Chapter 10
Cost-Effective Evaluation of the Dizzy Patient

Neal M. Jackson and Seilesh Babu

Introduction

As the authors have explained in great detail in the preceding chapters, the evaluation of the vestibular patient can be challenging, multifaceted, and complex. Evaluation can include dedicated history, extensive physical exam, electrophysiologic testing of the vestibular system, and specific imaging protocols to evaluate anatomy of the vestibular and central nervous system.

Because of the multitude of subspecialty physicians and evaluation techniques available, there is a risk of high utilization and high costs. The purpose of the chapter is to review current literature and expert opinions from a variety of fields of medicine to study cost-effectiveness in evaluation of the vestibular patient.

The Challenge of the Dizzy Patient

It is well known that the dizzy patient interview can be very challenging for even the most experienced clinicians. This is multifactorial as balance includes multiple organ systems, and patients may describe the same sensation in various ways. A dizzy patient may have a great difficulty in describing the precise feeling or details of his or her dizzy symptoms [1]. For example, in one study, when dizzy patients were asked a series of questions to classify their type of dizziness and then reasked the same questions 10 min later, over half of the patients changed their dizziness

N. M. Jackson · S. Babu (✉)
Department of Neurotology, Providence Hospital, Michigan Ear Institute, Farmington Hills, MI, USA

S. Babu et al. (eds.), *Diagnosis and Treatment of Vestibular Disorders*,
https://doi.org/10.1007/978-3-319-97858-1_10

type. Patients may often endorse multiple dizziness categories (light-headed, room spinning, head swimming, etc.) [2]. Even patients with confirmed BPPV with observed nystagmus and assumed room-spinning vertigo sensation may often endorse light-headedness (and not vertigo), and over one-third of patients with cardiovascular causes may endorse vertigo (and not light-headedness) [3].

Because of patients' difficulty in describing symptoms, primary care and acute care providers may seek consultative referral to a neurologist, cardiologist, or otolaryngologist/neurotologist. Sometimes, patients end up seeing multiple specialists for the same dizziness symptoms. When the diagnosis is unclear or potentially multifactorial, patients might be referred to a panel of specialists to "rule out" each involved organ. A recent evaluation of patient experience showed that many patients are sent to multiple specialists, experience a delay in diagnosis, incur greater costs, and are sometimes not confident in the ultimate diagnosis [4].

Rates of true vestibular pathology in patients with dizziness can vary. One particular study utilizing multimodality assessments (Dizziness Handicap Index (DHI), rotational chair, and head thrust dynamic visual acuity) examined elderly dizzy patients and concluded that only 38% of patients truly have peripheral vestibulopathy and 1% had central vestibulopathy. Of those with peripheral vestibulopathy, BPPV was the etiology in 63% [5].

Some patients experience their dizziness acutely and therefore present to acute care providers in the emergency department. In fact, there are increasing annual costs of dizziness evaluation in the emergency departments in the USA; this is due to both an increased number of visits and increased rates of testing (e.g., imaging) [6]. Therefore, a section of this chapter will address evaluation of the acute vestibular syndrome in the emergency department and the role of neuroimaging.

Cost-Effectiveness

Cost-effectiveness in healthcare pertains to the relation of monetary expenditure to perceived health gain. This can be done utilizing various methods of analysis to answer specific questions. For example, when a new but more expensive technology occurs, a cost-effective analysis can be done to assess the measured expenditure of a new test or treatment in light of the standard practice. If the new test is more expensive and less effective, there is little reason to favor it. If the new test is less expensive and more effective, then likely it will gain favor. When the new intervention is more expensive and seems more effective, a cost-effective analysis may be done to determine if the new intervention is "worth" the added cost—and this perceived value is based on funds available, cultural attitudes, etc.

Multiple formulas and philosophical approaches exist to evaluate cost-effectiveness. A cost-effective ratio is typically a ratio between monetary cost (typically measured in US dollars) and some measure of health gain. Monetary

costs may vary significantly based on contracts, insurance status, etc. Additionally, health gains can be very difficult to quantify.

Whereas objective outcome measures like HbA1C levels in diabetic patients may be more straightforward to calculate, health gains with respect to dizziness are not as objective. Given the variety of dizziness etiologies, there is no true gold standard of diagnosis or treatment outcome. Quality of life, patient satisfaction, and quality-adjusted life years (QALYs) are just a few of the measurements used to quantify effectiveness.

While cost-effectiveness is important to avoid wasteful utilization of limited resources, there are caveats to consider. First and foremost, there can be biases in cost-effective evaluations, as in other scientific literature. Selection bias in choosing which health gains outcomes to include may unfairly set the standard too high or too low. Second, a cost-effectiveness study referencing actual monetary costs is usually not true costs but instead assumed averages or ranges based on costs as a specific institution at a specific time for one specific test; the specific costs often vary based on complex and evolving contracts, insurance deductibles, and market forces which can modulate prices. Also, one must consider the value of the intervention to the individual patient as well as the value of the intervention to the population as a whole. Therefore, cost-effectiveness should be critically considered in clinical care, and any guidelines on cost-effectiveness should be interpreted carefully [7].

With regard to specific cost-effective evaluation of dizziness, there is limited literature to guide the interested clinician. Most studies are from single institutions and examine only the cost-effectiveness of one intervention in one specific clinical scenario. However, expert opinions from emergency medicine, neurology, and otolaryngology about clinical appropriateness may be combined with a fundamental understanding of relative costs to gauge some degree of cost-effectiveness. For example, a Dix-Hallpike test has minimal costs, whereas an MRI costs thousands of dollars.

Evaluation of Dizziness in the Acute Care Setting

As mentioned previously, the presentation of dizziness in emergency departments is becoming more common and more costly in the USA. About 1–3% of all ED visits pertain to dizziness [6]. Most causes are not otologic but instead cardiovascular or due to other medical pathologies. Nevertheless, in the acute care setting, dizzy patients have been found to have longer stays and more resource utilization including imaging, and yet many patients did not receive an actual diagnosis (e.g., vestibular neuritis, BPPV) beyond their stated symptom (i.e., dizziness) [8].

In the acute care setting, it is important to determine if the dizzy patient is experiencing acute vestibular syndrome (AVS) or another form of dizziness. AVS can be defined as acute, sudden-onset, non-remitting, and persistent dizziness that resolves over days to weeks. The use of the words like “vertigo” or “light-headedness” is irrelevant to diagnose AVS.

For the patient with AVS, the most critical outcome of an emergency department visit is to either diagnose or confidently rule out posterior circulation stroke.

Initial evaluation begins with chief complaint and history. As discussed earlier, dizzy patients have difficulty in precisely describing their symptoms, so a clear history is not considered essential. In the elderly dizzy population in the ED, the use of the term "vertigo" as opposed to "dizziness" or "light-headedness" does not correlate with a stroke diagnosis [2]. And patients in the acute setting may have even greater difficulty in describing the exact feelings of their dizziness as they may be experiencing extreme anxiety, nausea, or vomiting.

For the acute care provider, it is necessary to consider the differential diagnosis which includes benign conditions (such as BPPV, vestibular neuritis, labyrinthitis, multiple sclerosis, vestibular migraine, temporal bone fracture with otic capsule injury, Meniere's attack) and more emergent conditions (posterior circulation stroke). It is frequently necessary to evaluate for cardiac and neurologic causes of imbalance.

On physical examination, vital signs are essential to rule out orthostatic hypotension or signs of any cardiovascular disease. Next, a neurologic exam including cranial nerve exam and cerebellar and gait testing is critical to rule out focal deficits. Otoscopy can be done to investigate for less likely causes of dizziness such as suppurative otomastoiditis, erosive cholesteatoma, or recent otic capsule trauma. Neuro-otologic assessment includes examining for spontaneous nystagmus, gaze-evoked nystagmus, or ocular misalignment.

In patients without focal neurologic deficit, positional maneuvers such as the Dix-Hallpike test should be performed. For patients with sudden onset dizziness, one of the most common etiologies is benign positional vertigo (BPV). Interestingly, the Dix-Hallpike maneuver requires no addition costs but is surprisingly rarely performed in dizzy patients. According to one study looking at patients presenting to the ED with dizziness, in those diagnosed with BPPV, the Dix-Hallpike exam maneuver was only documented in 21.8% of cases, and the canalith repositioning maneuver (CRP) was only done in 3.9% of patients diagnosed with BPPV [9]. This may be related to the fact that there is limited confidence among ED providers in performing the Dix-Hallpike maneuver, the Epley canalith repositioning maneuver, and HINTS (Head Impulse, Nystagmus, Tests of Skew) compared to cranial nerve testing or ABCD2 [10]. A retrospective study of patients who ultimately underwent the Epley CRP found that delayed diagnosis caused the average patient to spend over $2000 in medications, multiple doctor visits, and other ineffective interventions [11].

Special attention has been paid in the EM literature with regard to the importance of the physical exam in the evaluation of patients with acute vestibular syndrome. An excellent primer by Edlow and Newman-Toker is recommended to understand nuances of evaluation of the vestibular system during AVS as compared to during the non-acute setting [12].

The ABCD2 (age, blood pressure, clinical features, duration of symptoms, diabetes) is a clinical prediction tool used to estimate the chance of a stroke after CVA and is based on factors including age greater than 60 years, elevated blood pressure,

clinical features like unilateral weakness or speech disturbance, duration of symptoms, and diabetes. However, its accuracy has been questioned, and a recent study suggests that HINTS (Head Impulse, Nystagmus, and Tests of Skew) may be more diagnostic [13].

HINTS is a combination of different oculomotor exam maneuvers that includes the head impulse test (HIT); observation of nystagmus in primary, left, and right gaze; and assessment for skew deviation. The HIT relies on the vestibulo-ocular reflex (VOR) in which head movements are sensed by the inner ears and used to guide the oculomotor reactions to keep the eyes fixated on a target. The VOR requires that the examiner watch the patients' eyes as the upright head is quickly rotated horizontally, and the patient is instructed to maintain gaze on the examiner's nose. In a "normal" patient without any vestibulopathy, with sudden horizontal rotation of the head, the eyes should continue to fixate on the examiner's nose. However, if the head is turned and the VOR fails, then there a corrective saccade is observed—this would indicate a peripheral vestibulopathy. It is important to understand that for patients with AVS, a "normal" HIT with intact VOR suggests the vestibular system is intact and therefore, this clinical combination of AVS with intact VOR is actually concerning for central stroke. It is important to note that the HIT with an intact VOR will only be "positive" with saccades in patients with acute vestibulopathy due to peripheral causes and will be "negative" in patients with central dizziness.

Nystagmus testing involves close observation of eye motion in all nine visual fields. Most patients with acute vestibular syndrome with nystagmus will show horizontal nystagmus with a fast phase in one direction. Nystagmus due to peripheral vestibulopathy will beat more quickly when looking in the direction of fast phase and beat more slowly when looking in the opposite direction. If the direction of the fast phase changes with eccentric gaze, this is strongly suggestive of a central lesion such as stroke.

Skew deviation refers to a disconjugate vertical gaze and is suggestive of central lesion. It results from disruption of the vestibular input, especially the otolithic inputs, to the oculomotor nuclei through the brain stem.

A recent systemic review examined the importance of distinguishing benign peripheral process (vestibular neuritis or labyrinthitis) from a more treacherous posterior circulation ischemia. Vertebrobasilar ischemic stroke does not always have obvious focal neurologic deficits. CT has poor sensitivity, and MRI with diffusion-weighted imaging (DWI) will not reliably show stroke in posterior fossa in the first 24–48 h, having sensitivity around 80% [14]. In a review of vascular risk factors for patients with suspected posterior circulation ischemia who underwent computer tomography angiography (CTA) and neurology consultation, the risk factors for posterior circulation ischemia in dizzy patients were increasing age, increasing blood pressure, and focal neurologic deficits. CTA did not yield significant diagnostic information [15].

In a population-based analysis, TIA/CVA was considered rare (3%) among patients complaining of dizzy symptoms. The use of the word vertigo or other descriptors did not correlate with presence of a TIA/CVA [16].

As opposed to classifying dizziness predominantly on the patient's descriptors, another line of thought has been to distinguish four separate vestibular syndromes based on timing and causative factors: acute vestibular syndrome, chronic vestibular syndrome, episodic vestibular syndrome, and triggered vestibular syndrome. In this paradigm, acute vestibular syndrome is sudden onset with persistent symptoms lasting days to weeks (vestibular neuritis/labyrinthitis vs. posterior circulation CVA). Chronic vestibular syndrome includes prolonged dizziness lasting weeks to months; consider medication side effects or slowly growing posterior fossa lesions. Episodic vestibular syndrome is mainly intermittent, may arise spontaneously, and can last minutes to days. This could be Meniere's disease, migraine-associated vertigo, or posterior circulation TIA. Finally, triggered vestibular syndrome lasts less than 1 min and is elicited by change in body/head position, suggestive of BPPV or orthostatic hypotension.

Analysis of imaging for dizziness in the acute care setting suggests that CT head scans have a very low yield. A recent study at a metropolitan teaching hospital showed <1% sensitivity with CT head scan for dizziness. The use of CT scan can also lead to prolonged ED stay times due to time spent waiting for the scanner, radiologic interpretation, etc. and also lead to increased costs. There is low dose but certain radiation exposure. For these reasons, patients presenting with dizziness or syncope may not benefit from CT unless they have recent head trauma, focal neurologic deficit, or advanced age [17]. In a 2015 study, Canadian physicians who ordered CT scans for stroke evaluation may have been falsely reassured by negative head CT, as patients who were discharged after a false-negative CT scan were actually twice as likely to have a stroke compared to patients not scanned [18].

MRI scans may have a role in acute vestibular syndrome patients. A large study reviewing the characteristics of central lesions detected by diffusion-weighted MRI in the ER showed a 3.6% prevalence of central lesions. Risk factors were age >50 years, hypertension, non-whirling dizziness, and any focal findings.

A large study by Ahsan et al. showed that CT brain/head only had a yield of 0.74% (6/1028). Of the patients who had positive CT findings, associated symptoms included vomiting, facial droop, altered vision, ataxia, and blurred vision; none had isolated dizziness. MRI had clinically significant pathology on 11/90 scans (12%) [19].

With regard to the role of neurology consult and neuroimaging in the emergency department, there are various practice patterns that currently exist. Headache and focal neurologic deficit were associated with neurology consult and imaging, whereas greater age (>60 years) and prior stroke predicted use of only neuroimaging. Interestingly, positional symptoms prompted neurology consultation and not imaging. Twenty-one percent of neurology consultations were retrospectively associated with a serious neurologic diagnosis (stroke, tumor, MS, etc.). Seven percent of neuroimaging had significant findings pertaining to dizziness [20]. Therefore, it would seem that neurology consults are more diagnostic and less costly than MRI. However, timeliness and availability of dedicated neurologists may be limited.

A study examining the costs attributable to dizziness evaluations in the USA in 2011 showed that while otogenic and vestibular diseases were the most common

causes of dizziness, cardiac causes of dizziness were much more costly overall to evaluate.

Overall, the cost-effective evaluation of the dizzy patient in the acute care setting should include history and physical examination with close attention paid to vital signs, neurologic exam, dedicated oculomotor exam, and neurotologic maneuvers (HIT, Dix-Hallpike maneuver). If focal neurologic deficits or truly positive Dix-Hallpike provocation are observed, then the diagnosis may be streamlined. HINTS requires essentially no additional cost and may be more accurate than DWI MRI for stroke diagnosis. If imaging is pursued, head CT has very low yield. MRI scan may be helpful in elucidating other central pathologies (CVA, MS, mass lesion, etc.) but may miss acute ischemic stroke in the first 24–28 h.

Cost-Effective Evaluation in the Otolaryngology/ Neurotology Clinic

In the otolaryngology/neurotology clinic, patients typically do not present with acute vestibular syndrome. The differential diagnosis most commonly includes peripheral causes (BPPV, Meniere's disease, vestibular neuritis/labyrinthitis, etc.) and central causes (migraine dizziness, multiple sclerosis, etc.). Mass of the IAC/CPA should also be considered.

Muelleman et al. recently reviewed the epidemiology of dizzy patients who visited a neurotology clinic at an academic institution [21]. Only 57% of the patients ultimately were diagnosed with a peripheral vestibular etiology. Overall, the most common causes were Meniere's disease (23%), vestibular migraine (19.3%), BPPV (19.1%), and non-migraine central causes (16.4%). Some patients had multiple diagnoses (migraine plus BPPV or migraine plus Meniere's disease).

At some institutions, the patient's self-reported symptoms are obtained prior to the clinic visit. In one interesting study, a simple question assessment asking about association of hearing loss, duration of vertigo, and if vertigo is "true vertigo" or an alternative feeling of disequilibrium suggested a correct basic categorization of BPPV, Meniere's disease, VN, and labyrinthitis in 60% of patients [22]. Another study requiring patients to complete a 37-question survey dedicated to the patient experience of dizziness was able to accurately predict the cause of dizziness in about 78.5% of the time [23]. While history is not completely diagnostic, it may be a very inexpensive way to categorize the dizziness and potentially initiate treatment.

The physical examination of the dizzy patient should include vital signs, otoscopy, cranial nerve exam, and standard neurotologic maneuvers such as Dix-Hallpike maneuver, head impulse test (HIT), Fukuda step test, Romberg balance test, and others. Frenzel goggles can aid in suppressing visual fixation and visually magnifying nystagmus for the observer.

As BPPV is one of the most common peripheral vestibulopathies and its examination maneuver is seemingly straightforward, special attention has been paid to its diagnosis. In fact, the American Academy of Otolaryngology-Head and Neck Surgery recently updated its guidelines on BPPV, which is diagnosed with the Dix-Hallpike test. The cost-effective management of BPPV with CRP has also been studied. A retrospective study of patients who ultimately underwent the Epley CRP found that delayed diagnosis caused the average patient to spend over $2000 in medications, multiple doctor visits, and other ineffective interventions [11].

Some patients whose symptoms or exam findings are not sufficiently diagnostic may undergo additional evaluation of the vestibular system. A typical vestibular battery includes close monitoring of the eyes for nystagmus using either videonystagmography (VNG) or electronystagmography (ENG). The eyes are observed at rest, tracking visual objects, when the head is in certain positions, and with caloric stimulation of the horizontal semicircular canal. Testing requires VNG goggles, a computer with software, and time with a trained audiologist. It is the most widely utilized vestibular test. It can be very effective in confirming the laterality of a vestibulopathy in cases of unilateral Meniere's disease.

Critics of the VNG may state that the only part of the inner ear that it tests is the horizontal semicircular canal at a low-frequency stimulation through caloric stimulation and does not provide information about the rest of the vestibular function of the one inner ear. A 2011 paper shows that vestibular testing does have costs and may not necessary alter management significantly [24].

There can be significant variation in the use of vestibular diagnostic testing for patients presenting to otolaryngology clinics [25].

Rotational chair can be helpful in evaluating both inner ears at various frequencies, including higher frequencies compared to low-frequency caloric stimulation with VNG. However, rotational chair can be very expensive to purchase and requires space in the office.

Other electrophysiologic testing of the inner ear discussed in greater detail in other chapters (e.g., ABR, ECOG) is generally considered not as sensitive or specific as MRI for retrocochlear pathology.

VEMP testing is not routinely employed for vestibular patients. One of its greatest utilities is in the diagnosis of superior semicircular canal dehiscence (SSCD), although thin slice CT imaging with images in the plane of the canal is considered the best single test.

Imaging for Dizziness

If vestibular testing is not helpful in evaluation, imaging can play a role in evaluation of dizzy patients. Due to relatively higher costs compared to physical exam or vestibular testing, imaging is often used to confirm a suspected diagnosis (e.g., confirmation of SSCD in patients with suspected third window disorder) or to rule out

other lesions (e.g., posterior fossa mass lesion in patient with asymmetric hearing loss and vestibulopathy).

CT imaging of the temporal bone can be helpful in diagnosis of a fistula of the inner ear such as horizontal semicircular canal erosion due to cholesteatoma, superior semicircular canal dehiscence, or temporal bone fracture. Otherwise, CT of the head or temporal bones is not very diagnostic in the evaluation of much more common causes of vestibulopathy (BPPV, Meniere's disease, migraine dizziness, or central causes). There is cost, radiation exposure, and limited yield; therefore, it is not very cost-effective.

MRI is a more sensitive test for dizziness. It is considered the gold standard for evaluation of retrocochlear pathology such as acoustic neuromas, which are known to cause hearing loss as well as dizziness. With regard to acoustic neuromas, there is a precedent for MRI to be more sensitive and specific over ABR. An analysis of cost-effectiveness of MRI scan in patients with abnormal VNG/ENG was published in 2015 by Gandolfi et al. [26]. The study examined patients with unilateral weakness >20%, abnormal oculomotor testing, or nystagmus on positional testing who underwent MRI to rule out retrocochlear pathology; the positive detection rate was 5.5% for electrophysiologic testing (ABR) for patients with asymmetric hearing loss [27].

The American College of Radiology has published guidelines regarding expert panel recommendations on appropriateness of imaging for specific indications [28]. For isolated vertigo, MRI with and without contrast is preferred over MRI without. MRI with and without contrast is more sensitive to acoustic neuroma/vestibular schwannoma, meningioma, multiple sclerosis plaques (hyperintense plaques on fluid-attenuated inversion recovery or T2-weighted images), as well as acute/chronic ischemic disease.

For patients with either episodic or persistent vertigo, MRI with and without is slightly preferred over MRI without contrast in evaluation of dizzy patient. However, some studies have shown a low yield from MRI for audiovestibular dysfunction. One study looking at 52 consecutive patients with audiovestibular dysfunction who underwent MRI found that 0% had any pathology [29].

Due to the relatively high cost of standard MRI with contrast and relatively low yield, there has been interest in the utility of less expensive non-contrasted scans. The concept of using SSFP (steady-state free precession) sequences such as CISS (constructive interference in steady state) or FIESTA (fast imaging employing steady-state acquisition) to detect mass lesions can be done without the cost and potential allergic risk from administration of gadolinium contrast.

The cost-effectiveness of non-contrast MRI for vestibular schwannoma in patients with asymmetric hearing loss has been recently studied [30]. In this particular study, a "screening" MRI utilizing non-contrast T1 axial and coronal images as well as axial SSFP sequence of the IACs and posterior fossa was employed. Scans with filling defect in the IACs or CPA were considered suspicious for mass and therefore received a more thorough imaging evaluation. A "full" MRI of IACs included the same sequences as the "screening" MRI plus post-contrast axial and coronal T1 sequences of posterior fossa as well as whole brain axial T2, FLAIR, and

DWI sequences. The cost of a contrasted MRI was around $4000, and non-contrast MRI costs were around $2872. While this particular study was focused on patients with asymmetric hearing loss, further study of a "screening" MRI might be interesting for asymmetric vestibulopathy.

Conclusion

Cost-effective evaluation of the dizzy patient begins with a dedicated cost-free history of the duration, trigger, and associated symptoms of the dizziness. For patients with vestibulopathy, a dedicated cost-free physical exam including neurologic exam, oculomotor exam, Dix-Hallpike maneuver, and head impulse test is essential. The use of Frenzel goggles, which have limited up-front costs, is encouraged to enhance observation of nystagmus. Weber and Rinne tuning fork tests are also minimally costly and can quickly suggest if sensorineural or significant conductive hearing loss is present. Vestibular testing including videonystagmography with caloric stimulation and rotational chair requires special equipment and trained audiology personnel; testing can help detect subtle oculomotor abnormality, confirm laterality of vestibulopathy, and provide a relative degree of remaining vestibular function. CT scans of the head and temporal bones are usually low yield for dizziness, whereas MRI scan may detect some central pathologies as well as tumors of the IAC/CPA. It is unclear if the recent interest in "screening" MRIs with T2 non-contrasted CISS for IAC/CPA masses will be effective for evaluation of vestibular patients.

In general, cost-effectiveness calculations can be challenging. The costs of evaluation are difficulty to capture, and the gained health from diagnosis and treatment of dizziness is difficult to quantify. A review of the expanding literature from the fields of Emergency Medicine, Neurology, Physical Therapy, Otolaryngology, and Otology/Neurotology indicates there is a growing interest in cost-effectiveness with an emphasis on accurate physical exam and a focus on avoiding misdiagnosis of posterior circulation strokes and intracranial lesions.

References

1. Edlow JA. Diagnosing dizziness: we are teaching the wrong paradigm! Acad Emerg Med. 2013;20(10):1064–6.
2. Newman-Toker DE, Cannon LM, Stofferahn ME, Rothman RE, Hsieh YH, Zee DS. Imprecision in patient reports of dizziness symptom quality: a cross-sectional study conducted in an acute care setting. Mayo Clin Proc. 2007;82:1329–40.
3. Newman-Toker DE, Dy FJ, Stanton VA, Zee DS, Calkins H, Robinson KA. How often is dizziness from primary cardiovascular disease true vertigo? A systematic review. J Gen Intern Med. 2008;23:2087–94.

4. To-Alemanji J, Ryan C, Schubert MC. Experiences engaging healthcare when dizzy. Otol Neurotol. 2016;37(8):1122–7.
5. Chau AT, Menant JC, Hübner PP, Lord SR, Migliaccio AA. Prevalence of vestibular disorder in older people who experience dizziness. Front Neurol. 2015;6:268.
6. Saber Tehrani AS, Coughlan D, Hsieh YH, Mantokoudis G, Korley FK, Kerber KA, Frick KD, Newman-Toker DE. Rising annual costs of dizziness presentations to US emergency departments. Acad Emerg Med. 2013;20(7):689–96.
7. Hill SR. Cost-effectiveness analysis for clinicians. BMC Med. 2012;10(1):10.
8. Newman-Toker DE, Hsieh YH, Camargo CA, Pelletier AJ, Butchy GT, Edlow JA. Spectrum of dizziness visits to US emergency departments: cross-sectional analysis from a nationally representative sample. Mayo Clin Proc. 2008;83(7):765–75. Elsevier
9. Kerber KA, Burke JF, Skolarus LE, Meurer WJ, Callaghan BC, Brown DL, Lisabeth LD, McLaughlin TJ, Fendrick AM, Morgenstern LB. Use of BPPV processes in emergency department dizziness presentations: a population-based study. Otolaryngol Head Neck Surg. 2013;148(3):425–30.
10. Kene MV, Ballard DW, Vinson DR, Rauchwerger AS, Iskin HR, Kim AS. Emergency physician attitudes, preferences, and risk tolerance for stroke as a potential cause of dizziness symptoms. West J Emerg Med. 2015;16(5):768.
11. Li JC, Li CJ, Epley J, Weinberg L. Cost-effective management of benign positional vertigo using canalith repositioning. Otolaryngol Head Neck Surg. 2000;122(3):334–9.
12. Edlow JA, Newman-Toker D. Using the physical examination to diagnose patients with acute dizziness and vertigo. J Emerg Med. 2016;50(4):617–28.
13. Kattah JC, Talkad AV, Wang DZ, Hsieh YH, Newman-Toker DE. HINTS to diagnose stroke in the acute vestibular syndrome: three-step bedside oculomotor examination more sensitive than early MRI diffusion-weighted imaging. Stroke. 2009;40(11):3504–10.
14. Tarnutzer AA, Berkowitz AL, Robinson KA, Hsieh YH, Newman-Toker DE. Does my dizzy patient have a stroke? A systematic review of bedside diagnosis in acute vestibular syndrome. Can Med Assoc J. 2011;183(9):E571–92.
15. Chen K, Schneider AL, Llinas RH, Marsh EB. Keep it simple: vascular risk factors and focal exam findings correctly identify posterior circulation ischemia in “dizzy” patients. BMC Emerg Med. 2016;16(1):37.
16. Kerber KA, Brown DL, Lisabeth LD, Smith MA, Morgenstern LB. Stroke among patients with dizziness, vertigo, and imbalance in the emergency department: a population-based study. Stroke. 2006;37(10):2484–7.
17. Mitsunaga MM, Yoon HC. Journal Club: head CT scans in the emergency department for syncope and dizziness. Am J Roentgenol. 2015;204(1):24–8.
18. Grewal K, Austin PC, Kapral MK, Lu H, Atzema CL. Missed strokes using computed tomography imaging in patients with vertigo: population-based cohort study. Stroke. 2015;46:108–13.
19. Ahsan SF, Syamal MN, Yaremchuk K, Peterson E, Seidman M. The costs and utility of imaging in evaluating dizzy patients in the emergency room. Laryngoscope. 2013;123(9):2250–3.
20. Navi BB, Kamel H, Shah MP, Grossman AW, Wong C, Poisson SN, Whetstone WD, Josephson SA, Johnston SC, Kim AS. The use of neuroimaging studies and neurological consultation to evaluate dizzy patients in the emergency department. Neurohospitalist. 2013;3(1):7–14.
21. Muelleman T, Shew M, Subbarayan R, Shum A, Sykes K, Staecker H, Lin J. Epidemiology of dizzy patient population in a neurotology clinic and predictors of peripheral etiology. Otol Neurotol. 2017;38(6):870–5.
22. Kentala E, Rauch SD. A practical assessment algorithm for diagnosis of dizziness. Otolaryngol Head Neck Surg. 2003;128:54–9.
23. Roland LT, Kallogjeri D, Sinks BC, Rauch SD, Shepard NT, White JA, Goebel JA. Utility of an abbreviated dizziness questionnaire to differentiate between causes of vertigo and guide appropriate referral: a multicenter prospective blinded study. Otol Neurotol. 2015;36(10):1687.

24. Phillips JS, Mallinson AI, Hamid MA. Cost-effective evaluation of the vestibular patient. Curr Opin Otolaryngol Head Neck Surg. 2011;19(5):403–9.
25. Piker EG, Schulz K, Parham K, Vambutas A, Witsell D, Tucci D, Shin JJ, Pynnonen MA, Nguyen-Huynh A, Crowson M, Ryan SE. Variation in the use of vestibular diagnostic testing for patients presenting to otolaryngology clinics with dizziness. Otolaryngol Head Neck Surg. 2016;155(1):42–7.
26. Gandolfi MM, Reilly EK, Galatioto J, Judson RB, Kim AH. Cost-effective analysis of unilateral vestibular weakness investigation. Otol Neurotol. 2015;36(2):277–81.
27. Cueva RA. Auditory brainstem response versus magnetic resonance imaging for the evaluation of asymmetric sensorineural hearing loss. Laryngoscope. 2004;114(10):1686–92.
28. National Guideline Clearinghouse (NGC). Guideline summary: ACR Appropriateness Criteria® hearing loss and/or vertigo. In: National Guideline Clearinghouse (NGC) [Web site]. Rockville: Agency for Healthcare Research and Quality (AHRQ); 2013 Jan 1. [cited 2018 Mar 02]. Available: https://www.guideline.gov.
29. Al-Barki AA, Hudise JY, Malik N, Junaid M, Almothahbi A. Role of MRI in audio-vestibular dysfunction; is it cost-effective? Int J Otorhinolaryngol Head Neck Surg. 2018;4:80–2.
30. Crowson MG, Rocke DJ, Hoang JK, Weissman JL, Kaylie DM. Cost-effectiveness analysis of a non-contrast screening MRI protocol for vestibular schwannoma in patients with asymmetric sensorineural hearing loss. Neuroradiology. 2017;59(8):727–36.