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APPLICATION OF THE VALSALVA MANEUVER IN MEDICINE AND SPORT

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ABSTRACT

The Valsalva maneuver, named after Antonio Maria Valsalva, is one of the vagal maneuvers. It is defined as a forced expiration against a closed glottis, leading to an increase in intrathoracic and intra-abdominal pressure. Over the years it has become a subject of interest

to many clinical researchers who have comprehensively studied its physiology and clinical significance. As a result, the application of the Valsalva maneuver has expanded to become a versatile technique applied across a wide range of medical specialties as a diagnostic and therapeutic tool. Additionally, it has found its use in sport among athletes. The aim of this article is to present the current state of knowledge about the clinical significance of the Valsalva maneuver and show that this simple physiological technique described in the 18th century remains a valuable tool in modern clinical practice and has found its use in sport. The review was based on chosen literature obtained from the PubMed electronic database, Google Scholar electronic database, and other scientific articles. Search terms included keywords listed below.

Keywords: *Valsalva maneuver; vagal maneuver; respiratory maneuver; autonomic system*

INTRODUCTION

The Valsalva maneuver (VM), one of the vagal maneuvers [1], is a forced expiration against a closed glottis, which leads to an increase in intrathoracic and intraabdominal pressure, resulting in complex hemodynamic changes through the baroreflex and other compensatory reflex mechanisms, including increased vagal parasympathetic tone. This physiological response occurs involuntarily in various everyday activities such as defecation, sneezing, coughing, vomiting, playing wind instruments, blowing up balloons, heavy lifting, or during labor [2,3].

Maneuver was introduced by an Italian physician Antonio Maria Valsalva in his work called *"De aure humana tractatus"* published in 1704 [4]. He described it as "air is forced inwards with occluded nostrils and mouth" [2,5]. To perform VM, the patient in a supine position blows against the resistance into the mouthpiece with tubing linked to a manometer to maintain 40 mmHg pressure strain for 15 seconds. It is usually preceded by a full inspiration and followed by a release of the expiratory straining as breathing restores to normal. The indicators of the properly executed VM are reddening of the face, plethora, jugular vein distension, full expansion of the rib cage, and increased tension of the abdominal muscles. Patient’s vital signs should be closely monitored during the whole procedure [6].

Initially associated as a method used in otorhinolaryngology to inflate the Eustachian tube and to expel pus or foreign bodies from the ear [2,5], over the years VM has become a subject of interest to many clinical researchers who have comprehensively studied its physiology and clinical significance. As a result, the application of the Valsalva maneuver has expanded to become a versatile technique applied across a wide range of medical specialties as a diagnostic and therapeutic tool [7]. Additionally, it has found its use in sport among athletes, who use VM for health benefits and performance enhancement.

PHYSIOLOGY

Understanding the physiology of the Valsalva maneuver is essential for recognizing its clinical applications. During the maneuver cardiovascular response results in numerous hemodynamic changes that can be observed as variations in heart rate and arterial blood pressure. By comprehending the changes healthcare professionals and others can interpret cardiovascular response and use the Valsalva maneuver in their practice. Based on these characteristic hemodynamic changes Valsalva maneuver can be divided into four phases [8,9].

Phase I

The first phase corresponds to the onset of strain. Forced expiration against the closed airways results in increased intrathoracic and intraabdominal pressure, leading to compression of the heart and blood vessels. The systolic and diastolic arterial blood pressure rises, and pulse pressure remains stable. A decrease in heart rate is observed due to the transient rise in blood pressure stimulating baroreceptors in the carotid sinus and aortic arch [10-14].

Phase II

In the second phase of the Valsava maneuver sustained high intrathoracic pressure causes reduced venous return to the heart, along with a decrease in left atrial pressure. These changes result in a reduction in the end-diastolic and end-systolic volume of the left ventricle, stroke volume, and cardiac output. The arterial blood pressure gradually drops, the systolic more significantly than the diastolic, activating the baroreceptor reflex to compensate. The sympathetic nervous system triggers the increase in heart rate and peripheral vasoconstriction to maintain blood pressure. The gradual rise in the peripheral venous pressure can be observed as a distension of the jugular vein, which is considered an indicator of a properly performed maneuver.

The second phase is often divided into two subphases: early phase II and late phase II. Early phase II is connected to the initial fall in blood pressure due to reduced venous return. Late phase II is the phase of pressure recovery, corresponding to the partial recovery in blood pressure due to sympathetic activation [10-14].

Phase III

The third phase involves the release of the strain pressure. The intrathoracic pressure drops abruptly (returning to a baseline), leading to a decrease in the peripheral venous pressure as previously compressed vessels start to expand. Consequently, the diastolic and systolic arterial blood pressure falls rapidly. Heart rate increases and vasoconstriction is potentiated as a reflex response [10-14].

Phase IV

In the fourth phase, the cardiac function improves due to the restoration of venous return to the heart. There is an increase in the diastolic ventricular filling and the stroke volume and cardiac output rise. These changes combined with sustained vasoconstriction result in a so-called pressure overshoot. In this phenomenon, the arterial blood pressure rises significantly, typically 20-40 mmHg above baseline values. In response to the elevated blood pressure, baroreceptors activate the compensatory reflex response. The parasympathetic activity increases, which slows down the heart rate (vagal bradycardia). In the end, the cardiovascular system eventually stabilizes and returns to a normal state [10-14].

APPLICATION IN MEDICINE

Supraventricular tachycardia (SVT) treatment

The Valsalva maneuver is recommended as a first-line therapy for hemodynamically stable patients with supraventricular tachycardia [15,16]. It works through parasympathetic response in phase IV of the maneuver in which there is a sudden drop in the heart rate [12]. Activation of the vagus nerve releases a neurotransmitter called acetylcholine, which acts on the AV node to slow down its electrical conduction from the atria to the ventricles and reduces the firing rate of the AV node. It can interrupt the abnormal electrical pathway and restore normal sinus rhythm leading to termination of the arrhythmia [13,17].

The REVERT trial published in 2015 showed that the modified Valsalva maneuver is significantly more effective in terminating SVT than the standard Valsalva maneuver, with a success rate of 43% compared to 17%. The patient, in a semi-recumbent (45°) position, exhales forcefully with a pressure of 40 mmHg for 15 seconds, and instantly after the strain phase is laid flat with legs elevated to 45° for 15 seconds before returning to the initial position [18]. To generate the recommended standard intrathoracic pressure of 40 mmHg, blowing into a 10 mL syringe to move the plunger can be used [19].

Echocardiography

- **Patent foramen ovale:**

The Valsalva maneuver increases the sensitivity of detecting the atrial shunt in patients with a patent foramen ovale (PFO), which can be unmasked with contrast echocardiography using agitated saline [20]. In phase III of the maneuver, the pressure in the right atrium is transiently increased due to the sudden venous return, facilitating the atrial shunting from right to left if a PFO is present [21]. The person performing the examination can see the passage of contrast microbubbles from the right atrium to the left atrium through a PFO. Thanks to a Valsalva maneuver their number is notably increased [22]. It makes a PFO easier to visualize during the echocardiographic examination.

- **Hypertrophic cardiomyopathy**:

In hypertrophic cardiomyopathy, the Valsalva maneuver is applied during echocardiography to identify patients with latent or provoked left ventricular outflow tract obstruction (LVOTO) by increasing the LVOT gradient during the strain phase of the Valsalva maneuver. It aids in assessing the dynamics, severity, and clinical correlation of symptoms related to LVOTO, thereby helping to choose the best treatment strategy [21,23].

- **Diastolic function:**

Another use in echocardiography is the assessment of left ventricular diastolic function. It can be applied to differentiate between normal and pseudonormal left ventricular filling based on changes in mitral valve velocity and E/A ratio. A drop in the E/A ratio of 0.5 or more, or an increase in A wave velocity during the standardized Valsalva maneuver, strongly corresponds with elevated left ventricular filling pressure, indicating the presence of diastolic dysfunction [24].

Heart murmurs differentiation

The Valsalva maneuver can be a useful tool in the auscultation of heart murmurs, whose intensity can increase or decrease depending on the phase of the Valsava maneuver (Table 1). During the strain phase of the maneuver, most of the heart murmurs diminish their intensity, becoming less harsh as a result of the decreased venous return to the heart and reduced preload. The exceptions are murmurs associated with hypertrophic obstructive cardiomyopathy and mitral valve prolapse [13,25]: aforementioned hemodynamic changes cause exacerbation of the LVOT obstruction [23] and earlier prolapse of the mitral valve in systole with an early onset of the click [21], escalating the murmurs. During the release phase of the maneuver, the majority of the murmurs intensify, those originating from the right side of the heart preceding those from the left [13].

MURMUR	**THE STRAIN PHASE**	**THE RELEASE PHASE**
Aortic stenosis	decrease	increase
Aortic regurgitation	decrease	increase
Pulmonary stenosis	decrease	increase
Pulmonary regurgitation	decrease	increase
Tricuspid stenosis	decrease	increase
Tricuspid regurgitation	decrease	increase
Mitral stenosis	decrease	increase
Mitral regurgitation	decrease	increase
Hypertrophic obstructive cardiomyopathy	increase	decrease
Mitral valve prolapse	increase	decrease

Table 1. Changes in the intensity of the heart murmurs in the strain and the release phase of the Valsalva maneuver [13,25].

Autonomic dysfunction assessment

The Valsalva maneuver is widely used in the assessment of autonomic function by observing changes in blood pressure and heart rate induced by the stimulation of cardiovascular reflexes [26]. Fluctuations in blood pressure serve as an indicator of sympathetic function, while the parasympathetic function is portrayed by the Valsalva ratio defined as the maximum RR interval in phase IV divided by the shortest RR interval in phase II of the maneuver. Interpretation of its values is shown in *Table 2* [27].

VM is applied in the diagnostic of:

- **Cardiac autonomic neuropathy (CAN)**, which is a severe complication of diabetes mellitus – VM is one of the five tests in the Ewing battery used to diagnose patients with CAN [26]. In the presence of autonomic dysfunction reflex bradycardia related to pressure overshoot in the last phase of VM is attenuated compared to normal autonomic response [28].
- **Postural orthostatic tachycardia syndrome (POTS)** – VM helps to identify patients with POTS and to differentiate the subsets of this syndrome. Studies have shown that patients with neuropathic POTS present excessive drops in systolic and diastolic blood pressure in the early phase II and diminished recovery of blood pressure in the late phase of the maneuver. In the hyperadrenergic subset of POTS pressure overshot during phase IV of VM is exaggerated [29].
- **Orthostatic hypotension (OH) –** VM can be performed to distinguish between late-onset, early-onset, or immediate orthostatic hypotension and to recognize patients who need prolonged head-up tilt table test in the diagnostic process of OH [30].

VALSALVA RATIO $= RR_{max}/RR_{min}$	
⩾1,21	normal
1,20 -1,11	borderline
⩽1,10	abnormal

Table 2. Valsalva ratio – values interpretation [27].

Reduction of pain

Pain reduction can be indicated as another clinical application of the Valsalva maneuver, which is said to alleviate both physical and psychological aspects of pain [31]. The mechanism of action is complex, but it is believed that there is a close link between pain modulation and systems that are in control of hemodynamics, resulting in antinociception activation due to the baroreceptor reflex. Patients focusing on performing this non-pharmacological technique, are also distracted from the unpleasant stimuli of invasive procedure [32]. Studies show that VM decreases the severity of pain during peripheral vein cannulation [31,32], skin puncture during spinal anesthesia [33], removal of the femoral arterial sheath in patients undergoing percutaneous coronary intervention [34], and pain caused by etomidate and propofol administration [35, 36].

Radiological diagnostics

In radiology, the VM aids in diagnosing various conditions. One of them is hernia, which can be detected more easily in ultrasonography and computer tomography as the protrusion of its sac becomes more pronounced due to increased intraabdominal pressure from the maneuver [37]. In head and neck imaging among others it can help detecting the Jugular phlebectasia by inducing maximum dilation of the jugular vein and enhance diagnostic certainty of laryngocele if the case is unclear [38]. In abdominal ultrasonography, VM increases the echogenicity of hepatic haemangioma and highlights the echogenic rim making the diagnosis more certain [39]. It can also be applied in the phlebologic practice in the Doppler ultrasonography evaluation of varicocele [40].

Neurosurgery

In neurosurgical practice, the VM is performed during the procedure of dural closure to assure that there is no leakage of cerebrospinal fluid, and if it is to locate the tear. Surgeons can also ask their patients to execute intraoperative VM during transsphenoidal resection of pituitary region masses to provide better visualization of tumors as with the maneuver the pituitary gland descends and soft tumors can extrude [41,42].

Dentistry

Application of VM can detect the presence of communication between the maxillary sinus and the oral cavity after dental extraction by highlighting the occurrence of bubbles in the dental alveoli [43]. Another use in dentistry is to detect ruptures in the sinus membrane during sinus lift procedures [44].

Other uses

- to insert intrauterine devices as an alternative to the tenaculum use [45];
- to assess the prolapse of pelvic organs [46];
- to aid in detecting isolated hyoid bone fracture during nasendoscopy [47];
- to detect stress urinary incontinence by measuring "Valsalva leak point pressure" [48];
- to ease the venous cannulation by increasing the vessel diameter [41];
- to diagnose radicular or neuropathic pain [41];
- to test the Eustachian tube function [49];
- to identify supraclavicular adenopathy [50];

APPLICATION IN SPORT

As mentioned before, VM occurs involuntarily during many daily activities, such as lifting heavy weights [2,3], but it is also applied intentionally with full consciousness by performing athletes in different sports disciplines and in recreational physical activities to improve performance, achieve better results, and for health benefits [12].

Sports medicine

The American Heart Association (AHA) published a recommendation for preparticipation physical examination to screen athletes for cardiovascular abnormalities and identify those at high risk of sudden cardiac death (SCD). The evaluation consists of 14 points regarding personal history, family history, and physical exam. One of the listed elements of physical examination is cardiac auscultation, which should be performed dynamically with the use of the Valsalva maneuver to detect any cardiac murmurs, especially murmur of LVOT obstruction [51]. VM can also aid in the diagnostic of autonomic dysfunctions, syncope [52], and hernias, which athletes are prone to [53], and echocardiographic examination in the prevention of SCD [54].

Equalizing ear pressure

In sports like skydiving, scuba diving, and freediving athletes are exposed to sudden pressure changes. As they descend, the hydrostatic and atmospheric pressure rises, pushing the tympanic membrane inward, which leads to a reduction in the middle ear space. This may result in middle ear barotrauma if the pressure is not equalized [55]. One of the most frequent techniques used by these athletes to equilibrate ambient pressure with middle ear cavity pressure is the Valsalva maneuver. It must be performed with a closed mouth and nares but with open glottis. The rise in the nasopharynx pressure generated by increased intrathoracic pressure causes normally closed Eustachian tubes to open, pushing air into the middle ear and equalizing the pressure [56]. The study showed that VM as a pressure equalizer is as effective as other techniques [57], but must be performed correctly, quickly, and gently, and divers should be aware of its limitations (e.g. in freediving it stops being successful at depths of several meters) and potential complication [58]. Worth mentioning is the risk to divers with patent foramen ovale suffering decompression sickness as VM increases pressure in the right atrium and creates a significant risk of arterial gas embolism [59].

Core stability

The Valsalva maneuver is an inevitable part of resistance exercises, occurring during strength training when more than 80 % of maximal voluntary contraction is achieved [60]. Therefore, it is a well-known breathing technique among athletes, especially in powerlifting and weightlifting, who are taught to perform it correctly for their safety and benefit. One of the proposed profits of this respiratory maneuver is maintaining core stability. VM increases intraabdominal pressure and abdominal, paraspinal, and intracostal muscle activity and thickness, consequently increasing spinal stiffness. Proper vertebral alignment and stability are essential for posture control, balance, and weight support. It enables athletes to enhance their performance by lifting more while reducing the risk of injury [60,61,62]. Although VM is not free of complication, because it might cause for instance syncope, and some experts still advise against it, the studies by M. Haykowsky et. al. indicated additional benefits. The research showed that performing VD during resistance exercise results in significantly lower cerebrovascular transmural pressure than without VM and may provide protection from cerebrovascular damage [63]. Additionally, it prevents an alteration in left ventricular systolic function and reduces left ventricular wall stress, having a cardioprotective effect [64].

RISKS

As with any diagnostic and therapeutic tool, the Valsalva maneuver is not without potential side effects, though they are extremely rare [13]. The reported complications are presented in *Table 3*. There are no absolute contraindications [65], but extra caution is required for patients prone to arrhythmia formation and those with high sensitivity to abrupt changes in heart rate and blood pressure [6,13]. It shouldn't be performed by the patients with recent myocardial infarction or stroke, unstable angina pectoris, severe valvular defects, and hemodynamically unstable [66]. An important limitation is patient's capability to cooperate and follow instructions to perform VM effectively [65].

CARDIOLOGICAL	hypotension, severe hypertension, bradycardia, AV block, prolonged sinus pauses, chest pain, arrhythmias, asystole, sudden cardiac death
NEUROLOGICAL	headache, dizziness, altered vision, syncope, epidural hematomas, intracranial hypotension, cerebrovascular stroke
OPHTHALMOLOGICAL	increased intraocular pressure, hyphema, retinopathy, maculopathy
OTOLARYNGOLOGICAL	tinnitus, vertigo, tympanic membrane rupture, hemotympanum, hearing loss
OTHERS	nausea, pneumomediastinum, pneumothorax, Wunderlich syndrome, urinary incontinence

Table 3. Adverse effects of Valsalva maneuver [13,28,65,67,68].

CONCLUSIONS

The Valsalva maneuver proves that certain medical techniques are timeless. Despite rapid advanced development in medical technology, this known for ages physiological maneuver continues to be a crucial tool in the contemporary practice of different medical specialties. It is costless, non-invasive, low risk, easy to perform, and doesn't require any specialized equipment. These advantages make VM very accessible and worth recognition as due to the complexity of the hemodynamic changes induced by VM, the list of its various applications still increases, highlighting its clinical significance as a diagnostic and therapeutic tool.

In sport, the use of the Valsalva maneuver is limited, but some studies suggest that it can play an important role as a neuroprotective and cardioprotective agent during resistance exercises, although further research is needed.

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