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Annals of Otolaryngology and Rhinology

Review Article

Voice, Respiration and Brain Regulation, A Review

Mette Pedersen*, Sanila Mahmood, and Bilal H. Akram

Ear, Nose, Throat Clinic, The Medical Centre, Denmark

Abstract

This study examines how voice, respiration and brain regulation are connected. It observes how the anatomical mechanisms of respiration are connected to the physiological mechanisms. In this study, a British Library London search was made. For the latest 5 years 32 references were found, but no articles were found that covered the subject. Further research, restricted to respiration, was made through the database PubMed. Few relevant articles were found. This search shows that the area has not been a major subject and further research is necessary.

Especially the pre-Bötzinger complex's influence on the rhythmogenesis of respiration is of interest. The pre-Bötzinger complex is situated in the brain stem, where the whole respiratory center is located. Respiration and voicing is connected to each other, as breathing control is very important to carry out precise control of vocal fold movement. Furthermore, certain parts of the brain show functional connections both when carrying out controlled breathing and pronouncing syllables. The aspects thereof are discussed, related also to voice therapy.

***Corresponding author**

M. Pedersen, Ear Nose Throat specialist, IBC Cambridge, UK, Ministry of science. COST 2103, The Medical Centre, Østergade 18 1, DK - 1100 Copenhagen, Denmark, Tel: +45 33137700; Fax: +45 33137705; Email: m.f.pedersen@dadlnet.dk

Submitted: 17 January 2017

Accepted: 09 February 2017

Published: 10 February 2017

ISSN: 2379-948X

Keywords

- Voice
- Respiration
- Breathing
- Voice Therapy

INTRODUCTION

Breathing is a continuous and indeed a fundamental physiological process in life. The respiratory movements in breathing occur as an automatic mechanism responsible for vital behaviors such as gas exchange in the lungs and pH regulation.

A search at British Library London was made and found 32 references with the search words: Voice and Respiration and Brain Regulation– for the latest 5 years. Upon reading the abstracts none relevant articles covered all the parameters. Further research was made through the database PubMed where the search was specified to respiration without time limit. Here we found few relevant articles. This shows that the area has not been a major subject. Further research is necessary now since much voice therapy and voice connection is based on respiration connection. Furthermore, a position paper on Voice, Speech and Language therapy in Adult Respiratory Care from 2015, also showed that no articles covered the subject about voice, respiration and brain regulation (Royal College of Speech and Language Therapists 2015).

We consider the problem of respiration function related to brain regulation and voice to be extremely important. Some studies illustrate the development of the topic focusing on the periaqueductal gray matter (PAG) [1], and the voice-related cortical potential [2].

Training of voices and especially voice treatment in pathology has to be related to new knowledge of brain regulation of respiration from the Pre-Bötzinger complex. Treatment should focus much more on brain coordination than on respiration where no evidence was found.

Anatomical mechanism of the respiratory system

Breathing consists of two phases: Inspiration and expiration. The inspiration is always active while the expiration in rest is passive. The inspiration is caused by a process of active movements especially the diaphragm, which is responsible for most of the inspiration in rest. Other muscle groups are used for deeper breathing such as external intercostal muscles, scalene muscles and sternocleidomastoids. Expiration is caused by relaxation of the diaphragm and is therefore passive in rest. The active expiration, including voicing uses the internal intercostal muscles and the abdominal muscles.

Physiological mechanism of the respiratory system

Rhythmic neural activity is generated and organized as neural circuits in the brainstem driving the continuous respiratory breathing movements in mammals during normal breathing [3]. This neuronal activity produces a respiratory rhythm which pulsates the breathing mechanism.

This neural circuit in the brainstem is referred to as the respiratory central pattern generator (CPG) responsible of generating rhythmic breathing patterns [3]. CPGs consists of interconnected neurons organized in a network controlling the output of motor neurons [4,5]. These pattern generators can be divided into constitutive pattern generators and conditional pattern generators. A constitutive pattern generator generates

persisting patterns of activity throughout a lifetime of an organism. The respiratory CPG is a constitutive active pattern generator producing automatic movements throughout life. However, the conditional pattern generators generate patterns of activity which are not occurring persistently throughout life, but time limiting movements e.g. locomotion (the act of power of moving from place to place), swallowing and chewing [5] (Figure 1).

Arrangement of the respiratory network within the brainstem and respiration rhythmogenesis

Neural circuits in the brainstem have shown to generate the respiratory motor output leading to normal breathing. It is hypothesized that intrinsic rhythmically pacemaker neurons are driving the respiratory rhythm generation (rhythmogenesis) [7-9] (Figure 2). A group of neurons located rostral in the ventrolateral medulla oblongata, the pre-Bötzinger Complex, is hypothesized to be essential for the rhythmogenesis [6-11]. These neurons with respiratory activity in the ventrolateral medulla oblongata are as a collective group called the ventral respiratory group (VRG) [10]. The VRG contains different subpopulations of interacting excitatory and inhibitory interneurons which represents the respiratory Central Pattern Generator (CPG) [3].

The pre-Bötzinger Complex consists of a group of neurons that might generate respiratory-related outputs [12]. The pre-Bötzinger Complex has been proposed to be responsible for generating the inspiratory rhythm while other regions of the VRG, such as the Bötzinger complex and the retro trapezoid nucleus/ parafacial respiratory group, is thought to be responsible for the expiratory activity [7]. Perturbations and ablations of neurons in the pre-Bötzinger Complex have shown to alter and eliminate the respiratory rhythm of neonatal rats [10,13-16] (Figure 3). An intact pre-Bötzinger complex has therefore proven to be essential for generating normal respiratory rhythm in mammals.

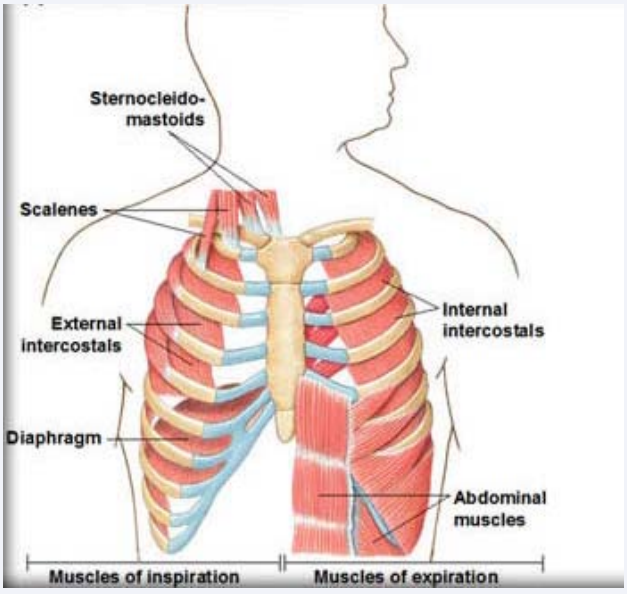

Figure 1 Illustration of breathing muscles.

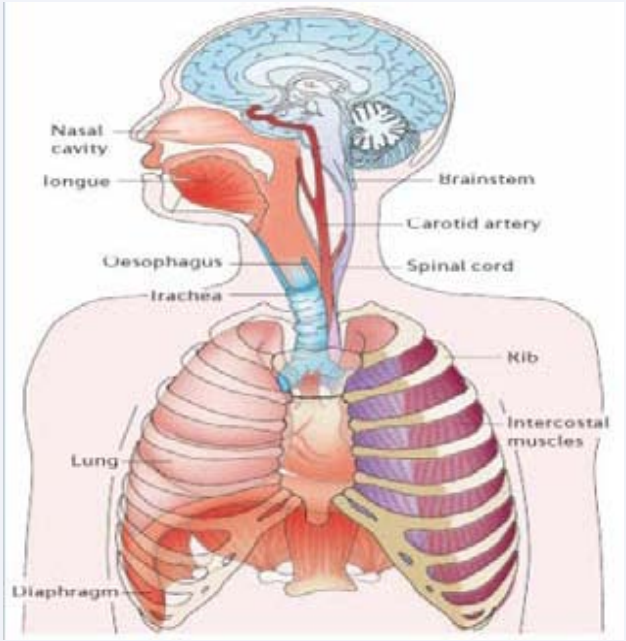

Figure 2 Rhythmic neural activity is generated and organized as neural circuits in the brainstem driving the continuous respiratory breathing movements in mammals during normal breathing [7].

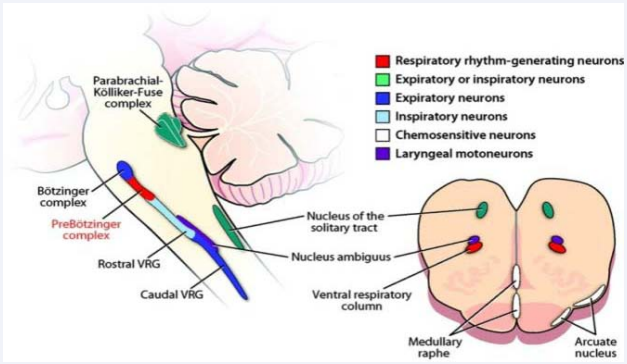

Figure 3 Brainstem and the pre-Bötzinger complex .

Brainstem and the pre-Bötzinger complex

Respiratory cycle: During a respiratory cycle consisting of inspiration and expiration the Central Pattern Generator (CPG) generates only the inspiratory phase while the expiratory phase is passive during quiet breathing [5].

Voice and respiration: Voice plays an important role in human communication. The genetically determined vocal reactions are controlled by the lower brain stem.

Breathing control is very important to precise control of vocal fold movements. Prolonged controlled expiration is necessary to maintain adequate subglottic air pressure to start and sustain voice production [17]. The involvement of the volitional control over respiration must be studied more basically in order get a better understanding of phonation for speech [18]. So, what do we know till now about brain regulation of voicing from the literature.

Brain activity during production of syllables and during production of controlled breathing: There are similar positive functional connections of the left laryngeal motor complex during voluntary voice production (i.e., both syllables /i?i and /ihi/) and during controlled breathing (Figure 4).

Positive functional connections of the left laryngeal motor complex during voluntary voice production (i.e., both syllables /i?i and /ihi/) and during controlled breathing are:

Ventrolateral prefrontal cortex, Insula, thalamus, caudate nucleus, putamen, cerebellum. Functional connections of the right laryngeal motor complex during the referred voice production were comparable to networks of the left laryngeal motor complex, but involved less brain regions, the positive connections of the right laryngeal motor complex during breathing were observed with the right dorso lateral prefrontal cortex, posterior cingulate cortex and left putamen.

These findings show a left hemispheric lateralization of the functional networks during voice production, but not during controlled breathing which has a more symmetrical bilateral brain activity [17].

Perspective: There is a need for further research in the area. The neural activity produces a respiratory rhythm which pulsates respiration. Breathing control is very important to precise control of vocal fold movements [5,6]. It has been shown that prolonged control expiration is necessary to maintain adequate subglottic air pressure to start and sustain voice production [17].

A study compared voluntary voice production and controlled breathing, it showed positive functional connections of the left laryngeal motor complex. It also showed, during voice production, that the left hemisphere of the brain is primarily used, which is not the case during controlled breathing, when a more symmetrical, bilateral brain activity are found [18].

Peripheral studies using phonetograms and Air-flow measurements have been made. A multivariate statistical analysis in 16 male brain injury was made [19,20], showing dysregulatory air pressure function without periphery changes in the vocal fold movements. Our results at that time were shocking; in the way that not only the sub glottal air pressure but also the voice intensity regulation in phonetograms was reduced in brain damaged young clients. This means that voiced communication

Synapses between brainstem and the peripheral respiratory organs during inspiration and expiration:

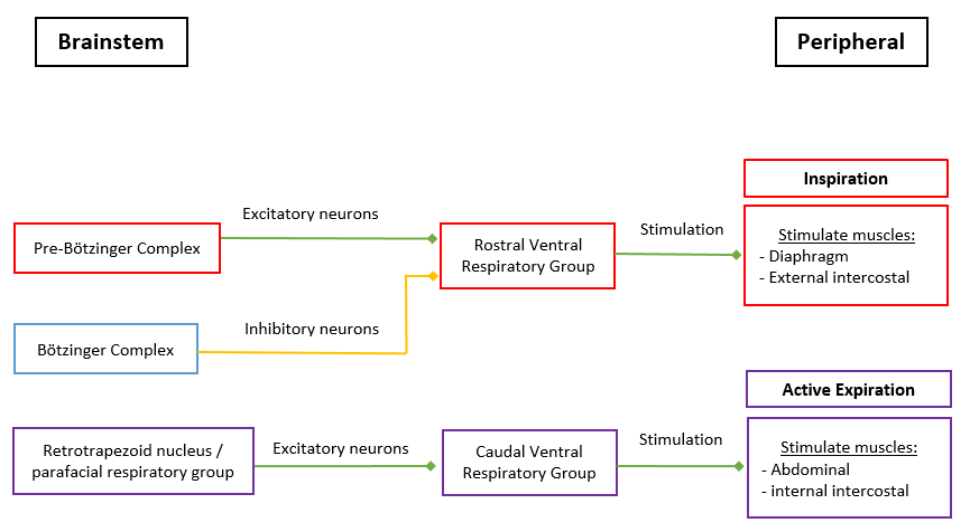

Figure 4 Synapses between brainstem and the respiratory (peripheral) organ during inspiration and active expiration. Modified from [3-6].

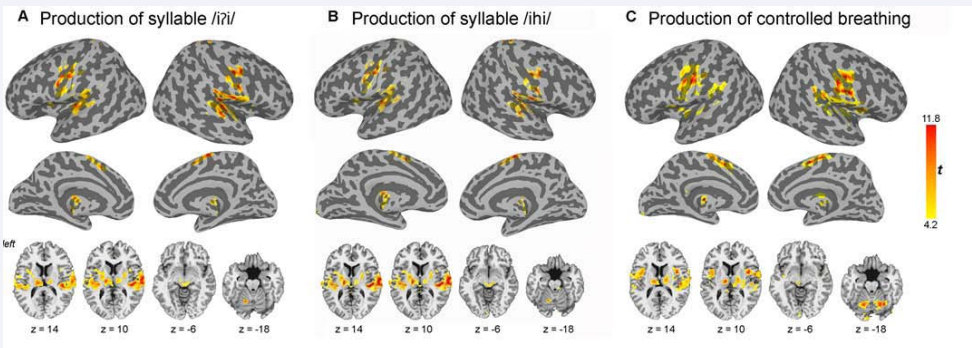

Figure 5 Brain activity during production of syllable´s and during production of controlled breathing [17].

was limited to notes without intensity regulation. Somehow the central regulation of voice is of course severally damaged under these circumstances (Figure 5).

The connection of well-known periphery measurements of phonetograms and air flow compared with central regulation of voice in pathology might in the future be the basis of new knowledge of the central regulation of voice in normal and pathological cases (in prospective randomized trial comparing voice, respiration and brain regulation). Further systematic approaches to voice therapy is a demanding aspect, also on cellular level.

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Cite this article

Pedersen M, Mahmood S, Akram BH (2017) Voice, Respiration and Brain Regulation, A Review. Ann Otolaryngol Rhinol 4(1): 1160.