REVISTA ESPAÑOLA DE FISIOLOGIA, 51 (4), 177-186, 1995

Evaluation of the Left Ventricular Performance through Equilibrium Radionuclide Angiocardiography

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(Received on September 27, 1994)

J. H. BOIX, F. ALVAREZ, M. TEJEDA, J. MONFERRER, E. ENRIQUE, O. AZNAR, E. KURET, F. PEYDRÓ and D. OLIVARES. *Evaluation of the Left Ventricular Performance through Equilibrium Radionuclide Angiocardiography.* Rev. esp. Fisiol. (J. Physiol. Biochem.), 51 (4), 177-186, 1995.

In patients with severe heart failure due to acute myocardial infarction (AMI) breathing with PEEP can be of additional therapeutic value. This study was designed to assess the effects of CPAP through face mask with 15 cm H_2O on left ventricular performance in AMI patients, using equilibrium radionuclide angiocardiography (ERA). In response to lung inflation, high levels of PEEP have been shown to decrease heart rate and stroke volume. The sum of the TPF pathological prolongation and the Mean-FR reduction suggests a decrease in the left ventricular compliance determined by the restriction imposed by the positive pressure. The global systolic performance is preserved.

Key words: Acute myocardial infarction, CPAP, Systolic function, Diastolic function, Equilibrium radionuclide angiocardiography.

The advantages obtained by using a continuous positive airway pressure (CPAP) on the gassy exchange in patients with different types of acute respiratory failure are related with the increase in the functional residual capacity and the intrapulmonary shunting reduction (7) which determines its final expiratory positive pressure component (PEEP). However, the pathophysiological effects that PEEP makes on the heart are controversial (45). The PEEP reduces cardiac output by limiting the venous return (1, 16, 39, 47), but when it is used as CPAP through face mask the decrease is less than when using mechanical ventilation (8, 41, 54).

It has also been proposed that the PEEP determines compromise of cardiac function by other mechanisms (11, 12, 16, 25, 28, 44). However, other essays not

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only refuse any negative inotropic effect attributed to the PEEP (13, 30), but furthermore evidence with its use in severe left ventricular failure after an AMI (22, 35), an improvement of the cardiac function. This improvement is mediated not only by reducing the left ventricular preload but also by an association of a reduction of the left ventricular afterload as consequence of the transmural pressure decrease (22, 45); an early incorporation of the CPAP is recommended in the therapeutical arsenal of the cardiogenic pulmonary edema (2, 45). The basic alteration in an AMI which leads to a left ventricular dysfunction is the loss of myocardial segments (34); the addition of high levels of PEEP for altering the subendocardial flow may suppose the developing of a systolic dysfunction with the appearance of segmentary abnormalities in the ventricular contraction as a demonstration of residual myocardial ischemia (17, 21, 24, 34). At the same time, the systolic dysfunction extension may be determinant for the irregularity in the relaxing speed and the diastolic filling (23).

Also, the ischemic cardiopathy produces an affection of the diastolic function in the acute phase after AMI, which goes with an increase of the diastolic volume and an increase of the left ventricular filling pressure and it is the origin of a cardiac insufficiency with normal systolic function (46).

The frequency of finding diastolic dysfunction with a normal ejection fraction can raise the 40% of the patients taken to hospital with an acute coronary disease (6, 49). The clinical recognition of this condition is very important since the ordinary therapy with inotropic agents or vesseldilators cannot only improve the diastolic dysfunction but it can also be deleterious (20). In these circumstances the incorporation of high levels of PEEP, even through face mask of CPAP, could suppose a worsening of the diastolic function when associated with a new decreasing factor of the myocardial distension by extracardiac compression (10,52). Likewise, and because of its interrelation, the left ventricular compliance alteration can affect unfavourably the systolic function of such ventricle (23).

The equilibrium radionuclide angiocardiography (ERA) was used as a more reproducible, objetive and quantitatevily precise technique than the noninvasive ones (42, 56), in order to evaluate the application of CPAP with levels of PEEP of 15 cm H_2O in the left ventricular performance after a recent AMI.

Materials and Methods

The protocol of this study was approved by the Ethical Commitee of the Institution. All patients (19 males and 4 females), and their relatives, who were admitted in our ICU with an AMI between October 1992 and October 1993 were informed about this essay and their consent was obtained. Patients average age is 54.8 ± 13.9 years (range from 33 to 76 years). The APACHE II index mean to their hospital entrance was 10.0 ± 5.2 (range from 3 to 20). During the acute phase 4 patients showed cardiac failure. At the moment of making this approach the treatment given to the patients was: mononitrate of isosorbide (40 ± 10 mg once daily), captopril (25 ± 12.5 mg twice daily), and acetylsalicylic acid (150 mg once daily). None of the patients showed supra or/and ventricular rhythm or trouble of conduction.

Equilibrium radionuclide angiocardiography (ERA).– Between the 3rd and 7th days of the clinical evolution, each patient had two ERA. The first one while the patient was breathing spontaneously

room air without any kind of device (Basal stay); the second one while the patient was breathing compressed air with a fraction of oxygen similar to the room air through a system of CPAP adapted to the face 60 minutes before (CPAP stay) with a PEEP of 15 cm H_2O.

Previous to the ventricular quantification the ventricular edges were delimited by semiautomatic systems (15). Finally, the data obtained from the valid cardiac cycles (10 min of acquisition) were added to create a left ventricular discontinuous curve of activity-time. As the radioactivity is proportional to the blood volume the curve activity-time represents a measure of the relative change of volume in relation to the time (56); the highest point of the curve belongs to the volume or endiastolic activity (end diastolic counts, EDC) and the lowest point to the volume or endsystolic activity (end systolic counts, ESC).

Analysed variables.– The discontinuous observations obtained were adjusted to a Fourier function with three harmonics. Afterwards, a first maths derivative in relation to the time was obtained. The left ventricular performance (both systolic and diastolic) was made, working out the two curves, volume and its derivative, variables of direct estimation and others of derivative calculation (4, 19). All these variables were normalized to the cardiac frequency in order to avoid arbitrariness in its evaluation. The physical coefficient of attenuation of the Tc-99m for every passed hour of the study (u = 0.81 mCi) was also considered, as well as the coefficient of biological cardiac attenuation (u = 0.01 mCi) and the coefficient of lineal attenuation of the thoracic soft parts (u = 0.15 mCi). However, the possible attenuating effect of the pulmonary hyperinsufflation (18), which the use of the CPAP and the PEEP conditioned in every patient, was not determined. The systolic arterial pressure (APs) and diastolic (APd) during the study was monitored every 10 min by esphingomanometry (Lohmeier B 606). The double product was obtained by multiplying every patient's APs in each study by the suitable heart rate (HR). The monitoring ECG was made through a Physio-Control monitor (Life Pack-10).

CPAP equipment.– The CPAP equipment consists of a continuous flow system of gas (Vital Signs 9250) without reserving bag, connected to a humidifier of cascade and to an unidirectional inspiratory valve of the face mask; another unidirectional valve, type threshold of resistance (Vital Signs 9010) of 15 cm H_2O was connected to the expiratory branch of the mask acting as PEEP. The face mask (Vital Signs 9035), of transparent plastic, has a blowing up by air padded to fit the mask to the patient's face and fit to its head by strips. The continuous inspiratory flow per min (73 ± 6.8 L/min) used was obtained after multiplying by four its expired volume previously measured.

Myocardial perfusions gammagraphies.– In order to evidence possible differences in the regional flow between myocardium segments due to variations of the vessel light calibre or the changes in the perfusion which could condition the use of CPAP, two perfusion studies were made in each patient; the first one with dipiridamol and without CPAP and the second one combining the dipiridamol with CPAP and PEEP of 15 cm H_2O. All the gammagraphies were estimated and compared by two observers without previous knowledge of any detail from the patient's clinical history. The test was considered as negative if modifications in the defects of captation found in the first gammagraphy were not observed.

Groups of patients.– A basal ejection fraction (EF) lower than 45 % was used to evaluate if the answer to the CPAP was equal in both groups of patients. Also, a basal time to peak filling (TPF) higher than 180 ms has been used to divide the patients into two groups.

Analysis of the data.– The data is presented as mean ± standard defflection, the differences obtained in the analysed variables have been evaluated by the no parametric Wilcoxon test for paired samples. Differences lower than $p < 0.05$ have been considered significant.

Results

After 60 min with CPAP, PEEP of 15 cm H_2O and FiO2 0.21, the following changes in the dynamic cardiac were observed: a minimum reduction of the HR ($p < 0.05$) and significant reduction ($p < 0.01$) of the radioisotopic end-diastolic activity and the radioisotopic activity by beat. In no patient during the time of the study were modifications observed in the atrioventricular or intraventricular conduction.

Systolic function.– Table I shows how left ventricular peak ejection rate (PER) decreases significantly with the CPAP and the passed time until the ejection peak (TPE) tends ($p = 0.05$) to extend. Once these variables are corrected for a given frequency, the tendencies noted in the previous analysis with uncorrected values are kept, but only ($p = 0.05$) the evidence of extension of the TPE is preserved (fig. 1).

Diastolic function.– With the CPAP, the diastolic time necessary to get the maximun peak of filling (TPF) is lengthened significantly and it becomes pathologic (higher than 190 ms), the average speed of the early diastolic filling (Mean-FR) reduces significantly and the filling speed when the first third of the diastole ends (1/3FR) tends to decrease ($p = 0.05$). These variables corrected for a frequency given the length of the TPF and the reduction of the Mean-FR, keep the statistic differences. The tendency to the previously shown reduction for 1/3FR now does not reach the statistic significance (table II and fig. 2).

Group of patients.– Differences in patients' behaviour whose basal EF was lower than 45 % after the CPAP, were not appreciated.

In patients with a normal basal TPF or a pathologically lengthened-TPF the addition of CPAP and PEEP condition their pathological length.

Table I. *Systolic function in AMI patients with CPAP.*

	Not normalized variables		Normalized variables	
	Basal	With CAP	Basal	With CAP
EF (%)	51.37 ± 12.94	49.70 ± 11.78	54.93 ± 19.06	54.78 ± 17.54
TES (ms)	330.43 ± 46.34	336.78 ± 50.35	358.52 ± 120.9	337.78 ± 121.3
PER (counts/s)	2.90 ± 0.85	2.67 ± 0.80*	3.01 ± 0.88	2.87 ± 0.82
TPE (ms)	130.97 ± 35.87	146.30 ± 30.78*	144.34 ± 58.16	162.60 ± 47.97*
1/3EF (%)	16.27 ± 6.21	14.88 ± 5.26	17.18 ± 8.40	16.41 ± 7.08
1/3ER (counts/s)	2.59 ± 0.95	2.43 ± 0.78	2.72 ± 0.99	2.61 ± 0.82

* $p < 0.05$ basal vs CPAP

Table II. *Diastolic function in AMI patients with CPAP.*

	Not normalized variables		Normalized variables	
	Basal	With CAP	Basal	With CAP
PFR (counts/s)	2.20 ± 0.66	2.05 ± 0.64	2.31 ± 0.78	2.23 ± 0.83
TPF (ms)	134.45 ± 55.0	206.50 ± 96.2*	163.45 ± 75.6	221.56 ± 109.7**
MEAN-FR (counts/s)	0.93 ± 0.33	0.78 ± 0.23**	0.95 ± 0.30	0.83 ± 0.22*
1/3FF (%)	41.30 ± 18.8	37.18 ± 15.8	46.14 ± 29.0	43.18 ± 24.9
1/3FR (counts/s)	1.67 ± 0.67	1.23 ± 0.75*	1.68 ± 0.55	1.36 ± 0.80

* $p < 0.05$ basal vs CPAP
** $p < 0.01$ basal vs CPAP

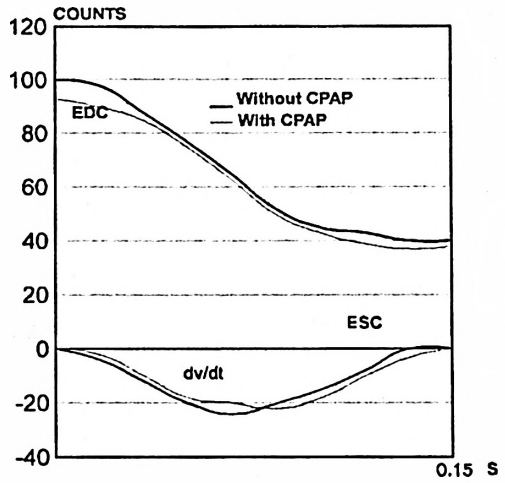

Fig. 1. *Curves of systolic initial activity (volume) and with CPAP.*
The end-diastolic activity is inferior in the curve with CPAP and its length is slightly superior; the rest of designs is superposed.

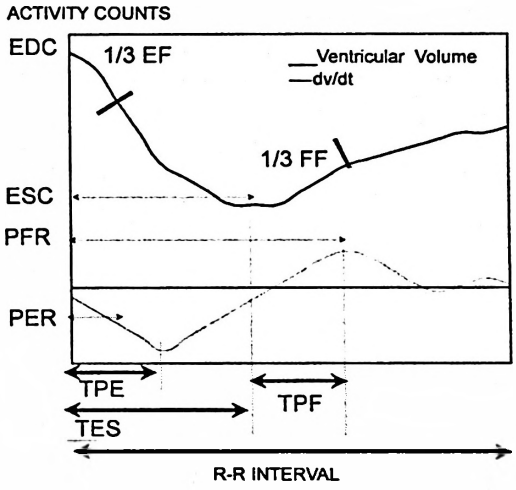

Fig. 2. *Curve of basal activity (volume).*
The same curve shows slow points and suffers a slightly down and right toward deflection with CPAP through face mask and PEEP 15 cm H_2O.

Discussion

Systolic function.– By using the CPAP through a face mask and valves of PEEP of 15 cm H_2O a little reduction in the cardiac frequency and the EDC (left ventricular preload) is observed, former is attributed to the nerve vagus estimulation by pulmonary hyperinsufflation (12) and later to the reduction of the venous systemic return to the right heart (1, 14, 39, 47) or/and by the right ventricular afterload increase (25). The present study does not allow to delimit quantitatively the percentage with which each of these possible mechanisms contribute to the left ventricular preload reduction. Although no modifications of the left ventricular afterload can be verified by us, the absence of an ESC activity during application of the CPAP is a clearly indicator which allows to eliminate its significant elevation.

The maintenance observed in the patients' systolic and diastolic AP contrasts with the hemodynamic evolution expected from the secondary decrease of the cardiac output. This difference may be the result of established compensatory adjustments in patients with clinically moderate severity (basal ejection fraction in the range of normality) and who received at the moment of the study low doses of vesseldilator, insufficient to provoke relative hypovolemy or to reduce the vascular reactivity. In some patients with heart failure the addition of PEEP produces an increase of the cardiac output because it reduces the left ventricular impedancy (9, 22, 35, 36, 38, 45, 53). The double product stability also shows that the possible establishment of these compensatory mechanisms have not suposed an increase in the myocardial oxygen uptake. An ideal sign of left ventricular systolic function should be independent from the preload, afterload and heart rate and should be sensible to the early damage of the myocardial function (43, 48). The ejection fraction (EF), even varying directly with the preload and inversely with the afterload, it is a sure sign, sensible, highly reproducible and with a wide clinical application because it can be quickly determined by no invasive methods (42,56). The ischemic cardiopathy alters the ventricular ejection both quantitatively (volumetric variation) and qualitatively (rhythm or ejective sequence) according to the grade and extension of such damage. The ejective rhythm alterations appear because of the alteration of the segmentary contractility of the ischemic zones; on the contrary the variable reduction of the total volume ejected is in relation to the extension of the previous necrosis.

The global EF has not had any significant modifications after the CPAP. This behaviour has been similar in patients with a previous normal behaviour such as low EF.

Nevertheless the EF has been criticized for measuring only the average of all the events which happen in the systole and it has been postulated that the analysis of the left ventricular systolic first third where 40 % of the volume is ejected could have additional importance because it would identify troubles of function in an early phase of the systole (26). But the study of the early systole in our patients through the ejection fraction of the first third of the systole (1/3EF) and its ejective rate (1/3ER) neither allowed to identify significant changes in these indicators for this reason nor to make obvious modifications of myocardial inotropic states associated to the use of CPAP.

When our patients breathed through the mask of CPAP the PER decreased significantly which could suggest a reduction of the myocardial contractility by decreasing the initial impulse. However, when the PER is normalized according to the cardiac frequency, its difference is less important, thus coinciding with the information previously given by the EF and 1/3EF.

With the use of the CPAP a tendency exists that the systolic time to get the maximum speed (TPE) extends even after its normalization for the heart rate, although always with normal values. This fact may be the first demonstration of a reduction of the contractile acceleration, probably due to variations in those other factors which also determine the ventricular function such as the decrease in the diastolic distensibility, the changes in the ventricular geometry, inertia, myocardial elasticity and viscosity (27, 38, 50); they potentially conditioned for the myocardial limitation that the CPAP with 15 cm H_2O of PEEP represents (13, 30). Thus in the conditions of the study the use of 15 cm H_2O of PEEP does not alter the left ventricular

systolic function. The significance and trascendence of the minimun changes, that its application induces, should be nuanced.

Diastolic function.– In patients with a coronary disease with the presence of anormalities in the left ventricle, diastolic properties have been detected even in those who present a global systolic function within normal limits (20); the coronary ischemia can delay the ventricular relaxation and alter the compliance (6). Patients with a coronary disease manifest alteration at the ventricular compliance both acute and chronic; transitory changes in the compliance are induced by the acute ischemia episodes while the rigidity by myocardial fibrosis after a residual infarct is responsible for the chronic changes in the compliance. The mechanisms invoked to postulate about these changes induced by the myocardial ischemia are numerous (23, 27, 38). In a strict way, the decrease of the compliance through the ERA cannot be proven because with this the volumes are determined only in a relative way, expressed according to the activity not being possible to be correlated with changes in the intraventricular pressures. The diastolic time measured until the maximun speed of ventricular filling (TPF) is obtained in patients with myocardial ischemia periods clinically apparent or not, has shown to be longer than in normal people (inferior to 180 ms), both at resting and in exercise (6, 29, 33). This index includes the relaxing isovolumetric period and the quick filling period (50-80 % of the diastolic filling in this interval). In the ischemic coronarypathy the lengthening of TPF is produced at the expense of the relaxation isovolumetric period, which being an active process that requires high energy to inactivate the actinemiosine bridges, is very sensitive to myocardial ischemia (32). In our patients globally considered while breathing through the CPAP with 15 cm H_2O of PEEP a pathologic and significant lengthening of the TPF is observed, even after normalizing it by the frequency. This behaviour, is significant in all the groups of patients. But only with the analysis of the activity-time curve obtained by ERA, the isovolumetric relaxation cannot be confirmed as responsible of such lengthening since not knowing the moment of aortic closing and mitral opening its duration cannot be delimited. Together with the TPF lengthening a significant reduction of the mean speed of diastolic repletion coexists measured during the quick repletion period, which persists after its normalization with the cardiac frequency.

In AMI patients, the maximun speed of the basal diastolic filling (PFR) stands out by some obviously reduced values (inferior to 2.7 counts/s) which coincide with the findings that other authors show in the context of the acute coronary disease and that they attribute to local alterations of their regional relaxation by areas of necrosis and ischemia periods clinically apparent or silent (3, 51, 56). During the use of CPAP the persistence of a similar abnormality of the PFR, even after being normalized for the cardiac frequency, reflects the absence of reciprocal changes in other factors that may influence them, which helps reject the coronary ischemia and the isovolumetric relaxing period as responsible for the reduction in the ventricular distensibility observed. The reduction of the fraction speed of filling measured after the first third of the diastole (1/3FR) has been used as imcomplete ventricular relaxing indicator in patients with coronary ischemia when other methods fail (29). However, it is a variable extremely sensitive to changes in the cardiac frequency.

Therefore, under the present conditions the distensibility modification sug-

gested by using the CPAP must be explained from probable changes in the intrinsic myocardial properties imposed by the extramyocardial restriction of a PEEP of 15 cm H_2O.

The found changes suggest that the use of 15 cm H_2O of PEEP with face mask of CPAP is a cardiogenic protective mechanism faced to acute overloads of volume. However in patients with a severe reduction of the left ventricular myocardial distensibility, elevated levels of PEEP still with CPAP could aggravate the diastolic dysfunction and also affect adversely the systolic function in virtue of the interelation systole-diastole. For this reason, these levels of PEEP should always be carefully individualized and monitored.

J. H. BOIX, F. ALVAREZ, M. TEJEDA, J. MONFERRER, E. ENRIQUE, O. AZNAR, E. KURET, F. PEYDRÓ y D. OLIVARES. *Evaluación de la función ventricular izquierda por ventriculografía radioisotópica de equilibrio*. Rev. esp. Fisiol. (J. Physiol. Biochem.), 51 (4), 177-186, 1995.

En pacientes con insuficiencia cardíaca debida a infarto agudo de miocardio (IAM), la utilización de PEEP puede presentar valor terapéutico. Se evalúan los efectos de la CPAP aplicada mediante máscara facial con 15 cm H_2O en el funcionamiento del ventrículo izquierdo en pacientes con IAM, usando ventriculografía radioisotópica de equilibrio. En respuesta a la insuflación pulmonar, altos niveles de PEEP muestran disminución de la FC y del volumen sistólico. La suma de la patológica prolongación del TPF y de la reducción del Mean-FR sugiere una disminución en la distensibilidad ventricular izquierda determinada por la restricción impuesta por la presión positiva. No se producen variaciones en la función sistólica global.

Palabras clave: Infarto agudo de miocardio, CPAP, Función sistólica, Función diastólica, Ventriculografia radioisotópica de equilibrio.

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