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Developing a Portable Percussion Device for the Rehabilitation of Patients with Respiratory Diseases

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Having been escalating over the last 3 decades, lung conditions are one of the most significant causes of fatalities worldwide main purpose of developing a portable percussion device for the rehabilitation of patients with respiratory diseases is to drain lung secretions of patients hospitalized in ICU or other patients. The designed device somehow simulates physiotherapist's hand move. Since the manual percussion is limited and harmful to the physiotherapist, the new device is looking for a mechanism to somehow do the linear hand move of physiotherapists. The linear move must include two main factors: 1) control of the speed of strike, and 2) control of the strength of strike. These two factors are varied across different patients. To use an electrical solenoid is, therefore, the best mechanism. Given its portability, the device can be easily used at both sides of the patient (at the back and in front of the rib cage) to get secretions drained percussion move and vibration shouldn't be done on bone bumps along spinal column-sternum- abdomen, some ribs- stitched areas-kidneys-liver- or beneath rib cage. Reviewing the existing mechanisms of percussion, qualities such as convenience, portability and energy source availability make it possible for people other than the physiotherapist to use this technique. This device is capable of regulating speed, strength, and course according to the specific needs of patients.

Key words: physiotherapy of lung system, percussion, pulmonary diseases, techniques for cleansing the nasal passages.

Respiratory disease, which is usually related to lung condition, includes a group of diseases which disrupt lung function by damaging some part of the respiratory system[1,2]. Lungs are the vital part of the respiratory system playing a part in supplying oxygen to different body tissues and taking carbon dioxide out. Bronchus, Bronchiole and Alveoli are critical parts of the lungs which may be damaged by a respiratory disease. The damage sometimes happens to lung tissues or its blood vessel[1]. A number of people are annually affected by lung condition, causing individual's daily performance to decline[2,3]. In England, lung system related diseases are the most common reason for visiting a GP[1,4]. Lack of physical activity due to long rests in ICU or spinal damages which prevent man from moving around makes body fluids concentrated which in turn results in concentrated and viscous pulmonary secretions. This gives rise to a decline in the amounts of breath, volume of breath, and causes atelectasis. This condition also makes the lungs susceptible to infections[5,6]. Respiratory physiotherapy is, therefore, a critical step for these types of patients [7]and its various methods are employed depending

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on the conditions of patients (surgery, intensity of the disease etc.)[8]. Those diseases that need to be treated with respiratory physiotherapy are: operations on chest, poor health of respiratory system muscles, fragility of ribs, respiratory diseases like pneumonia, pulmonary embolism, bronchiectasis, atelectasis, chronic bronchitis, emphysema, asthma, respiratory system cancer, and diseases such as cardiac ischemia, thrombophlebitis, waris etc. Lung physiotherapy is recommended before and after all types of surgeries[9]. Respiratory physiotherapy has its own principles and methods which are applied, according to the patient's conditions. These techniques are:

Percussion: this technique is used to more move secretions and removes viscous mucus from the lungs. By using cup-shaped hands, percussion is placed on a lung segment being drained (Fig. 1).

Vibration: this airway clearing technique is used along with percussion for postural drainage. It is used during deep exhales-while the patient is taking deep breathes- to get secretions to move towards larger airways.

Shaking: this is rougher than vibration and used during exhales with the aid of hands.

Postural drainage techniques: depending on the lungs anatomy and trachea and bronchial tree, postures are prescribed to the patient (Fig. 1).

a) Stimulating patients to cough and training them in this regard
b) Respiratory exercises
c) Carrying out suction

The devices and methods of respiratory physiotherapy employ the above mentioned techniques. These devices include manual or mechanical percussion, positive expiratory pressure, oscillatory, and high frequency chest wall oscillation. One of the techniques used by physiotherapists is manual percussion technique where the physiotherapist lifts the patient's head to some extent and their feet up to 30 cm, and then repeatedly beats on the areas where secretions are concentrated in a rhythmic and hammer-like way and afterwards the patient discharges secretions giving coughs and taking deep breathes[10]. In this technique, as the physiotherapist gets tired, the frequency of strikes will decline; this technique also causes problems to the physiotherapist's wrist joint[11]. As for a patient with lung disease, it takes about 15 to 30 minutes to get secretions drained, yet the above mentioned problems prevent the physiotherapist doing it right. Low income and problems emerging during the treatment will deprive most of patients with lung disease of the treatment. Developing a portable device for physiotherapy of the lung system is promising in that it reduces the challenges faced by the physiotherapist and is really an inexpensive way of treatment in comparison[12]. It is noteworthy that percussion can't be performed on bone bumps along the spinal column, sternum, abdomen, some of the ribs, stitched areas, kidneys, or beneath rib cage and the ideal frequency of strikes differs from a physiotherapist to another (considering the factors mentioned, the number of strikes ranges from 0.1 to 8 Hz[13], and the strength or magnitude of strikes differs as well (depending on the gender, age, weight, and BMI of patients, the extent of force is varied)[13]. The portability of the device allows for us to put it on a spot in the lung system that is the best for the drainage of concentrated secretions[13]. A variety of devices have been, therefore, developed for cleansing the lung system, including:

Positive expiratory pressure: this device have secretions detach from the lung, resisting the patient's exhales.

oscillatory devices: this manual device works by blowing into it and make the respiratory tract vibrate by creating an open-closed cycle.

High frequency chest wall oscillation: this device looks like a vest and makes the chest vibrate by putting pressure via a generator which fills or empties the device from outside.

Given the test, the duration of device application, and the type of disease, each of these devices can or can't work[14-16]. In most cases, however, the techniques used by physiotherapists doesn't differ from other ways and even work better than the mechanism mentioned under certain circumstances[10,17-19]. But as mentioned earlier, this method has limitations and disadvantages. According to the duration and frequency of strike, this method takes a great deal of energy, and making vibration after the manual percussion causes problems to the physiotherapist and gets him/her fatigued[11]. We are, therefore, trying to develop a device that bears a close resemblance to

the physiotherapist's practice, reduces damages to the physiotherapist, is capable of performing physiotherapy on all lobes of the lung in full, could be used by the patient, and the patient could use it on his/her own, according to the type of disease. Given the existing problems, the mechanical percussion device developed by us is useful in this regard[20,21]. This device does percussion on the external parts of the chest and the affected lobes of the lung and has programmed in terms of strength and speed. The device is portable and can be moved across the patient's chest as the patient lies in positions necessary for secretions drainage (Fig. 1).

Subjects and methods

The review of the mechanisms of existing percussion as well as their portability, convenience, and energy source availability produced the following results, as shown in the table below.

Considering the information presented above, we were looking for the best method for the mechanical percussion (this device was registered by the names of Ali Abedinpuor and Kamran Azma and numbered 139350140003009674 in the Department of Real Estate Registration of Islamic Republic of Iran- Industrial Property Department), and eventually, simulated the linear move of the hand by means of solenoid.

Device mechanism

Since the speed and strength of strikes are two main factors in percussion, the best mechanism is to use electrical solenoid. The variables are voltage, current, on-off time, force, and speed. Solenoid for the best performance was designed given the needs of the project.

As an electrical current passes through a coil, a magnetic field will appear around it; if the current is constant, the extent of the magnetic field will also be constant at each point around the coil. Accordingly, the direction of the magnetic field is also constant. On the other hand, if an electrical current is varied, the magnetic field will be varied. It means that the direction and intensity of the magnetic field constantly vary. In this device, since we were looking for a certain amount of force as to determine the peak of strike, the results were satisfactory and changes in voltage caused changes in the force of solenoid. The results are presented in the following table.

Also, the extent of the device's course can be electronically and mechanically regulated. With on-off time, we can control the length of plunger course as well as speed which are varied depending on the patient's fatty tissues and particulars.

Measuring solenoid force

A dynamometer was used to measure solenoid force. To measure force at different positions of plunger, 8 one mm washers were placed between dynamometer and plunger and after taking off each washer, we measured force at any given position and eventually obtained the right results

Getting force increased and decreased

According to laws of physics, we can control the force of solenoid by controlling voltage and current. As electrical current in the wire rises or falls, so does force.

RESULTS AND DISCUSSION

After using the device continually, patients with pulmonary and respiratory problems improve and their respiratory system functions far better than before. Since some patients find it difficult or impossible to move to receive respiratory physiotherapy, this device can aid the physiotherapist. The mechanical percussion is superior to other devices due to its portability and convenience able use. The device can be, also, used more convenienceably than vest-like devices. Since ICU patients and patients with spinal injuries can hardly move around, it is preferable to use portable local devices like the mechanical percussion. Speed and strength control and regulation is another advantage of the device which can be adjusted depending on patients' particulars and factors. According to the range of force to get percussion moved, the developed device can produce the same amount of force. Comparison between voltage and plunger force A number of research studies have studied the efficacy of devices which have yielded different results depending on the type and method of each device as well as the way by which the amount of drained secretions was measured[22]. To measure the efficacy of the lung system, spirometer which is a common way for measuring lung capacity is used. Regardless of problems faced by a patient with pulmonary disease, each of existing devices can

Table 1. The review of the mechanisms of existing percussion

Device	The Vest®	Flutter®	Acapella®	Designed device[1]
Portability	Hardly	Yes	Yes	Yes
Regulation of speed	Yes	-	-	Yes
Regulation of strength	Yes	-	-	Yes
Regulation of course	-	-	-	Yes
Applicable at specific spot of the lung system	-	-	-	Yes
vibration	Yes	Yes	Yes	Yes
Portable energy source	Electrical	No	No	Electrical
Device vibration	-	-	-	No
improving mucosa with mechanical oscillation	Yes	-	-	Yes
Unblocking airways via heightening exhale pressure	-	Yes	Yes	-
Patient's ability to use the device	Yes	Yes	Yes	Yes
Silent functioning	-	Yes	Yes	Yes
Use possibility in different positions	-	-	-	Yes
Convenienceable use	Moderate	Good	Good	Great

[1]Portable device for physiotherapy of pulmonary system

Table 2. Comparing voltage and plunger force

Voltage	Force
9 volts	10 Newton
13 volts	20 Newton
17 volts	30 Newton
20 volts	50 Newton
24 volts	70 Newton

be used depending on the type and seriousness of the disease. A patient with Fibrocystic disease, for example, who is in need of continuous physiotherapy, any device or instrument capable of meeting their needs is preferable. It is the case for patients in bed. Whether the patient needs to be trained to use the device or to be assisted by a physiotherapist with the device are two factors in reviewing these kinds of devices. The mechanical percussion is useful in this regard. On the other hand, pressure on the physiotherapist's body and skeletal-muscular damages reduce. It goes without saying that use of a mechanism to reduce the weight of the device will produce good results. Another good point about this device is its source of energy. Since the device is power operated, it is really convenient. That patients with pulmonary diseases don't have to go to clinic or hospital reduces not only damages resulting from air pollution in metropolitans, but also transportation expenses on the part of patients. Unfortunately, the vast

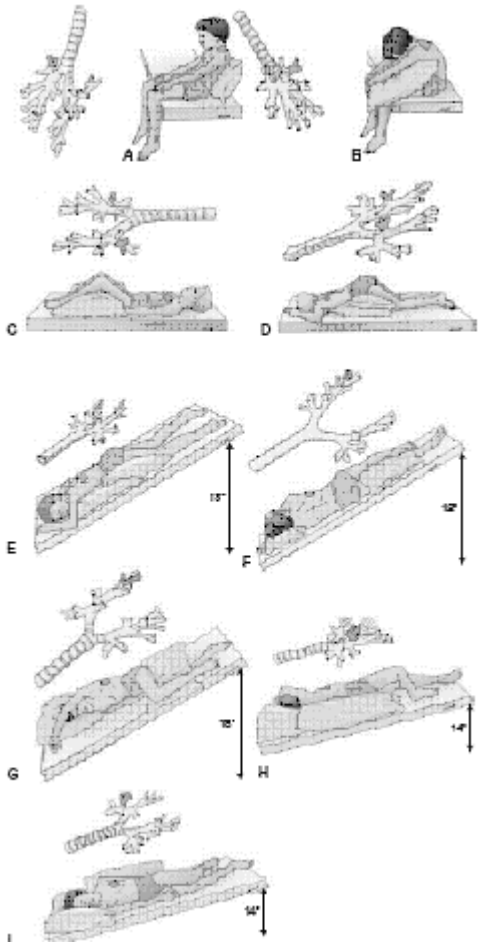

Fig. 1. Postural positions appropriate for lung drainage

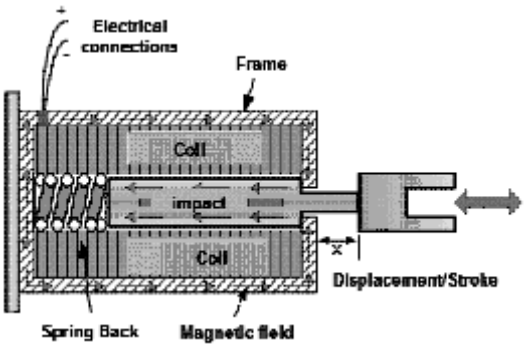

Fig. 2. Constituents of a solenoid

Fig. 3. Measurement of solenoid force

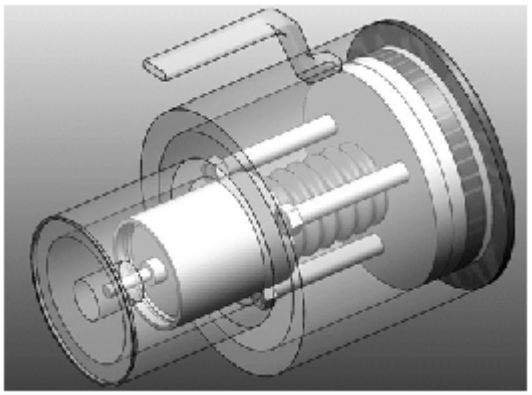

Fig. 4. The device

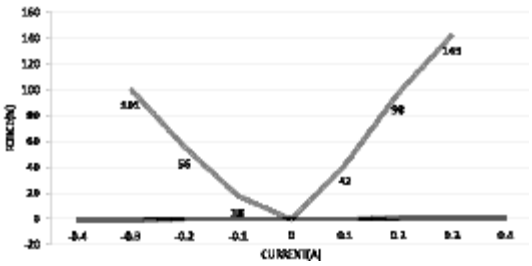

Chart 1. Force changes in terms of current

majority of patients with pulmonary diseases are on low income, do demanding jobs, and are subject to different pulmonary diseases. Since physiotherapy clinics don't usually admit patients with pulmonary diseases, a device that can be used at home is quite handy.

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