Yield of Diagnostic Tests in the Evaluation of Syncopal Episodes in Older Patients

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Yield of Diagnostic Tests in the Evaluation of Syncopal Episodes in Older Patients

A Thesis Submitted to the Yale University School of Medicine in Partial Fulfillment of the Requirements for the Degree of Doctor of Medicine

By
Mallika L Mendu
Class of 2009
ABSTRACT: YIELD OF DIAGNOSTIC TESTS IN THE EVALUATION OF 
SYNCOPAL EPISODES IN OLDER PATIENTS 

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Syncopal episodes are common among older adults; etiologies range from benign to life- 
threatening. We determined the frequency, yield, and costs of tests obtained to evaluate 
older persons with syncope. We also calculated the cost per test yield and determined 
whether the San Francisco Syncope Rule (SFSR) improved test yield. 

Review of 2,106 consecutive patients 65 years and older admitted following a syncopal 
episode. 

Electrocardiograms (99%), telemetry (95%), cardiac enzymes (95%), and head computed 
tomography (CT) (63%) were the most frequently obtained tests. Cardiac enzymes, CTs, 
echocardiograms, carotid ultrasounds, and electroencephalography all affected diagnosis or 
management in <5% of cases and helped determine etiology of syncope < 2% of the time. 
Postural blood pressure, performed in only 38% of episodes, had the highest yield with 
respect to affecting diagnosis (18-26%) or management (25-30%) and determining etiology 
of the syncopal episode (15-21%). The cost per test affecting diagnosis or management was 
highest for electroencephalography ($32,973), CT ($24,881), and cardiac enzymes 
($22,397) and lowest for postural blood pressure ($17-$20). The yields and costs for 
cardiac tests were better among patients meeting, than not meeting, SFSR. For example,
the cost per cardiac enzymes affecting diagnosis or management was $10,331 in those meeting, versus $111,518 in those not meeting, the SFSR.

Many unnecessary tests are obtained to evaluate syncope. Selecting tests based on history and examination and prioritizing less expensive and higher yield tests would ensure a more informed and cost-effective approach to evaluating older patients with syncope.
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INTRODUCTION

Syncope, defined as the sudden, transient loss of consciousness with spontaneous recovery, is common, accounting for 3% of emergency department visits and up to 6% of hospital admissions.\textsuperscript{1} Older patients present more often with syncope, have higher rates of hospitalization, and greater morbidity, than younger patients.\textsuperscript{2} Syncope in older patients often results from the effects of several coexisting illnesses or medications.\textsuperscript{3} Evaluation of older patients following a syncopal episode is challenging because there is a wide spectrum of possible etiologies, ranging from benign to life-threatening cardiac conditions. Furthermore, it is important to identify non-life threatening causes of syncope, such as postural hypotension, that are treatable to prevent the significant morbidity associated with the condition due to trauma. Because of the varied causes of syncope, clinicians may pursue a range of diagnostic investigations. Despite thorough evaluations, however, the etiology of syncope frequently remains undetermined.\textsuperscript{4,5} Given the prevalence of syncope among older patients, and the high cost of the extensive diagnostic testing utilized, syncope evaluation represents a large burden on healthcare costs.

SYNCOPE IN OLDER PATIENTS

Syncope is the seventh most common reason for the emergency admission to acute hospitals of patients older than age 65 years, and 80% of syncope admissions are for patients over the age of 65 years.\textsuperscript{6} Syncope occurs in 23% of patients older than 70 years during a 10-year period.\textsuperscript{7} The Framingham Study showed that the yearly incidence of syncope increased with age, 1.1% per year in patients 70-79 years and 1.7% per year in patients over 80 years. Certain elements of evaluation are more challenging in this population compared to younger patients. In general, geriatric patients are prescribed more medications, have more comorbidities and a worse functional profile than younger individuals.\textsuperscript{8} Obtaining an accurate account of the episode may be challenging as recovery
from syncope may be associated with amnesia in older individuals resulting in inaccurate or absent history. Distinguishing a syncopal episode from a mechanical fall, also common in older patients, can be difficult. Older patients are more likely to have atypical presentations of conditions such as myocardial infarction, pulmonary embolism, and aortic dissection. Finally, there are data to suggest that older patients have worse outcomes after a syncopal episode. One study determined that serious events in the 14-days following a syncopal episode increase with age and that most serious events occur in patients age 60 years and older. Therefore, the issue of when to hospitalize older syncope patients is challenging.

There is often a lower threshold in favor of hospitalization for older than younger patients. The increased frequency of hospitalization also suggests that older patients undergo more extensive testing than younger patients following syncopal episodes.

**PATHOPHYSIOLOGY**

Understanding the pathophysiology of syncope sheds light on the complexity of the condition in older patients. This complexity likely contributes to the tendency to pursue extensive diagnostic testing in these patients. Syncope is the result of a sudden and transient reduction of blood flow to the brain that causes a temporary cessation of cerebral function. The body's ability to compensate for hypotensive stresses decreases with age. Age-related physiological changes account for this higher incidence of syncope in the older and include: changes in heart rate, blood pressure, cerebral blood flow, intravascular volume regulation, and baroreflex sensitivity. In older patients with structural heart disease, low blood volume in combination with diastolic or systolic dysfunction can lead to a low cardiac output increasing susceptibility to postural hypotension. Hypertension, found in 30% of adults 75 years and older, increases the risk of postural hypotension due to reduced baroreflex sensitivity causing a fall in cerebral blood flow at higher blood pressures. It is a combination of these physiological changes and age-related disease that threaten blood pressure homeostasis and increase susceptibility to syncope. It is estimated that 25% of
older syncope patients have age-related postural hypotension. Estimates of the prevalence of orthostatic hypotension among the older range from 6% in community dwellers to 33% in hospital inpatients.3

Cerebral blood flow is reduced by 25% in healthy adults over age 60 years due to decreased cardiac output and vascular stiffening associated with aging.10 Older adults are also vulnerable due to reduced blood volume secondary to decreased renin and aldosterone levels, further exacerbated by diuretic treatment. The autonomic nervous system becomes impaired with age, affecting its ability to control heart rate and vascular resistance. However, a reduction in the parasympathetic response protects older patients from vagally mediated reductions in heart rate and blood pressure, which may contribute to lowering the incidence of vasovagal syncope in older patients.

ETIOLOGIES OF SYNCOPE IN OLDER ADULTS

The unique pathophysiology of syncope in older patients is reflected in the different frequencies of etiologies in this population compared to younger patients in all age groups with the condition. The most common etiologies of syncope in all age groups are vasovagal, postural hypotension, and cardiac arrhythmia. Varied frequencies of these etiologies are reported among older patients. A recent study of older patients reports the following frequencies: postural hypotension 20-30%, cardiac arrhythmias up to 20%, vasovagal up to 15%, multiple etiologies up to 30%, unknown 34-37%.7 Another study compared the frequencies of etiologies in patients older than 75 years with syncopal episodes to patients of all age groups and found vasovagal syncope to be most common in the older patient (36%), though less frequent than in syncope patients of all ages (44%), followed by postural hypotension (31% compared to 23%), cardiac (16% compared to 15%), drug-induced (5% compared to 5%), multifactorial (3% compared to 4%), unexplained (9% compared to 10%).9 Although this study did not compare older patients to younger patients (but rather to a general population that included both younger and older patients), results indicate that
certain etiologies, such as postural hypotension, are more common with increased age and others, such as vasovagal, are less common with increased age.

**Vasovagal Syncope**

The exact mechanism responsible for vasovagal syncope is unknown but is thought to involve a lack of communication between the autonomic nervous system and cardiovascular system. Healthy older adults are not as prone to vasovagal syncope as younger patients because of an age-related decline in baroreceptor sensitivity. The frequency of vasovagal syncope reported in older patients varies from 1-5 % in one study to 36%. Despite this wide variability, vasovagal syncope has consistently been shown to be less common with increasing age. Therefore, though vasovagal syncope is often not considered a disease in young adults with isolated episodes, such episodes should be evaluated as a medical condition in older patients. Some authors delineate vasovagal syncope into three forms: cardioinhibitory (involving bradycardia primarily), vasodepressor (involving hypotension primarily) and a mixed form. Others differentiate between classical vasovagal syncope, precipitated by emotional or postural stress, and non-classical vasovagal syncope. Most patients with vasovagal syncope describe a precipitating factor such as acute stress, prolonged standing, micturition, defecation, and cough. Situational syncope is consider a subtype of the condition defined by a situational precipitant. A variety of non-specific symptoms, including fatigue, weakness, diaphoresis, nausea, visual defects, dizziness, headache, abdominal discomfort, often accompany the episode.

**Postural Hypotension**

Postural hypotension is defined as a drop in systolic blood pressure ≥ 20 mmHg, or a drop in diastolic blood pressure ≥10mmHg from lying to standing positions according to consensus definitions; recordings obtained in the standing position should be taken after two minutes of standing. A wider range of definitions exist in the literature, with respect to older patients. Prevalence of the condition is reported as 4-33 % in community-living
older persons and 7-17% in an acute care setting. One study reported that in 2004 there were approximately 80,094 postural hypotension related hospitalizations, an overall rate of 36 per 100,000, and that hospitalizations increased with age. Standing can cause a 40% reduction in stroke volume and decrease in arterial pressure, which stimulates baroreceptors in the aortic arch and carotid sinus regulated through the autonomic nervous system. Therefore, autonomic nervous system dysfunction can underlie postural hypotension in the form of primary autonomic failure syndromes (pure autonomic failure, multiple system atrophy, shy dropper, parkinson’s disease) or secondary autonomic dysfunction (diabetes mellitus, multiple sclerosis, spinal cord lesions, chronic renal failure, chronic liver disease). Autonomic nervous system dysfunction is thought to underlie most cases of postural hypotension in older patients.

Cardiac Syncope

Cardiac arrhythmias and structural heart disease result in syncope as a result of circulatory demands exceeding cardiac output. In older patients arrhythmias are the most common form of cardiac syncope. Sick sinus syndrome is a common form of sinus node disease associated with syncope, characterized by bradycardia and paroxysmal SVT leading to syncope in 25-75% of patients.

RECOMMENDED EVALUATION OF SYNCOPE IN OLDER ADULTS

A number of authors over decades describe recommendations for evaluating syncope. Most of these reviews are based on clinical practice and expert opinion. However, more recent reviews have focused on existing literature and have outlined recommendations based on both expert consensus and existing data, notably the European Society of Cardiology guidelines.

General Recommendations

Several authors recommend that an initial evaluation of syncope include a thorough history, physical exam (with an emphasis on cardiac and neurological findings), postural
blood pressure measurements, and electrocardiogram (ECG). The results of this evaluation should be utilized to help divide patients into two groups, those with certain or suspected diagnosis and those with unexplained syncope.\textsuperscript{1,3,6,10} These recommendations are based primarily on expert opinion. Further evaluation schemes and recommendations have been developed by various authors. Kapoor WN. 2002 and Brignole M. 2007 recommend, based primarily on expert opinion, that for those with unexplained syncope and a history of structural heart disease or abnormal ECG additional testing such as echocardiogram, stress testing, and loop monitoring should be pursued.

**European Society of Cardiology Recommendations**

The European Society of Cardiology is the group that has written most extensively on the diagnostic evaluation and classification of syncope. This group has presented a number of evaluation recommendations, and these recommendations are currently the only guidelines with respect to the evaluation of syncope based on both existing literature and expert consensus.\textsuperscript{10} The European Society of Cardiology established a Task Force on Syncope, consisting on experts in the field of syncope, who evaluated the existing literature in peer-reviewed journals and established classes of recommendations; for example, class I indications for diagnostic testing are defined as "evidence and/or general agreement that a given diagnostic procedure/treatment is beneficial, useful and effective." These recommendations include guidelines with respect to cardiac testing. Specifically, in patients with suspected heart disease or palpitations associated with syncope, echocardiogram (ECHO) and prolonged ECG monitoring should be utilized initially; only if these tests are non-diagnostic should electrophysiology testing be pursued. Telemetry should be utilized only if patient is at risk of life-threatening arrhythmias or if ECG abnormalities and/or clinical features suggest arrhythmic syncope (class I indications). If a patient presents with chest pain related to the episode, in addition to ECHO and ECG monitoring, stress testing should be utilized as an initial diagnostic step. Loop recording is recommended in patients who...
have unexplained syncope despite a thorough evaluation in patients with clinical or ECG findings suggestive of an arrhythmic etiology. Indications for holter monitoring include suspected structural heart disease, abnormal ECG, palpitations, and symptoms suggestive of arrhythmia or age over 60 years. With respect to vasovagal diagnostic testing, class 1 indications for tilt table testing include patients with recurrent episodes in the absence of organic heart disease, patients with recurrent episodes in the presence of organic heart disease if cardiac causes are excluded, and when it is of clinical value to demonstrate susceptibility to vasovagal syncope. Routine use of basic laboratory tests (measurement of electrolytes, blood counts, tests of renal function and glucose level) is not recommended unless indicated by a clinical finding.

**Importance of History in Evaluation of Syncope**

A thorough, direct history alone has been shown in some studies to result in diagnosis in approximately 45% of syncope cases. Certain etiologies, such as vasovagal syncope, are more easily diagnosed solely on historical information, compared to other etiologies such as syncope secondary to cardiac causes. One review suggests that as part of the history three questions should be considered:

1. Is the loss of consciousness attributable to syncope?
2. Is heart disease present? (the presence of heart disease has been determined to be an independent predictor of a cardiac cause of syncope with sensitivity of 95% and specificity of 45%, whereas absence of heart disease ruled out cardiac cause in 97%)  
3. Are there important clinical features that suggest etiology? Information regarding premonitory period, including symptoms such as light-headedness, nausea, sweating, weakness and visual disturbances, should be collected.

**Evaluation Strategies**

A few studies have examined diagnostic patterns to determine effective evaluation strategies. One study found that in patients with suspected vasovagal syncope diagnostic yields across all tests, particularly cardiac and neurological testing, were low, and abnormal
results had no affect on final diagnosis, and few patients who had suspected vasovagal on admission were discharged with a different diagnosis. Another study showed in a retrospective chart review that neurological tests had a low yield and were over utilized compared to higher yield testing. A few studies have examined the use and utility of individual testing including brain natriuretic peptide, cardiac enzymes, electrocardiogram, echocardiogram, telemetry, holter monitoring, loop recording, electrophysiological testing, head computed tomography, brain magnetic resonance imaging, carotid ultrasound, electroencephalogram, and tilt table testing.

**SPECIFIC DIAGNOSTIC TESTS IN THE EVALUATION OF SYNCOPE**

**Brain Natriuretic Peptide**

Brain natriuretic peptide (BNP), used as a potential measure of underlying heart disease, has been studied as a test used to evaluate syncope. One study found that a BNP value of 40 or greater was 82% sensitive and 92% specific for a cardiac cause, which includes organic cardiac disease, tachycardia, and bradycardia, of syncope. Another study showed that BNP was useful as a predictor of serious outcome for patients with cardiac syncope; a BNP of greater than 100 had a modest sensitivity of 67% for serious outcome whereas values greater than 1000 had both an excellent positive predictive value and specificity of 100%.

**Cardiac Enzymes**

Few studies have examined the value of cardiac enzymes in the evaluation of syncope. A “rule-out” myocardial infarction (MI) protocol, involving serial cardiac enzymes, is often utilized in patients with syncope despite absence of chest pain or coronary artery disease. This is surprising as it is uncommon for older patients with syncope to present with an MI. Older studies show that between 6% and 21% of older patients with a myocardial infarction present with an episode of syncope, and illustrate increasing frequency of such an incidence with age. Two more recent studies suggest a much lower incidence.
One study reviewed emergency department patients presenting with syncope and found that 77% underwent a "rule-out" protocol. Only one out of 80 patients tested "ruled-in" for MI, and the patient had symptoms of unstable angina including chest pain. The authors subsequently recommended limiting a rule-out protocol to syncopal patients with acute cardiac symptoms. Similarly, another study conducted a retrospective review of patients over the age of 65 years admitted with syncope and found that 62% received serial cardiac enzymes testing. Three out of 141 subjects presenting with syncope were diagnosed with an MI resulting based on positive cardiac enzymes. Two of these patients reported chest pain associated with the episode, and the third patient had a history of dementia and was unable to provide an accurate history. All three patients had non-specific ECG findings. The authors recommended that only patients with pertinent historical findings consistent with cardiac ischemia such as chest discomfort or patients from whom an adequate medical history cannot be elicited should have cardiac enzymes testing.

**Electrocardiogram (ECG)**

Electrocardiogram is a vital component to the initial evaluation of syncope as it can help determine the presence or extent of structural heart disease, but as a diagnostic tool it results in a definitive diagnosis in only 5% of cases. It is important to note that except for older patients often presenting with a multitude of symptoms and signs, acute coronary syndromes rarely present as syncope as the sole manifestation. Conflicting data exist with respect to ECG as a predictor of adverse outcomes; one study found that an abnormal ECG was associated with arrhythmia or death with an odds ratio of 3.2, whereas another found that an abnormal ECG was predictor of arrhythmia with an OR of 8.1. The San Francisco Syncope Rule found an abnormal ECG, along with a history of congestive heart failure, dypsnea, low Hct, and hypotension, in syncope patients was associated with an increased risk of short-term adverse events. The most alarming ECG signs in a patient with syncope is alternating complete right bundle branch block with left anterior or posterior fasicular
block, suggesting trifascicular conduction system disease and intermittent or impending high-degree AV block. Left and right bundle branch block, on the other hand, are common in older adults and without accompanying symptoms do not predict syncope.  

**Echocardiogram (ECHO)**

One author suggests that indications for echocardiogram (ECHO) include abnormal ECG, exercise induced symptoms, major cardiac risk factors, brief syncope from a seated or lying position, absence of prodrome, or history of palpitations. No study to date has examined the diagnostic utility of ECHO for the evaluation of syncope.

**Telemetry**

One study examined the use of telemetry in syncope patients and found that the mean duration of telemetry use was 4.8 days. The studied examined 102 patients admitted for unexplained syncope, likely cardiogenic syncope (based on a number of criteria including a history of cardiac disease, clinical presentation suggestive of cardiac disease, physical examination findings, and electrocardiogram findings) who obtained telemetry testing. Telemetry detected significant events in 30% of these syncope patients, and contributed to the diagnosis of cardiac syncope in 18%. Eighty-five percent of this population had at least one cardiovascular risk factor, and 54% had a prior history of syncope. Other clinical predictors included age older than 86 years, history of heart failure, history of atrial fibrillation, and current digoxin use.

**Holter Monitoring**

Ambulatory holter monitoring is often employed in an outpatient setting and is useful when history is suggestive of arrhythmic etiology or patients with unexplained syncope at increased risk of arrhythmias. One study found that 19% of syncope patients had diagnostic changes on holter over 24 hours; of these patients 21% presented with symptoms typical of arrhythmia and 79% without such symptoms. This study selected all 1,512 patients referred to an outpatient center for holter monitoring for the condition of syncope over a five
year period. Another study showed that by extending monitoring to 48 or 72 hours arrhythmias a larger percentage of the 826 patients referred to an outpatient center for holter monitoring for syncope over a five year period. Predictors associated with higher yields with holter use have been identified and include structural heart disease, depressed left ventricular function, previous myocardial infarction and age older than 90.33

**Loop Recorder**

Continuous-loop event monitoring allows long-term monitoring lasting weeks or months. An external loop recorder (ELR) is an event monitor that correlates physiological symptoms with recorded cardiac rhythms. Implantable loop recorders (ILR) are inserted subcutaneously and have a life of 18-24 months. In a randomized trial of patients with unexplained syncope in which ILR compared to ELR, ILR was more likely to provide diagnosis (52% yield in the ILR group vs. 20% yield in the ELR).34 Pooled data from four recent studies illustrates that diagnosis was found in 34% of ILR patients, of whom 52% had bradycardia and 11% and tachycardia.

**Electrophysiological testing (EP testing)**

Diagnostic yield has been shown to be as high as 50% in patients with structural heart disease (only 10% in those without structural disease) and 34% in those with abnormal ECG. However, EP studies have low sensitivity for diagnosing bradycardia.35 One study reported that among syncopal patients with heart disease, 21% had inducible ventricular tachycardia and 34% had bradycardia, whereas in syncopal patients with no reported heart disease and a normal ecg only 1% had ventricular tachycardia and 10% bradycardia.19 A study is diagnostic if the following arrhythmias are identified: sinus bradycardia, bifascicular block and baseline HV interval of greater than 100 ms, 2\textsuperscript{nd}/3\textsuperscript{rd} degree His-Purkinje block, high degree His-Purkinje block, induction of sustained monomorphic ventricular tachycardia, and induction of rapid SVT which reproduces hypotensive or
spontaneous symptoms. Inducible ventricular tachycardia has a poor prognosis, with 30% mortality at 3 years, due to risk of cardiac arrest.19

Head Computed Tomography

Little evidence exists in the literature supporting the use of head CT to diagnose syncope. One author suggest that head CT should be pursued only in patients with a significant likelihood of seizure, acute focal neurological symptoms, or history of headache prior to episodes.36 An early study found that head CT was diagnostic in 4% of syncope patients, all of whom had focal neurological findings or history suggestive of seizure.37 A more recent study reviewed 649 patients and found that head CT resulted in a diagnosis in only 2% of cases.22 Another study evaluated 393 patients of whom 39% underwent head CT, and found that 5 patients met diagnostic criteria of an abnormal result,38 and recommended head CT only in patients with neurological findings. Of the patients with diagnostic results one was found to have focal neurological findings, two had a new headache, and the remaining two had a history of head trauma.

Brain Magnetic Resonance Imaging (MRI)

An extensive review of the literature revealed no studies that examined the utility of brain magnetic resonance imaging testing for the evaluation of syncope. Pires et al. 2001 did not support the frequent utilization of the brain MRI, based on evidence of the low yield of all neurological testing.

Carotid Doppler Ultrasound (Carotid US)

Carotid doppler ultrasound is not indicated in the routine evaluation of syncope because transient ischemia attacks are rarely accompanied by the loss of consciousness. However, theoretically fixed neurovascular obstructive lesions may potentiate cerebral effects of decreasing cardiac output and therefore disrupt blood flow to brain centers mediating consciousness. One study to date has examined the utility of carotid US in syncope evaluation.39 The study’s main finding was that carotid US identified related CVA
lesions in 1.4% of patients. By limiting carotid US to those with new focal neurological symptoms or carotid bruits on physical exam, testing would have been reduced in half, and all the patients with diagnostic positive findings would have been identified. Of the 140 patients studied, 78% underwent Carotid US. The test contributed to a diagnosis in 3 patients, 2 of whom had focal neurological features associated with their syncopal episode (including bilateral carotid bruits on physical exam in one patient). The third patient had a known intracranial mass but no additional neurological findings. The authors emphasized that although it is likely that the neurovascular disease contributed to the pathophysiology of the syncope episodes, it was not necessarily the primary etiology. Predictors of a positive test were identified and include history of stroke, TIA, carotid disease, coronary artery disease, focal neurological findings, and carotid bruits on physical exam. The authors conclude that carotid US may be recommended in patients with such predictors (particularly focal neurological symptoms and carotid bruits). By utilizing such predictors, 95% of patients with a positive test and 100% with a diagnostically useful test would have been identified.

**Electroencephalogram (EEG)**

Electroencephalogram is not recommended for syncopal episodes and provides diagnostic information in less than 2% of syncope patients. A retrospective review of all EEGs performed over the course of four years for patients presenting with syncope showed that only 1.46% of patients had epileptiform discharges, and these findings had no impact on management.

**Tilt Table Testing (TTT)**

The use of tilt table testing has been examined primarily in younger patients. No existing studies have explored the use of TTT in older patients. Also studies have shown that reliance on history alone may eliminate the need to use TTT to diagnose vasovagal syncope.

**PROGNOSIS AND RISK STRATIFICATION**
Authors have attempted to address concerns about unnecessary hospitalizations and testing for patients with syncopal episodes by determining patient characteristics that predict adverse outcomes. Serious or adverse outcomes are defined as death, myocardial infarction, arrhythmia, pulmonary embolism, stroke, subarachnoid hemorrhage, significant hemorrhage or anemia requiring transfusion, a procedural intervention to treat a related cause of syncope or any condition causing or likely to cause a return ED visit, and hospitalization for a related event. By risk stratifying patient clinicians may be able to better utilize appropriate testing, and some studies have defined decision rules that aim to predict outcomes for this purpose. The most significant factor in the prognosis and risk stratification of patients with syncope has been proven to be the presence of heart disease. In the 1980s studies showed patients with a cardiac cause had a higher 1-year mortality (18% -33%) than patients with noncardiac causes (0-12%) or patients with an unknown cause (6%). Structural heart disease and abnormal ECG have been identified as two of the major risk factors for poor outcome. Other factors identified in these studies for the purposes of risk stratification include age greater than 45, history of heart failure, and history of ventricular arrhythmias. Based on a review of existing literature in peer-reviewed journals the European Society of Cardiology includes the following predictors of recurrence: age greater than 45 years, recurrent syncope at the time of presentation, and greater than four episodes up to time of admission.

A prospective observational study developed and implemented a clinical decision rule based on symptoms, ECG findings, past medical history, and physical exam to predict adverse outcomes or critical interventions. The rule identified 66 out of 68 patients with subsequent critical intervention or adverse outcomes with a sensitivity of 97%, a specificity of 66%, and a negative predictive value of 99%. If the decision rule had been utilized to stratify patients, hospital admissions could have been reduced by 48%. This study has yet
to be prospectively validated. Other studies have attempted to utilize similar clinical
decision models to predict adverse outcomes.

**San Francisco Syncope Rule**

A decision rule, titled “The San Francisco Syncope Rule”, was developed to identify
predictors of poor outcome at 1 week; patients meet the rule if they have at least one of the
following: abnormal ECG, shortness of breath on presentation, hematocrit less than 30,
history of congestive heart failure, or systolic blood pressure less than 90 mm Hg.\(^3\) The rule
had a sensitivity of 96% and specificity of 62% in identifying patients at risk for short-term
outcomes. The San Francisco Syncope Rule was prospectively validated in the same
hospital in a subsequent study and shown to perform with 98% sensitivity and 58%
specificity.\(^4\) Other studies have found comparable degrees of sensitivity in subsequent
validation attempts;\(^4^5,4^6,4^7\) however, one study showed a significantly lower sensitivity of 74%
but comparable specificity of 57%.\(^4\) This study did utilize a patient population that was
unique with respect to demographics (a larger percentage of Black and Hispanic patients
and frequency of syncope admissions was lower) and used a different methodology with
respect to interpretation of electrocardiograms.

**IMPLEMENTING DIAGNOSTIC ALGORITHMS**

In addition to implementing decision rules such as the San Francisco Syncope Rule,
diagnostic algorithms have been developed by healthcare institutions to improve syncope
testing practices. Diagnostic algorithms often employ established recommendations, such
as the European Society of Cardiology, to determine clinical decision making. Several
studies have examined the utilization of diagnostic algorithms to improve syncope
evaluation methods in an attempt to reduce unnecessary testing and improve the accuracy
of diagnoses. Two studies found that algorithm implementation reduced the frequency of
unknown diagnosis to 14-17.5% of patients.\(^4^9,5^0\) Another study showed that rates of
diagnosis increased with the implementation of a diagnostic protocol, but there was no
reduction in costs.\textsuperscript{51} A study by Brignole et al. 2005 utilized the 2004 European Society of Cardiology diagnostic guidelines and found that a definite diagnosis was established in 98% of patients.\textsuperscript{52} In addition, this guideline-based approach to syncope management resulted in improved overall diagnostic yield and reduced hospital admission. Sarasin et al. 2007 conducted a recent prospective trial to evaluate the implementation of a diagnostic protocol on testing in syncopal patients.\textsuperscript{53} After an initial evaluation (consisting of history, physical exam, ECG, and basic laboratory studies), patients were assigned to a control or intervention group. The intervention group, standardized based on patient characteristics such as recurrent syncope, normal ECG and no history of heart disease, underwent testing such as TTT and CSM; patients with heart disease and abnormal ECG underwent ECHO and holter; patients with established coronary artery disease underwent stress testing and if positive underwent coronary angiography; patients with previous MI, ejection fraction less than 40% underwent an EP study). A cause of syncope was identified in 39% of patients in the intervention group vs. 11% in the control group. Although more tests were ordered in the investigational group (432 versus 362), yield was higher (38% versus 9%).

Some centers have sought to formalize these diagnostic protocols by implementing syncope management units (SMUs). One study demonstrated savings of 4 million dollars a year in its institution due to introduction of SMU.\textsuperscript{54} The SEEDS study (Syncope Evaluation in the Emergency Department Study) established a syncope unit consisting of continuous cardiac monitoring for up to 5 hours, hourly postural check, and ECHO in the presence of abnormal ECG or cardiovascular findings on exam.\textsuperscript{55} Other testing available included TTT and EP study. The SMU resulted in a significantly increased diagnostic yield, decreased hospital admission and reduced hospital stay.

**ECONOMIC IMPLICATIONS OF EVALUATING SYNCOPE**

Despite the prevalence of syncope and attempts to improve diagnostic yield, little is known about the costs related to evaluating the condition. One study estimated that
syncope as a condition results in 2.4 billion dollars in healthcare costs annually and
represents 460,000 hospital admissions in a given year. Another study examined the cost
per hospital admission of syncope patients in 1993 among all United States' hospitals, and
found that mean annual costs ranged from $4929 to $8907, with costs rising in patients with
recurrent admissions. The authors attribute the majority of this expenditure to diagnostic
testing costs, but did not pursue analysis of the contribution of individual tests to the overall
cost associated with syncope admissions. The lack of information about the cost associated
with evaluating syncope may be a result of the discrepancy between revenue and cost
incurred by hospitals admitting syncope patients. Though the amount charged for
hospitalizations is available, there is an absence of information with respect to costs
incurred by healthcare institutions with syncope admissions. However, despite a lack of
data it is not surprising that estimates of the cost associated with the condition are in the
billions, as syncope is common and often results in extensive utilization of testing.

Though there is a scarcity of data with respect to the cost of evaluating syncope,
there have been studies examining the use of diagnostic testing in clinical practice for all
conditions. Wennberg et al. have studied the issue of the overuse of inpatient diagnostic
testing in patients with chronic illnesses and have proposed that drastic healthcare cost
savings could be achieved by reducing such practices. These authors advocate for further
research to determine the most cost-effective approaches to evaluation of all conditions and
promote the implementation of data driven evaluation methods in healthcare institutions to
reduce costs. This research may be applied to the condition of syncope, which lacks clear
guidelines with respect to cost-effective diagnostic practices. Studies examining the
diagnostic practices employed in evaluating syncope have suggested that extensive testing
leads to unnecessary expenditure. The implication in these studies is that much of the
testing used to evaluate syncope is unnecessary and that by reducing such practices costs
may be reduced.
GAPS IN KNOWLEDGE AND OBJECTIVES

A few studies have examined the utility of individual testing in the evaluation of syncope, however, the contribution of magnetic resonance imaging (MRI), echocardiogram, telemetry, and other tests to the diagnosis or management of syncope is still unknown. Specifically the question of how often these tests contribute to diagnosing or managing syncope remains unanswered. The use of postural blood pressure recordings in the evaluation of syncope has never been examined in the existing syncope literature.

Several authors have suggested schemes for evaluating syncope, based primarily on expert consensus rather than empirical evidence, and attempts to reduce unnecessary testing by the use of algorithms to improve syncope evaluation methods have been pursued. However, results from these studies showed improvement in the percentage of patients in which an etiology was identified but continued use of low yield testing, and adoption of algorithms did not lead to cost reduction. Identification of specific tests with low yields with respect to diagnosis or management of syncope has yet to be pursued. The contribution of diagnostic testing to the costs associated with syncope has not been determined. Also a calculation of the cost per test that affects diagnosis or management, which takes into account both yield and cost, has not been pursued to date.

Though attempts have been made to develop decision rules to predict outcomes in order to risk stratify patients, it is unclear whether the yield and cost-effectiveness of evaluation can be improved by identifying older adults presenting with syncope in whom test results are likely to affect diagnosis or management. Patient characteristics such as those used in The San Francisco Syncope Rule (SFSR) may serve this latter purpose.

The use of decision rules like the SFSR for the purposes of predicting testing results has not been pursued to date.

The specific objectives of this study were to:
• determine the yield of diagnostic testing used in the evaluation of syncope. We sought to examine how often diagnostic tests were obtained to evaluate older persons presenting with syncope and whether or not these tests affected diagnosis or management.

• determine the costs associated with diagnostic tests in the evaluation of syncope. In addition to calculating the total cost associated with each form of testing, we sought to calculate the cost per test that affected diagnosis or management, which incorporates both cost and yield. By undertaking these calculations our aim was to elucidate low yield, expensive testing.

• explore whether patient characteristics could help guide testing practices. We utilized the San Francisco Syncope Rule (SFSR) to determine whether such patient characteristics were associated with the likelihood of cardiac test results affecting diagnosis or management. Our aim in this analysis was to demonstrate whether the yield and cost-effectiveness of testing could improve by utilizing such patient characteristics.

METHODS

Study Design and Population

The study included all patients 65 years and older admitted to an acute care hospital between July 1, 2002 and December 31, 2006 with an admission or discharge diagnosis of syncope. Patients were identified based on the presence of an International Classification of Diseases–Clinical Modification (ICD 9-CM) code of 780.2 as a primary or non-primary diagnosis in the hospital billing records. Up to 10 diagnoses are listed, enhancing the likelihood that patients with syncope were identified. Based on review of the medical records, all patients with presumed loss of consciousness (LOC) were included. Patients in whom absence of loss of consciousness (e.g. near syncope) was documented were
excluded. The study was approved by the School of Medicine's Institutional Review Board. Consent was not obtained from participants because we reviewed existing data; in accordance with federal guidelines no subject identifiers were included in the data collected.

Records from 2209 admissions in 2009 patients were reviewed. We excluded 103 admissions because of the complete absence of laboratory data, imaging, electronic medical record, or paper chart. Admissions were included if partial data were available; there were 2106 admissions included for 1920 patients.

Data Collection

For each admission, emergency department, inpatient admission, and progress notes; discharge summaries; and laboratory and imaging data were abstracted. We employed methods recommended to ensure the validity and reliability of data collected, including a standardized abstraction form, precisely defined variables and criteria, and a pilot study of 60 charts to refine criteria.61

Data collected included patient age and gender; dates of admission and discharge; whether presumed loss of consciousness was documented in the record and whether the episode was witnessed; symptoms and activity at the time of episode and whether symptoms predicted a significant test result; health conditions; cardiac and neurological examination findings; postural blood pressure recordings; and cardiac enzymes. Reported etiology of the syncopal episodes was ascertained from the discharge summary. If no etiology was reported in the discharge summary, then progress note documentation was used. Results of electrocardiogram, echocardiogram, head commuted tomography, carotid ultrasound, stress testing, head magnetic resonance imaging, and electroencephalography were abstracted from the test reports and progress notes.

A second reviewer blindly abstracted a random sample of 40 admissions. To measure interrater agreement, we used the prevalence-adjusted, bias-adjusted kappa statistic.62,63 The mean PABAK statistic was 87% (±20%) for the diagnostic test variables.
Criteria for Defining Results of Diagnostic Tests

An abnormal finding for imaging was defined as any abnormality, no matter how minor, not seen on prior testing as written in the test reports (for example, mild mitral regurgitation on echocardiogram and mild slowing on electroencephalography). If no mention was made of prior testing, the result was assumed to be new. Abnormal cardiac enzyme results were defined as any troponin-I level > 0.05 (the hospital’s reference value).

For postural blood pressure, recordings were documented based on position (supine to sitting, supine to standing, or supine to sitting to standing) and location obtained (emergency department and inpatient medicine floors). Postural blood pressure was defined using two sets of criteria, “strict” and “loose”. The strict criteria for postural hypotension was a drop in systolic blood pressure ≥ 20 mmHg, or a drop in diastolic blood pressure ≥ 10 mmHg from lying to standing positions. The loose criteria for postural hypotension was ≥ 10 mmHg drop in systolic or diastolic pressure or a systolic pressure drop to ≤ 90 mm Hg from lying to sitting or standing positions. This definition incorporated the variability in methods used to assess blood pressure changes and the wide range of definitions used in the literature, particularly for older patients.

A test result was considered to have affected diagnosis or management if it was noted in any of test reports, progress notes, or discharge summaries that the test contributed to, confirmed or established any diagnosis or management decisions. This definition included documentation of negative and positive test results and all diagnoses, including those not related to syncope. We also recorded whether it was documented anywhere in the medical record that a test result helped determine the etiology of the syncopal episode. Examples of a test affecting diagnosis included an electrocardiogram identifying atrial fibrillation and postural blood pressure recordings identifying postural hypotension. Examples of a test affecting management included an electrocardiogram resulting in the management of atrial fibrillation with anti-coagulation and beta-blockers and postural blood
pressure recordings resulting in the management of postural hypotension with hydration. The criteria detailed above for test results were defined independently such that a test result could be abnormal but not considered to have affected diagnosis or management or vice versa.

Patients were considered to have met the SFSR criteria if they had history of congestive heart failure, hematocrit <30%, abnormal electrocardiogram, shortness of breath, or systolic blood pressure < 90mmHg at presentation.30

Recurrent Admissions

163 patients out of 1920 total patients had more than one admission during the four and a half year study period, representing 349 admissions. The percentage of admissions in which a given test was obtained was calculated as the number of admissions in which test was ordered divided by total number of recurrent admissions (349). The percentage of patients in whom a given test was obtained was calculated as the number of patients in whom test was ordered divided by total number of patients with recurrent admissions (163). Percentage of repeated testing for a given test was calculated as number of patients in whom the test was ordered in more than one admission divided by number of patients in whom test is ordered.

Cost Calculations

Standard billing charges for this hospital were used to calculate the charge per test. For imaging and electrocardiography, this included professional fees associated with interpretation. Similar to other studies, we used billing charges for testing and converted charges to costs by multiplying charges by the hospital's cost to charge ratio,64 because the hospital does not calculate costs based on individual testing but rather by patient admission. In order to determine the cost incurred by the hospital a cost to charge ratio of 0.34, determined by dividing the cost incurred to the hospital for an admission divided by the amount charged to an admitted patient, was used based on this acute care hospital's cost to
charge ratio from the State of Connecticut’s Annual Report on the Financial Status of Connecticut’s Acute Care Hospitals for Fiscal Year 2007. This ratio was similar to the cost to charge ratio for syncope patients admitted during the study period of 0.35, determined by dividing the cost incurred to the hospital for a syncope admission divided by the amount charged to a syncope admission patient. The cost for telemetry was estimated as the difference in cost between a monitored and unmonitored bed. For postural blood pressure, we estimated $5 per test, assuming that it required five minutes at a nurse’s wage of $60 per hour, the highest nursing salary on a medicine service. Nurses most often obtain postural blood pressure recordings at this hospital. We defined the cost per test affecting diagnosis or management as the cost per test multiplied by the number of tests obtained divided by the number of test results that affected diagnosis or management.

**Statistical Analysis**

Statistical analysis was performed using SAS (version 9.1). Yields were reported as percentages. Denominators were the number of tests obtained and the numerators were the number of tests in which findings were abnormal, affected diagnosis, affected management, or helped determine the etiology of the syncopal episode. We stratified patients into those meeting or not meeting SFSR criteria to compare testing results and cost per test affecting diagnosis or management. The Fisher exact test was used to compare test results in patients meeting and patients not meeting the SFSR. A two-sided P value < 0.05 was used to indicate statistical significance.

**RESULTS**

**Patient Characteristics**

Characteristics of the 1920 patients are presented in Table 1. The mean age was 79 (±7.9) years; 53% were female. One hundred and sixty-three patients (8.5%) had two or more admissions for syncope during the four and a half year period, resulting in 2106
The most common preexisting health conditions included hypertension (66%), hyperlipidemia (32%) and coronary artery disease (32%). The most commonly reported etiologies were vasovagal and orthostatic hypotension. For 47% of episodes, the etiology was reported as unknown or not reported in the records.

**Diagnostic Testing Obtained in Syncope Evaluation**

The frequencies of tests obtained, abnormal findings, and yields are shown in Table 2. The most frequently obtained tests were electrocardiogram (99% of admissions), telemetry (95%), and cardiac enzymes (95%). Only 5% of admissions had abnormal enzymes defined as any elevation in troponin-I. Echocardiogram (63%) had the highest frequency of abnormal findings; most of these were minor structural changes such as mild mitral regurgitation. Only 2% of echocardiograms revealed new findings, most often aortic stenosis, that were reported to have contributed to the syncopal episode. Similarly, for electrocardiogram and telemetry most findings were minor such as premature ventricular contractions. Telemetry results helped determine the etiology, such as atrial fibrillation or bradycardia, for 5% of syncopal episodes.

Postural blood pressure was performed in 38% of patients; only 24% of patients had recordings obtained in the recommended manner, namely lying to standing. Postural blood pressure had the highest yield with respect to affecting diagnosis (18% using strict criteria) and management (25% using strict criteria), and was the test most frequently reported to have helped determine the etiology of the syncopal episode. The tests with the lowest likelihood of affecting diagnosis or management or determining the etiology of the syncopal episode were head CT, carotid ultrasound, EEG, and cardiac enzymes.

Head CT affected diagnosis or management in only 28 of 1327 (2%) admissions in which a CT scan was obtained; 25 of these involved clinically suspected neurologic disease such as brain metastases, new neurological symptoms, or recent head trauma. Therefore, the CT scan revealed an unsuspected finding only 0.03% of the time (4/1327). Similarly, 17
of the 20 cases in which MRI result affected diagnosis or management were suspected based on history or examination; the MRI scan revealed an unsuspected finding only 1.9% of the time (3 of 154).

Cost of Diagnostic Testing in the Evaluation of Syncope

The costs per test affecting diagnosis or management are shown in Table 3. This cost was highest for EEG ($32,973), head CT ($24,881), and cardiac enzymes ($22,397) and lowest for postural blood pressure ($17-$20). Examples of the cost per test that helped determine the etiology of syncope include $99,525 for head CT, $77,144 for cardiac enzymes, $65,946 for EEG and ($23-$33) for postural blood pressure.

Role of the San Francisco Syncope Rule in Cardiac Testing

As shown in Table 4, with the exception of cardiac stress testing, cardiac test results were much more likely to have affected diagnosis or management or helped determine the etiology of the syncopal episode in patients meeting the SFSR than in patients not meeting criteria. The costs per cardiac test affecting diagnosis or management also were much higher among patients not meeting the SFSR than patients meeting the SFSR. For example for cardiac enzymes, the cost per test affecting diagnosis or management was $10,331 in those meeting, versus $111,518 in those not meeting, the SFSR.

Recurrent Admissions

As shown in Table 5 most of the patients who presented with recurrent admissions had 2 admissions (143 of 163). The frequency of testing obtained in recurrent admissions and recurrence of testing is shown in Table 6. The most frequently repeated tests were electrocardiogram (98% of patients had the test on a subsequent admission), cardiac enzymes (94%), and telemetry (89%). The most infrequently repeated tests were neurological testing: carotid ultrasound (6%), electroencephalogram (3%), and MRI (0%); however, 47% of patients who obtained a head CT had the test repeated on a subsequent admission. The percentages of testing that affected diagnosis or management were
unchanged for specific tests in the subset of recurrent admissions compared to overall admissions as detailed in Table 2.

DISCUSSION

Yield of Testing

In this study, we found that cardiac and neurologic tests were commonly obtained in the evaluation of syncope in older patients despite minimal effect on diagnosis or management. Other than MRI scans, neurological test results affected diagnosis or management in fewer than 2% of cases. In the few cases in which neurological tests were helpful, neurological conditions were suspected based on history or examination. Cardiac testing, particularly cardiac enzymes obtained in over 95% of admissions (and 94% of repeated admissions), also had low yields overall. Conversely, postural blood pressure recordings had the highest yield, but were performed in only about a third of admissions; recordings were frequently performed inadequately particularly in the emergency department. This disparity between performance and yield was even more pronounced when contribution to determining etiology of syncopal episodes was compared. Postural blood pressure helped determine the etiology of syncope in 16-21% of cases compared to cardiac enzymes in less than 1% of cases.

Recurrent Testing

Nine percent of patients in this study had recurrent admissions for syncope. Repeated testing was common with electrocardiogram, telemetry, cardiac enzymes, and head CT. Recurrent admissions with repeated testing contribute further to the low yield of testing illustrated in this study.

Etiologies of Syncopal Episodes

As in previous studies, vasovagal episodes and orthostatic hypotension were the most frequently reported etiologies. Because these etiologies are based on medical record
reports, it is not possible to verify the accuracy of the stated etiologies. The lack of an etiology in almost half of patients despite extensive testing was also similar to prior reports of older adults. The fact that no etiology was reported in almost 50% of episodes, despite the multiple tests, attests to the complex nature of syncope. Though there was no difference in the average number of tests ordered between patients who had an established etiology of syncope and those who did not, neurologic testing was more heavily utilized in patients without an established etiology compared to those with an established etiology. As suggested by other authors, this high percentage of undiagnosed cases may be a symptom of the random use of low yield testing. Algorithm-based evaluations, which we did not examine in this study, by design have resulted in higher percentages of patients with a diagnosed etiology.

**Cost of Evaluating Syncope**

The lowest likelihood of useful test results and, therefore, the highest costs per yield were incurred by EEG, head CT, and cardiac enzymes. Although only troponin-I was used to define abnormal results, the total cost per set of cardiac enzymes included creatine kinase and creatine kinase MB. If troponin-I alone was obtained the cost per cardiac enzymes affecting diagnosis and management would decrease from $22,397 to $4813. Postural blood pressure measurements represented the lowest cost per test affecting diagnosis and management at $17. This figure maybe lower or higher in actual practice based on who is performing the blood pressure measurements (our assumption utilized five minutes of the highest nursing salary on a general medicine floor) but the magnitude is likely accurate for comparison to other testing costs.

**San Francisco Syncope Rule to Guide Cardiac Testing**

Application of the San Francisco Syncope Rule markedly improved yields and lowered costs without compromising identification of persons with life threatening cardiac conditions. The finding was most notable for cardiac enzymes. Cardiac enzymes affected
diagnosis or management in only four of 1255 (0.3%) patients not meeting SFSR criteria. Significant differences in yields were also seen for echocardiogram and telemetry between those meeting and not meeting SFSR criteria.

Comparison of Findings to Prior Studies

While ours was the first study to evaluate cost from the perspective of effect on diagnosis and management, the low yields for most of the tests were consistent with prior studies. Grossman et al. and Link et al. also found that serial cardiac enzymes had little impact on diagnosis in syncope. 25,27 Head CT, 38 carotid US, 39 and EEG 40 are all known to rarely identify lesions contributing to syncope. The diagnostic value of postural blood pressure recordings supports guideline recommendations that the initial evaluation of syncope should entail history, physical examination, electrocardiogram and postural blood pressure measurements. 2,7,8,56

Study Strengths

Strengths of our study include a large sample size, standardized medical abstraction, consistent definitions and criteria, and blinded re-abstraction to ensure reliability. In defining criteria for tests affecting diagnosis and management, we reported results that contributed to any diagnosis or management decision in any way. For imaging studies, we included any abnormally, no matter how minor, not seen on prior testing. We used broad and inclusive criteria to define a test’s utility so that we would not underestimate the yield of any diagnostic test. If we had utilized definitions that were too limited, our assertion that certain tests have limited diagnostic yield this would be less reliable.

Study Limitations

There are limitations to our study. First, we report the retrospective experience of a single hospital – although comparison to previous studies suggests that this experience is representative of other hospitals. 2,33,34,41,42,43 Also because we used the ICD 9-CM code of 780.2 to identify syncope admissions it is possible that we may have missed some patients
with syncope without this ICD 9-CM code. These patients were likely either admitted primarily for other conditions and may have developed syncope during the course of the admission or were admitted with an established etiology; in either situation an extensive workup for syncope was likely not pursued in these patients since they were not given an ICD 9-CM code of syncope and their exclusion should not introduce any bias into the study. Also as we included patients with an admission or discharge, primary or non-primary diagnosis the number of missed patients is likely small and should not affect our results. Second, all clinical decisions may not have been documented in the medical record. For example, we likely underestimated the contribution of negative results to diagnosis or management. Only 3% of test results that were reported to have affected diagnosis or management were negative results; no negative test results were noted to have helped determine the etiology of the syncopal episode. Third, because we did not evaluate tests performed after the hospitalization, we could not comment on outpatient-based tests such as loop recorders and tilt table testing. Records of electrophysiological studies performed during hospitalizations were not available and were not included in the study. We also did not evaluate the yield of commonly performed laboratory testing such as hematocrit and glucose. Finally, our calculation of costs using a cost to charge ratio (as defined in the methods section) is an estimation based on charges, which is an approach to cost calculation used by other studies in the absence of hospital estimates of cost.56,62 The hospital's cost to charge ratio utilized in the calculation was nearly identical to the cost to charge ratio of patients admitted with syncope, which supports the accuracy of our estimation. Our calculation of costs may have underestimated total costs because it does not include all tests and procedures performed nor the cost of hospitalizations, estimated to be between $7460 and $9950 per admission.

Implications
Because syncope is a common reason for hospital admission, the evaluation of this condition is currently an important source of revenue for hospitals. Extrapolating our results nationally, assuming approximately 460,000 hospitalizations per year for syncope, yearly costs associated with the most commonly obtained tests may be nearly 6 billion dollars. The issue of revenue compared to cost incurred is significant as there is an absence of data with respect to the costs incurred by healthcare institutions associated with evaluating syncope patients. Further delineation of cost versus revenue would shed light on effective means to reduce healthcare budgets. The main sources of cost associated with the evaluation of syncope are the cost of hospitalization and the cost of diagnostic testing; approaches to reduce either sources of cost would help alleviate the burden on healthcare budgets. Studies have examined efforts to reduce the cost of hospitalization, by reducing the duration of hospitalization for syncope patients, enforcing strict guidelines on patients admitted for the condition, and by creating syncope management units. Our study has examined the issue of the cost associated with testing, and reducing such costs is an approach yet to be adopted in order to reduce the overall cost of evaluating syncope.

The low yield of most tests means that a significant number of unnecessary tests are obtained in evaluating syncope. This unnecessary testing contributes to substantial healthcare cost. Studies have demonstrated that unnecessary testing is a significant contributor to rising healthcare costs; such testing has been proposed as a target for cost savings. Research exploring chronic illnesses in the Medicare population has illustrated that the availability of resources often leads to the overutilization of such resources and to an increase in expenditure. Syncope is similar to such chronic conditions which affect predominantly older patients and often involve varied diagnostic testing. In the case of patients hospitalized for syncope, both local clinical practice and availability of testing likely contribute to the overutilization of resources in evaluating the condition. Given the easy availability of neurologic and cardiac testing it is not surprising that these tests are often
employed in evaluating syncope and that a large percent of these tests do not contribute to diagnosing the condition. However, our results suggest that clinicians should be more selective when ordering tests to evaluate syncope and that such an approach has the potential to drastically lower costs.

Our study results suggest how clinicians might be more selective when obtaining tests to evaluate syncope, by avoiding low yield testing that has been elucidated in this study. One goal of the evaluation of syncope is to detect conditions, particularly life-threatening ones such as arrhythmias, which may be present in patients with syncope. Though our data suggests that cardiac testing, particularly cardiac enzymes, is often low yield, we also recognize that there are certain patients for whom such testing is applicable and useful. For this reason we sought to utilize patient characteristics such as the SFSR criteria to identify such patients. In this study we found the SFSR criteria to be helpful in identifying patients very unlikely to benefit from cardiac testing. Using the SFSR criteria markedly improved the yield of cardiac tests in comparison to the general study sample. There have been conflicting studies regarding the validation of the SFSR; other criteria, yet to be validated, have been used to predict adverse outcomes and may be helpful as well in serving as predictors of diagnostic yield. Our results suggest that using patient characteristics such as the SFSR may help determine in whom certain tests, particularly cardiac enzymes, and perhaps telemetry, are indicated, resulting in a marked savings costs without adversely affecting the identification or management of patients with life-threatening etiologies. This finding indicates a need for further research regarding predictive and feasible criteria that can be utilized as screening tools for testing. Such tools would improve the utilization of appropriate testing and could also reduce costs.

Because almost one quarter of older patients who experience a syncopal episode suffer serious injuries such as a hip fracture during the episode, another goal is to identify non-life threatening, but treatable, etiologies such as postural hypotension. Our study
suggests that this inexpensive test is greatly underutilized, resulting in many missed opportunities to institute effective treatment strategies such as medication reduction. The underutilization of postural blood pressure recordings observed in this study may be due to a number of factors. First, local clinical practice often dictates the utilization of testing in conditions such as syncope; clinicians at this institution may have been more likely to order cardiac enzymes as opposed to postural blood pressure recordings due to customary practice. Second, ease of obtaining postural blood pressure recordings must be considered. Often recordings must be obtained by the clinicians themselves, which requires more time than ordering laboratory or imaging testing. Finally, despite the consensus guidelines defining postural hypotension, there is no clear standard definition for older patients with postural hypotension. A range of definitions exist among older patients and studies have examined the reliability of postural blood pressure recordings,\(^6^7\) indicating a need to further develop criteria for postural blood pressure and improve reliability of measurements. Studies such as this that illustrate the utility and cost effectiveness of postural blood pressure recordings may promote the utilization of this test.

Finally, our findings convincingly show that neurological imaging is not warranted in the evaluation of syncope unless there is a suspected neurological disease or event. Low yield neurologic testing has been illustrated in prior studies and this finding further supports the use of history and physical examination findings to direct testing. Our results reveal that neurologic testing could be drastically reduced and by eliminating unwarranted neuralgic testing associated costs would be significantly reduced.

Availability of national guidelines may help lessen the roles of local custom and uncertainty in the ordering of unnecessary tests. The fact that syncope is a condition with a multitude of etiologies that come under the purview of several medical specialties may have hindered the development of comparable guidelines in this country. Despite this challenge, relevant specialists such as cardiologists, geriatricians, neurologists and general internists
should consider jointly addressing the challenge of evaluating syncope and promote an evidence-based approach to diagnosis. Instituting evidence-based diagnostic guidelines, such as have been developed by the European Union,\textsuperscript{18} might lessen the extent of unnecessary testing.

In summary, basing subsequent testing on the results of the initial history and examination and prioritizing higher yield tests would ensure a more informed and cost-effective approach to evaluating older patients with syncope.

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<table>
<thead>
<tr>
<th>Characteristics</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age – years (mean ± SD)</td>
<td>79.3 ± 7.9</td>
</tr>
<tr>
<td>Female</td>
<td>1,022 (53)</td>
</tr>
<tr>
<td>Length of stay – days (mean ± SD)</td>
<td>3.5 ± 4.0</td>
</tr>
<tr>
<td>Previous admission for syncope†</td>
<td>163 (9)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>1,265 (66)</td>
</tr>
<tr>
<td>Hyperlipidemia</td>
<td>666 (32)</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>607 (32)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>396 (21)</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>348 (18)</td>
</tr>
<tr>
<td>History of stroke</td>
<td>301 (16)</td>
</tr>
<tr>
<td>Dementia</td>
<td>251 (13)</td>
</tr>
<tr>
<td>Previous myocardial infarction</td>
<td>171 (9)</td>
</tr>
<tr>
<td>Atrial ventricular block</td>
<td>103 (5)</td>
</tr>
<tr>
<td>Sick sinus syndrome</td>
<td>67 (4)</td>
</tr>
<tr>
<td><strong>Symptoms preceding syncopal episode</strong></td>
<td></td>
</tr>
<tr>
<td>Lightheadedness</td>
<td>492 (26)</td>
</tr>
<tr>
<td>Chest pain</td>
<td>82 (4)</td>
</tr>
<tr>
<td>Mental status change</td>
<td>81 (4)</td>
</tr>
<tr>
<td>Symptoms suggestive of stroke II</td>
<td>24 (1)</td>
</tr>
<tr>
<td>Seizure</td>
<td>9 (0.5)</td>
</tr>
<tr>
<td><strong>Physical examination findings</strong></td>
<td></td>
</tr>
<tr>
<td>Abnormalities on cardiovascular examination††</td>
<td>656 (34)</td>
</tr>
<tr>
<td>Neurological deficits on examination§§</td>
<td>112 (6)</td>
</tr>
</tbody>
</table>

*Syncope is a temporary loss of consciousness due to a lack of blood flow to the brain, often caused by a drop in blood pressure.
†Previous admission for syncope is the number of patients who had been admitted to the hospital for syncope in the past.
§§Neurological deficits on examination include conditions such as weakness, numbness, or changes in sensation.
Table 1. Characteristics of study patients (N=1920*) (continued)

<table>
<thead>
<tr>
<th>Reported etiologies of syncopal episode†</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No etiology listed or unknown‡</td>
<td>980 (47)</td>
</tr>
<tr>
<td>Vasovagal</td>
<td>453 (22)</td>
</tr>
<tr>
<td>Orthostatic Hypotension</td>
<td>282 (13)</td>
</tr>
<tr>
<td>Arrhythmia</td>
<td>253 (12)</td>
</tr>
<tr>
<td>Dehydration</td>
<td>178 (8)</td>
</tr>
<tr>
<td>Other cardiac causes§</td>
<td>85 (4)</td>
</tr>
<tr>
<td>Situational§</td>
<td>68 (3)</td>
</tr>
<tr>
<td>More than one etiology listed</td>
<td>199 (9)</td>
</tr>
</tbody>
</table>

*1920 patients with 2106 admissions
† Previous admission for syncope includes admissions during four and half year study period
‡ Abnormalities on cardiovascular examination included any of abnormal rate, abnormal rhythm, murmurs, S3, S4.
§ Neurological deficits on examination included any of sensory, motor, cranial nerve, or mental status deficits.
ǁ Symptoms suggestive of stroke included acute neurological symptoms or signs such as motor deficits, dysarthria, excluding acute mental status changes.
¶ Reported etiology of syncopal episode was ascertained primarily from discharge summary. If no etiology was reported in the discharge summary, then progress note documentation of an etiology was used. Sum of percentages, calculated using a denominator of total number of episodes (2106), does not equal 100% because more than one etiology may have been listed for a patient. No
etiology listed or unknown included patients for whom no documentation of etiology was noted in the discharge summary or progress notes and patients for whom it was documented that no etiology could be determined. Other cardiac causes included aortic stenosis, cardiac ischemia etc. Situational etiology included etiologies such as micturition or defecation related syncope.
<table>
<thead>
<tr>
<th>Tests</th>
<th>Obtained</th>
<th>Abnormal Findings†</th>
<th>Affected Diagnosis‡</th>
<th>Helped determine etiology§</th>
<th>Affected Management¶</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrocardiogram</td>
<td>2081 (99)</td>
<td>438 (21)</td>
<td>147 (7)</td>
<td>72 (3)</td>
<td>153 (7)</td>
</tr>
<tr>
<td>Telemetry</td>
<td>2001 (95)</td>
<td>314 (16)</td>
<td>212 (11)</td>
<td>95 (5)</td>
<td>245 (12)</td>
</tr>
<tr>
<td>Cardiac enzymes</td>
<td>1991 (95)</td>
<td>108 (5)</td>
<td>31 (2)</td>
<td>9 (0.5)</td>
<td>29 (1)</td>
</tr>
<tr>
<td>Head commuted tomography</td>
<td>1327 (63)</td>
<td>138 (10)</td>
<td>28 (2)</td>
<td>7 (0.5)</td>
<td>28 (2)</td>
</tr>
<tr>
<td>Echocardiogram</td>
<td>821 (39)</td>
<td>516 (63)</td>
<td>35 (4)</td>
<td>13 (2)</td>
<td>36 (4)</td>
</tr>
<tr>
<td>Postural blood pressure-strict criteria§</td>
<td>808 (38)</td>
<td>230 (28)</td>
<td>142 (18)</td>
<td>122 (15)</td>
<td>202 (25)</td>
</tr>
<tr>
<td>loose criteria§</td>
<td>445 (55)</td>
<td>212 (26)</td>
<td>173 (21)</td>
<td>241 (30)</td>
<td></td>
</tr>
<tr>
<td>Carotid ultrasound</td>
<td>267 (13)</td>
<td>122 (46)</td>
<td>2 (1)</td>
<td>2 (0.8)</td>
<td>6 (2)</td>
</tr>
<tr>
<td>Electroencephalogram</td>
<td>174 (8)</td>
<td>68 (39)</td>
<td>2 (1)</td>
<td>1 (0.6)</td>
<td>2 (1)</td>
</tr>
<tr>
<td>Head magnetic resonance imaging</td>
<td>154 (7)</td>
<td>46 (30)</td>
<td>20 (13)</td>
<td>3 (2)</td>
<td>19 (12)</td>
</tr>
</tbody>
</table>
### Table 2. Diagnostic tests obtained in evaluation of syncopal episodes in older patients (N=2,106)* (continued)

<table>
<thead>
<tr>
<th>Test</th>
<th>Count (Percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac stress test</td>
<td>129 (6)</td>
</tr>
<tr>
<td></td>
<td>53 (41)</td>
</tr>
<tr>
<td></td>
<td>13 (10)</td>
</tr>
<tr>
<td></td>
<td>2 (2)</td>
</tr>
<tr>
<td></td>
<td>12 (9)</td>
</tr>
</tbody>
</table>

* There were 2106 admissions for 1920 patients

† Abnormal Findings were defined as abnormal values for cardiac enzymes and postural blood pressure as outlined in Methods; for imaging studies, abnormal findings were defined as any abnormalities that were not seen on prior testing as noted in the test reports.

‡ Denominators were the number of tests obtained. Affected Diagnosis was defined as any test result that were noted in test reports, progress notes or discharge summary to have contributed to, confirmed, or established any diagnosis; examples included an electrocardiogram identifying atrial fibrillation or postural blood pressure measurements meeting criteria for postural hypotension. Helped determine etiology of syncope was defined as any test results that were noted in test reports, progress notes or discharge summary to have helped determine etiology of the syncopal episode. Affected Management was defined as any test results that were noted in test reports, progress notes or discharge summary to have contributed to any management decision; examples included electrocardiogram resulting in the management of atrial fibrillation with anti-coagulation and beta-blockers or postural blood pressure recordings resulting in the management of orthostatic hypotension with hydration.
The strict criteria for postural blood pressure was a drop in systolic blood pressure ≥ 20 mmHg or a drop in diastolic blood pressure ≥ 10 mmHg from lying to standing positions. The loose criteria for postural blood pressure was defined as ≥ 10 mmHg drop in systolic or diastolic pressure or a systolic pressure drop to ≤ 90 mm Hg from lying to sitting or standing positions.
### Table 3. Costs of diagnostic tests in the evaluation of syncopal episodes (N=2106)*

<table>
<thead>
<tr>
<th>Tests obtained</th>
<th>Cost per test**</th>
<th>Total Cost ‡</th>
<th>Cost per test affecting diagnosis or management $</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electroencephalogram</td>
<td>$1,115X.34=$379</td>
<td>$65,946=(379X174)</td>
<td>$65,946/2=$32,973</td>
</tr>
<tr>
<td>Head commuted tomography</td>
<td>$1,545X.34=$525</td>
<td>$696,675=(525X1327)</td>
<td>$696,675/28=$24,881</td>
</tr>
<tr>
<td>Cardiac enzymes</td>
<td>$357X.34=$121</td>
<td>$694,298=(121X5738 sets)</td>
<td>$694,298/31=$22,397</td>
</tr>
<tr>
<td>Troponin-I alone</td>
<td>$78X.34=$26</td>
<td>$149,188=(26X5738 sets)</td>
<td>$149,188/31=$4813</td>
</tr>
<tr>
<td>Carotid ultrasound</td>
<td>$1,294X.34=$440</td>
<td>$117,480=(440X267)</td>
<td>$117,480/6=$19,580</td>
</tr>
<tr>
<td>Head magnetic resonance imaging</td>
<td>$3,316 X.34=$1127</td>
<td>$173,558=(1127X154)</td>
<td>$173,558/20=$8678</td>
</tr>
<tr>
<td>Cardiac stress test</td>
<td>$2,492 X.34=$848</td>
<td>$109,392=(848X129)</td>
<td>$109,392/13=$8415</td>
</tr>
<tr>
<td>Echocardiogram</td>
<td>$809 X.34=$275</td>
<td>$225,775=(275X821)</td>
<td>$225,775/36=$6272</td>
</tr>
<tr>
<td>Electrocardiogram</td>
<td>$221 X.34=$75</td>
<td>$156,075=(75X2081)</td>
<td>$156,075/153=$1020</td>
</tr>
<tr>
<td>Telemetry</td>
<td>$255 X.34=$87</td>
<td>$174,087=(87X2001)</td>
<td>$174,087/245=$710</td>
</tr>
<tr>
<td>Postural blood pressure†</td>
<td>$5</td>
<td>$4040=(5X808)</td>
<td>$4040/241=$17</td>
</tr>
</tbody>
</table>

* There were 2106 admissions in 1920 patients
Cost per test was calculated as the charge per test multiplied by the cost to charge ratio of 0.34, based on the 2007 Yale New Haven Hospital Cost to Charge Ratio from the State of Connecticut's Annual Report on the Financial Status of Connecticut's Acute Care Hospitals for Fiscal Year 2007.

† $5 calculated based on 5 minutes of nurses time at $60 per hour wage. Loose Criteria for postural blood pressure, as defined in Methods, was used to calculate costs. If strict criteria, as defined in Methods were used, then the cost per test affecting diagnosis or management was $20.

‡ The total cost is equal to the number of tests obtained multiplied by the cost per test.

§ Cost per test affecting diagnosis or management was calculated as the total cost divided by the number of tests that affected diagnosis or management. (Affected Diagnosis was defined as any test result that were noted in test reports, progress notes or discharge summary to have contributed to, confirmed, or established any diagnosis; examples included an electrocardiogram identifying atrial fibrillation or postural blood pressure measurements meeting criteria for postural hypotension. Affected Management was defined as any test results that were noted in test reports, progress notes or discharge summary to have contributed to any management decision; examples included electrocardiogram resulting in the management of atrial fibrillation with anti-coagulation and beta-blockers or postural blood pressure recordings resulting in the management of orthostatic hypotension with hydration.)
Table 4. Association between San Francisco Syncope Rule* and cardiac test results in older patients presenting with syncope (N=2106)*

<table>
<thead>
<tr>
<th>Test Results</th>
<th>Met SFSR (N=807)</th>
<th>Did not meet SFSR (N=1299)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cardiac Tests</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiac enzymes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obtained</td>
<td>766 (95)</td>
<td>1225 (94)</td>
<td>0.08</td>
</tr>
<tr>
<td>Affected diagnosis or management</td>
<td>27/766 (4)</td>
<td>4/1225 (0.33)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Helped determine etiology of syncope</td>
<td>8/766 (1)</td>
<td>1/1225 (0.08)</td>
<td>0.003</td>
</tr>
<tr>
<td>Cost per affect on diagnosis or management</td>
<td>$10,331</td>
<td>$111,518</td>
<td></td>
</tr>
<tr>
<td><strong>Telemetry</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obtained</td>
<td>770 (95)</td>
<td>1231 (95)</td>
<td>0.54</td>
</tr>
<tr>
<td>Affected diagnosis or management</td>
<td>146/770 (19)</td>
<td>99/1231 (8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Helped determine etiology of syncope</td>
<td>54/770 (7)</td>
<td>41/1231 (3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cost per affect on diagnosis or management</td>
<td>$457</td>
<td>$1,078</td>
<td></td>
</tr>
</tbody>
</table>
Table 4. Association between San Francisco Syncope Rule* and cardiac test results in older patients presenting with syncope (N=2106)* (continued)

<table>
<thead>
<tr>
<th>Test</th>
<th>Obtained</th>
<th>Affected diagnosis or management</th>
<th>Helped determine etiology of syncope</th>
<th>Cost per affect on diagnosis or management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Echocardiogram</td>
<td>333 (41)</td>
<td>26/333 (8)</td>
<td>9/333 (3)</td>
<td>$1,877</td>
</tr>
<tr>
<td>Cost</td>
<td>488 (38)</td>
<td>10/488 (2)</td>
<td>4/488 (0.8)</td>
<td>$7,151</td>
</tr>
<tr>
<td>Cardiac stress test</td>
<td>56 (7)</td>
<td>7/56 (13)</td>
<td>1/56 (2)</td>
<td>$6,582</td>
</tr>
<tr>
<td>Cost</td>
<td>73 (6)</td>
<td>6/73 (8)</td>
<td>1/73 (1)</td>
<td>$13,423</td>
</tr>
</tbody>
</table>

* There were 2106 admissions in 1920 patients

† San Francisco Syncope Rule defined as at least one of a history of congestive heart failure, hematocrit <30%, abnormal electrocardiogram result, shortness of breath, or systolic blood pressure <90mmHg.
Table 5. Recurrent admissions of syncopal episodes in older patients

<table>
<thead>
<tr>
<th>Number of patients with recurrent admissions during 4.5 year period</th>
<th>163</th>
<th>143</th>
<th>17</th>
<th>3</th>
<th>349</th>
</tr>
</thead>
</table>
Table 6. Repeated diagnostic testing obtained in evaluation of syncopal episodes in older patients (163 patients, 349 admissions)

<table>
<thead>
<tr>
<th>Tests</th>
<th>% Admissions Obtained* N=349</th>
<th>% Patients Obtained** n% N=163</th>
<th>%Repeated †</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrocardiogram</td>
<td>346 (99)</td>
<td>163 (100)</td>
<td>160/163 (98)</td>
</tr>
<tr>
<td>Telemetry</td>
<td>324 (93)</td>
<td>161 (99)</td>
<td>144/161 (89)</td>
</tr>
<tr>
<td>Cardiac enzymes</td>
<td>338 (97)</td>
<td>162 (99)</td>
<td>153/162 (94)</td>
</tr>
<tr>
<td>Head commuted tomography</td>
<td>233 (67)</td>
<td>138 (85)</td>
<td>65/138 (47)</td>
</tr>
<tr>
<td>Postural blood pressure</td>
<td>146 (42)</td>
<td>105 (64)</td>
<td>29/105 (28)</td>
</tr>
<tr>
<td>Echocardiogram</td>
<td>111 (32)</td>
<td>90 (55)</td>
<td>16/90 (18)</td>
</tr>
<tr>
<td>Carotid ultrasound</td>
<td>53 (15)</td>
<td>50 (31)</td>
<td>3/50 (6)</td>
</tr>
<tr>
<td>Electroencephalogram</td>
<td>31 (9)</td>
<td>29 (18)</td>
<td>1/29 (3)</td>
</tr>
<tr>
<td>Head magnetic resonance imaging</td>
<td>27 (8)</td>
<td>26 (16)</td>
<td>0/26 (0)</td>
</tr>
<tr>
<td>Cardiac stress test</td>
<td>24 (7)</td>
<td>21 (13)</td>
<td>3/21 (14)</td>
</tr>
</tbody>
</table>

* % Admissions obtained calculated as the number of admissions in which test was ordered divided by total number of recurrent admissions (349)

**% Patients obtained calculated as the number of patients in whom test was ordered divided by total number of patients with recurrent admissions (163)
% Repeated testing calculated as number of patients in whom the test was ordered in more than one admission divided by number of patients in whom test is ordered
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