Physiological Effects of Exsufflation with Negative Pressure (E.W.N.P.)

GUSTAV J. BECK, M.D., F.C.C.P. and LOUIS A. SCARRONE, M.D.
New York, New York

The method of producing rapid expiratory flow rates of air from the lungs has been termed Exsufflation With Negative Pressure,\(^1\)\(^2\)\(^3\) or E.W.N.P. Since the apparatus, shown in Figure 1,\(^*\) is capable of producing intrathoracic pressure changes greater than those effected by pressure breathing devices currently available, studies were made on the effects of E.W.N.P. on the cardiovascular system and, because of its use in postoperative patients with surgical wounds of the abdomen,\(^4\) on the changes in intra-abdominal pressure during this procedure. The changes in position of the diaphragm during E.W.N.P. in patients with an ineffective cough were also found of interest as an indication of the degree of aeration and deflation of the lungs accomplished by this apparatus.

The purpose of this report is to summarize the results obtained from determining the effect of E.W.N.P. on the following functions: heart rate, electrocardiogram, arterial blood pressure, venous pressure, cardiac output, intragastric pressure, and motion of the diaphragm in normal subjects and in patients whose spontaneous cough is ineffective.

**Principle of Operation**

Exsufflation With Negative Pressure is a method of mechanical coughing which utilizes (1) a gradual build-up of positive pressure of 20 to 40 mm. Hg. over a period of 1.5 to 2.5 seconds to achieve a full inflation of the lungs and a dilation of the bronchial tree\(^1\)\(^5\) and (2) a swift fall in pressure to 40 mm. Hg. below atmosphere. This pressure drop of 60 to 80 mm. Hg. beginning at the peak of the inspiratory phase results in a sudden expansion of the intrathoracic gases of 1/12th to 1/9th of the total lung volume. The kinetic energy of the current of air due to the establishment of a pressure gradient between the alveoli and the mouth is responsible for the movement of mucus from the smaller bronchi to the upper respiratory tract. During the expiratory negative pressure phase, volume flow rate of air are achieved which are often as high as those produced by a normal subject during his maximal natural cough.\(^1\) This mouthward directed high expiratory velocity includes the explosive decompression effect in expelling sputum, foreign bodies, or a thorotrast mixture toward the mouth.\(^5\) The expiratory phase is completed with the application of 40 mm. Hg. negative pressure for 1 to 1.5 seconds at the mouth. During this phase emptying of the lungs occurs. The apparatus

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\(^*\)This apparatus is manufactured by the Oxygen Equipment Manufacturing Company, East Norwalk, Conn.
is applied to the patient by means of a mask or mouthpiece. The sequence of pressure changes occurring at the mouth (the intramask pressure) is shown in Figure 2.

The unconscious patient is treated with the neck in a hyperextended position and frequent pharyngeal suction accompanies the procedure. The conscious patient is requested to allow the chest to be passively inflated without voluntary effort. Exsufflation With Negative Pressure has been used successfully in the relief of dyspnea and partial bronchial obstruction by elimination of mucous and purulent plugs or blood clots, as well as aeration of atelectatic lungs, in patients with poliomyelitis, Guillain-Barre syndrome, myasthenia gravis, paraplegia due to cerebral injury, fractured ribs, pulmonary emphysema, bronchial asthma, bronchiectasis and in various postoperative pulmonary complications.2 3

FIGURE 1: The portable E.W.N.P. apparatus is designed with adjustments for volumes, pressures and respiratory cycle timing. Separate outlets for inspiratory and expiratory airflows, containing a filter on the inspiratory side, are new additions to the original design for the prevention of cross-contamination of the two sides.
Methods

Electrocardiographic changes due to E.W.N.P. were observed during a control period of the patient's normal respiration and the period of E.W.N.P. The heart rate was computed from the electrocardiographic record. The electrical axis was determined from the AVR, AVL, AVF and V4 leads. X-ray films of the chest were taken during the maximal voluntary inspiratory and expiratory positions and compared with those produced by the mechanically-induced inspiration and expiration pressures of plus 40 mm. Hg. and minus 40 mm. Hg. Intramask pressures were determined by means of a sphygmomanometer during a control period and in the course of E.W.N.P. A pressure transducer amplifying and recording system was used in the determination of the intragastric pressures using thin rubber balloons, inflated moderately and located in the stomach. Normal subjects, pre- and postoperative patients, and those with bronchopulmonary diseases were tested. The subjects were thoroughly trained in the use of E.W.N.P. prior to each experiment. The cardiac output was determined in a normal subject by the radioactive sodium dilution technique during a control period and E.W.N.P. The value of this method in recording consistent absolute values has not yet been established. In most instances five exsufflations with E.W.N.P. were given in succession eight to 10 times in a row. For the purpose of presentation in this report the data were averaged and summarized. The pressure

FIGURE 2: Intramask pressure curve produced by (E.W.N.P.). Following a gradual rise of positive pressure in inspiration to 40 mm. Hg. above atmosphere in two seconds, a sudden pressure drop to 40 mm. Hg. below atmosphere occurs in 0.04 seconds. The negative pressure is maintained for approximately 1.5 seconds.
recording equipment was standardized immediately before and immediately after the recordings of intramask, intragastric, and venous pressures. The changes in gastric pressure were compared during normal ventilation, hyperventilation, natural cough, and E.W.N.P. The changes in venous pressure during normal ventilation, natural cough, and E.W.N.P. were similarly compared.

Results

Effect of E.W.N.P. on Heart Rate, Blood Pressure, and Electrical Axis of the Heart. Six normal subjects and six with pulmonary emphysema revealed an average increase in heart rate of 17 to 10 beats per minute respectively during the application of E.W.N.P. as compared to the control period. Two subjects revealed no change. Of 22 patients and normal subjects in whom blood pressures were taken, a slight but insignificant rise in blood pressure occurred during E.W.N.P. The range of blood pressure during the control period was from 190 to 105 mm. Hg. systolic and from 110 to 68 mm. Hg. diastolic. The mean increase in systolic pressure was 8 mm. Hg., and in the diastolic pressure 4 mm. Hg. On inspiration with E.W.N.P. the electrical axis of the heart in six normal subjects and six patients with emphysema was changed in a manner similar to that induced by a full normal inspiration. Similarly, no difference in electrical axis was observed when the electrocardiogram during normal expiration

<table>
<thead>
<tr>
<th>Experiment Number</th>
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<tr>
<td>AVERAGE</td>
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</tr>
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was compared to the expiratory phase of E.W.N.P. during the application of 40 mm. Hg. pressure below the atmosphere.

*Effect of E.W.N.P. on Venous Pressure.* In 12 normal subjects, patients with bronchopulmonary disease and poliomyelitis, the venous pressure rise during their own natural cough above the control level averaged 161 mm. of water. During E.W.N.P. the average rise in peak venous pressure in 17 subjects with bronchopulmonary disease and poliomyelitis was 58

![Tracings](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21273/)

**FIGURE 3:** Tracings, representing the venous pressure rises occurring during the voluntary cough and E.W.N.P. in a normal subject.

![Bar graph](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21273/)

**FIGURE 4:** In 17 patients with bronchopulmonary disease the venous pressure rise over the resting (control) venous pressure with E.W.N.P. did not exceed 150 mm. H₂O. During the natural cough in 12 patients the venous pressure rise ranged from 50 mm. H₂O to 260 mm. H₂O.
mm. H$_2$O. (Table I). The difference of the venous pressure changes during E.W.N.P. and a maximal natural cough are shown in Figure 3. The venous pressure changes occurring during natural coughing and E.W.N.P. in subjects with bronchopulmonary disease are shown in Figure 4.

**Effect of E.W.N.P. on Cardiac Output.** The radioactive sodium method of determining cardiac output was used in one subject. The total cardiac output in litres per minute was 4.5, 4.6 and 4.8 during the control period, and 6.8 liters per minute during E.W.N.P. at plus 30 and minus 40 mm. Hg. pressure, an increase of 2.1 litres per minute.

**Effect of E.W.N.P. on Position of the Diaphragm.** The position of the diaphragm in nine subjects with pulmonary emphysema was compared during both voluntary inspiration and inspiration produced by a positive pressure of 30 mm. Hg. and during voluntary expiration and expiration produced by a negative pressure of 40 mm. Hg. Increases in descent of the diaphragm induced by E.W.N.P. were 1 to 3 cm. above that recorded in voluntary inspiration in five of the nine patients. An increase in the ascent of the diaphragm during E.W.N.P., compared to normal expiration, occurred.

<table>
<thead>
<tr>
<th>TABLE II</th>
<th>THE EFFECT OF POSITIVE AND NEGATIVE PRESSURE ON THE POSITION OF THE DIAPHRAGM</th>
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<tr>
<td></td>
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<td>2 cm. to 3 cm.</td>
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*Figure 5: Chest x-ray during natural inspiration (A) and expiration (B) in a patient with pulmonary fibrosis and emphysema reveals markedly diminished diaphragmatic excursion.*
in four of the nine patients (Table II). These changes are illustrated in Figures 5 and 6.

*Effect of E.W.N.P. on Intragastric Pressures.* In nine patients the peak and mean intragastric pressure changes during normal breathing and hyperventilation were determined. The average peak and mean pressure changes during hyperventilation were 15.5 and 7.3 mm. Hg as compared to 7.11 and 3.7 mm. Hg. during normal breathing respectively. In 10 patients the intragastric pressures with E.W.N.P. were 26 mm. Hg. as compared to 7.1 mm. Hg. during normal ventilation. During a natural cough the average peak pressure of 10 subjects was over 85 mm. Hg. and the average mean pressure 32.4 mm. Hg. The individual cases are sum-

### TABLE III

<table>
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<tr>
<th>Subject</th>
<th>Normal Ventilation</th>
<th>Hyperventilation</th>
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<td>2.1</td>
<td></td>
<td>11.0</td>
<td>90+</td>
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</table>

*Figure 6A* and *Figure 6B*

*Figure 6:* Chest x-ray of the same patient revealed much greater diaphragmatic motion between inspiration (A) and expiration (B) induced by E.W.N.P. as compared to voluntary respiration, seen in Fig. 5.
Exsufflation With Negative Pressure, a method developed for the mechanical elimination of retained secretions, functions by means of a specially-designed alternating positive-negative pressure-type respirator. The intramask pressures are produced by the pressure and vacuum side of a blower unit: the gradual introduction of a volume of air sufficient to produce nearly maximal inflation of the lungs, utilizing a pressure head of 20 to 40 mm. Hg. above atmosphere over a period of 1.5 to 2.5 seconds, produces cardiovascular effects similar to those described in tank exsufflation, an earlier method of mechanical coughing. Since the pressure curve drops swiftly from 40 mm. Hg. above atmosphere to atmosphere in exsufflation, the mean effective positive pressure applied within the chest during the respiratory cycle is relatively low. In E.W.N.P. a still lower mean pressure is produced because of the high negative pressure during expiration. Pressure breathing has previously been shown to effect rises in venous pressure which were more marked in cases with congested and less compliant lungs than those of normal subjects.

The compensatory venous pressure rise was found to be dependent on the applied mean intrapulmonary pressure whether intermittent or continuous positive pressure was used and amounted to about 40 per cent of the applied intramask pressure. In normal subjects in whom...
the applied mean pressure is between plus 10 to 15 mm. Hg., a lowering of the cardiac output and a lengthening of the circulation time generally was found to occur. The increased amount of blood returning from the peripheral venous circulation during intermittent expiratory negative pressure breathing resulted in a lowering of venous pressure. The combination of inspiratory positive and expiratory negative pressure was more beneficial as an artificial respiration technique in experiments on dogs whose circulation was seriously impaired than intermittent positive pressure breathing. This has been recently confirmed clinically.

Exsufflation With Negative Pressure in subjects with relatively stable circulatory systems produced only minimal changes in arterial blood pressure and a slight rise in heart rate. The rise in venous pressure, averaging 5.8 cm. of water throughout the entire cycle of E.W.N.P., is higher than what would be expected with the mean intramask pressures obtained on this series of normal subjects. Since the inspiratory volume increases with the duration of inspiration, variations in venous pressure response due to E.W.N.P. depend in part on the lung volume of the subject. Also, larger venous pressure rises occurred in patients whose full cooperation was not enlisted during the experimental procedure, i.e., those in whom contracture of the thoracic musculature resulted in undue resistance to the inspiratory air flow. A greater venous pressure rise takes place under these circumstances than when passive inflation of the chest occurs.

**FIGURE 8**: Intragastric pressure curves in a normal subject show a markedly higher peak during a spontaneous cough than during E.W.N.P. and hyperventilation.
during the positive pressure phase. An increased venous pressure has been previously noted after the application of a compressing bandage or vest around the chest, which increases the rigidity of the thorax and thus transmits the increased intrapulmonary pressure to the peripheral venous reservoir. The increase in venous pressure during external chest compression may finally become as large as the applied mean positive pressure which was noted in subjects with "elastic" lungs; in the latter cases passive expansion of normal lung tissue absorbs 60 per cent of the pressure.

The moderate increase in cardiac output produced by E.W.N.P. in the one patient reported may possibly be ascribed to a combination of two factors: first, the negative pressure phase of the intramask pressure in this particular experiment was larger (minus 40 mm. Hg.) than the positive pressure phase (plus 30 mm. Hg.) resulting in a subatmospheric mean mask pressure throughout the respiratory cycle and conceivably a larger venous return to the heart over the period of the 10 cycles of E.W.N.P.

**FIGURE 9:** In a patient with pulmonary emphysema the peak intragastric pressure rise during spontaneous coughing is much greater than during E.W.N.P., hyperventilation and quiet respiration. The magnitude of peak pressures is similar to that of the normal subject.
than during the control period. Second, hyperventilation produced by the use of E.W.N.P. may have increased the cardiac output. The first explanation, assuming an increased venous return, appears less likely because of the consistent increase in venous pressure occurring during E.W.N.P.

It was apparent that the hyperventilation produced by E.W.N.P. in patients with bronchopulmonary disease caused diaphragmatic motion greater than that produced by the patient's own inspiratory or expiratory effort in some cases. A similar situation had been previously noted in patients in whom diaphragmatic motion was impaired by paralysis due to poliomyelitis. In patients with pulmonary emphysema increased diaphragmatic motion whether produced by E.W.N.P., the head-down position, or training in diaphragmatic breathing is an important contributory factor in improving ventilation of the alveoli of the lower lobes and drainage of their respective bronchioles.

A comparison between the mean venous pressure increases during E.W.N.P. and natural coughing reveals a much more pronounced rise during the human cough. The changes found indicate that the intrathoracic pressure rise produced by muscular contraction occurring during a natural cough are much higher than those of the positive pressure phase of E.W.N.P. The efficiency of the natural cough, however, is not entirely dependent on the pre-expulsion build-up of intrathoracic pressure. The high intrathoracic pressure head, is designed to facilitate the production of high expiratory velocities in an attempt to propel sputum through the larynx. In patients with pulmonary emphysema, the production of high intrathoracic pressures during the glottis-closure phase of the natural cough and the subsequent pressure drop may result in an even greater pressure difference between the alveoli and lumen of the bronchioles than that normally present. This high alveolar-bronchial gradient may result in a premature closure of the bronchioles and complete obstruction to flow of air from the alveoli to the larger bronchi. The high intrathoracic pressures produced by these patients during coughing are thus frequently ineffective in moving sputum from the bronchioles to the upper respiratory tract. Since high expiratory volume flow rates may be achieved with presumably low intrathoracic pressures during E.W.N.P., it may be an effective means for the elimination of sputum in emphysematous patients, i.e., in delivering it to the area of tracheal bifurcation where it may be expectorated.

Patients with abdominal wounds often have great difficulty with the elimination of sputum during the postoperative period. Elevation of the diaphragm due to gaseous distention with diminished diaphragmatic motility, pain during coughing due to the necessity for contraction of the abdominal musculature during the period of closure of the glottis, and the accumulation of large amounts of secretions in the tracheobronchial tree are contributory factors to postoperative pulmonary complications. On the fourth to sixth postoperative day, when the sutures lose some of their effectiveness in holding the wound together, a forceful cough may
produce wound disruption. The clinical effectiveness of E.W.N.P. in preventing and combating postoperative pulmonary complications was accompanied by absence of wound complications, and much less pain than produced by voluntary coughing. The study of the differences in intragastric pressure, which is a reflection of the intra-abdominal pressure during the natural cough with E.W.N.P., offered a reassuring explanation for the advantages of this mechanical method over the natural cough. Since the average peak gastric pressures produced by E.W.N.P. were less than one-third of those produced by the natural cough, and not accompanied by active musculature contraction, stress on the abdominal wound and the consequent production of pain were minimal.

SUMMARY

The effects of Exsufflation With Negative Pressure (E.W.N.P.), a mechanical method of eliminating retained secretions, were studied in respect to cardiovascular function, diaphragmatic motion, and intragastric pressure.

The physiological effects of E.W.N.P. were studied in 17 patients with bronchopulmonary disease with special reference to changes induced on the circulation. Although inspiratory pressures of 40 mm. Hg. were employed to inflate the lungs, the use of a negative lung deflating pressure of 40 mm. Hg. during the expiratory cycle resulted in comparatively low mean ventilatory pressures and, consequently, only slight rises in peripheral venous pressure, i.e., 5.8 cm. H$_2$O. In contrast, a much higher venous pressure rise took place during the patients' natural vigorous cough, i.e., 16.1 cm. H$_2$O. Small changes in arterial blood pressure also occurred during E.W.N.P., viz., an average increase of 8 mm. Hg. in systolic and 4 mm. Hg. in diastolic pressure in 22 subjects.

Changes in the electrical axis of the heart due to nearly maximal lung inflation and deflation were similar to those induced by the deepest possible voluntary inspiration and expiration.

Elimination of mucopurulent secretions by E.W.N.P. postoperatively seemed a somewhat safer procedure than the use of the patients' natural cough since intra-abdominal pressure was lower with this procedure: with E.W.N.P., the rise in intragastric pressure averaged 26 mm. Hg. in comparison to a rise of 85 mm. Hg. during the patient's cough. The reduction in pain at the wound site during the use of E.W.N.P. as compared to voluntary cough further suggested its value as a safety factor in respect to healing of abdominal wounds in the postoperative state.

An average rise of 8 mm. Hg. systolic and 4 mm. Hg. diastolic in arterial blood pressure took place in 22 subjects. The change in electrical axis of the heart during the positive and negative pressure cycles were similar to those induced by the deepest possible voluntary inspiration and expiration.

In 17 patients with bronchopulmonary disease and poliomyelitis an average venous pressure rise of 58 mm. H$_2$O over the control level occurred during E.W.N.P. as compared to that of 161 mm. H$_2$O in 12 of these
subjects during their own natural cough. The relatively slight rise in blood pressure and venous pressure during E.W.N.P. was related to the low mean mask pressure found in this type of pressure breathing. Higher rises occurred in subjects who resisted inspiratory inflation by the apparatus. In conscious patients, cooperation with the technique of E.W.N.P. is an essential factor in the effective use of this apparatus.

**RESUMEN**

Se estudiaron los efectos de la exufación a presión negativa (E.W.N.P.) con un procedimiento mecánico para eliminar las secreciones retenidas y se investigó la función cardiovascular, la movilidad del diafragma y la presión intragástrica.

Se estudiaron los efectos fisiológicos de la E.W.N.P. en 17 enfermos de afecciones broncopulmonares en especial con relación a los cambios provocados en la circulación. Aunque se emplearon presiones inspiratorias de 40 mm. Hg. para inflar los pulmones, el uso de una presión negativa para desinflar los pulmones, de 40 mm. Hg. durante el ciclo expiratorio produjo presiones medias comparativamente bajas y por consecuencia sólo elevaciones ligeras en la presión venosa periférica como 5.8 cm. H2O.

En contraste hubo un aumento mucho mayor de la presión venosa durante el esfuerzo vigoroso de la tos natural o sea como 16.1 cm. H2O. Ocurrieron también pequeños cambios en la presión arterial durante la E.W.N.P. o sea un término medio de 8 mm. Hg. en la sistólica y 4 mm. Hg. en la diastólica de 22 sujetos.

Los cambios en el eje eléctrico del corazón debidos a una inflación casi máxima y la desinflación fueron similares a los provocados por la inspiración profunda máxima, voluntaria y por la expiración.

La eliminación de secreciones mucopurulentas por la E.W.N.P. postoperatoriamente pareció un procedimiento algo más seguro que el uso de la tos natural de los enfermos puesto que la presión intrabdominal fué más baja con el procedimiento: con la E.W.N.P. la elevación de la presión gástrica fué como media 26 mm. Hg. en comparación con una elevación de 85 mm. Hg. durante la tos del enfermo. La reducción en el dolor en la herida durante el uso de la E.W.N.P. en comparación con la tos voluntaria sugiere además que tiene valor como un factor de seguridad en lo referente a la curación de las heridas abdominales postoperatoriamente.

Una elevación media de 8 mm. Hg. sistólica y 4 mm. Hg. diastólica en la presión arterial ocurrió en 22 sujetos. Los cambios en el eje eléctrico del corazón durante los ciclos de presión positiva y negativa fueron similares a los inducidos por las inspiraciones y expiraciones voluntarias más profundas.

En 17 enfermos con enfermedad broncopulmonar y poliomielitis la elevación arterial y venosa durante la E.W.N.P. estaba en relación con la media encontrada por la máscara en esta forma de respiración a presión. Ocurrieron elevaciones mayores en los enfermos que resistían a la inflación por el aparato. En los enfermos conscientes la cooperación con la técnica de E.W.N.P. es un factor esencial para el uso efectivo del aparato.
RESUME

Les auteurs étudient les effets de l'exsufflation en pression négative, procédé mécanique qui permet l'évacuation des sécrétions, au point de vue de la fonction cardiovasculaire, du mouvement diaphragmatique et de la pression intragastrique.

Les effets physiologiques de l'exsufflation en pression négative furent étudiés chez 17 malades atteints d'affections bronchopulmonaires en envisageant particulièrement les altérations apportées dans la circulation. Bien que les pressions inspiratoires de 40 mm. de mercure furent utilisées pour gonfler les poumons, une pression négative de désinsufflation de 40 mm. de mercure durant le cycle respiratoire amena des pressions ventila- toires comparativement faibles. Il en résulta des hausses de la pression veineuse périphérique qui restèrent légères : c'est-à-dire atteignirent 5,8 cm. d'eau. À l'opposé, à l'occasion d'un violent accès de toux, on assista à une élévation beaucoup plus grave de la pression veineuse qui atteignit 16,1 cm. d'eau. De petites modifications de la pression artérielle survinrent aussi pendant l'exsufflation en pression négative, une augmentation moyenne de 8 mm. de mercure de la pression systolique et de 4 mm. de mercure de la pression diastolique, chez 22 malades.

Des modifications dans l'axe électrique du coeur, dues à une extension et à une déflation proches du maximum, furent semblables à celles produites par l'inspiration et l'expiration volontaire la plus profonde possible.

L'élimination de sécrétions mucopurulentes par l'exsufflation en pression négative sembla après l'opération être quelque peu plus efficace que le moyen de la toux naturelle des malades, puisque la pression intra-abdominale fut plus faible avec ce procédé : avec l'exsufflation en pression négative, le taux de la pression intragastrique atteignit 26 mm. de mercure, en comparaison du niveau de 85 mm. atteint pendant la toux du malade. Le soulagement de la douleur à l'endroit de la cicatrice pendant l'emploi de l'exsufflation en pression négative, comparée à la toux volontaire, prouve sa valeur comme moyen de secours pour la guérison des blessures abdominales en phase postopératoire.

La moyenne de 8 mm. de mercure en systole, et de 4 mm. en diastole dans la pression sanguine artérielle se vérifia chez 22 malades. Les modifications dans l'axe électrique du coeur pendant le cycle de pressions positives et négatives furent semblables à celles produites pendant l'inspiration et l'expiration volontaire la plus profonde possible.

Chez 17 malades atteints d'affections bronchopulmonaires et de poliomyélite, le niveau moyen de la pression veineuse pendant l'exsufflation en pression positive, donne les chiffres les plus bas trouvés dans ce type de pression respiratoire. De plus hautes moyennes furent notées chez les sujets qui résistaient à l'inflation inspiratoire par l'appareil. Chez les malades conscients, la coopération à la technique de l'exsufflation en pression négative est un facteur essentiel pour l'efficacité de cette méthode.
ZUSAMMENFASSUNG

Die forcierte Ausatmung mit negativem Druck (hier mit der Abkürzung E.W.N.P. bezeichnet) ist ein mechanisches Verfahren zur Ausscheidung verhaltener Absonderungen, dessen Wirkung auf die Herz-Gefäßfunktion, die Zwerchfellbewegung und den Druck innerhalb des Magens untersucht wurden.

Die physiologischen Wirkungen der E.W.N.P. wurden an 17 Patienten mit bronchiopulmonalen Erkrankungen studiert unter besonderer Berücksichtigung der den Blutkreislauf betreffenden Veränderungen. Obgleich zur Aufblasung der Lungen ein Druck von 40 mm Hg angewandt wurde, führte die Verwendung eines negativen Druckes von 40 mm Hg zum Ablassen der Luft aus den Lungen während der Ausatmungsphase zu verhältnismässig niedrigen mittleren Ventilationsdruckwerten und folglich zu nur leichten Anstiegen des peripheren Venendruckes, d.h. 5,8 cm H₂O. Im Gegensatz dazu trat während des natürlichen heftigen Hustens des Kranken ein viel höherer Anstieg des Venendruckes ein, nämlich 16,1 cm H₂O. Es wurden auch geringe Veränderungen des arteriellen Blutdrucks während der E.W.N.P. beobachtet, nämlich (an 22 Versuchspersonen) ein durchschnittlicher Anstieg des systolischen Druckes um 8 mm Hg und des diastolischen um 4 mm Hg.

Die durch die fast maximale Auf- und Abblasung der Lunge hervorgehenden Veränderungen in der elektrischen Achse des Herzens ähnelten denen, die bei tiefstmöglicher willkürlicher Ein- und Ausatmung zustande kommen.


REFERENCES


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