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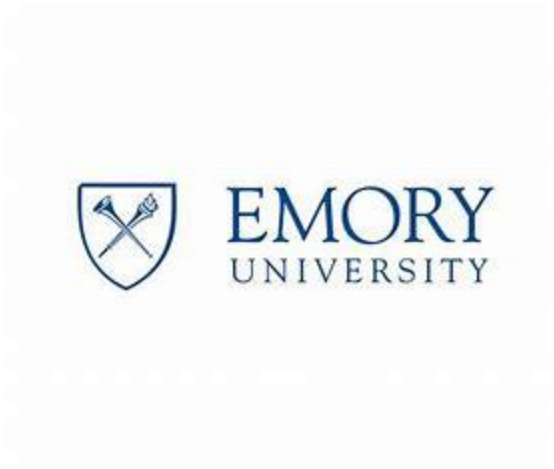

DNP Scholarly Project Proposal - HINTSSCAN+ AI App

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31 July 2024

Disclosure: The research team who developed the application was also the team who tested the application. There is no current plan to charge a fee for using the iOS application so, as of the time of this writing, there are no financial disclosures.

Funding: This research was made possible by funding from a grant from United Healthcare and the Emory Urban Health Initiative

ABSTRACT

This study examines the effectiveness of the HINTS+ (Head-Impulse, Nystagmus, Test of Skew, plus hearing) exam in detecting posterior circulation strokes, which often present atypically and delay treatment. This study evaluated a new iOS application to support HINTS exam use across clinical settings, aiming to improve stroke detection. Ten patients with vestibular symptoms were assessed using the application, with one correctly identified central and nine peripheral pathologies. The application showed 100% sensitivity and 66.7% specificity and allowed slowed video replay to allow examiners to assess nystagmus and head impulse saccades better than clinical non-video testing. Results suggest potential for wider HINTS application use, with future improvements through artificial intelligence. *Key words:* Posterior CVA, HINTS exam, Diagnosis, Emergency medicine, iOS application

BACKGROUND

Vertebrobasilar artery cerebrovascular accidents causing vertebrobasilar insufficiency (VBI) are often difficult to diagnose in urgent and emergency care settings. The main problem lies with the pathology being mimicked by more benign causes such as Benign Paroxysmal Positional Vertigo and vestibular neuronitis (Engler, Wood, & Cook, 2022). A highly sensitive exam that has been well established in the literature that has shown to be more pathognomonic

than imaging in some studies is called the HINTS+ exam. This exam appraises a head impulse test, nystagmus, test of skew, and a hearing assessment to risk stratify patients between benign causes of vertigo and VBI. Roadblocks to wider adoption and implementation of the HINTS+ exam are due to provider discomfort with performing and assessing the exam. The exam requires nuance and experience in tracking eye movements, especially in the head impulse test, to look for vestibular-ocular reflex (VOR) desynchrony. Use of video data to prognosticate HINTS exams has been proven to provide greater sensitivity and specificity with this exam. Roadblocks to using this technology in emergent and urgent care settings are due to proliferative costs of implementation and the equipment required to use this technology including the hardware and software.

SIGNIFICANCE:

The significance of this study is the possibility of increasing proper identification rates of posterior circulation strokes in the emergent and urgent care setting. The rapid implementation of this application could reduce door to intervention times for patients experiencing this condition. This application has the potential to aid in a very prominent issue in emergency medicine. Vertebrobasilar artery occlusions, also known as posterior circulation strokes, account for almost a quarter of all strokes and manifest themselves with nonspecific issues (Hoyer & Szabo, 2021). Identification tools such as the BEFAST tool and NIH Stroke Scale often miss these strokes entirely. “The vast majority of PCS [posterior circulation strokes] patients have a baseline NIHSS scores ≤4, and even a value of 0 cannot rule out the presence of stroke” (Hoyer & Szabo, 2021).

A solution that has been discussed for about a decade now by respected clinicians such as Dr. Scott Weingart (2010), has been to use smartphone cameras to track eye movements to allow

for a quicker and more cost-effective diagnosis. The novel idea that the DNP team is focusing its efforts on, builds off this concept with appraising proof of concept and development of an IOS application that uses artificial intelligence eye tracking technology to analyze the HINTS+ exam and properly diagnose VOR desynchrony to rule in VBI. This app would allow for cost effective and easily accessible software that could revolutionize diagnosis for this difficult but insidious pathology.

PURPOSE STATEMENT

The purpose of the proposed DNP project is to create an easily accessible IOS application that can perform the HINTS+ exam using eye tracking technology. Using this technology will hopefully reduce time to intervention and diagnose central vertigo with increased accuracy and decreased time.

POPULATION

The main population affected by VBI in the United States are African American males past the age of 70 (Lima et al., 2017). This prominence could be due to an increased incidence of smoking, diabetes, and hypertension in the population as well as reduced access to care. Although the pilot project was implemented in a Vestibular Physical Therapy clinic, ultimately, the target population for this project will be patients presenting to emergency departments with constant and acute vertiginous symptoms including nystagmus, dizziness, and nausea.

EPIDEMIOLGY

VBI can be caused by a multitude of factors. Although it is most frequently due to atherosclerosis, embolism and arterial dissection can also be causes (Lima et al, 2017). Less common causes include migraines, fibromuscular dysplasia, coagulopathies, and drug abuse

(Lima et al, 2017). Atherosclerosis can be traced to male sex and increased age. According to Lima et al (2017), it is most often found in men in the fourth decade of life who are obese, are smokers, and have arterial hypertension. Atherosclerosis in particular can be further exacerbated by food deserts. This is defined as people that live in low-income areas who experience lack of access to healthy food options (Kellie et al, 2017). In a 2017 study that focused on the Atlanta metropolitan area and included analysis of "food access, area income and individual income, both low-income area and low individual household income were independent predictors of a higher ten-year risk for CVD" (Kelli et al, 2017). Other social factors that correlate closely to increased risk of atherosclerosis include education level, race, and if the patient has other comorbidities such as diabetes or hyperlipidemia (Kellie et al, 2017).

ORGANIZATIONAL/ LOCAL KNOWLEDGE OF THE PROBLEM

The DNP project was first implemented in Emory's Dizziness and Balance Center. The clinic hosts a multidisciplinary team of specialists who are specially trained in the management and treatment of vestibular disorders. Specialty clinics like this have an intimate knowledge of the pathophysiology of vestibular disorders. Patients must receive a referral for eligibility in order to be seen. By conducting the project within a clinic that serves patients already diagnosed with vestibular conditions, one can enhance the ability to predict the app's specificity and sensitivity. Vertiginous symptoms are generally poorly recognized and treated among generalist specialties such as primary care and emergency medicine. By working with experts in the discipline, this study has a higher probability of developing into an opportunity to develop properly for use in those generalist settings.

Literature in the past has shown conflicting results on emergency provider efficacy and knowledge of the HINTS+ exam. A study by Nakatsuka & Malloy (2022) showed a dismal 20%

lower sensitivity and specificity for clinical HINTS+ exams when comparing emergency medicine physicians and neurologists. A small study by Gerlier et al. (2023) showed that new physicians with just a single day of training were able to accurately use head impulse testing to diagnose strokes 100% of the time. From these conclusions it can be inferred that organizational knowledge deficits in vertiginous emergency department presentations are more a device of undereducation. Development and institution of an artificial intelligence application could eliminate the need to intimately understand the aspects of this exam and more accurately initiate it, perhaps leading to more proper diagnoses and decreased morbidity and mortality.

PROJECT OBJECTIVES

Objectives of the proposed project include investigating the patient's true diagnosis to cell phone captured data and application inputs. Furthermore, to analyze the cost effectiveness of using cell phone application interface vs. telestroke systems, especially in rural, standalone settings. Finally, explore the availability of research on inexperienced health care providers performing the HINTS+ exam and barriers to using the test effectively.

CLINICAL QUESTIONS

The DNP team formulated a diverse set of clinical inquiries as part of the project. The first phase of the project will focus on the feasibility of using video hardware to track eye movements. The second phase of the project will include artificial intelligence to determine the app's sensitivity and specificity in correctly identifying VBI. Specifically, how does the accuracy of VBI diagnosis compare when using artificial intelligence via eye tracking versus traditional diagnostic methods? With both phase one and two, collected data will be evaluated to identify

specific patient demographics (e.g., age, gender) that influence the accuracy of VBI diagnosis using the iOS application.

ASSUMPTIONS AND LIMITATIONS

For the purpose of this research, it can be assumed that the patients are properly screened as high risk for VBI prior to the app being utilized on them. False positives will occur if a patient is screened using the application tool in the absence of spontaneous nystagmus. Another assumption that is paramount is that the provider is able to perform the exam correctly including the head impulse test maneuvers.

One limitation of this study is the novelty of developing an application using artificial intelligence to diagnose strokes using the HINTS+ exam. There is no historical data to support such an idea in part due to the developments of artificial intelligence technology being in its relative infancy. Validation will need to be scrutinized and attention will be paid to the efficacy of the development process and conferring studies. Multiple levels of testing may be necessary to properly implement this novel idea. Once development is completed, an unblinded experimental control trial in a neurology clinic using already diagnosed patients would allow for analysis of positive predictive value, negative predictive value, specificity, and sensitivity. Then, a multicentered randomized control trial would be indicated to assess the application's use in its target environment in emergency departments and urgent cares and compare it to target patients who were not diagnosed using the application.

THEORETICAL FRAMEWORK

A framework identified to help aid in the development of this project includes the Systems Engineering Initiative for Patient Safety (SEIPS). The SEIPS model is a comprehensive framework used in healthcare to enhance patient safety and quality of care. It views healthcare as a complex system involving various components, including healthcare professionals, patients, technology, policies, and physical environments (Carayon et al., 2006). Within this framework, it assesses the influence of individuals' characteristics, such as skills and attitudes as well as the design of tasks and processes performed in healthcare settings. It also considers the impact of tools and technology, like electronic health records and medical devices, and the physical and organizational environment (Carayon et al., 2006). This is particularly pertinent to the DNP project, as it revolves around the integration of technology. The HINTS+ IOS App's aim is to harmonize human interaction with technology, with the goal of simplifying the healthcare journey for patients. By examining how these elements interact, the SEIPS model aims to improve patient outcomes, safety, satisfaction, and the overall effectiveness of healthcare delivery.

Another framework that aligns with the objectives of the DNP project includes the Human Factors Engineering (HFE) approach. HFE is a multidisciplinary approach focused on optimizing the design of systems, products, and processes to ensure they are safe, efficient, and user-friendly for individuals (Anderson, 2023). This model emphasizes understanding the capabilities, limitations, and preferences of people within a particular context to design systems and products that align with their needs. In this case, patients with potential vertebrobasilar insufficiency. This framework is used to enhance the design of medical devices, electronic health records, healthcare facilities, and workflows to reduce errors, improve usability, and enhance overall safety and performance (Anderson, 2023). HFE integrates knowledge from various fields,

such as psychology, engineering, and ergonomics, to create designs that consider human factors, including cognitive, physical, and behavioral aspects. Ultimately, the HFE approach aims to optimize the interaction between humans and technology or systems, leading to improved outcomes, reduced errors, and increased user satisfaction.

LITERATURE REVIEW AND SYNTHESIS

A comprehensive literature search was performed using PubMed, CINAHL, and the Cochrane Library with limits including publication date within 10 years of present and English being the publication language. Exclusively in CINAHL, a limitation was set to exclude case studies due to their lower quality of evidence. Articles were included based on their applicability, especially those that took place in emergency departments and that included novel providers being trained and implementing the HINTS exam. Other tests and algorithms were included to examine if they were noninferior and/or more concise. Key words searched for included “head impulse test”, “HINTS exam”, “STANDING algorithm”, “posterior CVA”, and “posterior stroke”. Between the three databases, 569 articles were a match.

After reviewing abstracts for appropriateness, thirty articles were chosen based on their findings and significance. From there, a synthesis of evidence table was created based on the best and most relevant twelve articles. This table included important findings, types of evidence, and limitations of the studies. The twelve articles chosen were decided based off data obtained and feasibility of applying the research to the proposed EBP project.

Exclusively selecting articles for consideration occurs when these articles meet the strict GRADE criteria at a moderate or high level. This means that the articles were less likely to have contradictory information, unlikely to be biased and more likely to be directly related to the subject matter. This demonstrates a commitment to using only the highest-quality research and

recommendations. Adherence to these standards ensures that the information is robust and reliable, maintaining the integrity and credibility of the decision-making process.

Subsequently, these articles were categorized into three distinct themes, taking into account the similarities in ideas and premises explored within each article. These themes are as follows: “Comparison of Different Diagnostic Tests for Posterior Strokes”, “Ease of Use of the Diagnostic Tests”, and “Translation of Diagnostic Tests for Posterior CVA in the Emergency Department.” All articles chosen were analyzed using comparative analysis.

Theme 1: COMPARISON OF DIFFERENT DIAGNOSTIC TESTS FOR POSTERIOR STROKES:

The HINTS exam is a diagnostic test that takes into account a clinical head impulse test, the direction of nystagmus if present, and a test of skew to analyze for signs of stroke. If any of the categories are indicative of central causes, they point towards the need for a stroke rule out (Kattah, 2018). The head impulse test is concerning if there is an absence of corrective saccade during quick redirection of the head while the patient fixates their eyes on the examiner in different vertical planes. This exam is the most difficult portion with the most amount of nuance due to the subtlety of the saccade in most cases. The direction of nystagmus portion is positive if there is bidirectional nystagmus. This means as the clinician has the patient follow a finger towards the right and left outer fields of vision, the nystagmus beats change direction towards this lateral fixation point. The test of skew is performed by covering one patient eye at a time and quickly uncovering it to examine for vertical displacement which would be abnormal.

An observation-based study by Batuecas-Caltrio et al. (2014) has validated the use of the head impulse test in patients who present for dizziness and have diagnosed peripheral vertigo.

The test was abnormal, pointing to a peripheral cause, in all but one test out of 91 patients. This single centered study provides a very strong basis to ensure the efficacy of the head impulse test and the HINTS exam as well. An abnormal head impulse test indicates peripheral vertigo with a sensitivity of 100% and a specificity of 91% per another article by Lenin, Schneider, & Jahn (2013).

The STANDING algorithm assesses for nystagmus presence and direction, head impulse testing, and inability to stand or walk. The algorithm provides a flow path for these findings to rule in patients at risk for having a posterior stroke. Appraisal of the STANDING algorithm in a prospective study by Gerlier et al. (2023) showed that it may be too complex and extensive for provider implementation and use. This is due to the inclusion of maneuvers such as the Pagnini-McClure test and the Dix-Halpike test which may take too long for a concise and rapid triage. The algorithm is also in its relative infancy with this being one of few articles written on it, leading to not enough heterogeneous buy-in by providers and healthcare systems at this point in time. The article does show that the novice providers were proficient in head impulse testing, however. More validation would be beneficial to legitimize the overall algorithm.

A retrospective study by Guler et al. (2017) showed that there is more competence and ease of use with the HINTS exam, but a higher sensitivity with the STANDING algorithm. This means that the HINTS exam would be more translatable to providers. The HINTS exam is a concise way to rule out patients who experience acute vestibular symptoms and may have a posterior CVA. The exam should not take longer than approximately five minutes.

Video head impulse testing (vHIT) is a newer development that analyzes eye movements using a metric called gain to analyze the presence or absence of a corrective saccade. This measurement is recorded by tight fitting glasses called Frenzel goggles. There remains a need for

a skilled examiner to perform a video head impulse test due to the need for the maneuver to be performed correctly on different axes and quickly enough to illicit a response. Although the test requires more advanced software and hardware, the vHIT is highly accurate with 100% sensitivity and specificity according to an experimental study by Mutlu et al. (2020). This is supported by a prospective study by Abrahamsen, Christensen, & Hougaard (2018) which tested the inter-examiner and intra-examiner reliability of video head impulse testing and found them both to be high.

Perhaps the most extensive and current of all research performed on dizziness testing in emergency medicine is GRACE-3, a systemic review by Shah et al. (2023). This meta-analysis assessed the certainty of clinical tools using the GRADE system. The most sensitive (99%) exam which had a high specificity (85%) was the HINTS+ exam. This is the conventional HINTS exam with the addition of assessing for hearing loss. Acute hearing loss can be present in strokes affecting the vestibulocochlear system, which would not be present in peripheral vertigo. This is especially useful in the small number of posterior strokes that do not involve the medial vestibular nucleus (Kattah, 2018). This can be tested as simply as covering one ear and rubbing one's fingers together on the uncovered side to see if the patient can hear it. This quick addition increases the sensitivity of the HINTS exam by nearly 4% when compared to the traditional exam which had a sensitivity of 95.4%.

Theme 2: EASE OF USE OF THE DIAGNOSTIC TESTS:

Guler et al. (2017), appraised the results of inexperienced users that were emergency medicine (EM) resident physicians using a clinical head impulse test against video head impulse testing operated by a specialist otolaryngologist as a control. The new EM residents were able to

accurately identify all of the posterior circulation strokes in the group after a single day of training.

A single centered retrospective study by Dmitriew et al. (2021) showed that there may be a gap of knowledge in most emergency department providers. The HINTS exam was only used 3.1% of the time it was indicated and none of them had a true positive exam. Out of the total population that were candidates for the exam, 15.4% were diagnosed with stroke. This means that outside of experimental designs, there is a lack of understanding on when to use the HINTS exam and discomfort with using the exam. The overall appraisal of these two studies is that there needs to be a standardization of the education on the exam, possibly like the American Heart Association's Basic Life Support (BLS) certification for cardiopulmonary resuscitation (CPR).

Dmitirew et al. (2021) contrasts from another large single-centered emergency department study by Batuecas-Caletrío et al. (2014). This article showed a head impulse test sensitivity of 88% and a specificity of 96%. This study showed a much more appropriate use of the exam and showed that, when used correctly, there is a place for using it in emergency medicine. This study serves as a counterpoint to Dmitriew et al.'s findings, demonstrating that with correct training and understanding of the exam's application, it can be effectively used in emergency medicine settings. This further supports that, with the correct training, this exam is well validated and applicable to this setting.

Theme 3: TRANSLATION OF DIAGNOSTIC TESTS FOR POSTERIOR CVA IN THE ED:

A prospective cohort study by Korda et al. (2020) appraised the inter-examiner reliability of the head impulse test. The study showed promise with a high inter-examiner reliability of a

sensitivity of 93% and a specificity of 79%. This was due to the examiners being able to rule out stroke more effectively in patients with grossly abnormal tests that point towards a peripheral cause. Guler et al. (2017) reinforces the findings of Korda et al. (2020) by establishing inter-examiner reliability and inter-test reliability by re-examining the clinical head impulse test with video head impulse testing. This is more helpful because, in an emergency department or urgent care setting, the patients who do not have a stroke according to the exam will be more easily discerned and will not need to undergo extraneous testing. The downside to this is that some of the non-stroke patients may be included in the worrisome group due to a more indeterminate test, thus leading to a higher sensitivity and lower specificity. This is more palatable than the opposite circumstance, where strokes would be missed using the exam.

Emergency department and urgent care settings are fast-paced environments where minutes spent on exams can lead to a profound back up in the flow of the system. This means that the exam implemented in this setting must be concise, effective, and easily standardized. With these limitations in mind, the HINTS+ exam shows the most prospect to fill this gap.

As the articles above discussed, inter-examiner reliability, sensitivity, specificity, and positive predictive value for the HINTS exam is very high when the examiner is properly trained, and the training is standardized. This training will allow the nurse to be able to discern which patients are candidates for the HINTS exam by including those who have persistent vertigo and spontaneous nystagmus, especially in the presence of truncal ataxia or any other red flag signs that would lead to a positive National Institutes of Health Stroke Scale including difficulty speaking, imbalance, numbness, vision loss, and focal loss of strength (Engler, Wood, & Cook, 2022). Overall, the above comparisons have provided an effective scope of the literature as applicable to this hypothesis-generating purpose statement.

PRACTICE IMPLICATIONS

Perhaps the most extensive and current of all research performed on dizziness testing in emergency medicine is GRACE-3, a systemic review by Shah et al. (2023). This meta-analysis assessed the certainty of clinical tools using the GRADE system. The most sensitive (99%) exam which had a high specificity (85%) was the HINTS+ exam. This is the conventional HINTS exam with the addition of assessing for hearing loss. Hearing loss can be present in strokes affecting the vestibulocochlear system, which would not be present in peripheral vertigo. This is especially useful in the small number of posterior strokes that do not involve the medial vestibular nucleus (Kattah, 2018). This can be tested as simply as covering one ear and rubbing fingers together in the uncovered side to see if the patient can hear it. This quick addition increases the sensitivity of the HINTS exam by nearly 4% when compared to the traditional exam which had a sensitivity of 95.4%.

FUTURE RESEARCH STRATEGIES

Future research strategies in the field of posterior circulation vascular accidents (CVAs) should focus on optimizing the application and dissemination of the HINTS exam and related diagnostic tests for identifying posterior strokes. The development of standardized training programs and educational resources is imperative to improve the ease of use, especially among novice healthcare providers in the fast-paced environment of emergency medicine. Additionally, there is a need to explore the integration of emerging technologies, such as mobile applications, to aid in the execution of these exams, thus reducing barriers to their effective implementation. There has been no data procured about artificial intelligence integration with the exam and more research must be performed to provide proof of concept. Research efforts should also investigate the further refinement of diagnostic algorithms, such as the STANDING algorithm, to ensure

they align with the practical demands of triage in emergency departments and urgent care settings. Additionally, future studies could delve deeper into the utility of the HINTS+ exam, which includes hearing loss assessment, to enhance sensitivity in detecting posterior CVAs.

SETTING: POPULATION/SAMPLE

This study will prospectively be a multi centered, quasi-experimental trial. The setting wass the Emory vestibular clinic, which will allow for a broader sample population including patients who are experiencing peripheral vertigo as well as those who have experienced a central cause of vertigo. Sample size is prospectively set at 50 to 100 persons.

INCLUSION/EXCLUSION CRITERIA

Inclusion criteria includes voluntary participants that are experiencing either a central cause of vertigo or peripheral vertigo from any etiology. Participants must meet inclusion criteria to have the HINTS exam performed on them including spontaneous nystagmus, acute persistent vertigo, and a normal neurologic exam. Exclusion criteria will be anyone with atlantoaxial instability, neck trauma, or nuchal rigidity. Recruiting methods will include working with healthcare partners in the clinic to find and recruit patients who meet the inclusion criteria.

METHODS

Tools used to collect data will include paper consent forms, the iOS application itself, and an excel spreadsheet that tracks the application's accuracy. The quality of measure will be the researcher's diagnosis using the application versus the true diagnosis. The systematic and rigorous data collection will be procured through ensuring that variables are minimized to ensure as much interrater and inter-examiner reliability as possible. Data will be procured and evaluated retrospectively to assess for the efficacy of the application by evaluating its sensitivity,

specificity, positive predictive value, negative predictive value, and qualitative data from users on the ease of use and helpfulness of the app. Examiners will be trained on the app and how to perform the HINTS+ exam and will be responsible for obtaining and recording data. The examiners will be two emergency nurse practitioner students who were trained in performing the HINTS examination by a neurology physician. The application was used as laid out in Appendix C (see appendix c).

RESOURCES

Clinical resources at the Emory Balance Center clinic include the clinical lead, Dr. Lisa Gillig, DPT, staff clinicians, and available clinic resources. Emory University Libraries will be utilized for external literature resources.

KEY STAKEHOLDERS AND SITE SUPPORT

Key stakeholders include the researchers and primary investigators, the patients and participants, the healthcare providers it could aid, healthcare institutions including Emory Healthcare, educational institutions including Emory University, the technology developers who are developing the application, and the funding agencies including the UHI and United Healthcare. Dissemination to key stakeholders will include email updates and communications in succinct presentation using the situation, background, assessment, and recommendation (SBAR) format.

PROTECTION OF HUMAN RIGHTS

Human rights will be protected through only including case numbers on consent forms with no true identifying information. The patient will wear a face mask during the procedure.

RESULTS

There were ten participants with nine of which having peripheral causes of vertigo and one with a central cause. The examiners properly identified the sole cause of central pathology using the application with no false negatives. The application usage by the examiner participants had a sensitivity of 100%, a specificity of 66.67%, a PPV of 25%, a NPV of 100%, and an accuracy of 70%. Due to the small cohort, 95% CI was considerably variable for all statistics (see appendix a).

DISCUSSION AND CONCLUSIONS

Overall, the study showed promising results in a small cohort of patients. This study has promise to provide proof of concept for further research. Some limitations to the study include a small cohort, the examiners being unblinded, and the difference between study setting and intended setting. The application did allow for a streamlined process of screening in this simulated testing setting, with most full exams being concluded within five minutes from the start. Subjectively, being able to replay the video of the exam in half-speed allowed for a much easier and confident assessment of nystagmus direction, skew deviation, and head impulse test corrective saccade.

False positivity carries less severe consequence except for excess testing and radiation from CT imaging. Many participants did have positive central screening questions based on the application tool. Although positive answers for more severe parts of the questionnaire were almost globally absent (i.e. dysphagia, dysphonia, dyspraxia, etc.), presence of headache and gait abnormalities were common (see appendix b).

Although there were no true acute posterior stroke patients in the group, the promising results should be translated to this cohort as well. Small cohort studies carry more weight as a proof of concept for future research implications and development. Although this study was small, it should open the door for more development and future improvements to be made.

IMPLICATIONS AND RECOMMENDATIONS

Recommendations for further testing in an environment more synergistically aligned with the intended use of the application would be beneficial. This could be performed as a mutli-centered RCT in emergency department settings used by multiple different providers for its true intended purpose, to screen patients who present for new onset dizziness. A larger study in a more diverse population of patients would allow for more vigorous testing of the application and allow for more evaluation of inter-examiner reliability.

Recommendations for future development would include the incorporation of artificial intelligence (AI). This novel idea would take a considerable amount of research and development to incorporate, but could be very beneficial in eliminating human error in the exam. Eye tracking technology would need to be incorporated and the AI would need to learn how to distinguish a worrisome exam from a less worrisome exam. The head impulse test section would prove to benefit from this technology due to the possibility of just assessing the VOR ratio to assess for head-eye desynchrony. This is already incorporated into how video head impulse testing is assessed and creating a technology that could analyze this in real time on a platform that is readily available would possibly prove beneficial for emergency medicine clinicians.

EVALUATION OF PROCESS AND EXPERIENCE

Overall, the experience was a very positive one for the team. The process was a dynamic one and the time frame from research to development to implementation was shorter than would have been preferred due to time constraints. Given the short amount of turnaround time for every part of the process, the team feels as if the entire process was a success. The iOS application is in functional order, with a small cohort study that shows promise of efficacy. This work developed from a novel idea with very small aliquots of preceding data to support it into a working model that has potential to be further developed into a very intuitive tool. Being able to work with specialists in the field was very beneficial to help aide in further research and development. The team would like to say a very special thank you to Dr. Hope Bussenius DNP for aiding in every step of the way, being so supportive in getting grant funding, helping to secure a software developing team, and devoting so much time to the project. We would like to thank Dr. Calli Cook DNP for her support with the project and providing contact information to secure our study setting. We would like to thank the Emory Urban Health Initiative and United Healthcare for supporting us by providing the funds required to develop the application. We would like to thank Brad Waller for developing the iOS application and working with the team to improve it. We would like to thank Neurologist Dr. David Sandlin MD for his assistance and direction in developing the application and devoting time to training the team. We would like to thank Dr. Lisa Gillig DPT and the rest of the Emory Dizziness and Balance Center for being such gracious hosts for the study, their guidance, and work with participant recruitment.

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APPENDICES

Appendix a)

Statistic	Value	95% CI
Sensitivity	100.00%	2.50% to 100.00%
Specificity	66.67%	29.93% to 92.51%
Positive Likelihood Ratio	3.00	1.19 to 7.56
Negative Likelihood Ratio	0.00	
Disease prevalence (*)	10.00%	0.25% to 44.50%
Positive Predictive Value (*)	25.00%	11.69% to 45.64%
Negative Predictive Value (*)	100.00%	54.07% to 100.00%
Accuracy (*)	70.00%	34.75% to 93.33%

Appendix b)

Case #	Age	Gender	Ethnicity	Bidirectional Nystagmus	Test of skew	Head impuse	Gait	Hearing Test	Results	Central Results	True Diagnosis
39	57	F	Black	No	No	Abnormal	3	Normal	PERIPHERAL	Focal weakness or parethesias, gait unsteady, HA or neck pain	Vestibular Migraines
10	36	F	Black	No	No	Normal	3	Normal	CENTRAL	No central	BPPV
37	30	F	White	No	No	Normal	3	Normal	CENTRAL	Gait unsteady, headache/neck pain	Unilateral vestibular hy
23	69	F	Black	Yes	No	Normal	2	Normal	CENTRAL	Gait unsteady	Chiari Malformation
22	55	F	Black	No	No	Abnormal	2	Normal	PERIPHERAL	Gait unsteady, headache/neck pain, focal weakness or paresthesia	BPPV
28	80	F	White	No	No	Normaal	3	Normal	PERIPHERAL	Gait unsteady, headache/neck pain	Concussion, TBI
5	84	M	White	No	No	Abnormal	1	Abnormal	PERIPHERAL	No answers during screening, however exam showed unsteady gait and hearing loss in L ear	Vestibular Neuritis
48	51	M	White	No	No	Normal	2	Abnormal	CENTRAL	Gait unsteady, headache/neck pain	Nerve palsy on L - Perip
64	60	M	White	No	No	Abnormal	3	Normal	PERIPHERAL	N/A	Menieres
55	39	M	White	No	No	Abnormal	3	Normal	PERIPHERAL	Gait unsteady, headache/neck pain	Visual Vertigo

GAIT
3 = NORMAL
2 = MILD IMPAIR
1 = MODERATE IMPAIR
0 = SEVERE IMPAIR

Appendix c)

Order of app:

1. Criteria (if patient meets this criteria then continue)
    a. Are you experiencing spontaneous and continuous dizziness? This means without a trigger. Y/N
    b. If no, then stop (Thank you for your time, the HINTS exam is not recommended)
    c. If Yes, Go to onboarding
2. Onboarding demographic information
    d. Case # / Facility Setting (text)

e. Age (number)
f. Ethnicity (drop down: Black, White, Hispanic/Latino, Asian, American Indian, Pacific Islander)
g. Sex at birth (drop down: Male, Female, Intersex, Decline to State)

3. Constant dizziness **AND** nystagmus at rest? Y/N

If yes, HINTS Exam is recommended - Go to Central Features Questions
If not, HINTS Exam is not recommended - Stop

4. Central Features Questions - Symptoms of possible stroke

Focal weakness or parenthesis? Y/N
Dangerous D's - Diplopia Y/N
Dysarthria Y/N
Dysmetria Y/N
Dysphonia Y/N
Dysphagia Y/N
Vertical Nystagmus at rest? Y/N
Gait unsteady? Y/N
Headache or neck pain? Y/N

If any of the central features answers are yes, then immediate stroke workup is recommended, if no continue to the exam.

5. Exam:

Video #1
Step 1: Nystagmus - Changes direction with gaze? Y/N
If yes, proceed to step 2 to rule out a stroke
If no, rule out vestibular neuritis

Video #2
Step 2: Test of Skew - Vertical skew present? Y/N
If yes, proceed to step 3 to rule out a stroke
If no, rule out vestibular neuritis

Video #3
Step 3: Head and Impulse Test (HIT) - Saccade when the head is turned quickly in the opposite direction of the nystagmus? Normal/Abnormal

*Remember - to rule in vestibular neuritis means to rule out a stroke

Normal - Proceed to step 4 to rule out a stroke
Abnormal - Rule out vestibular neuritis (always seen in VN)

Video #4
Step 4: Unsteady gait - Y/N

If yes, proceed to step 5 to rule out a stroke.

Video #5
Step 5: Hearing Test - Normal/Abnormal

If abnormal, proceed to rule out a stroke.

Last page:
When to consider discharging a patient with dizziness and nystagmus:

- The screen is negative for central features
- No nystagmus changes direction with gaze or vertical skew
- There is a corrective saccade during the head impulse test
- Must see nystagmus that doesn't change direction **AND** an abnormal HIT
- No hearing loss