Carotid Ultrasound and the Emergency Department Physician: A Validation Study

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Abstract

This study aims to determine whether Emergency Department (ED) physicians can use an abbreviated bedside ultrasound protocol to accurately evaluate the condition of the carotid arteries. Our primary outcome was the accuracy with which the ED study predicted a category of stenosis as compared to the degree of stenosis based on a formal carotid ultrasound. The secondary outcome was the accuracy with which the ED physician measured peak systolic velocity (PSV) as compared to the measurements obtained during a formal ultrasound study, the current gold standard.

We trained four emergency medicine residents and one emergency medicine attending physician to perform an abbreviated carotid ultrasound protocol which measured the peak systolic velocity (PSV) of the internal carotid artery (ICA) and the common carotid artery (CCA) bilaterally and requires the practitioner to calculate the ratio of the two (PSV ICA/PSV CCA). Forty-five adult patients $\geq$ 55 years old were enrolled from December 2010 to January 2012, presenting with chief complaints of TIA, syncope, or near-syncope within 24 hours of their emergency room visit. The measurements and ratios obtained by our emergency physicians compared to those obtained by the formal ultrasound study all had p-values > .05, and thus were not statistically significant.

This pilot study was meant to be a preliminary look carotid disease in the emergency setting. Our findings confirm that properly trained emergency physicians are capable of performing the abbreviated carotid ultrasound protocol accurately.

Background

Cerebrovascular disease is the third most common cause of mortality in the developed world, with an estimated prevalence of 794 deaths per 100,000 (1). The incidence of TIA in particular was estimated by a population-based study to be 240,000 cases per year in the United States, with males and persons of African American descent demonstrating the highest rates of TIA among studied groups (2). In turn, hospitals continue to be strained from the growing number of patients requiring inpatient hospitalizations and extended stays in rehabilitation facilities for recovery from stroke and TIA.

Additionally, patients presenting with TIA pose several dilemmas for the ED clinician. First, the transient nature of the symptoms often forces the physician to rely on history alone instead of a history coupled with concrete physical exam findings. The differential diagnosis is clouded with the transient nature of TIA symptoms and the additional considerations of "non-ischemic" etiology with similar clinical presentations: seizure, syncope, and migraine. (3)

A second dilemma involves the determination of risk for a subsequent stroke. Investigators have developed prediction tools for the short term, namely the ABCD2 score (4,5). Regardless of clinical risk score, patients with high- grade carotid stenosis are at increased risk of stroke following a TIA. A study of 1707 patients with TIA noted 10% of patients returning to the same ED with a CVA within 90 days of the index TIA. Of this group of patients returning with CVA, approximately 50% had subsequent stroke within 2 days of the index TIA (3). The North American Symptomatic Carotid Endarterctomy Trial (NASCET) demonstrated a 90-day stroke risk of 20.1%, with most of the risk accruing within the first 20 days after the index TIA (6). Moreover, on multivariate analysis, including adjustment for ABCD2 score, the only independent predictor of early stroke risk (within 7 days) was the presence of large vessel occlusive disease (HR 5.9; 95% CI 2.2 to 15.9) (6). There is level I evidence that severe

(>70%) symptomatic extracranial carotid stenosis should be re-vascularized with carotid endarterectomy as quickly as feasible after TIA or minor stroke (7, 8).

More specifically, the internal carotid artery plays a clinically significant role in TIA and stroke, as stenosis greater than 70% increases the threat for a TIA or stroke (9). One study noted a 1.7% per year incidence of stroke among the 500 patients evaluated, and 5.5% per year incidence of stroke among those patients with ICA stenosis greater than 75%. Surgical intervention (via carotid endarterectomy) for clinically significant ICA stenosis can provide between 5-11% overall risk reduction for subsequent ipsilateral stroke between 30 days -2 years following the surgery, based on prospective data available thus far (10-13). Because of this risk and the need to identify those at greater risk than others, multiple prediction rules have been created, namely the ABCD score. However, the ability of clinical risk scores to identify treatment urgent patients, such as those with carotid stenosis requiring revascularization has not been established (14). Furthermore, regardless of clinical risk scores, patients with high-grade carotid stenosis are at increased risk of stroke following a TIA independent of any other factor (15).

Based on the existing literature that outlines increased patient risk for high-grade carotid stenosis, our study group was motivated to create and initiate a protocol in which the ED physician may be able to assess the carotid arteries for patients with clinically relevant presentations for TIA and stroke (16, 17). This study attempts to create and validate an ultrasound protocol for assessing the carotid arteries, and correlate its accuracy and reliability when compared to a formal carotid ultrasound performed in the ultrasound department by trained sonographers (18, 19). If validation is successful, we propose that low risk patients, (those with combined low-risk score and negative or low grade stenosis on ultrasound) to be successfully discharged home with outpatient follow up. Those patients with high-risk extra cranial carotid stenosis could then be promptly referred to the in-house vascular surgeon (20-24).

Purpose/Hypothesis

This study aims to determine whether Emergency Department (ED) physicians can use an abbreviated bedside ultrasound protocol to accurately evaluate the condition of the carotid arteries. If we can prove the ED physician is reliably accurate, this quick diagnostic test may be used in the future to identify previously undiagnosed high-risk patients, reduce the inpatient hospital stay for low-risk patients, or potentially eliminate the need for a follow-up visit as an outpatient. In order for the emergency physician to evaluate carotid artery stenosis there must be a protocol that is brief enough to allow safe and accurate estimation of carotid stenosis in a short amount of time. Because of time constraints in the emergency department, it is rare that the ED physician would have more than 5-10 minutes to complete an ancillary study in the department. We chose to abbreviate the formal ultrasound protocol by utilizing the peak systolic velocity (PSV) measurements using continuous color wave Doppler ultrasound and calculating ratios from those PSV values. Based on existing standardized criteria, these ratios can be translated directly into an estimate of internal carotid artery stenosis.

Methods

This pilot study enrolled 45 patients from December 2010 to January 2012. Patients were eligible for the study if they were aged 55 years and older presenting with a chief complaint consistent with the study definitions of TIA, syncope, near-syncope within 24 hours of their emergency room visit. Study definitions include the following: TIA defined as a sudden focal loss of neurologic function involving the brain or retina, supplied by a specific vascular territory, with complete recovery within 24 hours (25). Syncope was defined as a transient loss of consciousness (T-LOC) due to transient global cerebral hypoperfusion characterized by rapid onset, short duration, and spontaneous complete recovery. (26) Near-Syncope was defined as the sensation or subjective feeling that the patient was near total loss of consciousness.

Four resident emergency medicine residents and one attending completed a brief hour long training module designed to standardize the ultrasound protocol for the study. A certified ultrasonographer from our institution's radiology department provided this training to all the study personnel that performed scans on study patients. Patients under 55 years of age or presenting with acute stroke (ischemic or hemorrhagic), previous carotid endarterectomy, or those with a recent carotid ultrasound study within the last 6 months were excluded.

Specifically, those with a recent carotid ultrasound study must have a report that is easily accessed by the ED physician at the primary investigation site, with the report resulted in the hospital electronic medical record at the primary investigation site, or any site affiliated with the primary investigation site (i.e. a hospital-affiliated vascular lab). If it was determined by the admitting physician that the patient did not require a formal carotid ultrasound as a part of their workup, the patient was considered ineligible for the study. Informed consent was obtained per our institutional IRB protocol, and patient information was protected per IRB specifications. In the case of altered or demented patients, and those unable to consent for themselves, consent was obtained by a healthcare proxy or medical power of attorney.

Admitting physicians and patients were blinded to the results of the research study scan. The first ultrasound evaluation by the study team members was performed in the emergency department after the patient was admitted. The second ultrasound exam was performed by a trained ultrasonographer in our radiology department during the patient's inpatient workup, as per the current standard of care. This is a lengthier exam and has been thoroughly described elsewhere (14, 27).

Based on current standards, PSV is measured in the internal carotid artery (ICA) as well as the common carotid artery (CCA). These measurements are then used to calculate a ratio of the peak systolic velocities ICA/CCA, which have been shown to correlate to the degree of carotid stenosis. We use a previously determined correlation scale standardized by the Society of Radiologists Consensus Conference to categorize the degree of stenosis based on the measured PSV of each ICA and CCA and the ratio of the two. This is shown in the table below (28).

Stenosis	***PSV of ICA (cm/s)***	***Ratio: PSV ICA/CCA (cm/s)***
Normal	< 125	<2
<50%	<125	<2
50-69%	125-230	2-4
>70%	>230	>4
Near Occlusion	high, low, undetectable	variable
Total Occlusion	Undetectable	n/a

Table 1. Doppler Criteria for carotid artery diameter stenosis detection developed by the Society of Radiologists in Ultrasound Consensus Conference (28)

Emergency department carotid exams were performed using the ACUSON Antares Ultrasound Imaging System using a 7 MHz linear transducer. Peak Systolic Velocity (PSV) was recorded approximately 2 cm distal to the carotid bulb in the center of the common carotid artery (CCA). Next, the PSV most proximal to the bulb will be measured in the internal carotid artery (ICA). If a plaque was visualized, then measurements were made distal to the plaque. Two separate values (CCA PSV, ICA PSV) were obtained bilaterally and the ratio of the PSV of the ICA/CCA was calculated. Based on the ratio obtained, the patient was placed in one of the categories of stenosis listed in Table 1 above. Examples of the ACUSON Antares screenshots for CCA and ICA can be found in Figures 1 and 2, respectively.

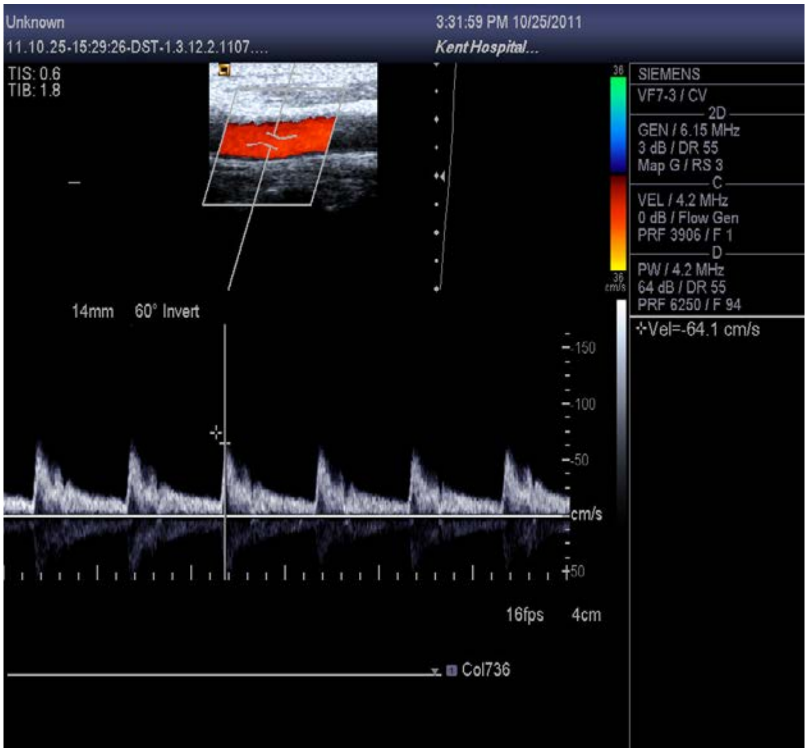

Figure 1- ACUSON Antares Screenshot of CCA measurement

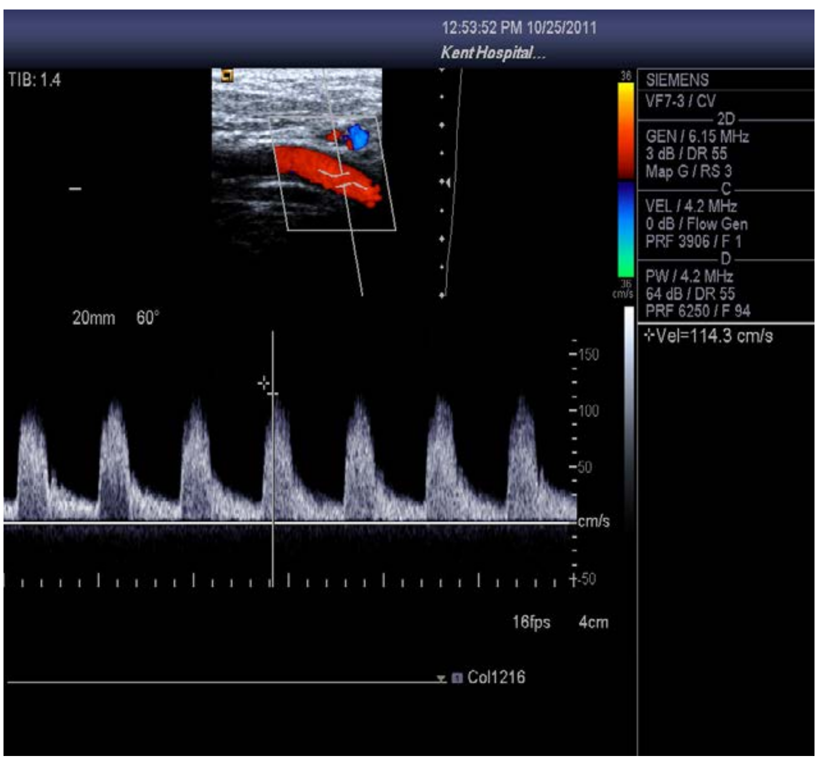

Figure 2- ACUSON Antares Screenshot of ICA measurement

All ED ultrasound exams were compared to a formal Doppler/duplex exam performed by a trained ultrasonographer using a standard full length protocol. The primary outcome was the accuracy with which the ED study predicted a category of stenosis as compared to the degree of stenosis as read by the radiologist from the formal carotid ultrasound performed by the trained ultrasonographer. The secondary outcome is the accuracy with which the ED physician measured the PSV as compared to the professional ultrasonographer.

Results

Forty-five patients had their carotid arteries evaluated using the abbreviated ED ultrasound protocol. Twenty-three patients presented with the chief complaint of TIA, 20 with syncope, 1 with near syncope, and 1 with both TIA and syncope, as indicated in Table 2. All measurements (left and right PSV CCA and PSV ICA) were successfully obtained in all 45 patients. The total ED carotid exam time ranged from 3-20 minutes with an average length of 7 minutes.

The ED study exam demonstrated 37 patients to have normal peak systolic velocities (PSV ICA <125) in their left ICA compared to 38 patients using the formal ultrasound exam. Seven patients were found to have an abnormal left ICA on ED exam (50-69% stenosis, PSV ICA 125-230) compared to 6 patients on formal exam. On further analysis of the left-sided measurements, 3 patients were measured as being abnormal on ED exam when they were not by formal exam, i.e. 3 false positives. Two patients were measured as being normal when they were found to be abnormal on formal exam, i.e. 2 false negatives. These data are represented in Table 3. One patient was found to have severe left ICA stenosis (>70%, PSV >230) on ED exam, which was confirmed on formal exam.

As described in Table 3, the ED study exam demonstrated 42 patients to have normal peak systolic velocities compared to 40 patients using the formal exam on the right carotid system. Two patients were found to have an abnormal right ICA on ED exam compared to 4 patients on formal exam. Analysis of the right-sided measurements demonstrated 0 false positives and 2 false negative. One patient was found to have severe right ICA stenosis on ED exam, which was confirmed on formal exam.

ICA/CCA ratios were calculated using both left and right ED and formal PSV values. 43/45 patients were found to have ratios <2 bilaterally, as indicated in Table 3. One patient had a ratio of 2 on the right by ED exam compared to a ratio of 2.2 by formal study. One patient had a ratio of 4.2 on the left by ED exam compared to a ratio of 4 by formal study. Applying the Student T-test, no significant difference was found when comparing the measurements of ED exam to formal exam groups (P-values: Left CCA 0.08, Left ICA 0.87, Right CCA 0.55, Right ICA 0.62, Left ICA/CCA 0.32, and Right ICA/CCA 0.83). The above data are summarized in Table 3.

Variables	Number of Subjects
Age	
55-64	7
65-74	12
75-84	17
$\geq$85	9
Sex	
Male	12
Female	33
Chief Complaint	
Syncope	20
TIA	24*
Near syncope	2*
	N = 45

*1 pt with TIA and near syncope

Table 2-Demographics of patient population

N=45 (average study time 7 minutes (3-20 mins)

L PSV ICA (89% Correlation)	R PSV ICA (96% Correlation)
3 false positives	0 false positives
2 false negatives	2 false negatives

Study ICA/CCA Ratios (cm/s)
<2 = 43
2-4 = 1
>4 = 1

Student T Test (p-values no difference >0.05)

L CCA	0.08	R CCA	0.55
L ICA	0.87	R ICA	0.62
L ICA/CCA	0.32	R ICA/CCA	0.83

Table 3 – Statistical Analysis of Data (CCA = Common Carotid Artery; ICA = Internal Carotid Artery; PSV = Peak Systolic Velocity)

Limitations

This prospective pilot study retains some limitations. First, the sample size prohibits us from having enough statistical power to determine whether or not an emergency medicine physician can accurately diagnose carotid disease with the study protocol outlined above. This study was meant to be a preliminary look at the ability of emergency physicians to evaluate the carotid arteries. Second, our study population is limited in pathology. Based on percent stenosis and not ICA/CCA ratio, 34 patients demonstrated normal carotid arteries, 10 patients demonstrated moderate degrees of carotid stenosis (50-69%) and 1 patient had severe carotid stenosis (>70%) on at least one side by formal study.

Our study was also limited in size due to incomplete data, as 10 (18%) of enrolled subjects did not get a formal ultrasound study while admitted to the hospital. Many enrolled patients were discharged from the hospital for an outpatient carotid ultrasound exam that our team did not have access to. This could have been rectified by requiring the admitting physicians to obtain a formal inpatient carotid ultrasound on all enrolled patients (though to reduce bias and avoid the potential financial complications, this was not required for our pilot study). With additional research on our abbreviated carotid ultrasound protocol, the inpatient teams should be notified of all enrolled study patients, and, therefore, will order the formal study to maximize the sample size and statistical power of the study.

Discussion /Conclusion

Our abbreviated ED carotid ultrasound study correctly identified 60% of the moderate group and 100% of the severe group. In clinical practice, identification of the severe group is most important as severe stenosis may actually change management in the ED. For instance, the results of our ED-based carotid study may prompt a more immediate vascular surgery consult (and perhaps a carotid endarterectomy during that hospital stay). Our sample did not include enough patients with severe disease; therefore, we cannot state with full confidence that emergency physicians can accurately diagnose pathology. This is an area that requires further investigation.

However, we can infer that properly trained emergency physicians are capable of performing the abbreviated carotid ultrasound protocol accurately. While we demonstrated (on a preliminary level) that emergency medicine physicians can identify and accurately classify normal carotid arteries, a more thorough investigation is warranted to provide additional data and confidence among the patient population with significant carotid artery stenosis.

Since the duration of this proposed ED carotid ultrasound exam is an important factor for its regular use in a busy emergency department, it is clear from our results there was a definite learning curve. After the first 10 ED exams, the exam time dropped from an average of 8 to 6.4 minutes. We showed that the abbreviated carotid ultrasound study can be effectively implemented into the everyday practice of the ED physician. When comparing our protocol to a common ultrasound exam in the emergency room, the average times we obtained on the carotid exam was similar to that documented for students learning a FAST exam (average from 2.7 to 5.4 minutes when done on a simulator dummy and 3.4 to 5.9 minutes when on a human subject). (29)

With cerebrovascular disease being the third most common cause of mortality in the developed world, it is paramount to find better ways to risk-stratify patients to effectively treat this devastating disease. The carotid ultrasound remains an important part of the inpatient workup of patients who present to the emergency department with symptoms consistent with TIA, syncope, and near syncope. With our abbreviated carotid ultrasound protocol, we would be able to minimize the additional inpatient/outpatient studies on these patients, and hopefully decrease the cost of this disease on the American health care system. Cerebrovascular disease is the most financially costly of all major diseases (30). Accelerated treatment of TIA in its acute phase has been shown to have an 80 percent reduction in secondary stroke risk in the first 3 months (30). Our abbreviated carotid study could help with accelerating the treatment and diagnosis of TIA by evaluating for stenosis early in the course of the disease process.

After additional research into a larger patient population with subjects exhibiting more pathology, we would like to optimize our current protocol by incorporating the ABCD2 score. In theory, this addition may increase the effectiveness of our developed protocol, and therefore risk-stratify patients with more accuracy. This could augment the ABCD2 score by also adding to the decision the amount of stenosis, which could potentially put a low risk patient on the score without the study into a moderate or severe category depending on the result. It could make the difference of sending a patient to next day follow up versus inpatient stay and vascular surgery evaluation.

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