Acute haemodynamic effects of nifedipine at rest and during maximal exercise in patients with chronic cor pulmonale

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ABSTRACT The pulmonary hypertension of cor pulmonale can be reversed by sustained correction of hypoxia but continuous oxygen treatment poses problems in clinical practice. Alternative methods of relieving pulmonary vasoconstriction have therefore been explored. Eight patients with chronic cor pulmonale (five of whom were men) were studied to measure the haemodynamic effects of the calcium antagonist nifedipine, both at rest and on maximal, symptom limited exercise. The mean duration of exercise was unchanged by nifedipine (7.8 (SD 3.3) compared with 7.3 (3.1) min). Cardiac output rose from 5.2 (1.5) l min \(^{-1}\) to 8.6 (3.3) l min \(^{-1}\) on exercise. Nifedipine increased resting cardiac output by 26%, but did not influence maximal exercise output. It did not significantly alter resting mean pulmonary artery pressure but reduced the level during exercise from 67 (15) to 52 (11) mm Hg. Nifedipine lowered resting pulmonary vascular resistance (PVR) by 32% and exercise PVR by 28%. It reduced supine mean systemic arterial pressure by 17%, standing pressure by 22%, and pressure at the maximal exercise level by 20%. Nifedipine lowered supine systemic vascular resistance (SVR) by 35%, standing SVR by 28%, and exercise SVR by 20%. Haemodynamic changes were achieved without adverse symptoms, alteration in arterial PO\(_2\), or impairment of calculated oxygen delivery. Nifedipine therefore reduced both pulmonary and systemic vasomotor tone at rest and during exercise. It did not alter exercise tolerance, which is probably limited by underlying respiratory disease. It seems possible therefore that nifedipine could delay the development of cor pulmonale, although this hypothesis remains to be tested.

Hypoxia from chronic lung disease leads to pulmonary vasoconstriction, pulmonary arterial hypertension, and ultimately cor pulmonale. Animal\(^1\) and human\(^2\) studies suggest that the pulmonary hypertension can be reversed by sustained correction of hypoxia, though the continuous oxygen treatment that appears to be necessary\(^3\) poses problems in clinical practice. Alternative methods of relieving hypoxic pulmonary vasoconstriction have therefore been explored. Rubin and Peter\(^4\) showed that hydralazine reduced pulmonary vascular resistance in patients with chronic obstructive lung disease studied at rest and during exercise. Brent et al\(^5\) reported a fall in pulmonary vascular resistance and improvement in the right ventricular ejection fraction at rest with terbutaline, a β\(_2\) adrenergic agonist. The calcium antagonist verapamil induced a fall in resting pulmonary vascular resistance and cardiac output in hypoxic patients.\(^6\) Nifedipine likewise reduced pulmonary vasoconstriction in patients with acute respiratory failure,\(^7\) and in patients with chronic cor pulmonale, where cardiac output also rose, and the effect was maintained after nearly two months of treatment.\(^8\) Mean pulmonary artery pressure fell in less than half of the patients studied, however, and some patients deteriorated clinically, for reasons which were not evident from the haemodynamic effects of nifedipine, which had been measured only at rest. We therefore undertook this study of patients with chronic cor pulmonale to measure the haemodynamic effects of nifedipine both at rest and at the maximal exercise level. Nifedipine has since been reported to reduce
pulmonary vasoconstriction at rest and during sub-
maximal exercise in patients with chronic obstructive
lung disease.\textsuperscript{9}

\textbf{Methods}

Eight patients (five of them men; 42–70 years) with
chronic cor pulmonale were studied after giving
informed written consent. The study had been
approved by the hospital ethical committee. All
patients had chronic airflow limitation, three also had
bronchiectasis, and all had experienced at least one
documented episode of clinical cor pulmonale charac-
terised by raised \textit{venous} pressure and peripheral
oedema. At the time of the study all patients were in
a stable state and had had no acute exacerbation
within the previous three weeks. No patient had overt
oedema. Treatment consisted of maintenance diuretic
treatment in seven of the eight patients (frusemide
40–200 mg daily, with additional spironolactone in
two patients), at least one bronchodilator in all
patients, domiciliary intermittent oxygen treatment
in six, digoxin in two, and maintenance oral pre-
dnisolone in one patient. Mean (SE) baseline values for
tests of respiratory function were: FEV\textsubscript{1} 0.66 (0.27) l,
forced vital capacity (FVC) 1.43 (0.66) l, arterial oxygen
tension (Pao\textsubscript{2}) 47 (6) mm Hg, 6.3 (0.8) kPa, arte-
rial carbon dioxide tension (Paco\textsubscript{2}) 53 (7) mm Hg
(7.1 (0.8) kPa). Radiographically, two patients
showed cardiac enlargement and six showed evidence
of pulmonary hypertension (diameter of one or both
lower lobe pulmonary arteries > 18 mm). Electro-
cardiographic features of pulmonary hypertension—p
pulmonale and/or right axis deviation (> 100°) and/or
right ventricular hypertrophy voltage criteria—were
present in three patients.

Patients were admitted to the investigation room
and rested supine until the study (for about three
hours). They were studied while breathing room air,
diuretics having been withheld for 24 hours and other
treatment (including oxygen) for 12 hours. In each
patient a Swan Ganz triple lumen thermodilution
catheter was advanced from an antecubital vein to the
pulmonary artery and a radial artery cannula was
inserted.

Vascular pressures, with the mid chest as reference
point, were measured with Gould P50 transducers
connected to a Physio-control VSM 1 monitor; mea-
surements were averaged over five respiratory cycles.
Mean systemic arterial pressures were obtained elec-
tronically; because of considerable respiratory swings
in pulmonary arterial pressure, means were calculated
manually from phasic pressures in mid expiration.
Cardiac output was measured from thermodilution
data. Values that varied by more than 10\% were dis-
carded and an average was obtained from at least
three acceptable measurements. Left atrial pressure
was not measured (and is here ignored as it is un-
reliably estimated from pulmonary wedge pressure
in these patients). The derived haemodynamic indices
were:

\[
\text{mean pulmonary vascular resistance (dyn s cm}^{-5}) = \frac{\text{mean pulmonary artery pressure (mm Hg) x 80}}{\text{cardiac output (l min}^{-1})} \\
\text{Systemic vascular resistance (dyn s cm}^{-5}) = \frac{\text{mean radial artery pressure (mm Hg) x 80}}{\text{cardiac output (l min}^{-1})} \\
\text{Oxygen delivery (ml min}^{-1}) = \text{cardiac output x } [(1.34 \times \text{Hb} \text{ arterial O}_2 \text{saturation %}) + (0.003 \times \text{Pao}_2)]]
\]

where cardiac output is measured in l min\textsuperscript{-1}, hae-
moglobin (Hb) in g dl\textsuperscript{-1}, and Pao\textsubscript{2} in mm Hg.

Arterial and mixed venous blood gas tensions were
measured with Radiometer electrodes. Oxygen satu-
ration was calculated from temperature corrected
blood gas data on the basis of Hill’s equation.\textsuperscript{10}

Exercise tolerance was individually assessed by two
practice tests on the day before the study. These prac-
tice tests also served to minimise the learning or train-
ing effect of repeated testing on exercise tolerance. A
training effect has been found in healthy subjects,\textsuperscript{11}
but not always in patients with limited exercise toler-
an.\textsuperscript{12} A work load was fixed to allow each patient
to exercise for at least three minutes. The exercise
protocol before and after nifedipine was identical,
with the patient encouraged to pedal for as long as he
was able. Exercise haemodynamic measurements were
made in the last 90 seconds of exercise.

Resting supine haemodynamic measurements were
made at 15 minute intervals until stable recordings
were obtained (after 15 minutes in six patients, after
30 minutes in two). The study was then performed
according to the protocol shown in figure 1. Haem-
dynamic measurements were made and blood was
sampled for gas analysis, in the supine position, after
the patient had stood for three minutes, and at the
maximal symptom limited exercise level on the bicycle
ergometer. The patient then rested supine until hae-
modynamic measurements returned to baseline after
some 20–30 minutes. Nifedipine (20 mg) was then
given sublingually. One hour later the patients had the
measurements repeated in the supine and standing
positions and during exercise.

Results are given as means with standard errors in
parentheses and compared with Student’s \textit{t} test for
paired data. The validity of the \textit{t} test results was
confirmed with two way analysis of variance and Tu-
key’s procedure for multiple comparisons.

\textbf{Results}

The mean duration of symptom limited exercise was
unchanged by nifedipine (7.8 (3.3) min compared with 7.3 (3.1) min). The predominant symptom that limited exercise before nifedipine treatment was breathlessness in six patients and fatigue in two. After nifedipine, breathlessness was the limiting symptom in four and fatigue in four patients.

The heart rate increased from 95 (17) beats/min while patients were resting supine to 136 (15) during maximum exercise (fig 1a). Nifedipine did not alter the resting heart rate but lowered the exercise heart rate. Cardiac output rose from a normal level of 5.2 (1.5) L/min \(^{-1}\) while they were resting supine to 8.6 (3.3) L/min \(^{-1}\) during exercise (fig 1b). Nifedipine increased resting cardiac output by 26\%, but did not influence maximal exercise output. Readings for cardiac output during exercise did not show any greater variability than measurements made during rest.

Mean pulmonary pressure was high at rest (41 (17) mm Hg) and rose with exercise to 67 (15) mm Hg (fig 2a). Nifedipine did not alter resting pulmonary pressure significantly but reduced the exercise level to 52 (11) mm Hg (a reduction of 22\%). Pulmonary vascular resistance (PVR) rose only slightly and not significantly with exercise (from 736 to 768 dyn s cm \(^{-5}\)) (fig 2b). Nifedipine lowered resting PVR by 32\% and exercise PVR by 28\%.

Nifedipine reduced resting supine systemic arterial mean pressure by 17\%, standing pressure by 22\%, and pressure at the maximal exercise level by 20\% (fig 3a), without causing any symptoms of postural hypotension. Systemic vascular resistance (SVR), unlike PVR, rose on standing and fell with maximal exercise. Nifedipine lowered supine SVR by 35\%, standing SVR by 28\%, and exercise SVR by 20\%.

Haemodynamic changes were achieved without any significant alteration in arterial oxygen tension before or after nifedipine (fig 4a). Calculated oxygen delivery was not impaired by treatment with nifedipine (fig 4b).

**Discussion**

Previous studies have reported salutary effects of nifedipine in acute respiratory failure at rest and in clinically stable cor pulmonale at rest and during submaximal exercise. Our study extends these observations by showing that haemodynamic benefits are maintained at the maximal exercise level when
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Patients are breathing air.

Nifedipine reduced pulmonary and systemic vaso-motor tone at rest and on maximal symptom limited exercise in patients with chronic cor pulmonale breathing air. The rise in cardiac output without intrapulmonary shunting or a rise in pulmonary artery pressure suggests that nifedipine had a pulmonary vasodilator effect. It did not alter exercise tolerance, probably because in these patients tolerance is limited by underlying respiratory disease. Patients were, however, able to reach maximal exercise at lower pulmonary pressure, heart rate and systemic pressure without any reduction of either arterial oxygen tension or calculated oxygen delivery. Nifedipine treatment is therefore unlikely to improve limiting symp-

**References**


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