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Head-up-tilt testing in children: new perspectives using beat-to-beat blood-pressure monitoring

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Abstract

The head-up-tilt-test in pediatric patients for the evaluation of syncope shows a sensitivity of 35-85% and often requires pharmacological stimulation in order to improve its diagnostic value. We used a new device for beat-to-beat blood pressure monitoring combined with impedance cardiography in a 12-year-old girl during tilt testing. A seven seconds asystolia was provoked. The haemodynamic parameters showed clearly the drop in heart rate as well as in cardiac output, and returned to normal values after tilting back the patient. With the help of this new monitoring device, the sensitivity and specificity of head-up-tilt-testing can probably be improved.

MeSH: Tilt-Table Test, Cardiac Output, Heart Arrest, Cardiac Output, Syncope, Case report

Introduction

Evaluating syncope in paediatric patients frequently presents a diagnostic challenge. The patient's history is not easily obtained and often reported incompletely by the patient's parents, but it is essential for making the right decisions about appropriate diagnostic tools. Careful physical examination is time consuming in children though it is warranted in order to distinguish between potentially harmful cardiac syncopes and neurocardiogenic spells with a more favorable prognosis. Furthermore, the small size of children limits certain diagnostic procedures such as exercise testing or electrophysiological testing. On the other hand syncope occurs in around 15% of children up to the age of 18 years[1,2] and is therefore a complaint frequently encountered in pediatric outpatient clinics as well as in pediatric cardiology clinics.

One of the most valuable procedures in testing for syncope is the head-up tilt test.[3] As it is done as an additional examination in the adult patient with normal results of

cardiac testing by physical examination, resting ECG and resting blood pressure monitoring, its usefulness in the pediatric age is limited for several reasons. Patient collaboration is poor in a test lasting at least 45 minutes and, in order to improve sensitivity of 35% - 85%,[4] sometimes requiring intravenous pharmacological stimulation. It is also often difficult to persuade children's parents to give their consent to bend their child on a tilt table and tilt it up until a syncope happens. And finally, there is limited value of the results by monitoring only ECG and blood pressure during this long lasting test and neglecting any information about cardiac output, total peripheral vascular resistance and stroke volume.

We used a new device for head-up tilt testing which links beat-to-beat blood pressure monitoring with impedance cardiography in order to improve our diagnostic capability. The patient was a 12 year old girl suffering from three near-syncope faints in the past.

Case report

A 12-year-old girl presented at our institution with three episodes of near syncope. The patient's family history was negative for syncopes as well as for other inheritable disorders and she was not on any medication. She could perform moderate aerobic sports (cycling, hiking, swimming) without any problems. All three spells occurred in the morning and were interpreted as orthostatic intolerance. The physical examination revealed a systolic murmur; the 12-lead-ECG was normal. By echocardiography a discrete prolapse of the mitral valve with trivial mitral regurgitation was diagnosed.

Head-up-tilt table testing was performed in a quiet room at 9 am after a light breakfast with enough fluid intake in order to avoid dehydration as a cause for positive testing. The room temperature was 18 degrees centigrade. The patient was positioned supine on the tilt table without a venous line for 20 minutes. As the patient relaxed and power spectral analysis of heart rate variability showed an increasing vagal tonus, the tilt table was set in the upright position of 60 degrees within 10 seconds according to the guidelines.[2] The test was to be continued until symptoms would arise or to a maximum length of 45 minutes of upright position.

The monitoring device (“Task Force Monitor”, CNS Systems, Graz, Austria) consisted of a central computer driving several monitoring systems working independently from each other.

Beat-to-beat blood pressure was measured by a finger cuff measuring online beat-to-beat blood pressure on the 2nd and 3rd finger of the left hand and using the so called vascular unloading technique. The pulse signal with its variables is measured for every heartbeat and transformed into a pulse waveform similar to that obtained by invasive arterial blood pressure monitoring. The waveform is displayed on the master screen giving the relative values of beat-to-beat blood pressure.

Calibration of this system occurs through a conventional non-invasive blood pressure cuff positioned on the right upper arm and is performed every five minutes.

We obtained a standard 6-lead-ECG from the patient's chest giving its signal to the central monitoring device, which in turn measures beat-to-beat heart rate and consecutive R-R-intervals. Every R-R-interval is displayed in milliseconds and correlated online with the changes in beat-to-beat blood pressure given in millimetres of mercury. At this point, baroreceptor sensitivity can be calculated according to the sequence method.

By analysing online the heart rate variability it was possible to gain a power spectral analysis delineating the low-frequency band (0,1 Hz, LF) and high frequency band (0.3 Hz, HF). Thus, sympathetic (LF) and parasympathetic (HF) dominance of the autonomous nervous system can be shown during the test and a LF/HF ratio of greater 2 was used for defining a prominent sympathotonus.

Stroke volume measurement is possible through impedance cardiography. Three electrodes were positioned on the right and left lateral chest wall immediately adjacent to the xiphoid as well as in the neck, respectively. A fourth, reference electrode, is set on the left foot. The relative changes in chest impedance measured by these electrodes are transmitted to the central device and transformed into an online waveform signal shown on the monitor giving the beat-to-beat stroke volume and its changes over time and within the cardiac cycle. By multiplying stroke volume and heart rate we obtain the cardiac output in absolute values and standardized for body surface area (cardiac index). From the two variables of cardiac output and mean arterial blood pressure it is possible to calculate total peripheral vascular resistance and its changes during the tilt test.

Results

During head-up tilt table testing the patient's haemodynamic parameters were within normal limits when the girl was in the supine position. However, four minutes after tilting, we noticed an increase in heart rate to a maximum of 110/min compensating the fall in stroke volume from 49 ml to 39 ml due to venous pooling and reduced cardiac preload. The overall TPVR increased from 1578 dyne to 1720 dyne. The cardiac output was maintained at the same level of 3.6 l/min as before. Together with the patient's complaint of dizziness we noted a dramatic decrease in heart rate to 36/min followed by an asystolic period of seven seconds. The beat-to-beat blood pressure dropped down to 62/34 mmHg. Immediately after tilting back to the supine position the patient recovered fully. The ECG-signal showed a stable sinus rhythm of 70/min without any rhythm or conduction disturbances, the blood pressure returned to normal values and stroke volume and cardiac output followed. Therefore, the diagnosis of neurocardiogenic syncope of the cardioinhibitory type with asystolia was made.

Figure 1 The patients haemodynamic parameters before tilting: two ECGtracings, the pulse-form of the beat-to-beat blood pressure and the impedance signal with their respective absolute values on the right of the display.

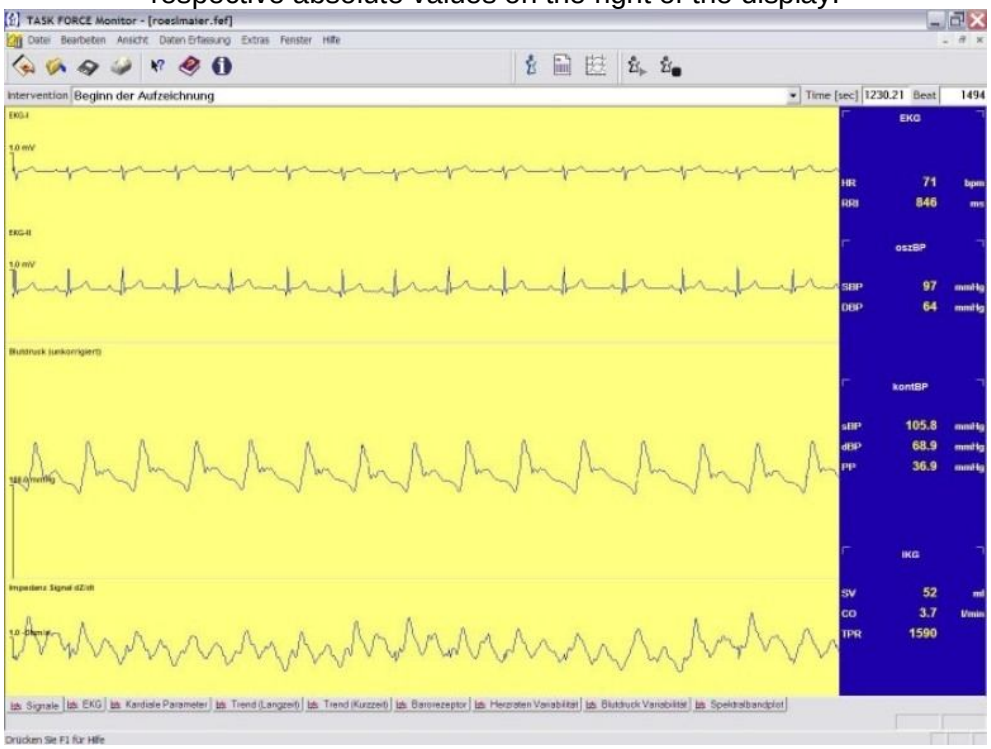

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Figure 2 The same parameters during asystolia: a seven-seconds period without any stroke volume.

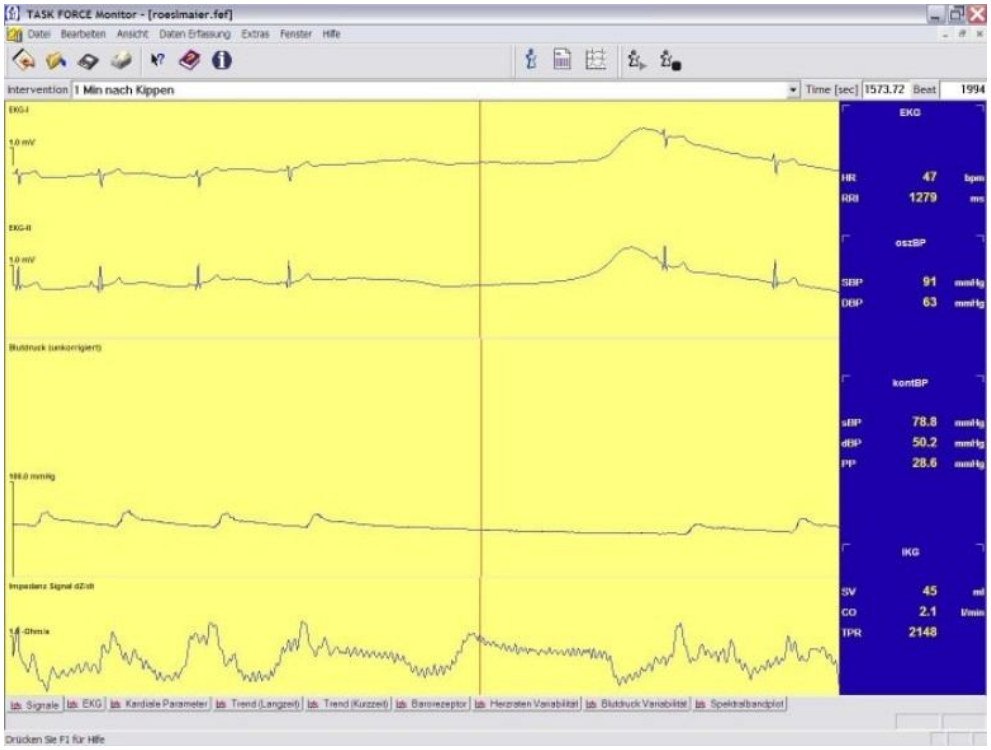
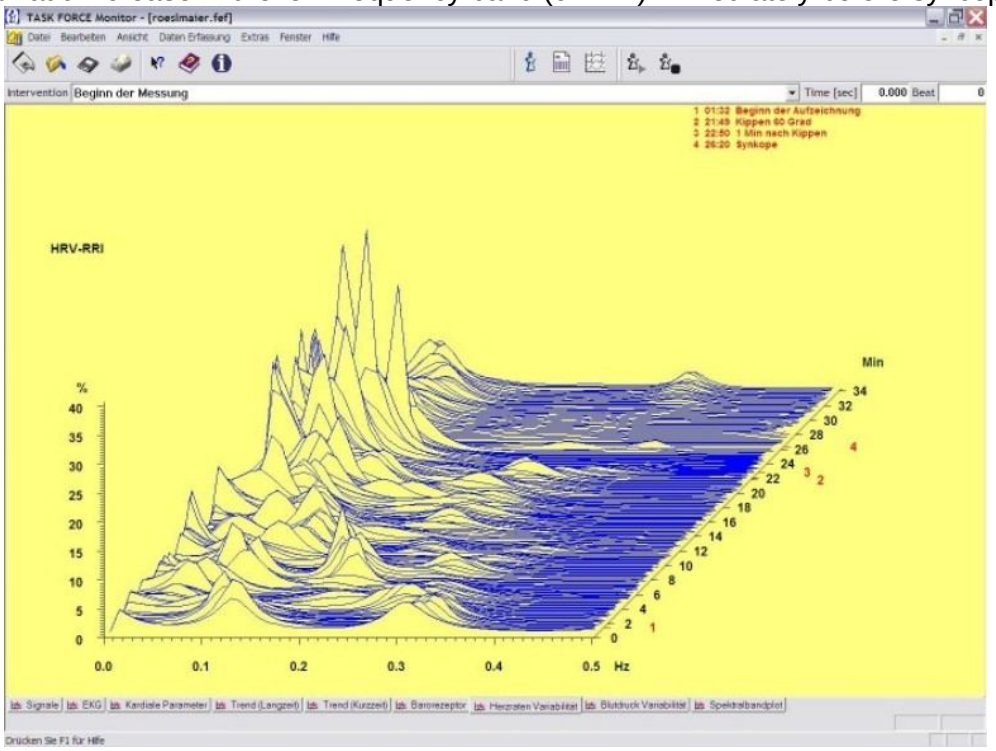


Figure 3 Power spectral analysis of heart rate variability during the test: note the dramatic increase in the low frequency band (0.1 Hz) immediately before syncope.



Discussion

Since the differential diagnosis in syncope of unknown origin is widely spread, there have been many attempts to rationalize and improve the diagnostic procedures.[2] Beyond physical examination and careful medical history nearly every diagnostic procedure could be considered. Especially time- and money-consuming procedures such as EEG, cranial MRI or electrophysiological studies have to be reviewed on the basis of their contribution to the diagnosis.[5]

For paediatricians the benefit of such evaluations for the child has to be much more pronounced. Dealing with scared parents means discussing the risks and advantages of each procedure several times. Therefore there have been many attempts to improve the sensitivity of head-up tilt testing in paediatrics without pharmacological stimulation or invasive monitoring, because putting a venous or arterial line in a child means not only frightening the patient but also falsifying the test's results.

The new device we used in our patient allows us to monitor several haemodynamic variables online during the test and therefore provoking a syncope is not necessary any more.

As we showed, relaxation of the given patient is quantifiable when the ratio of low frequency (LF) and high frequency (HF) can be calculated progressively during the first test phase. A ratio of <2 is considered as dominant vagotonus, according to the literature.[6,7] As in our patient, we were able to start tilting as soon as relaxation occurred without the need for strict time periods given by a tilt table protocol.[2,3,8]

During the tilt phase, the ratio LF/HF increased as an indicator of the girl's activated sympathetic tone, and immediately before the syncope the ratio raised markedly supporting the pathophysiological model of excessive sympathotonus leading to reactive vagotonus and vasodilatation and/or cardioinhibition. By considering these changes during the tilt phase, an increasing ratio of LF/HF is a strong predictor of an upcoming syncopal event confirmed by a rapid decline in heart rate or blood pressure.

Beat-to-beat blood pressure monitoring by the finger pulse cuff is a precious tool in tilt-table-testing as it shows the real decline of blood pressure without the “blind” 20 seconds period usually given by the conventional Riva-Rocci method: in our patient the pulse signal weakened during bradycardia and stopped during asystolia, the real blood pressure level could be measured and would have been probably missed using a conventional arm cuff with a measure time of at least 20 seconds. This fact showed once again the need for beat-to-beat blood pressure monitoring during tilt tests as requested by the guidelines.[2,3]

By ECG the diagnosis of a bradycardia of 40/min followed by an asystolia of 7 seconds leads to the classification of this syncope as a cardioinhibitory type IIb.[2,3,4] Except for that the patient was in stable sinus rhythm and we could therefore exclude any structural cardiac disease.

What about impedance cardiography? It has been shown that the method which had been abandoned in past for poor correlation with the real situation[9] nowadays offers better results in adults.[10] The newly designed electrodes together with a fast data processing computer allows us to sample the measured stroke volume of each heart beat, and by calculating the mean value over a given period inherent confounding errors such as intrathoracic air content can be excluded.

There is concern about the reliability of this method in children. It is questionable whether smaller stroke volumes are scanned properly and if higher breathing frequencies falsify the results. There is, however, certainly a great potential in this method because it allows monitoring the tendency of TPVR, stroke volume and cardiac output in a given patient during the test. As we saw in our 12-year-old girl, stroke volume decreased due to venous pooling during the tilt phase. The overall cardiac output remained stable due to the increased heart rate.

So, beyond any concern about the reliability of this method, this new device for head-up tilt-table testing is probably a useful tool and offers new perspectives in haemodynamic testing of children. The trend of haemodynamic changes in the individual is shown in real time and correlates with the signs and symptoms during the test. The specific changes before neurocardiogenic syncopes such as excessive sympathotonus together with normal stroke volume and peripheral vascular resistance can be monitored in real time. Provoking a syncope is therefore unnecessary if the trend fits the pathophysiological pattern. So the conventional tilt test protocol of 45 minutes can be shortened, and as provoking a syncope is not necessary any more the test itself becomes less dangerous and frightening for patients, parents and medical staff.

A limitation of this method is the up to now unproven correlation of the absolute values given by the impedance cardiography method to invasive testing in children and therefore further studies are warranted.

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