HINTS Bedside Exam: Efficacy in Improving Detection of Stroke in Patients Presenting to the ED for Dizziness

Nash W. Keene

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HINTS Bedside Exam: Efficacy in Improving Detection of Stroke in Patients Presenting to the ED for Dizziness

Abstract

Background: Worldwide, stroke is the second most common cause of mortality and third most common cause of disability. There are certain areas within the brain, that when affected by ischemia, do not present the way most providers are used to. Strokes in the posterior fossa area can present with a combination of symptoms known as acute vestibular syndrome (AVS). The HINTS exam is a bedside assessment which looks at oculomotor findings to detect stroke located in these areas. The HINTS exam has been shown to have a higher sensitivity and specificity than early imaging. However, this is not an exam that is being widely used throughout emergency departments (ED). Can the HINTS bedside exam improve detection of stroke in those patients presenting with AVS?

Methods: An exhaustive search was conducted using Medline-OVID, CINAHL and Web of Science using the keywords: HINTS and stroke. Relevant articles were assessed for quality using GRADE. A search on the NIH clinical trials site reveals there are no trials currently registered relating to the use of the HINTS exam for diagnosing stroke.

Results: A total of four articles were included in this systematic review. Three of these met the inclusion criteria while the fourth was included due to the relationship to the others. These were all prospective, cross-sectional studies. The first enrolled 101 subjects and showed the HINTS bedside exam had a higher sensitivity and specificity than other general neurologic signs and initial MRI. The second study, with 190 enrolled participants, showed that the HINTS exam was superior to another stroke detection method (ABCD2) and early MRI as well. The third article, 190 enrolled participants, looked at the HINTS and HINTS “plus” exam in identifying small,

Conclusion: The HINTS beside exam has been demonstrated to be an effective method in detecting stroke in those patients presenting with AVS to the emergency department. This is especially true in those with known stroke risk factors. There is a need for further research to demonstrate the same results in a larger sample size and to see whether the results are consistent when emergency department providers administer the tests instead of specialists.

Keywords: HINTS, stroke

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Keywords
HINTS, stroke, dizziness, acute vestibular syndrome
Subject Categories
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HINTS Bedside Exam: Efficacy in Improving Detection of Stroke in Patients Presenting to the ED for Dizziness

Nash Keene

A Clinical Graduate Project Submitted to the Faculty of the
School of Physician Assistant Studies
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Faculty Advisor: Duc Vo, MD
Clinical Graduate Project Coordinator: Annjanette Sommers, PA-C, MS
Biography

Nash Keene is originally from Virginia but grew up mostly in Oregon. He received a Bachelor of Science degree from Corban University in Salem, Oregon, in 2011, with a major in Health Science and minor in Biblical Studies. For the two years following graduation he worked as a Physical Therapy Aide and CNA II before entering Physician Assistant School in 2013. He is interested in pursuing a career in Emergency Medicine.
Abstract

Background: Worldwide, stroke is the second most common cause of mortality and third most common cause of disability. There are certain areas within the brain, that when affected by ischemia, do not present the way most providers are used to. Strokes in the posterior fossa area can present with a combination of symptoms known as acute vestibular syndrome (AVS). The HINTS exam is a bedside assessment which looks at oculomotor findings to detect stroke located in these areas. The HINTS exam has been shown to have a higher sensitivity and specificity than early imaging. However, this is not an exam that is being widely used throughout emergency departments (ED). Can the HINTS bedside exam improve detection of stroke in those patients presenting with AVS?

Methods: An exhaustive search was conducted using Medline-OVID, CINAHL and Web of Science using the keywords: HINTS and stroke. Relevant articles were assessed for quality using GRADE. A search on the NIH clinical trials site reveals there are no trials currently registered relating to the use of the HINTS exam for diagnosing stroke.

Results: A total of four articles were included in this systematic review. Three of these met the inclusion criteria while the fourth was included due to the relationship to the others. These were all prospective, cross-sectional studies. The first enrolled 101 subjects and showed the HINTS bedside exam had a higher sensitivity and specificity than other general neurologic signs and initial MRI. The second study, with 190 enrolled participants, showed that the HINTS exam was superior to another stroke detection method (ABCD2) and early MRI as well. The third article, 190 enrolled participants, looked at the HINTS and HINTS “plus” exam in identifying small, <10mm, strokes compared to early imaging. The study found that the physical exam finding identified these patients with greater accuracy than MRI up to 48 hours after symptoms onset.

Conclusion: The HINTS beside exam has been demonstrated to be an effective method in detecting stroke in those patients presenting with AVS to the emergency department. This is especially true in those with known stroke risk factors. There is a need for further research to demonstrate the same results in a larger sample size and to see whether the results are consistent when emergency department providers administer the tests instead of specialists.

Keywords: HINTS, stroke
Acknowledgements

To my wife: Thank you for supporting me in order for me to succeed these last 2 years. I would not be where I am without your dedication, patience, accountability and love.
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List of Abbreviations

ED       Emergency Department
HINTS    Head Impulse, Nystagmus, Test of Skew
AVS      Acute Vestibular Syndrome
APV      Acute Peripheral Vestibulopathy
DM       Diabetes Mellitus
CI       Confidence Interval
LR       Likelihood Ratio
HTN      Hypertension
CVA      Cerebrovascular Accident
HLD      Hyperlipidemia
URI      Upper Respiratory Infection
DWI      Diffuse-Weighted Imaging
MRI      Magnetic Resonance Imaging
A-Fib    Atrial Fibrillation
MI       Myocardial Infarction
h-HIT    Head Impulse Test
HINTS Bedside Exam: Is it Able to Improve Detection of Those with Stroke Presenting to the ED for Dizziness

BACKGROUND

Worldwide, stroke is the second most common cause of mortality and the third most common cause of disability. Of all strokes, 80% are ischemic in nature, meaning a lack of blood flow and oxygen are delivered to the cerebral tissue. Not all strokes present as the classic triad of slurred speech, unilateral facial droop, and arm weakness that providers are taught. Another presentation is acute vestibular neuritis (AVS), which includes new continuous vertigo, nausea or vomiting, motion intolerance, and gait instability lasting days to weeks. In fact, 20% of ischemic strokes are known to involve the posterior circulation of the brain, and the most common symptom associated with this area is dizziness or vertigo. Studies show that less than half of AVS due to stroke presentations have limb ataxia, dysarthria, or other obvious neurological features. More than 4 million emergency department (ED) visits per year in the United States are due to dizziness, and the most common causes of these symptoms are thought to be vestibular neuritis (70%) and posterior fossa stroke (25%). Differentiating these conditions is an important problem facing ED providers caring for patients acutely. The HINTS, standing for head impulse, nystagmus, and test of skew, is an exam performed at the bedside to help in correctly identifying stroke in AVS. These three beside exams are focusing on oculomotor findings which have been shown to be more sensitive for stroke than early MRI in the first 48 hours whilst maintaining a high specificity. The head impulse exam looks for the presence of clear, reproducible, re-fixation saccade while having the patient...
focus on an object and turning the patient’s head side to side.\textsuperscript{10} If this is present, then it would be an abnormal head impulse test (h-HIT) and likely a peripheral pathology to a patient’s dizziness.\textsuperscript{10} The second exam, which evaluates nystagmus, is looking for nystagmus which changes direction with eccentric gaze.\textsuperscript{11} Nystagmus associated with acute peripheral vestibulopathy (APV), likely a benign condition, should present primarily as horizontal which increases when gazing to the direction of the lesion.\textsuperscript{12} The third and final exam, skew deviation, looks for vertical ocular misalignment that results from a left-right imbalance of vestibular tone.\textsuperscript{13} This is usually detected with an alternating cover-uncover test. The rapid assessment, detection, and appropriate treatment of these patients is needed in order to prevent complications.\textsuperscript{14} It is estimated that cerebellar strokes missed on the initial ED visit may represent up to an 8-fold increase in death.\textsuperscript{7} These misdiagnoses are largely due to the false-negative rate of advanced imaging, 20\% in first 24 hours.\textsuperscript{7} To avoid complications, such as missed opportunities for thrombolysis, delayed surgery for posterior fossa edema and initial minor infarctions progressing to posterior fossa strokes, something must be implemented to heighten our suspicion for this confusing presentation.\textsuperscript{14-16} Is the HINTS beside exam able to improve detection to avoid these potentially life altering or threatening conditions?

**METHODS**

An exhaustive search of available medical literature was conducted using Medline-OVID, CINAHL and Web of Science using the keywords: HINTS and stroke. The bibliographies of the articles were further searched for relevant sources. Articles with primary data evaluating efficacy of the HINTS beside exam detecting stroke were included. The articles also had to assess the use of the HINTS exam in patients presenting
with dizziness to the ED compared to advanced imaging or another stroke detection method. The search was then narrowed to include only English language articles. Relevant articles were assessed for quality using the Grading of Recommendations, Assessment, Development and Evaluation (GRADE). A search on the National Institute of Health (NIH) clinical trials site revealed no currently registered trials, at any phase, relating to the use of the HINTS exam for detecting stroke.

RESULTS

The initial search results returned 53 total articles for analysis. After screening relevant articles for primary data, human studies, and deleting duplicates a total of three articles\textsuperscript{9,14,19} met the specified inclusion criteria. There was one other article\textsuperscript{10} found which evaluated the head impulse test alone that was the original research that sparked the other above studies. This study\textsuperscript{10} will also be reviewed because of its close relationship.


This was a prospective, cross-sectional study\textsuperscript{10} performed in the United States focusing on the use of the head impulse test to differentiate between those with AVS due to cerebellar stroke or vestibular neuritis. It evaluated patients presenting with AVS that were high risk for stroke over a 6 year period. This was conducted at a single urban, academic hospital which serves as a regional referral center for 25 community hospitals. The study enrolled 43 patients, separated into two different groups. The study population was 65\% men (28/43). Mean age was 64 years old with an age range from 26-92. There were 30\% who only had one stroke risk factor, while 70\% had two or more.\textsuperscript{10}
Group 1 participants were recruited based on symptoms. These patients had to have acute vertigo, nausea, retching vomiting, at least one stroke risk factor (ie, hypertension, diabetes, hyperlipidemia, cigarrete smoking, atrial fibrillation, eclampsia, recent cervical trauma, prior myocardial infarction, prior cerebrovascular accident, hypercoagulable state), and nystagmus and gait instability on examination. Exclusion criteria were patients with any of the following: recent upper respiratory infection (URI), prior known diagnosis of Menieré disease, previous attacks of vertigo with a history of fluctuating, or long-standing hearing loss suggesting Menieré. The first examiner, likely an ED provider, made the diagnosis of AVS and then contacted the study neuro-ophthalmologist if the patient had known stroke risk factors. Of the 43 registered, 33 were recruited into this group.10

Group 2 were patients admitted with a radiographic diagnosis of ischemic cerebellar stroke. Neurology house staff then notified the study neuro-ophthalmologist of a potential subject without revealing the clinical details. To be enrolled in Group 2, patients were required to have truncal instability or gait imbalance, but not nystagmus, in the absence of significant limb weakness, limb ataxia, or other obvious brainstem signs (ie, hemisensory loss, hemianopsia, dysarthria, oculomotor signs other than horizontal nystagmus, or other cranial neuropathy). Of the 43 registered, 10 were recruited into this group.10

All patients underwent neurologic and vestibular examination by the neuro-ophthalmologists according to a standard protocol. Both groups also underwent neuroimaging and were admitted for observation to have serial examinations evaluating for evolution of vestibular or neuro-ophthalmic signs. The reference standard for
diagnosis of stroke was evidence of acute stroke by neuroimaging. Magnetic resonance imaging with diffuse-weighted imaging (MRI-DWI) on the day of index was generally the standard. The reference standard for identifying APV was absence of acute stroke in the brainstem or cerebellum by MRI-DWI, lack of neurologic signs on serial examination, and a characteristic clinical course in follow-up.\textsuperscript{10}

The study\textsuperscript{10} showed that a negative head impulse (h-HIT) was the most useful clinical sign for differentiating between central and peripheral causes of AVS (91% stroke vs 0% APV). This demonstrated that a negative h-HIT was a strong predictor of stroke (100%, n=13/13), even in those presenting with nystagmus that was pseudo-labyrinthine, meaning they had horizontal nystagmus consistent with a peripheral cause. However, they found that a positive h-HIT was not sufficient enough to conclude that the AVS was due to a peripheral cause, being that 30% (n=3) of the patients with AVS with a positive h-HIT in fact did have an underlying stroke.\textsuperscript{10}

The authors found two major limitations to their study. One was an internal validity issue due to the partially masked examiner. The study examiner was masked to the imaging results but not to the patient’s clinical history, general neurologic exam, or eye movement findings at the time of the h-HIT. This exam requires a certain degree of skill and interpretation and is potentially subject to the examiners bias. The second limitation, an external validity issue, has to do with the sample group coming from a high risk population, being that each participant had at least one stroke risk factor. They state that care should be taken when drawing conclusions about the population prevalence of stroke patients among those presenting with acute vestibular syndrome.\textsuperscript{10} This study showed 81% (34/42), compared to a prior report\textsuperscript{18} of 25% (6/24).
Kattah et al (2009)

This is a prospective, cross-sectional, study of patients presenting with AVS focusing on those at high risk for stroke. This data is derived from an ongoing study of stroke patients with AVS over the past 9 years. This is a continuation of the Newman-Toker et al (2008) study outlined above, so the methods detailed there are the same in this trial. The original 43 subject’s clinical data are also presented here in a larger series (101 subjects). This study evaluated the use of three bedside oculomotor findings instead of the single head impulse test. So, this study takes into account the sensitivities and specificities of the entire HINTS exam: head impulse, nystagmus and test of skew. They defined HINTS exam as either benign (abnormal h-HIT plus direction fixed horizontal nystagmus plus absent skew) or dangerous (normal/untestable h-HIT plus direction-changing horizontal nystagmus present/untestable plus skew deviation present/untestable).  

Of the 101 high-risk patients with AVS, 76 of them were found to have a central lesion, 69 with an ischemic stroke, 4 hemorrhages, 2 with demyelinating diseases, and 1 with an anticonvulsant toxicity. (See Table 2.) The HINTS bedside exam demonstrated a sensitivity of 100% and a specificity of 96% compared to MRI-DWI at 72% and 100%. This also demonstrates a positive likelihood ratio of 25 (95% confidence interval (CI), 3.66-170.59) and a negative likelihood ratio of 0.00 (95% CI, 0.00-0.11). MRI-DWI was falsely negative in 8 patients with ischemic stroke. These negative scans were obtained with in the first 48 hours of symptom onset, including four that were negative greater than 24 hours. The patients who initially had negative MRI-DWI had follow-up imaging an average of 3 days later, which revealed the strokes. The findings
also showed that the HINTS exam was more sensitive than general neurologic signs (100% versus 51%), obvious ocular motor signs (100% versus 32%) or both together (100% versus 67%).

The authors state that the study proves that finding one of three dangerous, subtle oculomotor signs is more sensitive than any of the other classic neurological signs for identifying stroke in AVS. They also state that they have shown a benign HINTS exam “rules out” stroke better than a negative MRI-DWI in the first 24–48 hours from symptom onset.

Many of the possible limitations concerned with this study were the same as Newman-Toker et al (2008), such as: a partially unmasked examiner, high-risk population, and dependence upon a specialists for interpretation. Another limitation mentioned was the selective retesting of patients with imaging based on evolving neurological signs. They state this could have misclassified some strokes as APV, increasing the sensitivity of the HINTS bedside exam. However though, all the patients with APV were followed to ensure no new neurologic signs or deficits arose.


Again, the detailed methods are explained above in Newman-Toker et al (2008), while the difference with the methods are stated below. For Newman-Toker et al (2013), the objective was to compare ABCD2 method to HINTS with MRI-DWI used as the definitive test. There were 108 of the 190 patients who presented that had their radiographic and oculomotor findings published in the previous article. They recruited patients with at least 1 hour of AVS symptoms but no longer than 1 week of AVS
symptoms and whose symptoms did not abate within the first 24 hours. They did include patients with a shorter duration of symptoms to increase the utility. This was also implemented because most patients present to the ED within 24 hours of symptom onset and those with symptoms greater than one hour will likely be symptomatic for at least 24 hours. Patients were excluded for recurrent attacks of vertigo, history of treated benign paroxysmal positional vertigo, vestibular migraine, or idiopathic recurrent vertigo. Exclusion also occurred if the patient was too lethargic to complete testing. The ABCD2 method is a point system based on their age, clinical features, duration of symptoms and whether diabetes is present or not. They used a score of greater than or equal to 4 as their threshold for pursuing a stroke diagnosis. They also evaluated the use of the HINTS “plus” exam which takes into account the presences of hearing loss.

The complete list of findings can be found in Table 4. The author’s state that the physical exam HINTS approach outperforms the risk-factor ABCD2 method substantially for detecting stroke in those with AVS. It also demonstrates a higher sensitivity than initial MRI-DWI (false negative was 14.3%). It was determined that an older patient with an estimated 50% pretest probability of stroke, who had a negative MRI-DWI within the first 24 hours would result in a post-test of 17%, while a benign HINTS exam would decrease the post-test probability to 3%. With the HINTS “plus” exam, seen in Table 4, the sensitivity is even higher than the HINTS exam alone. The author further states that the use of the ABCD2 greater than or equal to 4 for pursuing stroke as a diagnostic tool would result in 40 000-80 000 missed strokes and 110 000-220 000 nondiagnostic MRIs, at a cost of $135 to $270 million annually.
Limitations of the findings were described previously in the Kattah et al (2009). They included: a partially unmasked examiner, high-risk population, dependence upon a specialists for interpretation, and selective follow-up imaging.

Tehrani et al (2014) was a retrospective analysis devised to describe characteristics of small strokes causing AVS. The study methods were detailed in the above articles. They included patients with MRI-DWI strokes ≤10mm. The presence of anatomical loci were confirmed by four experts, two in posterior fossa neuroimaging and two in otoneurology.

Of the 190 patients presenting with AVS, 105 were caused by stroke and 15 of those were ≤10mm. They found that the most affected structure was the inferior cerebellar peduncle (73%), while the most affected location was the lateral medulla (60%). They found that 2/3 of these patients presented with isolated AVS, and only 27% had neurologic signs other than ocular findings at initial presentation. The HINTS “plus” exam had a 100% sensitivity compared to 47% with MRI-DWI when trying to detect small strokes. The 2 patients who had an abnormal h-HIT which would have suggested a peripheral cause of their AVS, but the presence of other dangerous HINTS (nystagmus and skew) findings correctly located the lesion.

The authors conclude that physical exam findings were far superior to early imaging to detect small strokes. In their practice, they do not rely on a negative MRI <72 hours after symptom onset if oculomotor findings suggest a central pathology, such as stroke. They suggest that to reduce duplicate imaging, it may be beneficial to hold initial imaging if appropriate until 48-72 hours after onset.
There were several limitations expressed by the authors. Small sample size was addressed and the possible missed small strokes even after second imaging was complete. If a stroke was misdiagnosed as a peripheral cause, this could overestimate the HINTS sensitivity.19

DISCUSSION

Strokes are a huge cause of mortality and disability in the United States.1 Up to 20% of ischemic strokes involve the posterior circulation of the brain, with the most common symptoms being vertigo and dizziness.4 The HINTS bedside exam is an effective,9,14,19 noninvasive, less costly approach to help identify these patients and preventing possible complications from delayed diagnosis.14-15 The three studies above9,14,19 evaluating the use of the entire HINTS bedside exam showed a superior sensitivity and specificity to early imaging than with MRI-DWI and to other stroke screening methods.14

These studies9,14,19 demonstrated several important factors about the HINTS bedside exam. The size of infarct did not make a difference, given that Tehrani et al (2014)19 looked at small strokes, ≤10mm, and Newman-Toker et al (2013)14 and Kattah et al (2009)9 assessed all strokes in the study population regardless the size. Emergency department providers have become increasingly dependent on MRI-DWI for acute stroke diagnosis.9 MRI-DWI was shown to have a false negative rate of 12% or higher depending on the location in the first 48 hours9 and in current clinical practice it is possible that up to 35% of strokes may be missed in emergency department patients presenting with a chief complaint of vertigo or dizziness.14 Care should be taken by providers not to “rule out” stroke with a single negative MRI within the first 48 hours of
symptom onset. Isolated AVS with a suspicious HINTS exam are being treated in some clinical practices with the same urgency as other non-disabling strokes.

In building upon the limitations described by the authors, there is two other major concerns which should be addressed in future research. The above studies, Kattah et al (2009), Newman-Toker et al (2013) and Tehrani et al (2014) were all building off of the original work in Newman-Toker et al (2008). All four of the studies data were from the same cross-sectional study that spanned from 1999 to 2011. Many of the articles were written by the same authors. This makes the need for a separate, larger study, even more crucial to analyze the effectiveness of the HINTS bedside exam. The usefulness can be seen from the above studies, but it will become that much more convincing and apparent after more research is complete. Neuro-ophthalmologists are not readily available, so in order for this to be a practical exam used in the ED, those working in the ED need to be able to utilize it with the same sensitivity and specificity seen in these studies. This will require training to make sure providers are able to recognize the sometimes subtle ocular movements which can occur, but this is an invaluable set of physical exam findings that should be common knowledge, especially to those on the front line of stroke detection. This will take extra time and possibly expenses by emergency departments for the initial training of providers, but would likely play a vital part of acute care and stroke diagnosis.

**CONCLUSION**

The HINTS bedside exam has been demonstrated to be an effective method of detecting stroke on those patients presenting with AVS to the emergency department. More specifically, the evidence supports its use with those patients who have known
stroke risk factors. Although there is need for additional studies to determine the accuracy of the exam when used by ED providers, this could be a very simple, quick, and precise test to improve assessment for stroke in clinical practice. This five minute exam, if used regularly, could lead to less complications, better outcomes, and improved healthcare in emergency departments for our patients. The 35% of potentially missed strokes in the ED presenting as dizziness or vertigo is unacceptable, and the HINTS bedside exam shows the ability to significantly decrease that statistic.
References


17. GRADE Website. GRADE Working Group. Available at: 


### TABLE 1. Characteristics of Reviewed Studies, GRADE profile

<table>
<thead>
<tr>
<th>Quality Assessment</th>
<th>Downgrade Criteria</th>
<th>Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outcome</strong></td>
<td><strong>Design</strong></td>
<td><strong>Limitations</strong></td>
</tr>
<tr>
<td>Kattah J, et al 2009</td>
<td>CVA</td>
<td>Minor limitations(^a)</td>
</tr>
<tr>
<td>Newman-Toker D, et al 2013</td>
<td>CVA</td>
<td>Minor limitations(^a)</td>
</tr>
</tbody>
</table>
a. Examiners were only blinded to imaging results, not to other clinical data
b. Downgraded due to uncertain generalizability beyond subspecialists
c. Bias is likely due to the articles’ relationship between the above articles and authors

Table 2. Key Clinical Features in Patients with AVS

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Table 3. Comparison of General Stroke Signs, Imaging and the HINTS Exam

HINTS to diagnose stroke in the acute vestibular syndrome: three-step bedside oculomotor examination more sensitive than early MRI diffusion-weighted imaging.
Kattah JC; Talkad AV; Wang DZ; Hsieh YH; Newman-Toker DE
DOI: 10.1161/STROKEAHA.109.551234

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<table>
<thead>
<tr>
<th>Table 4. Bedside Signs and Initial MRI With DWI Test Properties for Ischemic Stroke in AVS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity (n=69)</td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>General neurological signs*</td>
</tr>
<tr>
<td>Obvious oculomotor signs</td>
</tr>
<tr>
<td>Severe truncal ataxia</td>
</tr>
<tr>
<td>Any obvious signs</td>
</tr>
<tr>
<td>Initial MRI with DWI</td>
</tr>
<tr>
<td>Dangerous bedside HINTS</td>
</tr>
</tbody>
</table>

*Excluding severe truncal ataxia (this Table only).
†Of 25 ischemic strokes without obvious signs, 12 were pure cerebellar, 7 were lateral medullary, 5 were lateral pontine or middle peduncle, and one was a medial brainstem infarct.
‡False-negative initial MRI with DWI occurred in 5 patients with lateral medullary infarctions, one with lateral pontomedullary infarction, and 2 with middle cerebellar peduncle infarction.
NLR indicates negative likelihood ratio.
### Table 4. SUMMARY OF FINDINGS- Newman-Toker et al (2013)\(^{14}\)

<table>
<thead>
<tr>
<th>Test Properties</th>
<th>ABCD2 ≥ 4 (Five-item Rule(^a))</th>
<th>HIT (One-step Rule(^a))</th>
<th>HINTS (Three-step Rule(^a))</th>
<th>HINTS “Plus” (Four-step Rule(^a))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stroke only ((n = 113) stroke, (n = 77) nonstroke)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensitivity for stroke</td>
<td>61.1 (51.8–69.7)</td>
<td>90.3 (83.7–94.8)</td>
<td>96.5 (91.7–98.9)</td>
<td>99.1 (95.7–100.0)</td>
</tr>
<tr>
<td>Specificity for stroke</td>
<td>62.3 (51.2–72.6)</td>
<td>87.0 (78.1–93.2)</td>
<td>84.4 (75.0–91.3)</td>
<td>83.1 (73.5–90.3)</td>
</tr>
<tr>
<td>LR+ stroke</td>
<td>1.62 (1.17–2.24)</td>
<td>6.95 (3.89–12.43)</td>
<td>6.19 (3.68–10.42)</td>
<td>5.87 (3.58–9.64)</td>
</tr>
<tr>
<td>LR– stroke</td>
<td>0.62 (0.47–0.83)</td>
<td>0.11 (0.06–0.20)</td>
<td>0.04 (0.02–0.11)</td>
<td>0.01 (0.00–0.08)</td>
</tr>
<tr>
<td>Reduction missed stroke(^b)</td>
<td>Reference case</td>
<td>75.0</td>
<td>90.9</td>
<td>97.7</td>
</tr>
<tr>
<td>Any central cause ((n = 124) central, (n = 66) peripheral)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensitivity for central</td>
<td>58.1 (49.2–66.5)</td>
<td>91.1 (85.1–95.3)</td>
<td>96.8 (92.4–99.0)</td>
<td>99.2 (96.1–100.0)</td>
</tr>
<tr>
<td>Specificity for central</td>
<td>60.6 (48.5–71.8)</td>
<td>100.0 (95.6–100.0)</td>
<td>98.5 (92.8–99.9)</td>
<td>97.0 (90.4–99.5)</td>
</tr>
<tr>
<td>LR+ any central cause</td>
<td>1.47 (1.05–2.06)</td>
<td>&gt;91.1(^c) (NC)</td>
<td>63.9 (9.13–446.85)</td>
<td>32.7 (8.36–128.16)</td>
</tr>
<tr>
<td>LR– any central cause</td>
<td>0.69 (0.52–0.92)</td>
<td>0.09 (0.05–0.16)</td>
<td>0.03 (0.01–0.09)</td>
<td>0.01 (0.00–0.06)</td>
</tr>
<tr>
<td>Reduction missed central(^b)</td>
<td>Reference Case</td>
<td>78.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data are reported as percentages, except LRs, with (95% CI).

ABCD2 = age, blood pressure, clinical features, duration of symptoms, diabetes; AVS = acute vestibular syndrome; LR+ = positive likelihood ratio; LR− = negative likelihood ratio; HINTS = head impulse, nystagmus type, test of skew; HINTS “plus” = HINTS plus new hearing loss detected by finger rubbing; HIT = head impulse test.

\(^a\) The ABCD2 rule requires five historical elements. The standard HINTS approach has three physical examination elements, the most predictive of which is the HIT. HINTS “plus” adds the presence of new hearing loss by bedside finger rub as a predictor of a stroke syndrome.

\(^b\) These values represent the reduction in missed stroke or central causes relative to ABCD2 that would be projected if HIT, HINTS, or HINTS “plus” were used to determine the diagnosis instead of ABCD2.

\(^c\) The LR+ for HIT alone was calculated using a specificity of 99.0% and listed as “>” since the LR+ associated with 100% specificity (measured in this sample) is infinite.