	6th day	discharge value
whole group	7,341 ± 0,009	7,383 ± 0,051 * * *	7,393 ± 0,060 * * *	7,389 ± 0,050 * * *	7,394 ± 0,042 * * *	7,391 ± 0,042 * * *
GROUP I.	7,342 ± 0,022	7,382 ± 0,0052 *	7,399 ± 0,048 *	7,389 ± 0,055 *	7,396 ± 0,043 *	7,394 ± 0.043 *
% change comparing to admission value		0,554%	0,788%	0,639%	0,739%	0,715%
GROUP II.	7,341 ± 0,045	7,385 ± 0,051 *	7,388 ± 0,072 * *	7,390 ± 0,046 * *	7,394 ± 0,044 * * *	7,388 ± 0,043 * *
% change comparing to admission value		0,601%	0,636%	0,668%	0,7270%	0,642%
p for GROUP I. and II.	NS	NS	NS	NS	NS	NS

mean values ± SD

Graph 1



Graph 2



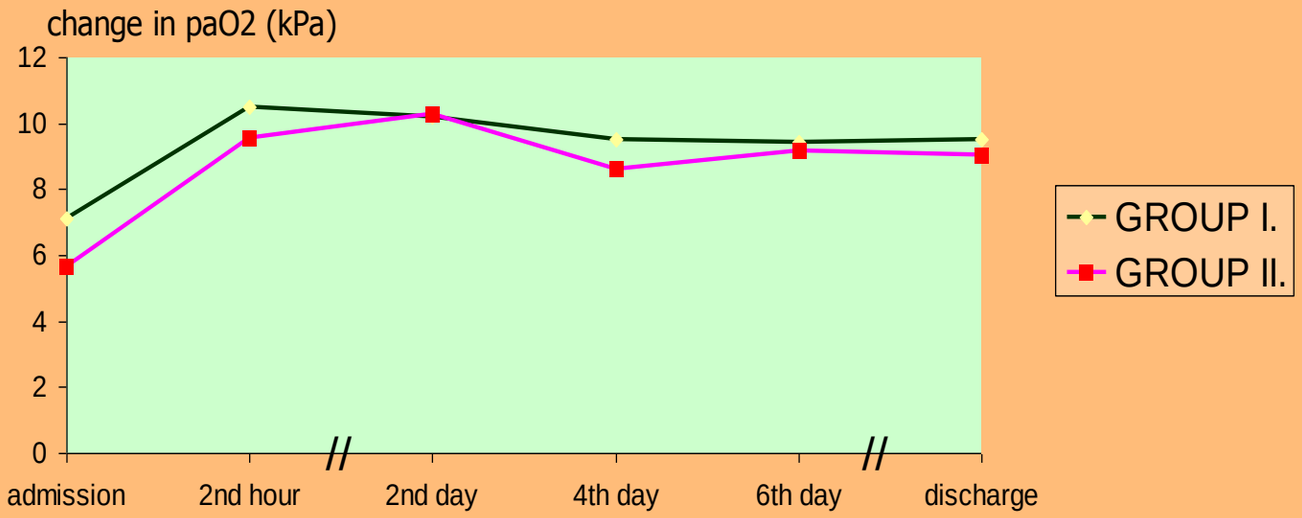
Changes in paO_2

Table 3

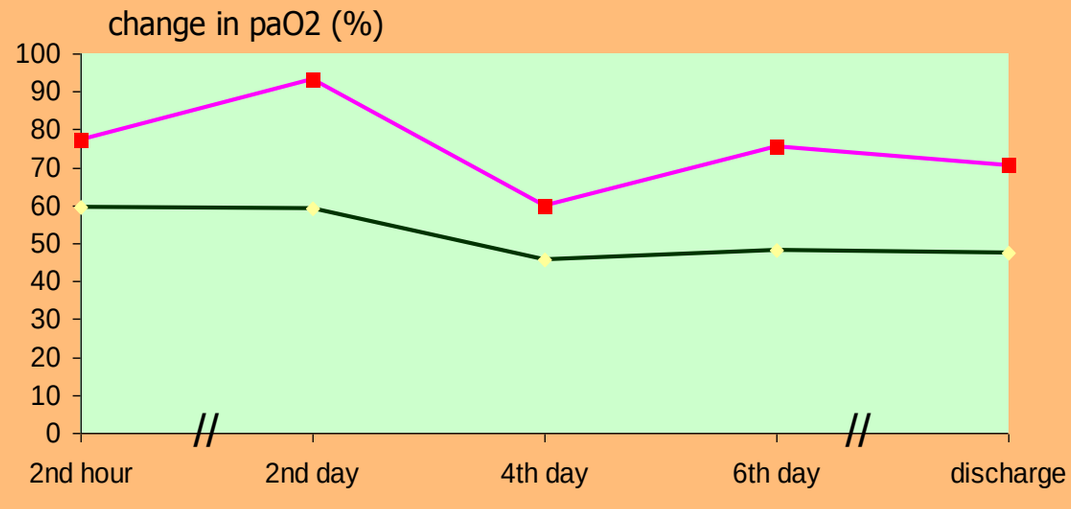
	admission value	2nd hour	2nd day	4th day	6th day	discharge value
whole group	6,39 ± 2,63	10,04 ± 3,04 * * *	10,25 ± 2,55 * * *	9,08 ± 1,94 * * *	9,29 ± 2,38 * * *	9,28 ± 2,25 * * *
GROUP I.	7,13 ± 3,20	10,52 ± 3,29 * * *	10,21 ± 1,92 * *	9,53 ± 2,36 *	9,34 ± 2,94 *	9,50 ± 2,86 *
% change comparing to admission value		59,46%	59,11%	45,86%	48,10%	47,51%
GROUP II.	5,66 ±1,70	9,56 ± 2,76 * * *	10,30 ± 3,11 * * *	8,63 ± 1,33 * * *	9,16 ± 1,71 * * *	9,05 ± 1,45 * * *
% change comparing to admission value		77,23%	93,09%	59,91%	75,63%	70,45%
p for GROUP I. and II.	0,040836	NS	NS	NS	NS	NS

mean values ± SD (kPa)

Graph 3



Graph 4



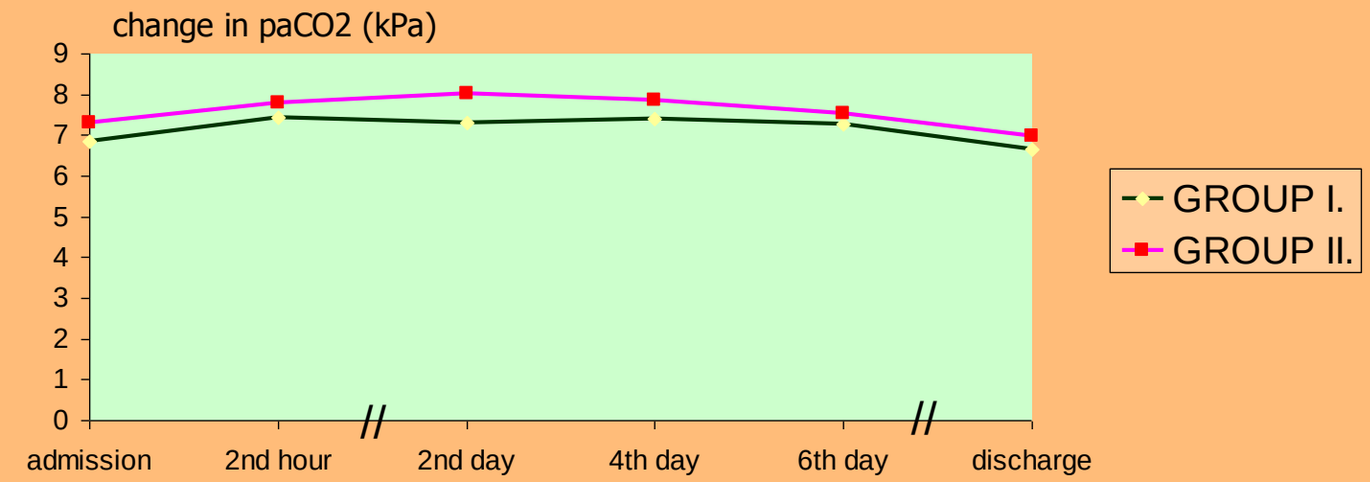
Changes in $paCO_2$

Table 4

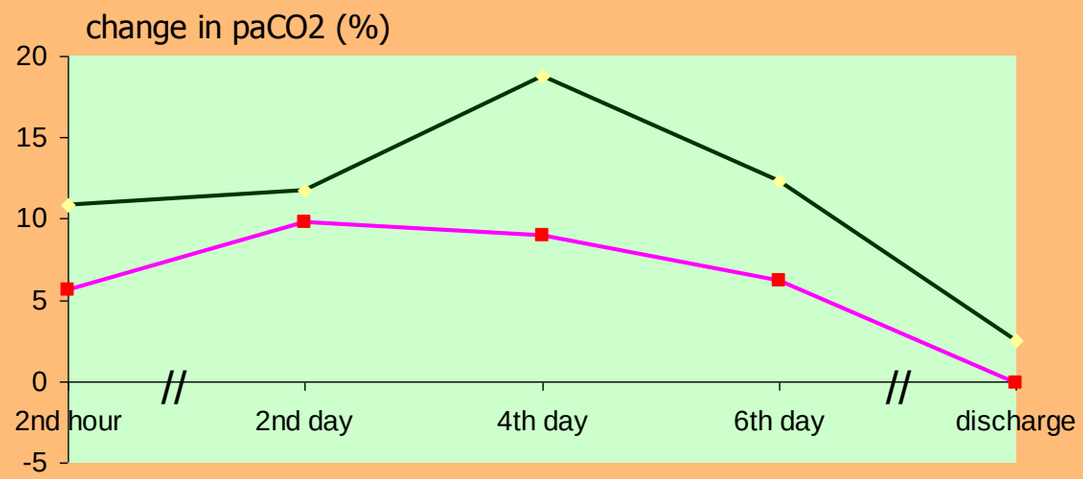
	admission value	2nd hour	2nd day	4th day	6th day	discharge value
whole group	7,07 ± 2,19	7,63 ± 2,43	7,68 ± 2,55	7,84 ± 2,32	7,42 ±1,98	6,87 ± 1,60
GROUP I.	6,86 ± 2,16	7,45 ± 2,09	7,31 ±1,80	7,39 ± 0,05	7,26 ± 1,71	6,66 ± 1,62
% change comparing to admission value		10,85%	11,73%	18,76%	12,32%	2,50%
GROUP II.	7,29 ± 2,25	7,80 ± 2,77	8,03 ± 3,13	7,86 ± 2,50	7,52 ± 2,26	6,99 ± 1,60
% change comparing to admission value		5,63%	9,76%	8,93%	6,19%	-0,10%
p for GROUP I. and II.	NS	NS	NS	NS	NS	NS

mean values ± SD (kPa)

Graph 5



Graph 6



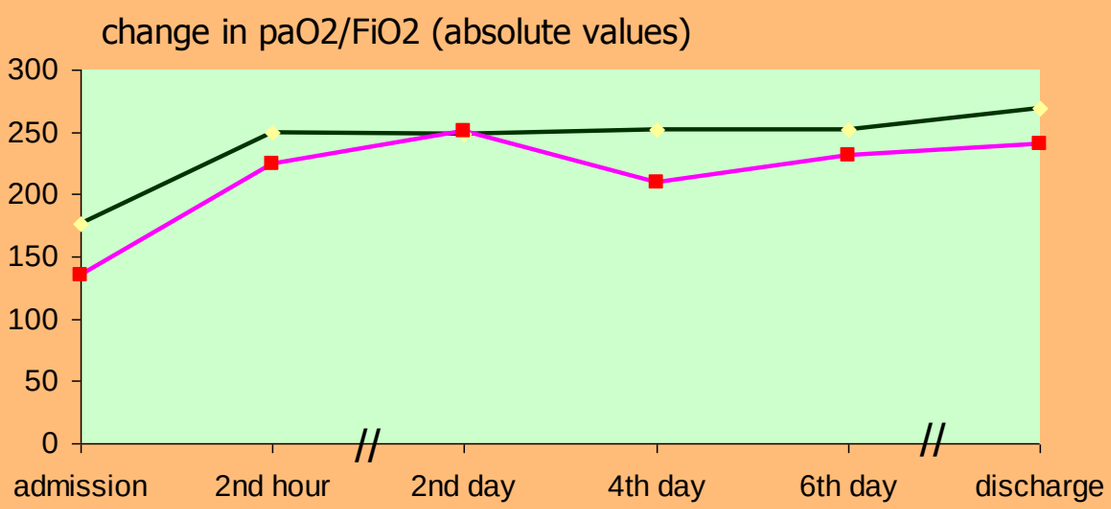
Changes in paO_2/FiO_2

Table 5

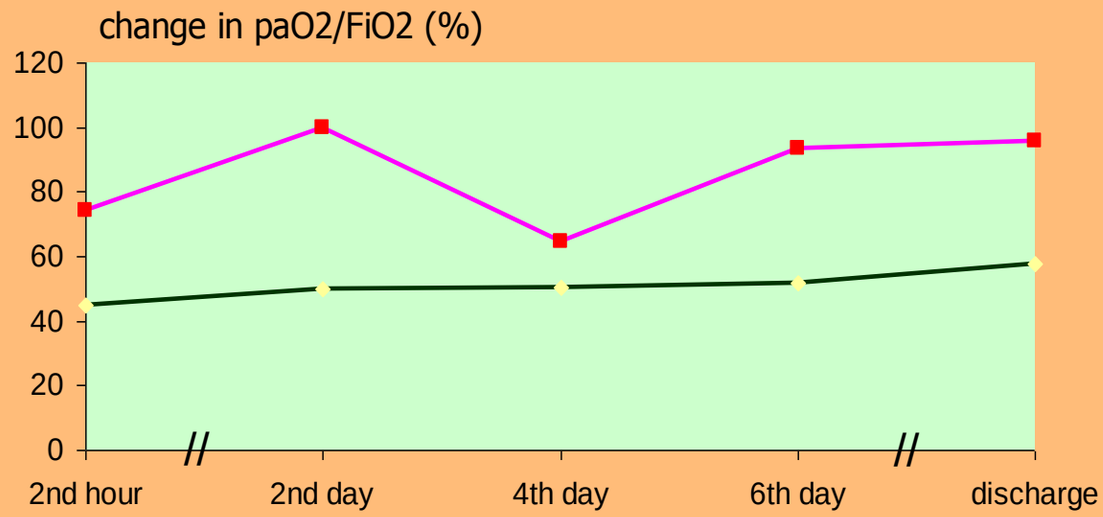
	admission value	2nd hour	2nd day	4th day	6th day	discharge value
whole group	155,39 ± 52,10	236,98 ± 84,47 * * *	259,7 ± 60,30 * * *	230,91 ± 54,78 * * *	241,49 ± 74,58 * * *	254,54 ± 80,22 * * *
GROUP I.	176,10 ± 51,20	249,47 ± 88,55 * *	248,72 ± 50,26 * *	251,98 ± 61,13 * *	251,96 ± 94,75 * *	269,16 ± 96,75 * * *
% change comparing to admission value		45,02%	50,05%	50,16%	51,80%	57,71%
GROUP II.	134,68 ± 45,21	224,49 ± 80,49 * * *	250,68 ± 70,27 * * *	209,85 ± 38,57 * * *	231,04 ± 47,02 * * *	239,93 ± 58,32 * * *
% change comparing to admission value		74,10%	100,00%	64,76%	93,32%	95,82%
p for GROUP I. and II.	0,005021	NS	NS	0,006876	NS	NS

mean values ± SD (%)

Graph 7



Graph 8



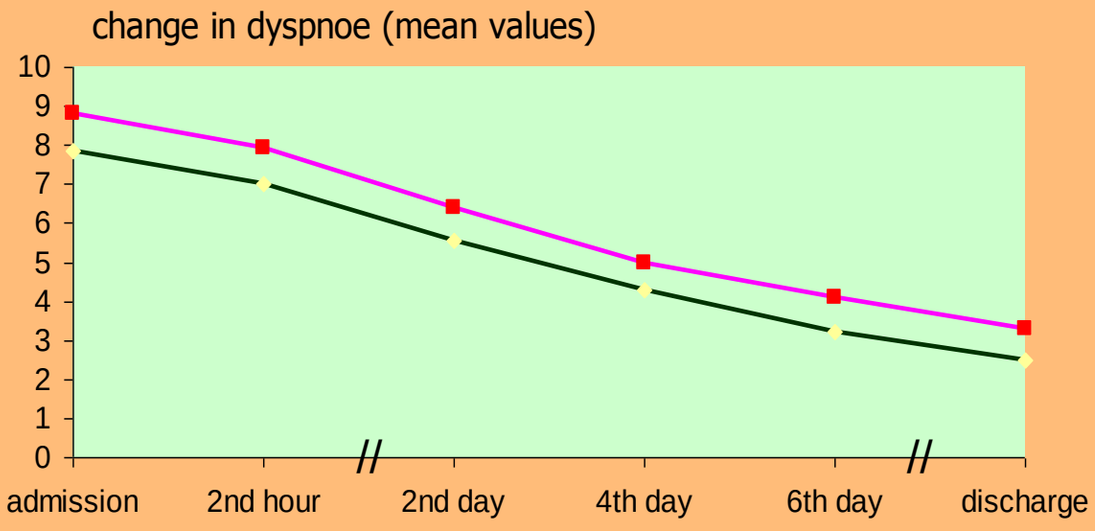
Changes in dyspnoea scale

Table 6

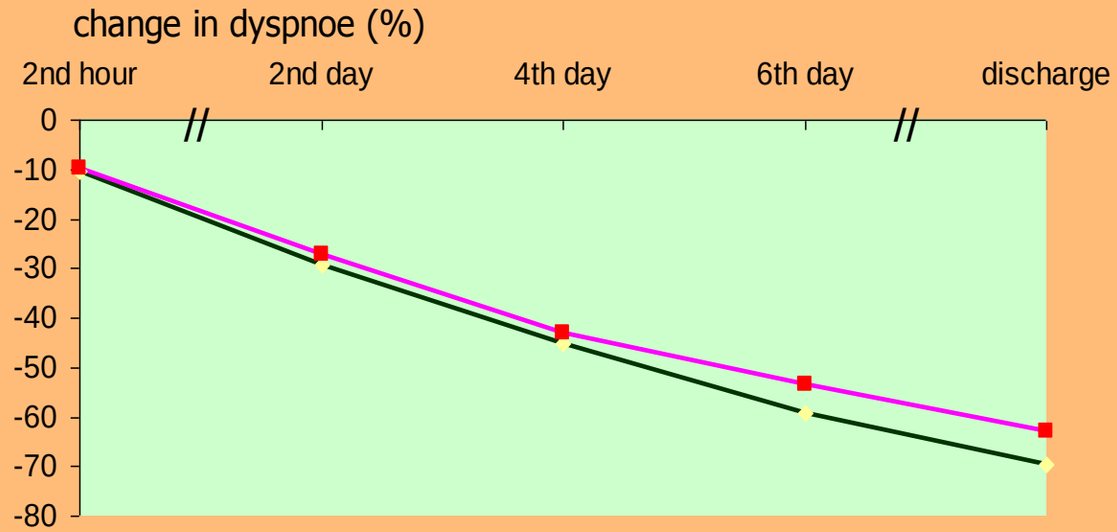
	admission value	2nd hour	2nd day	4th day	6th day	discharge value
whole group	8,33 ± 1,43	7,49 ± 1,41	5,98 ± 1,56	4,64 ± 1,49	3,65 ± 1,55	2,90 ± 1,06
GROUP I.	7,85 ± 1,72	7,03 ± 1,75	5,55 ± 1,76	4,30 ± 1,49	3,20 ± 1,47	2,50 ± 0,76
% change comparing to admission value		-10,51%	-29,3%	-45,22%	-59,24%	-69,75%
GROUP II.	8,80 ± 0,90	7,95 ± 0,76	6,4 ± 1,23	5,00 ± 1,45	4,10 ± 1,52	3,28 ± 1,19
% change comparing to admission value		-9,66%	-27,70%	-43,18/	-53,41%	-62,78%
p for GROUP I. and II.	0,018261	0,019775	0,042948	NS	0,032326	0,010169

mean values ± SD

Graph 9



Graph 10



Discussion:

- We found statistical significant differences in followed characteristics in both groupos:i:
  - number of ptson LTOT (higher in Group II.)
  - admission value of paO2 (lower in Group II.)
  - lenght of aplication of NIV (shorter for Group I.)
  - number of days of hospitalisation (shorter for Group I.)
- There were no statistical signnificant changes in HR, BF, BMI, FEV1 a FEV1/FVC % for both Groups at the admision and during appilcation of NIV-.
- In both Groups we can see continual increase of paO_2 a paO_2/FiO_2, which is higher for GROUP II. when shown in percentages – in spite of used lower concentration of inspired oxygen and worse parameters at admission in this group.
- There is an initial increase in $paCO_2$ in both groups which has no statistical significance and is followed by decrease at the end of hospitalisation. This increase is more expressed in Group I., while in Group II. we see the decrease bellow the admission level.
- For dyspnoea we found worse parameters at admission in Group II. however both groups demonstrate continual improvement of feeling of dyspnoea representated by Borg scale, with only a low level of statistical significance in benefit of Group I.
- When comparing both groups, there is no statistical defference or only a low medium level (p > 0,000 1).
- Both methods were well tolerated by pts, there were no complications in the whole group.

Conclusion:

NIV applied with HFJV via facial mask is good and easily accesible method of NIV which appears to be almost as effective as standard methods of NIV using bilevel positive pressure ventilation. For widesperad recommendation of its application we have obtain resuslts of larger group of patiens for mopre exact anylysis.