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Bottle-blowing in Hospital-treated Patients with Community-acquired Pneumonia

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A study was carried out to determine whether bottle-blowing has any positive effects in patients with pneumonia. In a prospective open study 145 adults with untreated community-acquired pneumonia requiring hospitalization were randomized to early mobilization (group A), to sit up and take 20 deep breaths on 10 occasions daily (group B), or to sit up and to blow bubbles in a bottle containing 10 cm water through a plastic tube 20 times on 10 occasions daily (group C). Peak expiratory flow (PEF), vital capacity (VC), forced expiratory volume in 1 sec (FEV_1) and serum concentration of C-reactive protein (CRP) were determined on admission, and on days 4 and 42. Fever duration and hospital stay were recorded. In a subset of 16 patients, single breath diffusion capacity of carbon monoxide was measured on 3 occasions. The patients in group A were hospitalized for a mean of 5.3 days, group B for 4.6 days and group C for 3.9 days. Treatment was a significant factor ($p = 0.037$) in a Cox regression model, with group C significantly better than group A ($p = 0.01$). The number of days with fever was 2.3, 1.7 and 1.6 in groups A, B and C respectively. These differences were not significant ($p = 0.28$). No significant differences were found between the groups regarding CRP, PEF, VC, FEV_1, or diffusion capacity. Intensive bottle-blowing shortens the hospital stay in patients with pneumonia. The underlying mechanism is not clear.

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INTRODUCTION

The effect of traditional chest physiotherapy, including postural drainage, percussion and vibration in patients with pneumonia has been assessed in a few studies (1–2). No positive results of active treatment have been found. In another study the effect of chest physiotherapy combined with positive pressure breathing administered with a Bird respirator was evaluated, and again had no clinical effect (3). Consequently, traditional chest physiotherapy has largely been abandoned in pneumonia (4), except in patients with large amounts of respiratory secretions or neuromuscular diseases.

Meanwhile, studies on the use of continuous positive airway pressure (CPAP) in surgical patients have shown an effect in the treatment of atelectasis, possibly through recruitment of collateral channels (5–6). On the assumption that intermittent positive airway pressure can "open up" closed alveoli, this principle has been applied in cases of primary pneumonia, and during the last decade most departments of infectious diseases in Sweden have introduced "bottle-blowing" as a regular treatment modality in patients with uncomplicated pneumonia. However, no investigations have been published regarding the effect of this treatment. For this reason we undertook the present study.

MATERIAL AND METHODS

The study was carried out from May 1990 to March 1994 as an open randomized prospective trial. It was approved by the Ethics Committee at the Örebro Medical Center Hospital and the patients gave their verbal informed consent to participation.

Patients

The initial study population comprised all 733 adult patients (>16 years old) admitted to hospital on Mondays to Thursdays with X-ray indications of community-acquired pneumonia. The reason for not including patients admitted from Friday to Sunday was purely practical: i.e. difficulties with the randomisation procedure on those days.

Patients were excluded from the study for the following reasons: (i) Antibiotic treatment already instituted ($n = 145$). (ii) Not capable of participating (unable to blow into the vitalograph because of fatigue or dementia in most instances) ($n = 241$). (iii) In need of traditional chest physiotherapy or bottle-blowing because of profuse respiratory secretions and inability to expectorate (e.g. neuromuscular diseases) ($n = 26$). (iv) Pronounced obstructive symptoms and in need of intravenous asthma therapy ($n = 3$). (v) Patient declined to participate ($n = 22$). (vi) Patient already included from an earlier admission ($n = 6$). (vii) Physiotherapist not on duty or the patient not reported to her (mostly because the patient was discharged within 24 h) ($n = 60$). (viii) Various reasons, e.g. that the patient did not live in the County of Örebro, drug abuse, HIV positivity, and others ($n = 85$).

Patients with underlying cardiopulmonary disorders, such as heart disease or chronic bronchitis, were included.

Treatment

When a patient with a preliminary diagnosis of pneumonia was admitted, the physiotherapist was called in. If the patient qualified for inclusion in the study (for exclusion criteria see "patients", above) the physiotherapist randomly allocated him or her to 1 of 3 groups by drawing a card from a sealed envelope. Group A served as controls and, as such, underwent early mobilization and were instructed in the technique of coughing by "huffing". Group B members were given the same instructions about coughing as group A and were also instructed to sit up with their feet on the floor and take 10 deep breaths and after a short break another 10 breaths on 1 occasion every h in the daytime from 9 a.m. to 8 p.m. except for breaks for meals at noon and 5 p.m. Group C

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members were instructed in the same way as group A and in addition were given a bottle containing 10 cm of tap water and asked to sit up with their feet on the floor and blow bubbles at a calm speed into the bottle through a plastic tube (10 mm in diameter) with an air pressure just sufficient to overcome the resistance of the water. This training was also accomplished 20 times, with a short rest after the 10th time, every h from 9 a.m. to 8 p.m. with breaks at noon and 5 p.m. for meals. After discharge, group C members continued the bottle-blowing 2 times 10 on 5 occasions each day for 14 days. The same 3 physiotherapists instructed all the patients.

C-reactive protein and erythrocyte sedimentation rate

The concentration of C-reactive protein (CRP) was determined by routine immunoturbidometry in sera obtained on the day of admission (day 1), on day 4 (± 1) and on follow-up day 42 (± 2). In addition, the sedimentation rate (ESR) was measured on days 1 and 42 (± 2).

Etiology

Samples from the blood, nasopharynx and sputum, if available, were taken for bacterial cultures and processed in accordance with standard procedures. Paired sera were tested for antibodies against Mycoplasma pneumoniae, Chlamydia group antigen, influenza A + B virus, adenovirus, and respiratory syncytial virus by complement fixation.

Isolation of pathogenic bacteria in blood or purulent sputum (>5 leukocytes/squamous epithelial cell) and/or a 2-fold antibody titer rise in paired sera was used as a criterion for assigning an etiological role in pneumonia to a particular microorganism. If 1 serum was missing, an isolated titer of $\geq 1/80$ was regarded as significant. For Streptococcus pneumoniae, growth in the nasopharynx was also regarded as a conclusive finding.

Lung function tests and clinical data

Forced expiratory flow during 1 sec (FEV_1), peak expiratory flow (PEF) and vital capacity (VC) were determined with a portable vitalograph (Vitalograph-alpha I, Vitalograph Limited, Buckingham, Great Britain) on day 1, day 4, and follow-up day 42. The same 3 physiotherapists performed all the tests.

In addition, on days 1, 4 and 42, 20 consecutive patients of group A or C (10 each) and between 17 and 70 years of age and with no pulmonary disease such as chronic obstructive pulmonary disease (COPD) underwent measurements of the single-breath diffusion capacity of carbon monoxide (DCO), (Medical Graphics Corporation System 1070, St Paul, MN, USA) at the Department of Clinical Physiology (groups A_{DCO} and C_{DCO}).

Information was collected from the medical records, about prior pulmonary disease, the duration of fever and any antibiotic treatment. Patients were recorded as having COPD if they were receiving regular bronchiolytic medication on admission. Two consecutive values above 38.0°C were denoted as 1 day of fever, and 1 value above 38.0°C as 0.5 days of fever.

The physician in charge of the patient was requested to pay no attention to the study. Antibiotic treatment and medical care were administered independently of the study.

Statistics

Treatment effects on the spirometric outcome at day 4 (short-term response) and day 42 (long-term response) were tested with analysis of variance (ANOVA) models. In these models, as well as in the subsequent models, treatment was defined as a factor variable with 3 levels, each level corresponding to 1 of the treatment groups, including the control group. The spirometric measurement at day 1 and ESR and CRP, also for day 1, were entered as covariates. Separate models were analysed for VC, FEV_1 and PEF. The effect of the treatment on the number of days with fever and on the duration of hospital stay was analysed by Kaplan-Meier techniques and Cox proportional hazard regression. In the regression model SR and FEV_1 on day 1 were included as covariates. Since the proportional hazard assumption, i.e., the proportionality of the hazard functions, was somewhat in doubt and since there was no censoring of observations, supplementary multiple linear regression analyses were performed. In these analyses the logarithm of the number of days in hospital and the number of fever days, with 0.5 added to avoid logarithms of zero, were regressed on treatment (3 categories) and the same covariates as in the Cox regression.

RESULTS

After the exclusions, there remained a total of 145 patients with symptoms of an acute lower respiratory tract infection and with an X-ray suggestive of pneumonia. There were 19 drop-outs during the study: 6 patients were unable to participate (2 in group A, 3 in group B and 1 in group C) as they became too tired to do any training and blow into the vitalograph, 7 patients wished to discontinue the trial after enrolment (2 in group A, 4 in group B and 1 in group C), and 6 patients were considered by a physician or physiotherapist to be in need of chest physiotherapy after 1 or 2 days (4 in group A and 2 in group B). Available data from these 19 drop-out patients are included in all analyses.

Conditions predisposing to the pneumonia and the etiology in the 145 patients are presented in Table I. The mean age was 65 years; there was a preponderance of men (58%) and 25% were current smokers. An etiological diagnosis was verified in 41% of the patients. The differences in baseline values between the groups were not statistically significant.

The mean numbers of days with fever and days in hospital stay were lowest in group C (bottle-blowing), highest in group A and intermediate in group B (Table II), although the Cox regression model showed no significant differences between treatments regarding fever days ($p = 0.28$). Treatment had a significant effect on length of hospital stay ($p = 0.037$). Group B had a non-significant hazard ratio ($p = 0.28$), compared to the controls, whereas the hazard ratio for group C was significant ($p = 0.01$). Fig. 1 shows the percentage number of patients still in hospital each day from day 1 to day 18, the day on which all patients in the 3 groups had left the ward.

The supplementary analysis with multiple linear regression showed somewhat higher statistical significance; $p = 0.016$ for the treatment effect with respect to hospital stay and $p = 0.004$ for the significance of the effect of bottle-blowing compared to the control group. No significance was noted for deep breaths in this analysis, and there was also a non-significant result in the test of any treatment effects on fever days.

The spirometric parameters are given in Table III. As expected, VC, FEV_1 and PEF increased from day 1 up to day 42. However, the increase was of the same magnitude in all groups and treatment differences could not be found in the ANOVA models. The treatment factor was not

Table I. *Characteristics, predisposing conditions and etiology in 145 hospital-treated patients with pneumonia*

Condition/etiology	Controls (Group A) $n = 48$	Deep breaths (Group B) $n = 47$	Bottle-blowing (Group C) $n = 50$
Male/female	27/21	25/22	32/18
Mean age, years (range)	64 (16–94)	67 (23–95)	63 (16–89)
Smokers yes/no/previous (no information)	11/26/11 (0)	13/26/6 (2)	12/23/14 (1)
Chronic obstructive disease	5	5	9
History of pulmonary disease	1	4	2
No chronic pulmonary disease (no information)	41 (1)	38 (0)	39 (0)
Streptococcus pneumoniae	13	10	11
Haemophilus influenzae	3	1	0
Moraxella catarrhalis	1	0	0
Neisseria meningitidis	0	1	0
Mycoplasma pneumoniae	3	0	0
Chlamydia spp	2	1	1
Virus	2	2	3
S. pneumoniae and virus	1	3	2
Etiology not verified	23	29	33

significant at day 4 for VC, FEV_1 and PEF ($p = 0.24$, 0.84 and 0.80 respectively) and at day 42 ($p = 0.99$, 0.70 and 0.31 respectively).

Of the 20 patients in whom the diffusion capacity of carbon monoxide was measured, 3 patients in Group A_{DCO} were found to have received antibiotic treatment before admission and were therefore not included in the analysis. Additionally, 1 patient in group C_{DCO} proved to be suffering from severe COPD and was excluded from further analysis.

After these exclusions, group A_{DCO} consisted of 4 men and 3 women, with a mean age of 42.6 years. In group C_{DCO} there were 6 men and 3 women with a mean age of 46.0 years. There was 1 smoker and 1 ex-smoker in each group. On admission, the mean CRP values were 163 and 169 mg/l in the respective groups. On days 1, 4 and 42 the mean DCO values in group A_{DCO} were 25.0, 26.6 and 27.1 ml/min/mmHg, respectively. The corresponding values in group C_{DCO} were 23.0, 24.9 and 27.5. The development over time of the mean DCO, as percentages of the expected values, in groups A_{DCO} and C_{DCO} is shown in Fig. 2. Expected values were derived from a European material (7). Summing up the whole study group of 16 patients, we found significant increases in DCO ($p = 0.0005$) from day 1 to day 42. There were no significant differences between the A_{DCO} and C_{DCO} groups.

DISCUSSION

Most pneumonia patients at Departments of Infectious Diseases in Sweden are encouraged to perform bottle-blowing regularly during their hospital stay. Many patients in this study, however (see Patients) were not capable of blowing into the vitalograph on admission. This test is somewhat more strenuous than bottle-blowing, but still many of our elderly patients are too senile or tired to manage bottle-blowing treatment. We also set a rather high limit for participation (20 bottle-blowings on 10 occasions each day) in order not to overlook a real effect because of insufficient treatment. However, most patients who managed the vitalograph test were also capable of doing the bottle-blowing, as described in Material and Methods.

Our findings are, of course, only valid for the somewhat less sick and more alert patients (although our patients were relatively old with a mean age of 65 years) and cannot be directly applied in all patients hospitalized with pneumonia.

We found it very difficult to perform the study blinded. For example, to put bottles on all bed-tables could lead to bottle-blowing in the control group (the patients were old and sick), etc. The trial was consequently open and the physician responsible for the patient was able to see which group the patient belonged to. The pressure on our hospital wards, however, is so great today that it is difficult for the physicians to pay regard to any study when deciding whether a patient can be discharged. Thus we do not believe that awareness of the study group affiliation of the patient would have had any influence on the date of discharge.

For various reasons, we had some drop-outs after randomization. There were distinct reasons for these changes

Table II. *Number of days with fever, length of hospital stay and serum CRP on days 1 and 4 in 145 hospital-treated patients with pneumonia*

	Controls (Group A) $n = 48$	Deep breaths (Group B) $n = 47$	Bottle-blowing (Group C) $n = 50$
Fever, days			
Mean/median	2.3/1.5	1.7/1.5	1.6/1.5
SD/range	2.1/(0–10)	1.2/(0–5.5)	1.0/(0–4.5)
(No information)	(0)	(1)	(0)
Hospital stay, days			
Mean/median	5.3/4.0	4.6/3.0	3.9/3.0
SD/range	3.9/(2–18)	3.3/(2–16)	2.9/(1–15)
(No information)	(0)	(0)	(0)
CRP day 1, mg/l			
Mean/median	158.6/142.5	132.9/107.0	151.4/139.0
SD/range	112.9/(8–512)	92.4/(6–399)	110.1/(11–500)
(No information)	(0)	(1)	(1)
CRP day 4, mg/l			
Mean/median	114.8/99.0	102.7/71.0	91.4/75.5
SD/range	80.0/(11–370)	82.7/(5–357)	68.3/(5–368)
(No information)	(8)	(9)	(10)

and all groups were affected. In an analysis of data from the 126 patients (excluding the 19 drop-outs) who were willing and able to do their training as scheduled, a somewhat more strongly significant difference was found with regard to hospital stay in group C versus A ($p = 0.007$ in the multiple regression model) than in the "intention to treat" analysis.

An etiological diagnosis was verified in 41% (60/145) of our patients. All 3 mycoplasma infections and 2/4 chlamydia infections were found in group A. Six of these 7 patients with atypical pneumonia were given penicillin and thus received no effective antibiotic treatment. However, the hospital stay and fever duration in these 6 patients was shorter than the mean in both group A and group C (results not shown), and thus in these patients antibiotic failure did not contribute to the longer hospital stay and fever duration that was found in group A as a whole. The overall antibiotic treatment given, with a predominance of phenoxymethyl- and benzyl penicillin, as is still our tradition (8), was evenly distributed among the 3 groups and we do not consider that the etiology or antibiotic treatment was a confounding factor for our results.

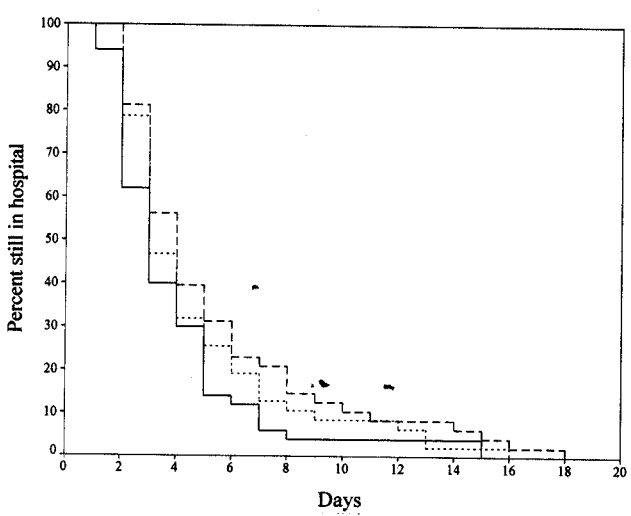

Fig. 1. The percentage number of patients of the 3 groups still in hospital on each day up to day 18. Treatment: —— = bottle-blowing, --- = deep breath, – – – = controls.

The spirometric results (VC, FEV_1, PEF) did not show any difference between the groups either during hospital stay or at follow-up, and we therefore cannot explain our results by any physiological change in the respiratory tract. The patients with the greater obstruction, i.e., those with an FEV_1 value below the mean on admission in group C, did not improve more than those without obstruction. In 8 healthy medical assistants of varying age and height, we compared the findings from our portable vitalograph with the results with the spirometer (MGC system 1070) in the physiological laboratory of the hospital. The results were almost identical and exclude technical reasons for our findings. One reason for the negative spirometric results might be a wide interindividual variation, which would have required a much larger study population to show a difference. The negative results may also indicate that the bottle-blowing method does not have any respiratory-physiological effects, or that VC, FEV_1 and PEF are not the best parameters with which to measure.

The diffusion capacity is probably one of the most sensitive routine methods for detecting changes in pulmonary function in the course of pneumonia (9, 10). Both a decreasing restrictive defect, as shown by a significantly increasing VC, and decreasing ventilation-perfusion mis-

Table III. *Spirometric parameters among 145 hospital-treated patients with pneumonia*

	Controls (Group A) $n = 48$	Deep breaths (Group B) $n = 47$	Bottle-blowing (Group C) $n = 50$
VC, day 1, (l)			
Mean	2.2	2.1	2.4
Range	(0.8–5.1)	(0.4–5.9)	(0.5–5.2)
VC, day 4, (l)			
Mean	2.4	2.3	2.4
Range	(0.7–5.4)	(0.3–5.5)	(0.6–5.3)
VC, day 42, (l)			
Mean	2.9	2.8	3.1
Range	(0.4–7.5)	(0.4–6.7)	(0.9–6.7)
FEV_1, day 1, (l)			
Mean	1.9	1.8	2.0
Range	(0.5–4.5)	(0.4–4.5)	(0.6–4.7)
FEV_1, day 4, (l)			
Mean	2.1	1.9	2.1
Range	(0.3–5.6)	(0.3–4.7)	(0.6–4.8)
FEV_1, day 42, (l)			
Mean	2.5	2.4	2.6
Range	(0.5–6.7)	(0.4–6.2)	(0.6–5.5)
PEF, day 1, (ml/min)			
Mean	308.0	282.9	333.0
Range	(72–684)	(78–808)	(90–720)
PEF, day 4, (ml/min)			
Mean	343.1	332.5	356.0
Range	(66–930)	(60–936)	(90–816)
PEF, day 42, (ml/min)			
Mean	419.1	419.1	445.5
Range	(72–972)	(66–1098)	(72–918)

match, are expected to contribute to an increasing diffusion capacity during recovery from acute pneumonia (11). In our 16 patients studied by DCO there was perhaps a tendency in favour of the bottle-blowing group ($p = 0.11$),

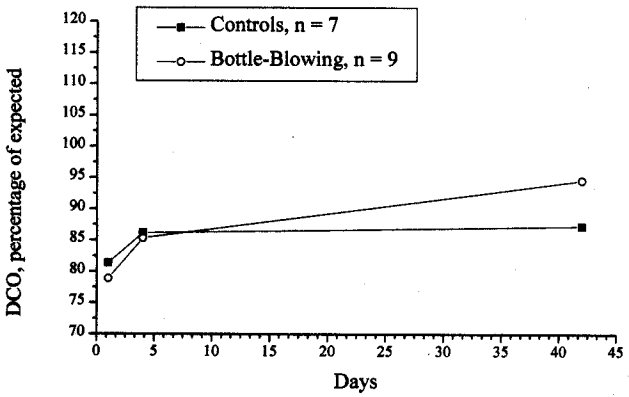

Fig. 2. The single breath diffusion capacity of carbon monoxide (DCO) in a subset of the bottle-blowing group and of the control group.

but the material is too small to allow any conclusions. To measure the diffusion capacity requires a cooperative patient who is able to hold his breath for 10 sec. Mildly ill patients are not admitted to hospital nowadays and so it took us several years to include these patients.

Group B (deep breaths) served as a middle course treatment in an attempt to determine whether specific benefit was obtained from the bottle-blowing method or whether the positive results were due to more unspecific mechanisms. The results support the latter possibility, perhaps because the patients in groups B and C automatically sat up more regularly in bed, felt psychological benefits from the activity and also possibly experienced more attention from the nursing staff. But the earlier discharge of the group C patients indicates a specific positive effect of the bottle-blowing itself. The shorter duration of fever and lower CRP on day 4 (though not statistically significant) in the bottle-blowing group, suggests that the treatment might have a draining effect by removal of infected respiratory secretion, and thus an antiinflammatory effect. It is also our strong impression that bottle-blowing induces coughing and sputum expectoration and improves the oxygen saturation. It might have been of interest, although controversial (2), to estimate the amount of sputum from each patient and day, but for practical reasons this was not done.

When planning the study we did not actually expect any effect of the bottle-blowing. The significantly shorter hospital stay in this treatment group was therefore to some extent surprising. The treatment is simple, inexpensive and as far as we can see without any side effects. The cost-benefit of the training is impressive and of course we find the results very interesting and promising. The study needs to be repeated by other investigators, but in the meanwhile, more intensively and enthusiastically than before, we are trying to use bottle-blowing as routine treatment in most of our patients with pneumonia.

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