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Vagal Techniques for Terminating Paroxysmal Tachycardia in Children: Assessment of Clinical-Electrophysiological Factors of Valsalva Test Effectiveness

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Vagal techniques constitute the first line of medical care for terminating paroxysmal supraventricular tachycardia in children and adults due to ease of application, relative safety and possibility of avoiding injection of antiarrhythmic drugs. Effectiveness of vagal techniques depends on the method of execution, as well as a range of clinical and electrophysiological factors, which require study and specification. ***The study was aimed*** *at studying effectiveness of the modified Valsalva test for terminating paroxysmal tachycardia in children.* ***Methods:*** *effectiveness of the Valsalva test for terminating paroxysmal tachycardia induced in the course of a transesophageal electrophysiological examination in children aged 7-18 years was studied retrospectively. Results: data of 306 children (mean age – 13.1 ± 3.2 years) were analyzed; 130 of them (42.5%) suffered from paroxysmal AV nodal reentrant tachycardia (PAVNRT), 176 – from paroxysmal AV reentrant tachycardia involving an additional AV connection (PAVRT). Valsalva test was effective in 88 children (28.8%) – 44 children (33.8%) with PAVNRT and 44 children (25.1%) with PAVRT. In most cases, tachycardia was terminated by means of anterograde block: PAVRT – in 65.5% of the cases, PAVNRT – in 92.7% of the cases. Children with ineffective Valsalva test featured longer duration of the disorder (p = 0.035), higher rate of the initial sinus rhythm before a tachycardic paroxysm (p = 0.043) and higher rhythm rate during tachycardia (p = 0.019), as well as high level of AV node conduction (p = 0.038).* ***Conclusion:*** *Valsalva test terminates paroxysmal tachycardia in not more than 1/3 of children with paroxysmal AV reentrant tachycardia. Test effectiveness depends on duration of the disorder and electrophysiological characteristics of AV node conduction. Valsalva test is especially effective in the onset of tachycardic paroxysm and terminates it by means of anterograde AV node block in most cases.*
Keywords: *children, paroxysmal supraventricular tachycardia, Valsalva test, transesophageal electrophysiological examination, effectiveness.*

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Rationale

Autonomic nervous system plays an important role in the onset and clinical course of paroxysmal tachycardia in children [1, 2]. Sympathetic stimulation by administration of isoprotenerol, or the vagolytic effect of atropine are used to induce tachycardia during an electrophysiological trial [3, 4]. Vagal techniques are conventionally used for first-line termination of supraventricular tachycardia (SVT) in children and adults, because they are simple to perform, relatively safe, and help avoid administration of antiarrhythmic agents [5–7].European Recommendations of 2013 state that vagal techniques for SVT termination in children have class I indications, level of evidence B [7].

Vagal techniques are efficient for termination of reentrant tachycardia, where the atrioventricular (AV) node is included in the reentry circle. This type of tachycardia includes paroxysmal AV reentrant tachycardia that involves an additional AV connection (PAVRT) and paroxysmal AV-nodal reentrant tachycardia (PAVNRT). These two subtypes jointly account for more than 90% of all paroxysmal SVT cases in children [4, 8, 9]. Vagus nerve stimulation by a vagal technique boosts the refractoriness of the AV nodal tissue, decreases the impulse conduction rate of the AV node, and breaks the reentry circle. It is suggested that it is mostly the left vagus nerve that causes a negative dromotropic effect in the AV node; and it is mostly the left sympathetic nerve that shortens the AV conduction time [10]. In patients with atrial tachycardia, vagal techniques are often unable to terminate the attack; however, they are useful in terms of diagnosis, because a transitory deterioration of AV conduction and the emergence of second-degree transient AV block result in an enhanced visualization of atrial P waves or F flutter waves [6].

A number of vagal techniques are applicable to children, including cold test (diver reflex, immersion), the Valsalva test, carotid sinus massage as well as some actions that trigger vagus-like reactions (taking deep breaths and making short exhalations, drinking water with ice, pressing the tongue root, evocation of cough or vomit, etc.) The efficiency of these techniques varies: a tachycardia attack is terminated in 10 to 60 percent of patients (data vary from source to source) [8, 11, 12]. Whether a vagal technique will be efficient depends on how well it is performed as well as on the child's age [8, 12]. For children in the first years of life, the cold test is the most effective option; for adolescents and young people, the best one is the Valsalva test [8]. Vagal techniques are used to terminate tachycardia with stable hemodynamics; only the cold test can be performed when preparing for an emergency cardioversion.

This study was aimed at assessing the efficiency of a modified Valsalva test for termination of AV reentrant tachycardia in children. Another goal was to find out what are the clinical and electrophysiological factors that determine the success of a vagal technique.

Methods

STUDY DESIGN

We carried out a retrospective analysis of data from the medical records of patients, who were hospitalized to the Surgery Department of Severe Rythmic Disorders and Cardiostimulation of Saint Petersburg City Clinical Hospital No. 31, with years of hospitalization ranging from 1998 to 2013.

FITTING CRITERIA

We collected the data of children who experienced hemodynamically stable induced AV reentrant tachycardia at an age of 7 to 18 years. Age-appropriate limits depended on the ability of schoolchildren to follow the doctor's instruction on how to perform the Valsalva test.

TRANSESOPHAGEAL ELECTROPHYSIOLOGICAL EXAMINATION

TEEPE and vagal techniques were performed in the room for electrophysiological heart examinations and pacemaker programming. For TEEPE, the doctors used the automatic unit Astrocard-Polysystem EP/L by Meditech, Russia. Bipolar electrode ПЭДСП-2 by SKB MET, Ukraine, was used as the transesophageal lead. Before TEEPE could be performed, antiarrhythmic drugs had been excluded for at least 5 half-lives, whilst cordaron administration had terminated at least 3 weeks before the study began. TEEPE was carried out in the morning fasted, no less than 3 hours from the latest meal.
TEEPE was carried out with diagnosis in mind, i.e. to verify SVT in children with complaints of heartbeat and no ECG-registered tachycardia attacks. The TEEPE protocol includes instructing the child on how to perform vagal techniques, in particular the Valsalva test [4]. Parents could attend the procedure if they wished.

VAGAL TECHNIQUE

The Valsalva test was carried out using a modified method that is widely accepted in pediatric arrhythmology. The child is in the horizontal position, takes a deep breath, strain the abdominal muscle for 10 to 15 seconds and exhale thereafter. The vagal technique was deemed an effective option for termination of paroxysmal tachycardia, if this exact method could terminate at least 2 TEEPE-induced tachycardia attacks. The Valsalva test was carried out within the first 30 seconds after induced tachycardia occurred, usually in 15 to 20 seconds. This period was necessary to assess the child's status and teach them the technique.

ETHICAL EXPERTISE

The Protocol for examination of children with supraventricular tachycardia, with inclusion of TEEPE was approved by the Ethical Committee of Federal Almazov North-West Medical Research Center (Protocol no. 25 dd. March 21, 2011). TEEPE was carried out under the child's informed consent, if the child was 15 or older; otherwise, the parents' informed consent was obtained.

STATISTICAL ANALYSIS

Data were processed statistically by means of STATISTICA v. 6.0 by StatSoft Inc., USA. The quantitative parameters were presented as mean values (± standard deviation), whilst the qualitative parameters were presented in absolute values as well as percentages of total number of observations. Quantitative data were compared using Student's t-test for independent samples; their correlation was analyzed by means of the Pearson correlation coefficient.

Results

GENERAL CHARACTERISTICS OF DATA

We have studied the results of vagal techniques in 306 children with paroxysmal AV reentrant tachycardia, 130 of whom, or 42.5 percent, had paroxysmal slow-fast AV-nodal reentrant tachycardia (PAVNRT), and 176, or 57.5%, had paroxysmal orthodrome AV reentrant tachycardia involving an additional AV connection (PAVRT, Wolf-Parkinson-White syndrome). Average age at the time of admission to the inpatient unit was 13.1±3.2 years.

PRIMARY RESEARCH RESULTS

The Valsalva test was efficient in 88 (28.8%) of children with paroxysmal tachycardia (44, or 33.8%, of children with PAVNRT, and 44, or 25%, of children with PAVRT, $p = 0.091$). A comparison of clinical, electrocardiographic, and electrophysiological parameters (based on TEEPE data) of children groups that displayed different Valsava test efficiency showed that where the vagal technique was inefficient in PAVRT-affected children, such inefficiency was associated with longer anamnesis of the disease, greater frequency of initial pre-induction sinus rhythm, and a greater heart rate (HR) during the tachycardia attack (a shorter tachycardia cycle). Children with PAVNRT and inefficient vagal techniques had a higher Wenckebach point, a short efficient refractory period of the slow pathway and the fast pathway (Table). Thus, the efficiency of vagal techniques when applied to PAVRNT-affected children depended on the electrophysiological properties of the fast and the slow pathways, which form the reentry circle in such a tachycardia.

Table. Data of anamnesis and transesophageal electrophysiological examination of children with different Valsalva test efficiency

Parameters	PAVRT (n = 176/306)			PAVNRT (n = 130/306)		
	Test (+) (n = 44/176)	Test (-) (*n* = 132/176)	*p*	Test (+) (*n* = 44/130)	Test (-) (*n* = 86/130)	*p*
Age, years	12.6 ±2.8	13.3 ± 3.5	0, 085	13.1 ± 3.2	13.6 ± 2.8	0.109
How long was the history of rhythmic disorders, years	2.3 ± 1.7	3.2 ± 2.1	0.035	2.1 ± 1.9	3.8 ± 2.7	0.031
HR, bpm	89 ± 17	99 ± 17	0.042	91 ± 18	107 ± 18	0.043
WP, imp./minute	188 ± 17	197 ± 19	0.057	185 ± 24	202 ± 19	0.038
ERP fp, ms	–	–	–	344 ± 81	286 ± 46	0.012
ERP sp, ms	–	–	–	263 ± 31	235 ± 25	0.035
ERP AVC, ms	277 ± 37	270 ± 39	0.078	263 ± 31	235 ± 25	0.038
DTC, ms	322 ± 36	296 ± 42	0.019	336 ± 41	292 ± 42	0.013

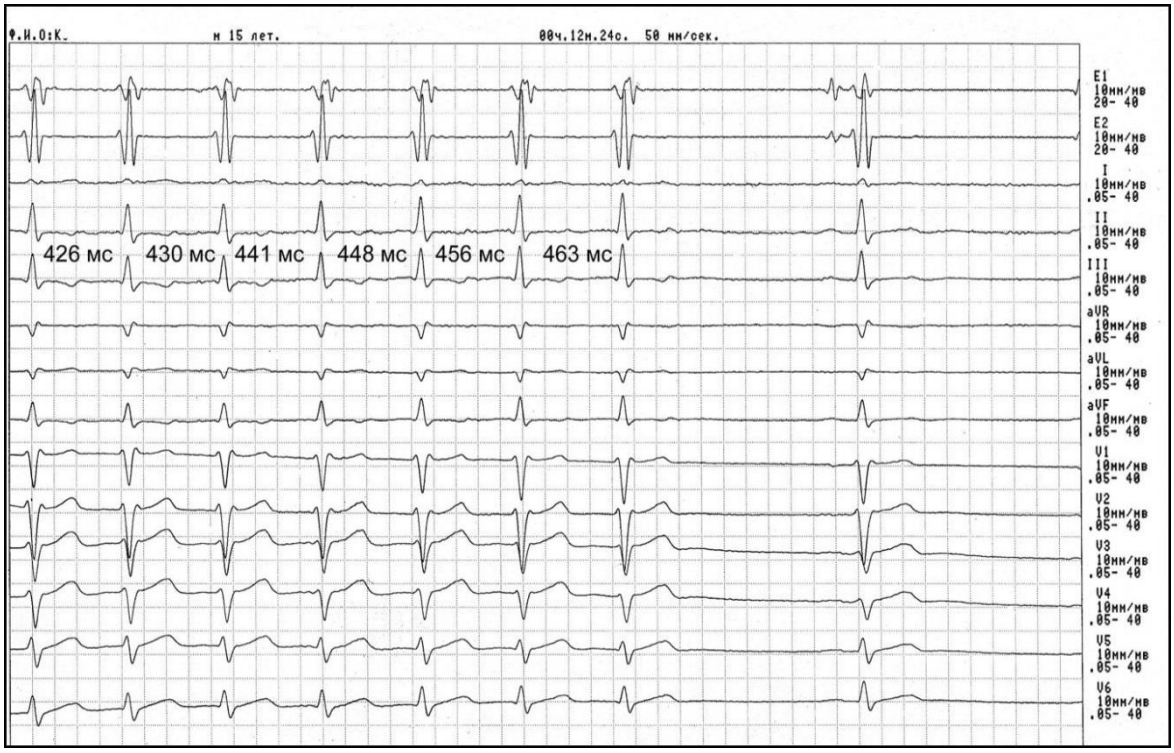
Note. HR stands for heart rate, WP stands for Wenckebach point, ERP fp stands for effective refractory period of the fast pathway, ERP sp stands for effective refractory period of the slow pathway, ERP AVC stands for effective refractory period of the AV connection, DTC stands for duration of tachycardia cycle (the RR-interval). Test (+): patients who had their tachycardia terminated; Test (–): patients in whom the Valsalva test was inefficient.

ADDITIONAL RESEARCH RESULTS

Using the transesophageal ECG records, we tested the electrophysiological termination of 186 induced tachycardia attacks (96 PAVRNT, 90 PAVRT) by means of the Valsalva test. Tachycardia was mostly terminated by anterograde block of the AV node (in the atria-to-ventricles direction): PAVRT was terminated this way in 59 (65.5%) cases, PAVNRT in 89 (92.7%) cases. In most cases, before paroxysmal AV reentrant tachycardia was terminated, it was slowed down, RR intervals were lengthened by increase in PR intervals i.e. by increasing the anterograde AV transmission time (Pic. 1).

Vagal techniques were efficient if applied at the very onset of induced tachycardia. 23 children out of 88, or 26.1%, did not manage to do the Valsalva test correctly within 30 seconds from the onset of the first induced tachycardia attack; they performed the vagal correctly technique in 40 to 60 seconds from the onset of induced tachycardia, and only 5 of them, or 21.7%, managed to terminate the attack. When tachycardia was induced for the second time, the Valsalva test

performed within 30 seconds from the induction was efficient in all 23 children. 76 children, or 24.8%, had spontaneous increases in tachycardia rhythms after tachycardia was induced. This rendered the Valsalva test inefficient.



Pic. 1. Fragment of transesophageal electrophysiological examination of Patient K., 15 years old (50 mm/s, E_1 and E_2 esophageal leads.

Note. Induced AV-nodal reentrant tachycardia was terminated by the Valsalva test by anterograde block of the slow pathway of the AV node. Before termination, the tachycardia cycle lengthened (the RR intervals increased).

Ф.И.О.	*Full name*
К.	*K.*
м	*M*
15 лет	*15 years of age*
00ч.12м.24с	*00:12:24*
мм/сек	*mm/s*
мс	*Ms*
мм/мв	*mm/mV*

ADVERSE EVENTS

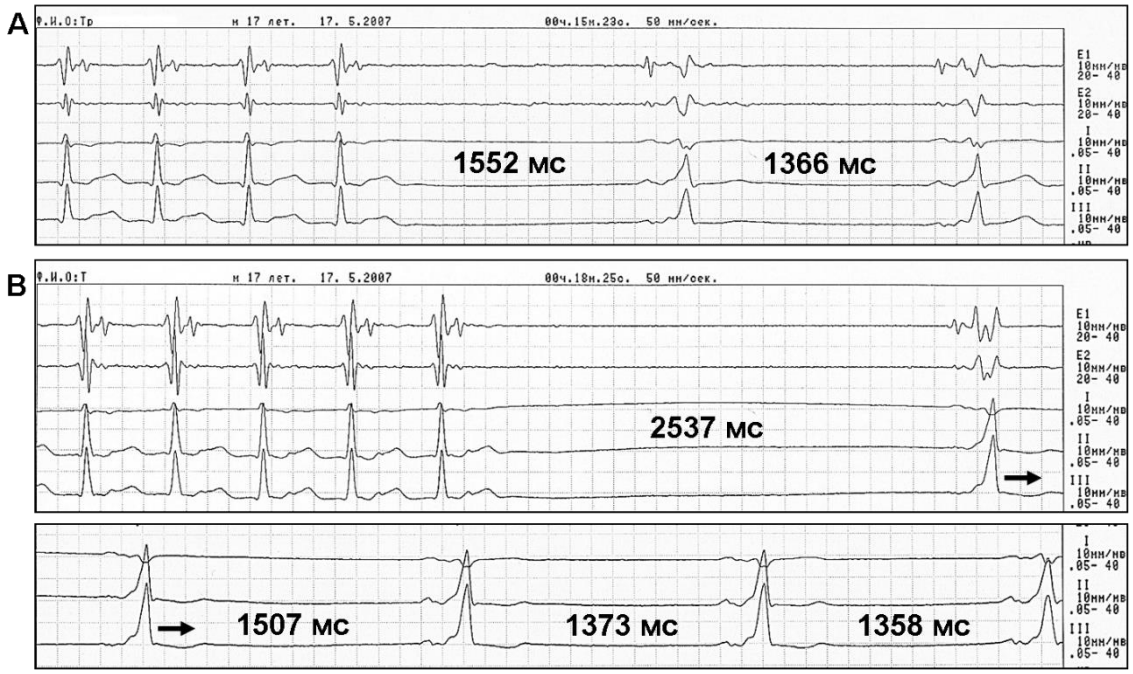
Correctly performed vagal techniques are considered relatively safe; however, they can trigger intense bradycardia or even asystoly, especially in children with sinus node dysfunction or those who permanently take antiarrhythmic drugs.

CLINICAL CASE EXAMPLE

Patient T., 17 years old. The medical record shows that this child was born in the second pregnancy (no pregnancy pathologies). Born in the 39th week. Had tachycardia attacks since the age of 15, up to 2 attacks a week with no clear association with physical exercises. The attacks were mostly diurnal and lasted 5 to 10 minutes, terminated on their own. Complaints of dizziness and asthenia at the time of spontaneous tachycardia termination. When patients tried to use vagal techndiques to terminate tachycardia, they experienced stronger dizziness, vision grayout, and

nausea. The ECG performed at the age of 16 showed a Δ-wave, sinus bradycardia with an HR of 44 bpm. Round-the-clock ECG monitoring was carried out at the same age and identified a transitory Δ-wave, average diurnal HR of 69 bpm, average nocturnal HR of 45 bpm. ECG did not register tachycardia. Diagnosis TEEPE was performed at the age of 17. TEEPE identified an autonomic dysfunction of the sinus node, intermittent Wolf-Parkinson-White syndrome, and PAVRT with average HR of 146 bpm, RP 123 ms. Spontaneous termination of induced tachycardia triggered a 1552-ms-long cardiac rhythm pause with subsequent short period of bradycardia down to 43 bpm (Pic. 2A). Termination of induced tachycardia by means of Valsalva test triggered a 2537-ms-long cardiac rhythm pause with subsequent longer-lasting bradycardia down to 40 bpm (Pic. 2B).

This clinical case shows that the use of vagal technique in children with intense bradycardia and autonomic dysfunction of the sinus node can trigger long cardiac rhythm pauses and lead to presyncopal or syncopal conditions.



Pic. 2. Fragments of transesophageal electrophysiological examination of Patient T, 17 years old, intermittent Wolf-Parkinson-White syndrome and autonomic dysfunction of the sinus node (50 mm/s, E_1 and E_2 esophageal leads).

Note. A: spontaneous tachycardia termination, a rhythm pause lasting 1552 ms; B: tachycardia termination by Valsalva test, a rhythm pause lasting 2537 ms with subsequent 2-minute-long bradycardia.

Tp Tr

T T

Discussion

SUMMARY OF THE PRIMARY RESEARCH RESULTS

In schoolchildren, the Valsalva test terminates AV reentrant tachycardia in no more than a third of all cases. The vagal technique is more efficient in children with lower AV conduction, lower rhythm rate during tachycardia or at the onset thereof. The longer is the history of the disease, the less efficient is the vagal technique. The Valsalva test is safe for children with hemodynamically stable tachycardia and without intense sinus node dysfunction.

DISCUSSION OF THE PRIMARY RESEARCH RESULTS

The Valsalva test terminated induced tachycardia in every third child with PAVRT and every fourth child with PAVNRT; in most cases, tachycardia was terminated by anterograde block of the AV node. When used by adults, vagal tests terminate PAVNRT less efficiently than they terminate PAVRT; in half of cases, tachycardia is terminated by retrograde block [13, 14]. It seems that termination of tachycardia by retrograde block is a rare case for children due to the high retrograde conduction via the AV node fast pathway or an additional AV connection. According to Z.C. Wen et al., PAVNRT is adults was mostly terminated by retrograde block. It is notable that those patients had lower Wenckebach points compared to patients who had tachycardia terminated by anterograde block [14]. Therefore, the fact that PAVNRT is mostly terminated by anterograde block of the slow AV node pathway is actually a specific feature of children.

It should be noted that the modified Valsalva test we used is different from the classical test Italian surgeon Antonia Maria Valsalva suggested in 1704. He has studied the structure of the middle ear and auditory tube and then recommended to make forced oral exhalations with tightly closed nostrils so as to cleanse the middle ear of pus [12, 15]. The classical Valsalva test is an exhalation into a mouthpiece connected to a manometer, which maintains a pressure of 40 mm Hg for 15 seconds. Termination of paroxysmal tachycardia requires a different technique: the patient takes a deep breath and does not exhale, while keeping the abdominal muscles tensed. This technique is still referred to as the Valsalva test, although it was first proposed by N.A. Lopatkin to examine varicocele patients. The method is also used in urology, phlebology, and other areas of medicine [15]. However, the pathogenesis of vagal activation is similar in both versions of the Valsalva test: increased intrathoracic pressure stimulates baroreceptors, which results in a phasic change of arterial pressure (AP) and HR.

The Valsalva test has 4 stages:

- Stage One: the AP increases due to the increase in intrathoracic pressure;
- Stage Two: inflow rate of venous blood falls down, which decreases the AP; the falling AP results in a reflectory increase in the tonus of the sympathetic nervous system. It also leads to vasoconstriction and HR increase. Then the AP rises up whilst the HR is slightly reduced.
- Stage Three begins immediately after the exhalation. A sharp decrease in intrathoracic pressure decreases the AP, boosts the tonus of the sympathetic nervous system and maximizes the HR; in Stages Two and Three of the Valsalva test, the sympathetic activation can speed up the AV nodal conduction, and tachycardia is most likely to be terminated by retrograde block, i.e. the block of the AV node fast pathway in case of PAVNRT, or retrograde block of the additional AV connection in case of PAVRT, as these pathways are incapable of sustaining sped-up circular transmission of the impulse.
- Stage Four (post-exhalation recovery until the AP is normalized): the AP is rising over 10 seconds, while the HR falls. During this stage, vagal stimulation is maximized, the refractory period in the AV node becomes longer, the AV conduction is slowed down, which finally terminates reentrant tachycardia by means of anterograde block, i.e. the block of the AV node slow pathway in case of PAVNRT, or the block of the AV node in case of PAVRT.

Whether vagal techniques will help terminate paroxysmal tachycardia depends on the electrophysiological properties of the conduction pathways included in the reentry circle. This was typical for PAVNRT-affected children, in whom the Valsalva test was inefficient, and the two pathways featured shorter effective refractory periods, whilst the Wenckebach point was greater. Greater initial AV node conduction seems to prevent maximum vagal stimulation from slowing down the impulse in the AV tissue; thus, such prevented slowdown is not sufficient for tachycardia termination.

As we examined children with paroxysmal tachycardia, we did not make comprehensive evaluations of the autonomic nervous system status. Nevertheless, children with inefficient Valsalva tests had a greater sinus rhythm prior to tachycardia induction, which is probably due to the greater sympathetic effect on the heart. In adults, paroxysmal AV reentrant tachycardia has a regular, "clock-like" rhythm [10]. In children, the rhythmic frequency can vary significantly during a tachycardia attack. 25% of children had a "boost", a spontaneous HR increase after tachycardia induction, which may be due to the greater sympathetic effects occurring during tachycardia. This can explain why vagal techniques are more efficient at the onset of tachycardia. Children with longer history of paroxysmal tachycardia often form an increased vagal tonus, which can lower the effect of vagal techniques per the known "initial level law", i.e. the greater is the initial tonus of the parasympathetic division of the autonomic nervous system, the weaker is the expected response to vagal stimulation. It is obvious that the status of the autonomic nervous system in children with paroxysmal tachycardia is an important factor of vagal technique efficiency. This can be an interesting topic for further research.

RESEARCH LIMITATIONS

Our research has shown that the Valsalva test is less efficient in children with paroxysmal AV reentrant tachycardia. However, it should be borne in mind that the efficiency of vagal techniques was assessed for TEEPE-induced tachycardia, not for spontaneous attacks. We identified the clinical and electrophysiological factors affecting the efficiency of the Valsalva test; but we did not carry out a regression analysis of the independent roles of such factors.

Conclusion

The modified Valsalva test that is used in pediatric arrhythmology for termination of paroxysmal tachycardia in children is efficient in no more than a third of all patients; its efficiency depends on the duration of the diseases as well as the electrophysiological parameters of the AV-nodal connection. In most cases, paroxysmal AV reentrant tachycardia is terminated by anterograde block of the AV node. It is recommended to use the Valsalva test at the very onset of tachycardia; use it cautiously if the child has an autonomic dysfunction of the sinus node.

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Conflict of interest

The authors declared they have no competing interests to disclose.

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