The Role of the Capnography Head-up Tilt Test in the Diagnosis of Syncope in Children and Adolescents

Jochanan E. Naschitz, MD*; Daniel Hardoff, MD‡; Irena Bystritzki, MD*; Daniel Yeshurun, MD*; Luis Gaitini, MD§; Ada Tamir, DSc∥; and Michael Jaffe, MB, ChB, MRCP, DCH‡

ABSTRACT. Objectives. To evaluate the role of the capnography head-up tilt test (CHUTT) in the diagnosis of syncope in pediatric patients.

Methods. The CHUTT is a head-up tilt test with concomitant capnometry. Hyperventilation on CHUTT was diagnosed when the patient's end-tidal carbon dioxide pressure (ETPCO₂) was ≤25 mm Hg. Hyperventilation syncope was diagnosed when three criteria were met: loss of consciousness, ETPCO₂ ≤25 mm Hg, and no significant drop in blood pressure. The cohort included 65 consecutive children and adolescents (mean age, 14.2 years) who were assessed for syncope by routine investigations and CHUTT.

Results. The cause of the syncope was established in 67% of cases: cardioinhibitory reaction in 17%, vasodepressor in 20%, psychogenic in 22%, and mixed neurally mediated-psychogenic in 8% of the patients. The history indicated a cause of syncope in 40%, the CHUTT in 49%, and a combination of the history and positive CHUTT in 66% of patients. Neither the patients' clinical data nor values of the blood pressure, heart rate, respiratory rate, and ETPCO₂ measured during recumbency predicted which patients would manifest hyperventilation or hypotension syncope on tilt.

Conclusions. The CHUTT contributes substantially to the diagnosis of syncope in pediatric patients. The CHUTT advances the understanding of the pathophysiological mechanisms of syncope and enables the physician to reassure the patient regarding the essentially benign nature of the condition. Because it is not possible to predict which patients would develop a hyperventilation syncope on the standard tilt test, the modification of this procedure by measuring the ETPCO₂ for the assessment of children with syncope should be considered.

METHODS

Definitions

Syncope was defined as a transient loss of consciousness associated with loss of postural tone, occurring in the standing or sitting position and followed by a rapid spontaneous recovery on assuming the supine position. Presyncope was defined as a sensation of impending loss of consciousness, characterized by light-headedness, dizziness, weakness, blurred vision, incoherence, slow response times to verbal stimuli, nausea, vomiting, or partial
loss of postural tone. Inclusion criteria for the cohort in this study were those patients manifesting either syncpe or presyncope as defined above, and all patients were subsequently referred to under the term syncpe. Cardiac and noncardiac causes of syncpe were differentiated, and the following categories were diagnosed: 1) Neuromediately-mediated syncpe, which results from reflex mechanisms that are associated with inappropriate vasodilatation, bradycardia, or both. The subtypes of neurally-mediated syncpe are cardioinhibitory, vasodepressor, situational, and carotid sinus syncpe. 2) Orthostatic hypotension that results either from autonomic insufficiency, volume depletion, medications, or advanced age-related physiologic changes. 3) Psychogenic syncpe that is associated with anxiety, depression, or conversion disorders. A number of definitions of psychogenic syncpe have been used by various authors, but all definitions include a loss or apparent loss of consciousness in the presence of a normal BP during the event. We diagnosed psychogenic syncpe when at least one of the following criteria were met: 1) impaired consciousness associated with distinct hyperventilation was observed by the clinician before the CHUTT; 2) loss of consciousness, ETIXPO2 ≤ 25 mm Hg, and no significant drop in BP on the CHUTT; and 3) a conversion reaction without hypocapnia was noted during the CHUTT. We therefore comprised within the category of psychogenic syncpe different clinical syndromes, including hyperventilation syncpe.

**Population**

Consecutive patients presenting with syncpe or presyncpe at the pediatric emergency room of the Bnai-Zion Medical Center from January 1, 1996, to December 31, 1996, were assessed prospectively and constituted the study group.

**Basic Evaluation**

The patients underwent a detailed history, a syncpe questionnaire, a general physical examination, BP recorded in the recumbent and erect positions, laboratory tests (a complete blood count, electrolytes, glucose, blood urea nitrogen, and urinalysis), and a 12-lead electrocardiogram. The CHUTT was performed in all patients. Patients with abnormal findings on cardiac auscultation or electrocardiogram were evaluated by a pediatric cardiologist and underwent a 24-hour ambulatory electrocardiographic monitoring and echocardiography. An electroencephalogram was performed only when the possibility of a convulsive disorder was considered.

**The CHUTT Protocol**

The CHUTT is a modification of the HUTT consisting of concomitant continuous recording of the BP, heart rate, and ETIXPO2. The BP was monitored using a mercury column sphygmomanometer with auscultatory BP readings by a physician. Heart rate was continuously recorded on an electrocardiogram monitor. The respiratory rate and the ETIXPO2 were continuously monitored with a Datex Normacap infrared capnometer (Normacap, Helsinki, Finland). Normal values of ETIXPO2 in our laboratory are within the range of 36 to 40 mm Hg. All parameters were recorded in the supine position for 10 minutes, and during head-up tilt to within the range of 36 to 40 mm Hg, and no significant drop in BP on the CHUTT, and 3) a conversion reaction without hypocapnia was noted during the CHUTT. We therefore comprised within the category of psychogenic syncpe different clinical syndromes, including hyperventilation syncpe.

**Endpoints of the CHUTT**

The following endpoints were observed: 1) Orthostatic syncpe was diagnosed when some degree of cerebral dysfunction and increase of heart rate of at least 10 beats per minute occurred during the first 3 minutes of the tilt associated with one or both of the following conditions: a fall of systolic BP of at least 20 mm Hg, and a fall of diastolic BP of at least 10 mm Hg compared with the last supine measurement. 2) Vasodepressor syncpe was diagnosed when some degree of cerebral dysfunction and increase of heart rate of at least 10 beats per minute occurred after the initial 3 minutes of the tilt associated with a BP fall of a similar degree. 3) Cardioinhibitory syncpe was diagnosed when a BP fall of a similar degree without an increase in heart rate was accompanied by some degree of cerebral dysfunction. 4) Hyperventilation syncpe was diagnosed when some degree of cerebral dysfunction occurred during tilt, associated with decrease of ETIXPO2 values to 25 mm Hg or less, unassociated with a fall in BP. 5) The term mixed hypotensive-hyperventilation syncpe was defined as occurrence of some degree of cerebral dysfunction during tilt, associated with a decrease of ETIXPO2 values to 25 mm Hg or less, and a concomitant drop of systolic BP of 20 mm Hg or more, a drop of diastolic BP of 10 mm Hg or more, or both.

The corresponding entities in category B differed from category A by being unassociated with impaired consciousness and postural tone.

**Syncpe Diagnosis**

The diagnosis required that either 1) the syncopal episode was witnessed by a physician and examination during the syncpe permitted an unequivocal diagnosis, or 2) when a spontaneous syncpe was not witnessed by the physician, a diagnosis of syncpe required that both the clinical history and results of syncpe evaluation conformed to one of the established variants of syncpe.

**Data Analysis**

The patient files and the CHUTT records were reviewed by two independent physician evaluators. Complete agreement between them was required to classify the patients according to an etiological category. The following aspects were evaluated: 1) analysis of the etiologies of syncpe and the contribution of diagnostic tests in establishing the diagnosis; 2) analysis of the endpoints reached on CHUTT; 3) examining the clinical factors that could predict pathological findings on the tilt test; and 4) scrutiny of CHUTT parameters during the supine phase (BP, heart rate, respiratory rate, and ETIXPO2) that could have predicted the occurrence of pathological features on tilt.

**Statistical Analysis**

The Kruskal-Wallis test or the t test were utilized as appropriate.

**RESULTS**

Sixty-five children and adolescents were evaluated, 21 males and 44 females, with a mean age of 14.2 years (standard deviation, 3.4; range, 6 to 17 years). During the year before the work-up a single syncopal episode had occurred in 21 cases, 2 to 4 episodes in 31 cases, and 5 or more episodes in 13 cases.

The etiologies of the syncpe were as follows (Table 1): cardioinhibitory syncpe in 11 patients (17%), vasodepressor syncpe in 13 patients (20%), psychogenic syncpe in 14 patients (22%), mixed hypotensive-psychogenic syncpe in 5 patients (8%), and unknown in 22 patients (34%). Orthostatic syncpe was not observed. Illustrative recordings are shown in Figures 1 and 2. A cardiac origin of the syncpe was not revealed at initial work-up and follow-up in any of the 65 patients.

The history of the episode indicated a cause of syncpe in 26 patients (40%), the physical examination in 3 patients (5%), when a cardioinhibitory faint or convulsive reaction were witnessed by a physician, and the CHUTT in 34 patients (52%). When the history and data of the CHUTT were combined, the cause of syncpe was established in 43 patients (66%) (Table 1). The various laboratory tests, electrocardiogram, echocardiography, and electroencephalogra-
phy did not indicate the cause of the syncope in any of the patients.

Endpoints reached during the CHUTT are shown in Table 2. The CHUTT provoked impairment of the consciousness in 11 cases (17%) including cardioinhibitory syncope (n = 2), vasodepressor syncope (n = 1), hyperventilation syncope (n = 4), mixed cardioinhibitory-hyperventilation syncope (n = 1), mixed hypotensive-hyperventilation syncope (n = 1), and conversion reaction (n = 2). Homeostatic disturbances that were not associated with impairment of the consciousness were observed on CHUTT in 23 patients (35%): vasodepressor (n = 12), hyperventilation (n = 8), and mixed hypotensive-hyperventilation reaction (n = 3).

The patients' clinical data (age, gender, frequency of faints, apparent triggering factors of faints) as well as the CHUTT parameters during the supine phase were correlated with the occurrence of pathological features during tilt. None of the parameters were significantly associated with the pathological outcomes on tilt.

Furthermore, baseline-to-tilt changes of the heart rate, BP, respiratory rate, and ETPCO₂ were compared in three subgroups: patients with hyperventili-
loration on tilt (n = 12), patients with hypotension on tilt (n = 15), and patients who had neither hyperventilation nor hypotension on tilt (n = 33) (Table 3). It was shown that mean values recorded in the supine phase (BP, heart rate, respiratory rate, and ETPCO₂) were similar in the three subgroups and therefore could not predict the subsequent occurrence of specific homeostatic abnormalities on tilt.

### DISCUSSION

The results of our investigation confirm the findings of earlier studies showing that cardioinhibitory, vasodepressor, and psychogenic syncope are the most frequent causes of transient loss of consciousness in childhood and adolescence. A detailed history and the CHUTT were the most important instruments in establishing the cause of syncope.

Various protocols of upright tilt testing are currently in use such as different schemes of the passive HUTT and HUTT in conjunction with provocative agents. Review of the adult literature shows a mean percent of positive responses on the passive HUTT in 49% and specificity of 90%, contrasting with isoproterenol-enhanced HUTT with a mean percent of positive response of 66% and a specificity of only 55%. We therefore chose a passive HUTT protocol: this 10 minute supine-30 minute passive HUTT when combined with capnography was designated as the CHUTT. With the aid of the CHUTT, hypcapnia and occasionally hyperventilation syncope can be diagnosed.

The pathophysiological mechanisms of the hyperventilation syncope are not completely understood. The trigger for spontaneous hyperventilation is not always obvious. The mechanism that links the hemodynamic challenge induced by tilt to the ensuing hyperventilation has also not been clarified. Two possible explanations are suggested. First, hyperventilation in this setting may be in fact a panic attack induced during tilt. However, full blown classic panic attacks are infrequently observed in the tilt laboratory. Second, hyperventilation may result from the triggering of the autonomic nervous system during tilt, leading to activation of the respiratory center and hyperventilation. In support of this proposed mechanism is the observation that discontinuation of the tilt is usually followed by relief of the symptoms within 2 to 5 minutes. This may be consistent with a reflex mechanism rather than a psychogenic reaction. It is evident that activation of the autonomic nervous system during tilt may generate a mixture of ventilatory and hemodynamic reactions.

The impairment of consciousness, the final step in the chain of events, can be explained by more than one mechanism. Several hypothetical pathophysiological mechanisms for the hyperventilation syncope have been proposed. First, the hypocapnia resulting from hyperventilation can induce vasodilatation in muscles and subsequent hypotension, which can progress to syncope. Second, if hyperventilation is combined with a self-induced Valsalva’s maneuver, the latter may play a role in the pathogenesis of syncope. Third, in the absence of vasodepressor or a cardioinhibitory reaction, hypocapnia resulting from excessive expiratory loss of carbon dioxide can induce diffuse cerebral vasoconstriction and cause a loss of consciousness. Hypocapnia may occur jointly with hypotension, and both mechanisms may synergistically promote cerebral ischemia and subsequent syncope. It is noteworthy that at a given level of hypocapnia syncope will not always result. More than one pathophysiological mechanism may therefore be active in precipitating the syncope in a given hyperventilating anxious patient. These aberrant mechanisms can be demonstrated with the CHUTT.

The diagnosis of hyperventilation is not difficult when the patient presents with a history of a sudden onset of rapid deep breathing followed by lightheadedness, weakness, and tingling of the extremities. The clinical picture, in conjunction with absence of abnormal cardiac or pulmonary findings or hypoxia, and termination of the incident by rebreathing into a paper bag permit one to make an immediate diagnosis. Frequently, however, the hyperventilation is not clinically obvious and neither the patient nor the physician is aware of a change in either the

### TABLE 3. Comparison of Parameters of the Capnography Head-up Tilt Test in Three Subgroups

<table>
<thead>
<tr>
<th>Patients</th>
<th>Hyperventilation Mean (Standard Deviation)</th>
<th>Hypotension Mean (Standard Deviation)</th>
<th>Neither Hyperventilation nor Hypotension Mean (Standard Deviation)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supine†</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart rate (bpm)</td>
<td>75.4 (17)</td>
<td>79.9 (14.2)</td>
<td>79.4 (14.2)</td>
<td>NS</td>
</tr>
<tr>
<td>Systolic BP (mm Hg)</td>
<td>106.7 (15)</td>
<td>108.7 (11.9)</td>
<td>102.9 (10.7)</td>
<td>NS</td>
</tr>
<tr>
<td>Diastolic BP (mm Hg)</td>
<td>65.4 (9.4)</td>
<td>64.7 (6.4)</td>
<td>65.3 (5.7)</td>
<td>NS</td>
</tr>
<tr>
<td>Respiratory rate/min</td>
<td>17.3 (3.8)</td>
<td>16.9 (2.8)</td>
<td>16.5 (2.1)</td>
<td>NS</td>
</tr>
<tr>
<td>ETPCO₂ (mm Hg)</td>
<td>36.4 (3.6)</td>
<td>38.3 (4.1)</td>
<td>39.3 (3.5)</td>
<td>NS</td>
</tr>
<tr>
<td>Tilt‡</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart rate (bpm)</td>
<td>101.3 (17.6)</td>
<td>102 (21.3)</td>
<td>108.7 (15.8)</td>
<td>NS</td>
</tr>
<tr>
<td>Systolic BP (mm Hg)</td>
<td>103.3 (15.5)</td>
<td>80.3 (14.6)</td>
<td>95.0 (10.9)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Diastolic BP (mm Hg)</td>
<td>65.0 (9.8)</td>
<td>50.3 (10.1)</td>
<td>60.0 (6.7)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Respiratory rate/min</td>
<td>28.1 (11.8)</td>
<td>20.0 (3.1)</td>
<td>18.0 (2.0)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>ETPCO₂ (mm Hg)</td>
<td>36.4 (3.6)</td>
<td>34.7 (5.1)</td>
<td>35.9 (4.6)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Duration of tilt (min)</td>
<td>23.8 (6.2)</td>
<td>25.9 (8)</td>
<td>29.1 (5.2)</td>
<td>=.05</td>
</tr>
</tbody>
</table>

* The three subgroups are patients with hyperventilation on tilt, patients with hypotensive events on tilt, and patients with neither hyperventilation nor hypotension on tilt. Excluded from analysis were 5 patients with mixed hypotenision-hyperventilation on tilt.
† Values at the end of the supine phase.
‡ Peak abnormalities during the tilt phase.
depth or frequency of respiration. The giddiness, faintness, or lightheadedness that often accompany hyperventilation may persist for hours and sometimes days, in contrast to the short duration of the syncope. Some authorities are of the opinion that hyperventilation probably does not cause a genuine syncope; however, this has been recently disputed. In the present study, out of 17 patients having hypocapnia on CHUTT, 4 patients had hyperventilation syncope and 2 had mixed hypotensive-hyperventilation syncope. The data provided by the CHUTT confirmed that an entity of hyperventilation syncope might exist.

The typical patient with hyperventilation syncope manifested features of a generalized anxiety disorder. Episodic losses of consciousness, sometimes associated with falls, occurred in clusters during a period of a few months. The triggering factor for the events varied in the same patient: from strenuous exertion to no apparent cause in most instances, such as relaxing seated on a chair. During rest it was not possible to predict which patients would develop a hyperventilation syncope on tilting (Table 3). Throughout the test the examiners were impressed by the patients’ restlessness and anxiety, which was rarely noted in the other categories of patients. Pallor and excessive tachycardia occurred during the tilt phase. The respiratory rate was only slightly increased in most patients even at the time of severe hypocapnia so that the hyperventilation was not obvious. Hyperventilation syncope was alleviated within 2 to 5 minutes by retilting the patient to the supine position. Hyperventilation syncope differed from the conversion reaction observed on the tilt table in 2 patients. Conversion reactions presented shortly after securing the patient to the tilt table, while still in the supine position; they were not associated with hyperventilation and hypocapnia. Their duration was between 10 to 20 minutes, and they were not mitigated by loosening the security girdles and changing the patient’s posture. Psychogenic syncope is, therefore, a comprehensive term including a variety of psychological and physiologic reactions, one of those being hyperventilation syncope.

The reproducibility of hyperventilation and hyperventilation syncope was demonstrated in a previous study, in which the specificity of the CHUTT in the diagnosis of hyperventilation syncope in adults was 100%. In that study hyperventilation syncope occurred only in patients with recurrent spontaneous syncope, but not in the control patients without a history of syncope, including subgroups of patients with generalized anxiety disorder, chronic fatigue syndrome, and arterial hypertension.

The incidence of hyperventilation syncope has not been determined. This is attributable to the hitherto absence of accurate criteria for its diagnosis and a low index of suspicion for a relatively unknown condition. In early studies only rare mention of the psychological causes of syncope were noted. More recent surveys, however, mention an underlying psychological disorder in nearly one-third of unselected young patients who presented for an evaluation of syncope. Unfortunately, tilt tests were not done in these studies and the diagnosis of hyperventilation syncope was based on the much-criticized voluntary hyperventilation test. Neurally-mediated syncope was not distinguished from psychogenic syncope.

In a previous study of a highly selected adult population, including 14 patients who had both spontaneous syncope and syncope on a HUTT that was not associated with hypotension, repeated evaluation with the aid of the CHUTT showed hyperventilation in 11 (78%) and hyperventilation syncope in 7 (50%) of the cases. In a second group of 50 consecutive adults with syncope, the CHUTT revealed hyperventilation in only 5 patients (10%) but none had a hyperventilation syncope on tilt. In the present study in 65 consecutive pediatric patients with syncope, the CHUTT revealed hyperventilation in 17 patients (26%), of which 4 (6%) had genuine hyperventilation syncope and 2 (4%) had mixed hyperventilation-hypotensive syncope.

In conclusion, the CHUTT contributes substantially to the diagnosis of syncope in pediatric patients. The CHUTT advances the understanding of the pathophysiological mechanisms of syncope and enables the physician to reassure the patient regarding the essentially benign nature of the condition. Because it is not possible to predict which patients would develop a hyperventilation syncope on the standard tilt test, the modification of this procedure by measuring the ETCO₂ for the assessment of children with syncope should be considered.

REFERENCES

The Role of the Capnography Head-up Tilt Test in the Diagnosis of Syncope in Children and Adolescents
Jochanan E. Naschitz, Daniel Hardoff, Irena Bystritzki, Daniel Yeshurun, Luis Gaitini, Ada Tamir and Michael Jaffe

*Pediatrics* 1998;101;e6
DOI: 10.1542/peds.101.2.e6

Updated Information & Services
including high resolution figures, can be found at:
/content/101/2/e6.full.html

References
This article cites 28 articles, 9 of which can be accessed free at:
/content/101/2/e6.full.html#ref-list-1

Subspecialty Collections
This article, along with others on similar topics, appears in the following collection(s):
Cardiology
/cgi/collection/cardiology_sub

Permissions & Licensing
Information about reproducing this article in parts (figures, tables) or in its entirety can be found online at:
/site/misc/Permissions.xhtml

Reprints
Information about ordering reprints can be found online:
/site/misc/reprints.xhtml
The Role of the Capnography Head-up Tilt Test in the Diagnosis of Syncope in Children and Adolescents
Jochanan E. Naschitz, Daniel Hardoff, Irena Bystritzki, Daniel Yeshurun, Luis Gaitini, Ada Tamir and Michael Jaffe
*Pediatrics* 1998;101:e6
DOI: 10.1542/peds.101.2.e6

The online version of this article, along with updated information and services, is located on the World Wide Web at:
/content/101/2/e6.full.html