Original article

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Yield and cost-effectiveness of tilt table tests combined with video-EEG

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ABSTRACT – *Aim.* To study the outcomes of a series of consecutive tilt table tests combined with video-EEG (TTVE) at a single center, and assess their cost-effectiveness compared with other neurophysiological tests.
Methods. We retrospectively reviewed medical records of patients who underwent TTVE studies between March 1st, 2013 to April 1st, 2018. Detailed clinical history, including patient demographics, reasons for referral, anti-seizure medications, and neurophysiological studies obtained prior to the TTVE studies were extracted from chart reviews. The fee for each neurophysiological test was identified from the Centers for Medicare & Medicaid Services.
Results. Fifty-two patients underwent TTVE studies. Thirteen patients (25%) were diagnosed with vasovagal syncope, two (3.8%) were diagnosed with postural orthostatic tachycardia syndrome, and three (5.8%) had psychogenic non-epileptic events during the test. Four out of 12 patients stopped anti-seizure medication(s) after the TTVE. Prior to referral for TTVE, an average of $3,748 per person was spent on neurophysiological tests, which were inconclusive. The average fee for one TTVE test was $535.32, and the fee per test affecting diagnosis or management (defined as the cost divided by the yield of the test) was $1,547.
Conclusions. The TTVE test is cost-effective in evaluating refractory episodes of loss of consciousness, atypical of epileptic seizures. In addition to diagnosing syncope, TTVE can be valuable in identifying psychogenic events.

Key words: syncope, seizure, psychogenic non-epileptic seizure, tilt table video-EEG, cost-effectiveness

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Transient loss of consciousness (LOC) is a common presentation of epilepsy and vasovagal syncope, among other conditions (Moya *et al.*, 2009). The diagnosis of LOC depends on history from patients or witnesses. Difficulties arise when history is insufficient or misleading. For example, patients may be amnestic to the episode and witnesses may be lacking. In addition, syncope can be also associated with such manifestations as myoclonic jerking, stiffness, and incontinence that mimic epileptic seizures (van Dijk *et al.*, 2014).

For the diagnosis of LOC, a routine EEG may be inconclusive since a typical event is unlikely to be captured during the test. Moreover, the incidence of epileptiform discharges (EDs) in routine EEG studies is similar between healthy adults and patients with syncope (1.4-1.8%) (Abubakr and Wambacq, 2005; Dantas *et al.*, 2012). Therefore, routine EEG has limited utility in the evaluation of syncope due to its low yield. Continuous video-EEG (VEEG) monitoring in epilepsy monitoring unit (EMU) or ambulatory EEG (AEEG) studies has been used to evaluate these patients. However, both tests are resource- and labor-intensive. In this study, we report the clinical findings of tilt table video-EEG (TTVE) studies. In addition, we investigate the cost-effectiveness of TTVE as well as other neurophysiological tests in this cohort.

Materials and methods

At our hospital, all EEGs, regardless of duration, including those obtained during the tilt table test, are obtained with concomitant video recording. We retrospectively evaluated consecutive patients who underwent TTVE from March 1st, 2013 through to April 1st, 2018 at George Washington University Hospital (GWUH). All information was collected via the GWUH as well as outpatient electronic medical records. Demographic data including: age, gender, reason for referral, medical history, medications, as well as previous neurophysiological study results were extracted from chart reviews. Anti-seizure medication changes after the TTVE were recorded from outpatient follow-up notes.

The TTVE study was performed in the cardiology laboratory. Patients underwent head up-tilt testing with simultaneous EKG and video-EEG after NPO for at least eight hours. Baseline recordings of blood pressure, heart rate, EKG and EEG were obtained. The patient was then tilted to 70 degrees. A continuous EKG was recorded while non-invasive blood pressure was recorded every three minutes and more frequently if the patient reported new symptoms. The test was continued for up to 40 minutes or until syncope or near syncope occurred that reproduced the patients'clinical symptoms. If no syncope or near syncope occurred at the end, then isoproterenol was infused to raise the heart rate by 20% and the patient was tilted with the same protocol for up to 20 minutes.

A 16-channel EEG with video was also recorded simultaneously. The international 10-20 system was performed utilizing the Natus System. Baseline background activity as well as EEG changes during the tilt table procedure were characterized as, for example: background slowing and EEG suppression and epileptiform activity. Symptoms and clinical events were recorded and documented by a cardiologist and an EEG technician during the TTVE study, and the EEG and video were further reviewed by an epileptologist after the test was completed.

The cost for each neurophysiological test was identified from the the Centers for Medicare & Medicaid Services which is available for public usage. The CPT codes, 95816 and 95953, were used to identify the cost of routine and ambulatory EEG (AEEG), respectively. The TTVE CPT codes were the combination of 93660 (tilt table part) and 95816 (EEG part). We chose national Medicare payment as the reference for this study. Total costs, including both professional and technical components, were reported for each neurophysiological test. The cost for an inpatient EEG telemetry study was calculated from the summation of the facility fee with the activity code 50700368 and the professional fee of the 24-hour video EEG with the CPT code 95951 (modifier 26). For the cost for each CPT code, the fee was identified from the national Centers for Medicare & Medicaid Services website which is available for public usage; https://www.cms.gov/apps/physician-fee-schedule/license-agreement.aspx. At our institution, all inpatients are charged the EEG reading cost (CPT 95951 with modifier 26) and the facility fee, which includes the EMU bed and the EEG equipment costs, among others. Other variable costs include those of imaging studies, blood tests, medications, and consultations. In this analysis, we only compared the TTVE costs with the combination of hospital facility fee and EEG reading costs, both of which are consistently charged for any EMU admission.

Results

A total of 52 patients (26 men; age range: 19-78) were identified. Reasons for referral included LOC (n = 35), presyncopal symptoms such as dizziness, a warm-feeling, nausea, near passing-out (n = 14), or other events of unclear nature, including body shaking, staring, or sudden loss of body tone episodes (n = 3). In this cohort, 12 patients were prescribed one or more anti-epileptic drugs (AEDs) prior to referral for TTVE tests. The most commonly prescribed AED was levetiracetam (n = 6), followed by lamotrigine (n = 2), lacosamide (n = 1), valproic acid (n = 1) or a combination of two medications (n = 2). Prior to the referral, 22 patients underwent inconclusive neurophysiological tests with one or more of the following: routine EEG, AEEG and VEEG (*table 1*).

The three reasons for referral are summarized as the following (*table 2*):

(1) ***Loss of consciousness (LOC).*** Among 35 patients who were referred due to LOC, six experienced an

Table 1. Characteristics of patients (n=52).

Age (in years)	**23-78**
Gender Male (%)	26 (50%)
Previous neurodiagnostic tests	
Routine EEG	14
Inpatient EMU	15
Ambulatory EEG	2
Previous treatment	
Levetiracetam	6
Lamotrigine	2
Lacosamide	1
Valproic acid	1
Polytherapy	2

habitual event of LOC accompanied by significant hypotension and/or bradycardia during the TTVE study. Characteristic EEG changes, such as diffuse slowing or background suppression were also recorded in these six patients who experienced LOC episodes during the study, consistent with vasovagal syncope, similar to the events at home. Three additional patients had hypotension and habitual pre-syncopal symptoms including dizziness, sweating and nausea. Though LOC was not elicited during the procedure, the final diagnosis for these three individuals after the TTVE was vasovagal syncope. One patient had typical pre-syncopal symptoms with associated HR increase, and was diagnosed with postural orthostatic tachycardia syndrome (POTS). Another patient had an episode of unresponsiveness without any cardiac or EEG changes; the event was consistent with a psychogenic non-epileptic event. The TTVE study for the remaining patients (n = 24) was inconclusive *(table 2)*.

(2) ***Pre-syncopal symptoms***. Of patients (n =14) referred due to pre-syncopal symptoms, three experienced LOC during TTVE, and one had hypotension and habitual pre-syncopal symptoms, but without LOC. Another patient was diagnosed with POTS, and the remaining nine patients had inconclusive results *(table 2)*.

Table 3. AED discontinuation after the study (n = 52).

Tilt table EEG findings	**Total**	**AEDs (Prior)**	**AEDs (After)**
Vasovagal syncope	9	1	0
Presyncopal symptoms	4	1	0
POTS	2	2	0
PNES	3	1	1
Inconclusive study	34	7	7

(3) ***Miscellaneous.*** Of the remaining three patients, two had habitual events without EEG or cardiovascular parameter changes. These events were consistent with PNES. The third patient did not have an event during TTAV, and the study was inconclusive *(table 2)*.

Table 3 summarizes the discontinuation of AEDs following the test results. In our cohort, four patients were misdiagnosed with epilepsy and received AEDs prior to referral. The TTVE results led to AED discontinuation in all of these four subjects. On the other hand, among patients who had inconclusive TTVE studies, seven patients, previously on AEDs, were continued on AEDs. One patient with a psychogenic non-epileptic event continued lamotrigine after the study, as the patient reported other episodes which were not captured during the TTVE.

Health care utilization and costs of neurophysiological tests are summarized in *table 4*. Prior to the TTVE tests, the summated cost of neurophysiological tests in this cohort was $187,478 and the average cost of an electrophysiological study was about $3,748 per person. The total cost of TTVE was $27,836 in this cohort, and the average cost for TTVE was $535 per person (*table 4*). Furthermore, among 52 patients, the diagnoses were confirmed in 18 subjects, including vasovagal syncope, POTS, and PNES, and the yield of TTVE reached 34.6% (18/52). Therefore, the cost per TTVE affecting diagnosis, which is defined as the cost of the study divided by the yield of the test, was $1,547 in this cohort (*table 4*).

Table 2. Results of tilt table EEG studies.

Reason for referral	**Vasovagal Syncope**	**Pre-syncopal Event**	**POTS**	**PNES**	**Inconclusive**
Loss of consciousness (n = 35)	6	3	1	1	24
Pre-syncopal symptoms (n = 14)	3	1	1	0	9
Miscellaneous (n = 3)*	0	0	0	2	1

*Reasons for referral include body shaking; confusion, staring; arm twitching, loss of muscle tone

Table 4. Health care utilization for syncope: electrophysiological tests.

Neurophysiological tests	N[1]	Cost per individual test	Cost for each type of test[2]	Total cost[3]	Average cost per person[4]	Cost per test affecting diagnosis[5]
Prior to the tilt table EEG						
Routine EEG	14	371.88	5206.32	194898.36	3748.0	N/A
Inpatient EMU	34[1]	5514.06	187478.04			
Ambulatory EEG	5[1]	442.8	2214			
Tilt table EEG studies						
Routine EEG	52	163.44	8498.88	27836.64	535.3	1547
Tilt table EEG	52	371.88	19337.76			

[1]For inpatient EMU or ambulatory EEG studies, total numbers of monitoring days are shown.
[2]The cost for each type of test is equal to the number of tests multiplied by the charge per test.
[3]The total cost measures summated charges for neurophysiological tests prior to the TTVE test or charges for TTVE tests (5206.32+18747.04+2214 = 194898.36; 8498.88+19337.76 = 27836.6).
[4]The average cost per person was calculated as the total costs divided by the number of all tests (19498.36/52 = 3748; 27836.6/52 = 535.3). The number reflects what the cost would be if the yield were 100%.
[5]The cost per test affecting diagnosis was calculated by the average cost (535.3) divided by the yield of TTVE tests (34.6%) (535.5/34.6% = 1547).

Discussion

The utility of the tilt table EEG study

The diagnosis of LOC can be challenging. On average, patients who were admitted for LOC, underwent four diagnostic tests during the admission based on an observational study (Schillinger *et al.*, 2000). Despite that, LOC remained unexplained in 48 patients (38%) (Schillinger *et al.*, 2000). In our cohort, patients often had already been evaluated, and undergone neurophysiological tests, such as routine EEG, AEEG or inpatient VEEG studies prior to referral for TTVE study. Typical events were captured in 18 of these 52 patients (34.6%), which included syncope, pre-syncopal symptoms as well as psychogenic non-epileptic events. Our results suggest that the tilt table EEG study is a relatively high-yield (18/52) diagnostic test for patients with refractory LOC compared to routine EEG studies which has a yield of 1.4-1.8% based on previous studies (Abubakr and Wambacq, 2005; Dantas *et al.*, 2012).

A failure of systemic circulation to perfuse the brain results in syncope (Wieling *et al.*, 2009). In our series, typical syncopal events were noted in nine patients, and those patients also had EEG diffuse slowing as the result of cerebral hypoperfusion. In addition, four patients had typical pre-syncopal symptoms with significant hypotension or heart rate changes. However, LOC or characteristic EEG changes were not observed in those patients. In our study, patients were returned to the supine position as soon as symptoms became prominent for patient safety and comfort. Despite systemic hypotension, cerebral perfusion can be maintained by autoregulation. Syncope only occurs when cerebral autoregulation finally fails to compensate, which then results in cerebral hypoperfusion (Schondorf *et al.*, 1997). We suspect that a lack of LOC or EEG changes is due to cerebral autoregulation despite systemic hypotension, and early returning to supine position prevents further worsening of symptoms for those patients.

A recent study concludes that routine EEG recording might not be clinically useful during the tilt table studies (Muppidi *et al.*, 2018). In our study, EEG was valuable for two reasons. First, diffuse slowing on the EEG corroborated the syncopal etiology of LOC. Second, combining video with EEG monitoring helped differentiate epileptic from non-epileptic events, including psychogenic events. In our cohort, three patients had typical events during the tests including jerking movements, loss of body tone, and reduced awareness, which were confirmed non-epileptic events due to a lack of either ictal EEG or cardiovascular parameter changes. Interestingly, two of these three patients had VEEG in EMU or ambulatory EEG studies previously, which were much longer in duration (> 24 hours), yet failed to capture an habitual event. The tilt table maneuver may have served as a trigger for a non-epileptic event. Therefore, a relatively high yield can be achieved, even though the duration of the tilt table EEG study rarely exceeds 60 minutes. A previous study also demonstrated that the head-up tilt maneuver can be a sensitive tool to trigger non-epileptic events. Furthermore head tilting is a safe, simple and inexpensive technique and could be utilized in the outpatient setting (Zaidi *et al.*, 1999).

Cost-effectiveness of the test

Typically, a routine EEG lasts 20-60 minutes, and is often performed in the supine position, which is often insufficient to capture a syncopal event. EMU or ambulatory EEG studies last significantly longer, typically 24-72 hours. An estimated hospital facility fee for EMU admission which includes a hospital bed and EEG equipment-related charges is $5,151 every 24 hours. With recent technological advances, ambulatory EEG services can utilize video recording which is often monitored in real-time (Syed *et al.*, 2019). However provocation methods are usually not utilized for patient safety. Regarding the relatively high cost and low yield, one inpatient study showed that the cost for each EEG study affecting diagnosis or management, obtained by dividing the average cost of each study by the yield of the tests, was as high as $32,973, which is the highest among image, laboratory or physiological studies (Mendu *et al.*, 2009).

On the other hand, TTVE is an outpatient procedure, and the cost is relatively low ($535.3 for both tilt table and EEG procedures). Furthermore, our study demonstrates a relatively high yield of the study (34.6%), which results in a cost of $1,547 per diagnosis. Therefore, the TTVE study is more cost-effective in evaluating LOC compared to other neurophysiological tests.

We conclude that better utilization of TTVE for LOC may lead to reduction in health care costs. Besides reducing the AED(s)-associated direct or indirect costs, patients likely have significantly fewer emergency room (ER) visits or hospital admissions, once the diagnosis is established. Fifteen patients were diagnosed with vasovagal syncope or POTS in this cohort. Conservative management, such as dietary modification, as well as medications, including fludrocortisone or midodrine, were recommended to patients. With treatment, these patients likely have fewer syncopal episodes, ER visits or admissions, which subsequently reduces health care utilization. Besides vasovagal syncope or POTS, three patients had psychogenic non-epileptic events in this cohort and mental health referrals were initiated. Significantly fewer ER visits and a reduction of cost ($1,783 yearly decrease) for patients with psychogenic non-epileptic events is consistent with previous studies (Razvi *et al.*, 2012).

This present study has a few limitations. We reviewed the patients who had recurrent, unexplained LOC or pre-syncopal episodes that warranted referral to the study. The results may not be applicable to patients who have a typical clinical history of syncope or epilepsy, for whom either a TTVEE is not necessary or further EEG testing is necessary. We suggest that patients with possible syncopal features may start with a TTVE before proceeding to long-term EEG studies. On the other hand, for patients with LOC and a clinical history that is mostly consistent with epilepsy, work-up with routine EEG, prolonged EEG or video-EEG monitoring is clinically warranted. In this cohort, patients could be followed by their primary care physician after the diagnosis was confirmed. Therefore, we were unable to verify the clinical outcome after the study, such as the frequency of ED visits or hospital admission. Furthermore, TTVE may be challenging to arrange at some centers as it requires the services of two specialties, cardiology and neurophysiology. Another limitation is the small sample size and the retrospective nature of this analysis. Despites these limitations, our findings should stimulate a larger prospective assessment of the utility of TTVE and associated health care cost reductions. □

Supplementary data.
Summary didactic slides are available on the www.epilepticdisorders.com website.

Disclosures.
None of the authors have any conflict of interest to declare.

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TEST YOURSELF

(1) A 30-year-old previously healthy woman reports 10 episodes of fainting over the last six months. These episodes often occurred after prolonged standing. Before losing consciousness, she had lightheadedness, nausea, and sweating. She felt tired after the events, but denied disorientation or confusion. Her physical examination is normal. What is the most likely diagnosis?

A. Transient global ischemia
B. Vasovagal syncope
C. Psychogenic event
D. Focal seizure with altered awareness

(2) What are the typical EEG findings during vasovagal syncope?

Note: Reading the manuscript provides an answer to all questions. Correct answers may be accessed on the website, www.epilepticdisorders.com, under the section "The EpiCentre".