Obstructive Sleep Apnea: Biomedical Devices for Treatment

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Abstract: The review of biomedical devices for Obstructive Sleep Apnea (OSA) treatment is presented.

I. INTRODUCTION

Obstructive sleep apnea (OSA) - a condition characterized by the presence of snoring, recurrent upper respiratory tract collapse at the level of the pharynx and the cessation of pulmonary ventilation during persistent respiratory effort, decreased blood oxygen levels, sleep fragmentation and excessive daytime sleepiness [1].

The basic marker of obstructive sleep apnea is a cessation of nasal-oral flow for 10 seconds or more, with persistent respiratory effort, which is due to collapse of airway at the level of the pharynx. In case of incomplete airway obstruction appears hypopnea - respiratory event with a partial reduction of nasal-oral flow, combined with falling oxygen saturation not less than 3%.

The prevalence of OSA is 5-7% of the total population older than 30 years. Severe disease affects approximately 1-2% of this group of individuals [2]. In persons older than 60 years the frequency of OSA increases significantly and is about 30% of men and 20% in women. In persons older than 65 years the incidence may reach 50% [3].

The mechanism of airway obstruction is as follows. When the person falls asleep there is a gradual relaxation of the muscles of the pharynx and increased mobility of its walls. This leads to a complete collapse of airway and cessation of pulmonary ventilation. Despite of it respiratory efforts continue, and even intensified in response to growing hypoxemia. Acute lack of oxygen leads to a stress response associated with activation of the sympathoadrenal system and the rise in blood pressure. The afferent information from various organs and systems reaches the brain and cause a partial arousal. The brain regains control of the pharyngeal muscles and open airways. In severe cases there may be up to 400-500 pauses in breathing per night.

II. BIOMEDICAL DEVICES USED IN OSA TREATMENT

Oral appliances for OSA treatment.

There are two categories of oral appliances used for OSA treatment: mandibular advance devices and tongue retaining devices.

Mandibular advance devices. The main mechanism of action is the forward displacement of the lower jaw and a corresponding increase in the anterior-posterior size of the pharynx. The use of some devices requires operation of dentist, as they are fixed to the teeth with special clamps. There are more than simple modifications, made of special polymer-like mouthpiece for the boxer. The device is heated in water and becomes soft, then mounted on the upper jaw and lower jaw is closed being displaced forward. The device hardening and at subsequent installation in the mouth moves the lower jaw anteriorly.

Tongue retaining devices. These kinds of devices are suction devices placed between upper and lower teeth. The tongue is pulled forward by this device during sleep period. Traction of tongue forward does not permit the obstruction of airway by the base of tongue.

These oral appliances are indicated in the treatment of snoring and mild-moderate OSA [4].

The treatment of OSA by a continuous positive airway pressure (CPAP) The method of OSA treatment by creating a continuous positive airway pressure (CPAP) was proposed by Sullivan CE et al. in 1981[5]. The mechanism of CPAP-therapy action is relatively simple. If the airways a little "blow up" during sleep, it will prevent its collapse and remove the main mechanism of the disease. To create a positive pressure uses a small compressor, which delivers a constant flow of air under a certain pressure in the airway through a flexible tube and nose mask. It is also advisable to use a heated humidifier, which provides heating and humidifying the incoming air into the airways.

Devices for CPAP-therapy. An important aspect of CPAP-therapy is its hardware. The success of treatment depends on how efficiently and effectively will operate medical equipment. There are a large number of models of CPAP-apparatus.

According the last review [6] treatment with positive airway pressure in European countries is undertaken with CPAP (in all countries) or APAP (95.2%) devices.

The basic unit with no additional features. The apparatus is a compressor, which feeds into the airways constant given volume of air per unit time. In case of system integrity and constancy of its volume pressure created by the apparatus would remain stable. However, the breath is a dynamic process associated with the cyclical increase (in inhalation) and decrease (in exhalation) of the system volume. Accordingly, during inhalation is an abrupt drop in pressure in the system, and during exhalation - its rise. The amplitude of oscillations can reach 2-4 cm of water column. This negatively affects the dynamics of breathing, especiall.

during exhalation against a pressure jump. In addition, if during the treatment occurs much leakage from the mask, it can lead to a significant drop in pressure and reduce the effectiveness of treatment. Thus, this type of equipment has several disadvantages, which may reduce the effectiveness of treatment.

Device with therapeutic pressure compensation. This type of devices is upgrade by introducing a pressure compensation function. In the apparatus is installed a sensor that monitors in real time the pressure in the breathing circuit (the tube), as well as low-inertial engine. When the pressure drop (on inhalation), the device accelerates the engine speed and maintains proper therapeutic pressure. If it is a jump in pressure (at expiration), the device slows the engine speed, which also ensures the stability of the pressure.
In the event of a leak from under the mask unit detects a

drop in pressure accelerates the engine speed and compensate for the leak. In addition, the presence of pressure compensation is important, if a person happens in locations at different altitudes above sea level. In high altitude environment the air becomes more rarefied and compressor of the unit should operate at a higher rate to maintain the proper therapeutic pressure. Thus, this type of devices tuned to the rhythm of breath any person and during the entire respiratory cycle is maintain constant pressure without significant discontinuities, which improves the subjective acceptability of treatment. In addition, the devices of this type provide a stable therapeutic pressure regardless of the occurrence of leaks in the breathing circuit or significant drops in barometric pressure.

Device with auto-adjusting of therapeutic pressure and memory function (APAP).

There were elaborated devices that provide automatic selection pressure in real time - the so-called Auto-CPAP or APAP devices. These devices use sophisticated algorithms for automatically adjust the therapeutic pressure, depending on the detected disordered breathing. The adjustment of pressure in real time is necessary for adaptation to a change of therapeutic pressure as a function of body position and sleep stage. Deep sleep, and sleep on back needs much more pressure to open the airway compared with the superficial sleep and sleep on side, respectively. Comparative studies have shown that in application of APAP devices mean therapeutic pressure was 30-40% lower compared with the required fixed pressure treatment, which improves the acceptability of treatment [7]. In this case the use of APAP provided similar efficacy to eliminate breath disorders compared with the use of CPAP devices with fixed pressure. During the pressure auto-adjusting the algorithm of apparatus monitors 5 parameters: inspiratory flow limitation, snoring, hypopnea, apnea, and the presence or absence of cardiac oscillations in the phase of sleep apnea. The normal inspiratory flow curve has a rounded peak. Inspiratory flow curve begins to change even with minimal narrowing of the airways that is not accompanied by snoring or sleep apnea /hypopnea. In this case it is noted a flattening of the inspiratory flow curve. The microprocessor unit analyzes the shape of the central part of the inspiratory flow curve in each respiratory cycle. If it is define two or more cycles with inspiratory flow limitation, the device increases the therapeutic pressure. The device can respond by an increase in pressure only on flow limitation without reducing the flow (lesser degree of obstruction) or on flow limitation with reduced flow (high degree of obstruction). These presets are given by medical staff and increase or decrease the sensitivity of the apparatus, respectively. Snoring is defined by the unit as high-pressure fluctuations in the frequency range that overlaps the curve of the respiratory flow. The appearance of snoring also is a signal to increase the therapeutic pressure. The progression of airway obstruction leads to significant decrease of the flow - hypopnea. In the case of complete cessation of breathing apparatus detects no flow - apnea. In the case of sleep apnea is a problem of differentiation between obstructive and central sleep apnea. Central apnea may be noted, firstly, during the REM-sleep in healthy individuals, and secondly, in patients with Cheyne-Stokes respiration. In the case of pressure increasing as a response to central sleep apnea may experience a paradoxical reaction in form of worsening of the central breathing disorders. Most CPAP machines are not able to differentiate obstructive and central sleep apnea. To avoid excessive pressure in response to central respiratory failure, in the apparatus provides the ability to install a certain value therapeutic pressure above which the device stops responding through increase in pressure in the development of apnea of any origin. This parameter is usually set at 10 cm of water column. So, if sleep apnea developed when therapeutic pressure was, for example, 7 cm of water column, the unit will increase the pressure. If apnea developed at the therapeutic pressure of 11 cm of water column, the machine it will not respond. It is clear that the algorithm can not always ensure adequate treatment of pressure change in the patient, especially if it combined obstructive and central respiratory disorders. In the some apparatus is used a new technology that allow, with sufficient accuracy to differentiate obstructive and central respiratory disorders. It is based on the detection of cardiac oscillations in the respiratory circuit. The heart's contractions are transfer to the lung tissue, which in turn creates a small pressure spikes in the bronchi and trachea. During the central sleep apnea the airways are open, and these oscillations of pressure may be determined by the device in the breathing circuit. If the unit detects cardiac oscillations, it is interpreted as a central apnea and device not increases the pressure. If the oscillations are not detected, it is interpreted as obstructive sleep apnea and therapeutic pressure increases. According to the manufacturer's method for detection of cardiac oscillation has a high specificity (99.7%) and sufficient sensitivity (63.2%).

III. CONCLUSIONS

There are different types of biomedical devices from very simple to sophisticate which can provide large options for apparatus treatment of OSA.

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