Teleneurology applications

Report of the Telemedicine Work Group of the American Academy of Neurology

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ABSTRACT

Objective: To review current literature on neurology telemedicine and to discuss its application to patient care, neurology practice, military medicine, and current federal policy.

Methods: Review of practice models and published literature on primary studies of the efficacy of neurology telemedicine.

Results: Teleneurology is of greatest benefit to populations with restricted access to general and subspecialty neurologic care in rural areas, those with limited mobility, and those deployed by the military. Through the use of real-time audio-visual interaction, imaging, and store-and-forward systems, a greater proportion of neurologists are able to meet the demand for specialty care in underserved communities, decrease the response time for acute stroke assessment, and expand the collaboration between primary care physicians, neurologists, and other disciplines. The American Stroke Association has developed a defined policy on teleneurology, and the American Academy of Neurology and federal health care policy are beginning to follow suit.

Conclusions: Teleneurology is an effective tool for the rapid evaluation of patients in remote locations requiring neurologic care. These underserved locations include geographically isolated rural areas as well as urban cores with insufficient available neurology specialists. With this technology, neurologists will be better able to meet the burgeoning demand for access to neurologic care in an era of declining availability. An increase in physician awareness and support at the federal and state level is necessary to facilitate expansion of telemedicine into further areas of neurology.

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GLOSSARY

AAN = American Academy of Neurology; **ACA** = Affordable Care Act; **CMI** = Center for Medicare and Medicaid Innovation; **DBS** = deep brain stimulation; **IOM** = intraoperative monitoring; **TBI** = traumatic brain injury; **tPA** = tissue plasminogen activator; **VA** = Veterans Affairs.

Telemedicine is a rapidly progressing field that is constantly revising the possibilities for high-quality patient care. Telemedicine includes multiple applications and services including remote videoconferencing (2-way video), e-mail, and other forms of technology. The use of telemedicine is now becoming integrated into the daily life of physicians, hospitals, specialty departments, home health agencies, and patients.[1]

Telemedicine in acute stroke demonstrates validated uses of telemedicine likely appropriate in other neurologic conditions. The benefits and lessons learned from telemedicine in acute stroke may serve as a model for the continued expansion of telemedicine into other areas of neurology.

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TELENEUROLOGY AND THE PATIENT Neurology telemedicine, also known as "teleneurology," has been used to improve access to neurologic expertise for patients in locations with a lack of access to specialists or for those patients with neurologic disabilities restricting travel or requiring time-sensitive care. Telemedicine provides services that cannot easily be provided face to face and improves the efficiency or effectiveness of existing services.[1] Wherever access to neurologic expertise is limited, either by inadequate numbers of providers or by impaired mobility of patients, exists a potential opportunity for introducing telemedicine to facilitate that access.

While teleneurology is currently most commonly applied in emergency stroke and neurocritical care,[2] it also has a role in managing patients with chronic neurologic diseases such as epilepsy,[3] Parkinson disease and other movement disorders, new neurologic outpatient referrals or consultations, community rehabilitation programs, neurology e-consults from domestic and global health sources, and e-mail triage of referrals from general practitioners.[2] Teleneurology thus is in the unique position to offer specialized care on a scale previously unmatched by conventional care.

For patients with acute or chronic disability due to neurologic diseases that impair mobility, access to neurologic care without extensive travel can be beneficial (table). Telemedicine services can also extend to chronic care facilities such as nursing homes, providing neurologic expertise to patients who otherwise could not be easily transported to a neurology office. Subspecialty neurology care such as movement disorders, epilepsy, or neuromuscular disease may require extended travel for patients in each direction to see an expert, typically located in a major metropolitan area. With telemedicine, an initial evaluation can be accomplished without the need for the patient to leave his or her community. If necessary, the specialist can arrange for patients requiring further study to be evaluated in-person.[2] Many patients appreciate the ability to reduce travel times while receiving the same high level of specialty care. In some cases, patients may live so far from major referral centers that an in-person evaluation is not possible. However, remote evaluation by telemedicine will reach patients in any area with appropriate connectivity, typically with a bandwidth on the order of 128 kB/s to 764 kB/s.[3]

Nearly half of the hospitals in the United States have fewer than 100 beds.[4] In most of these hospitals, there is no neurologist on staff readily available. Remote communities are underserviced and have no direct access to a neurologist.[5] Ninety percent of rural hospitals surveyed were receptive to involvement in a regional or state teleneurology network of care.[6] In many of these rural areas, there is not sufficient workload within a defined geographical area for a neurologic practice to become financially viable. This has led to a "geographical disparity" for neurologic care.[7] Time-sensitive neurologic diseases like stroke require rapid assessment by a neurologist or other stroke specialist. While helicopter transfer and telephonic consultations have a role, the majority of stroke specialists and emergency physicians surveyed agreed that telemedicine will reduce geographical differences in stroke management and is superior to telephone consultation.[8]

Patients can be evaluated and, in many instances, cared for at the rural hospital after a teleneurology consultation. Active teleneurology networks demonstrated an average of 60%–70% patient retention at the local level following telemedicine consultation.[9] A hub-and-spoke model has proven to be efficient, safe, and cost-effective. Many rural hospitals face overwhelming financial challenges. However, the cost per neurologic patient to the hospital can be reduced up to 35% using e-mail referrals instead of conventional face-to-face care.[10] Both an increase in hospital productivity and patient retention due to telemedicine contribute to the overall cost-effectiveness of teleneurology.[11] Keeping appropriately selected patients at the rural facility can further reduce considerably costly transfers and increase safety by limiting the transfers of unstable and critically ill patients. This can contribute to the financial viability of the rural health facility and rural health physicians, thus contributing to the overall cost-effectiveness of any regional teleneurology program.[12]

Table Benefits and barriers to telemedicine implementation

Benefits
• Increased practice outreach, development, and efficiency
• Decreased travel time and expenses for doctors and patients
• Expansion of educational opportunities and continuing medical education for physicians
• Individual and group education for patients about their neurologic disease
• Easy recruitment of patients into clinical trials
• Improvement of access to neurologic expertise for remote or underserviced areas
• Reduction in geographical disparity for neurologic care
• Decreased response time in stroke
• High patient and family satisfaction survey scores with their teleneurology care
Barriers
• Disruption of traditional doctor–patient relationship
• Physician reluctance to adopt novel technology in practice
• Limitations to billing and reimbursement for time spent
• Additional costs for technology
• Licensing, credentialing issues for out-of-state physicians
• Concern for malpractice liability
• Performing complete neurologic examination solely via telehealth, particularly evaluating muscle tone and strength, sensation, reflexes and funduscopic examination
• Obtaining neurodiagnostic tests such as EEG, EMG, and neuroimaging in remote settings

Beyond rural health care difficulties, urban hospitals also face major financial challenges and problems with access to rapid neurologic on-site expertise because of traffic patterns in large cities. These problems could be improved with telemedicine by decreasing patient need to travel and by improving outcomes from clinical management.

In 2005, the American Stroke Association proposed a new framework for stroke care delivery modeled after the successful trauma and coronary artery disease systems of care. The goal of this new framework, the Stroke Systems of Care, was to define strategies for implementation of a more coordinated delivery of stroke care across the continuum of services from prevention through rehabilitation.[13] This model recommends implementation of telemedicine as one strategy to increase access to acute stroke care in neurologically underserved areas, which include both geographically remote sites and urban areas with limited availability of neurologists with sufficient experience with acute stroke to provide expert care on an emergent basis. The term telestroke was first introduced in 1999 in a concept paper that recommended the use of high bandwidth, dedicated interactive videoconferencing and remote image review to provide the necessary acute stroke expertise lacking in most hospitals across the United States.[14] Since then, there have been extensive scientific validation studies of the component steps critical to successful telestroke evaluation, demonstrating the following:

1. The NIH Stroke Scale via telestroke is reliably performed by both physicians and nonphysicians compared to the traditional bedside evaluation in acute and subacute settings.[15]
2. Neurologists can reliably interpret unenhanced brain CT images for the purpose of confirming the diagnosis of acute ischemic stroke and establishing eligibility for IV tissue plasminogen activator (tPA).[16]
3. IV tPA can be administered safely through telemedicine and with outcomes comparable to those observed in patients being treated at tertiary care facilities.[16]
4. Audio-video telemedicine evaluation of an acute stroke patient leads to better decision-making and safety than telephone-only consultations.[5]
5. Telestroke networks have proven cost-effective.[17]

Opportunities exist for teleneurology beyond acute ischemic stroke. Already there has been demonstration of benefits of telestroke support for the inpatient phase of stroke care beyond just tPA evaluation and administration. Small pilot studies suggest benefits in rehabilitation telemedicine, "telerehabilitation," and prehospital care.[18] Telerehabilitation has the potential to enable successful postacute care for disabled patients in the home so that these patients with limited mobility do not have to travel and clinicians can improve function and prevent complications in a cost-effective manner.[19] Telemedicine for neurologic critically ill patients as well as routine hospital consultations are feasible utilizing this technology.[20] Telemedicine can also improve screening, consenting, randomizing, treating, and following subjects' enrollment in acute stroke clinical trials. Identification of appropriate patients is enhanced and examinations can be documented by study investigators allowing entry of patients who otherwise might be excluded.[21] Thus telemedicine has the potential to improve the recent trends in poor patient enrollment in the United States.

Movement disorders evaluation benefits from remote assessment, as studies have shown that telemedicine is useful for the evaluation and management of Parkinson disease, a disease where patient travel may be especially challenging and costly.[22] Telemedicine is already being employed in the following disciplines of neurology and allied specialties: dementia,[23] neuro-oncology,[24] adult and pediatric neurology, neurocritical care,[25] migraine,[26] multiple sclerosis,[27] epilepsy,[3] neurosurgery,[28] neuropathology,[29] and psychiatry.[30] Interpretation of epilepsy monitoring, EEG tracings, and intraoperative monitoring (IOM) are routinely done from distant sites. With the emerging testing of teleradiology imaging (including head CT and CT angiography) being transmitted to handheld devices (e.g., smartphones and tablets), an improvement in rapid access to patient imaging outside the hospital and home will be possible.

Telemedicine can greatly increase the ability of local hospitals or clinics to provide general neurologic consultation services, sleep studies, and EEGs in the absence of an on-site neurologist. In the intensive care unit setting, the use of robotic telemedicine has been shown to significantly reduce response times to cerebral ischemia and elevated intracranial pressure. This translates to significantly reduced lengths of stay and improved cost of care,[20] particularly for patients with a greater severity of illness.[31]

Furthermore, the increasing use of deep brain stimulation (DBS) and IOM via telemedicine is currently used for patients with essential tremor,[32] Parkinson disease,[22] and primary dystonia,[33] and is under investigation for epilepsy, obsessive-compulsive disorder, Alzheimer disease, depression, and other movement disorders.[34] The management of patients post-DBS requires assistance from highly specialized teams that may not be immediately available when there is a problem with the DBS system itself. Telemedicine can provide an effective tool to deal with concerns related to the technology involved in managing patients.

BARRIERS TO TELENEUROLOGY IMPLEMENTATION One drawback of telemedicine is the potential to disrupt the traditional doctor–patient relationship and the resulting reluctance to implement the technology

in routine practice. The treatment of illness has long been viewed as a holistic process, with human contact, personal interaction, and direct communication valued as critical components of effective and compassionate care. The fear that telemedicine may alter the doctor–patient relationship necessitates ongoing evaluation and new approaches to optimize the telemedicine interaction.

Despite teleneurology providing neurologic expertise to areas with limited or no neurology coverage, many sites will likely prefer in-person neurology service when available. Comparisons of the neurologic examination performed by teleneurology with in-person examination are limited and show variable correlations depending upon the element of the examination.[35] Further study of the application of teleneurology to stroke and other common and uncommon neurologic conditions is warranted. Process measures, reliability of consultation, and outcomes should be monitored to define the limits of telemedicine in this setting. Many small hospitals without neurology coverage are already using teleneurology to provide emergency or ongoing care. The benefits of providing this service to patients in remote areas must be validated through appropriate reports and studies.

For health care providers not specially trained in neurology, performing a complete neurologic examination, particularly the funduscopic examination (as technology matures, a portable retinal camera could be used to accomplish this) and evaluation of muscle tone, strength, sensation, and reflexes, is difficult to achieve. To overcome this barrier, the clinical provider should be present during the televideo examination and should conduct the neurologic examination in front of the camera. Alternatively, a nurse practitioner, physician assistant, registered nurse, or technician who has been trained in the neurologic examination (i.e., a "telepresenter") could conduct the neurologic examination under the videoconference supervision of a remotely located neurologist.

TELEMEDICINE AND THE PRACTICE OF NEUROLOGY The use of telemedicine encourages development of networks of providers willing to increase access to neurologic care in underserved rural areas. Telemedicine is a means to triage or pre-evaluate prospective patients to increase practice outreach and efficiency. Evaluation of patients using telemedicine can result in the decision not to see particular patients or to redirect them in the medical care system before an unnecessary clinic visit or hospitalization has been incurred, resulting in cost reduction.

The use of video links for epileptic patients in rural communities is one example of the potential of telemedicine in streamlining health services, with the approach shown to reduce travel time for both doctor and patient with no accompanying changes in quality of care.[36]

With the growth of retail medicine, delivery of neurology services to urgent care centers or employer health clinics may be facilitated by telemedicine. Primary care offices could utilize telemedicine to obtain rapid neurologic opinions when travel is difficult or the need for an appointment with a neurologist is unclear. These telemedicine applications offer the neurologist additional practice opportunities with a minimal time investment in addition to cost savings in unnecessary referrals or testing.

The education and supervision of residential fellows can be enhanced with telemedicine. For example, an attending physician's direct participation via telemedicine in the evaluation of a patient in the emergency department can improve the efficiency and timeliness of patient care. Furthermore, the capability to archive telemedicine sessions provides a library of simulation scenarios that can be reviewed in an educational setting to evaluate real-world patient encounters. Telemedicine applications can address several core competencies such as patient care, communication, professionalism, and systems-based practice.

Telemedicine networks also provide a unique opportunity for interaction between highly trained and experienced specialist neurologists at medical centers and local neurologists, and between emergency medicine, urgent care, primary care, and non-neurology specialists for educational and mentoring activities. Alliances between smaller hospitals and tertiary care centers (a hub-and-spoke system) for the provision of telemedicine services can easily be expanded to include educational activities. These interactions may include traditional education delivery as well as remote supervision of patient care, performance of procedures, or assessment of competencies along with quality control and performance improvement.

Furthermore, telemedicine facilitates clinical research by providing an infrastructure to recruit patients into clinical trials.[21] Information about a clinical study can be conveyed to the patient or surrogate and the consent process initiated. Telemedicine could be used to screen, consent via e-signature, randomize, treat by telepharmacy connections, and even follow up subjects who may remain remotely located in collaborating spoke hospitals. This approach can help recruit additional patients into acute stroke treatment and other clinical trials.

DEPARTMENTS OF VETERANS AFFAIRS AND DEFENSE TELENEUROLOGY Using teleneurology to provide high-quality neurologic care to veterans and to improve the efficiency of the limited number of neurologists in the Veterans Affairs (VA) system is under development.[37]

The VA initiative differs from many videoconferencing health systems being developed for the private sector

in that the VA will deliver direct patient care as well as neurologic consultations and education. In the remote epilepsy care model, veterans will only have to travel to their local community-based outpatient clinics where they will be connected by a sophisticated video conferencing system to an epileptologist. Follow-up management of the patient's epilepsy and anticonvulsants will be accomplished with the opportunity of the patient, caregiver, and primary care provider to interact in real time. Pilot plans are under way to expand this remote care system to include chronic care in patients with Parkinson disease, post-stroke, traumatic brain injury, spinal cord injury, and dementia.

The shortage of active duty neurologists leads to reliance upon neurologists in the local community to care for military service members, dependents, and retirees. For medical personnel operating in remote environments, neurology support via telemedicine consultation is critical. The US military currently relies heavily upon store-and-forward asynchronous telemedicine consultation for neurologic disorders in remote areas, and in particular, for deployed forces in active military theaters such as Iraq and Afghanistan. Store-and-forward consultations are asynchronous exchanges of information, which may include recorded video of patient signs and symptoms, but most often involve exchange of static data (e.g., text, laboratory values, still images). Military teleneurology cases represent the spectrum of neurologic disorders and have also focused on management of nonpenetrating (e.g., concussive) traumatic brain injury. eConsultation requests are generated by the referring provider (medic or corpsman, physician assistant, nurse practitioner, or non-neurologist physician) via e-mail to a central account which is monitored and distributed to a group of neurologists for workup and treatment recommendations. This system allows a neurologic team to provide recommendations for treatment and also allows 2-way real-time communication with the provider to obtain additional clinical information. In addition to diagnosis and treatment recommendations, critical decisions such as whether to medically evacuate a service member for further evaluation and treatment could be expedited by telecommunication. For forward-deployed military forces, more efficient utilization of resources has been realized, and all but the most complicated cases are managed locally, avoiding the risk and cost of evacuating patients for routine neurologic consultation. From October 2006 to December 2010, deployed health care providers using the military's telemedicine system received 508 general neurologic and 131 traumatic brain injury (TBI) consultation requests, of which 482 (95%) originated in Iraq or Afghanistan.[38] The most common diagnoses were migraine and other headaches (13%) and mild TBI (46%). For the majority of cases, consultants recommended local management. Eighty-four consultation requests resulted in recommendations ranging from routine to urgent or emergent medical evacuation, while 3 cases which were thought to require medical evacuation were able to be treated locally.[38]

AAN SUPPORT OF TELEMEDICINE With more than 25,700 members, the American Academy of Neurology (AAN) is dedicated to promoting the highest quality patient-centered neurologic care. In March 2010, the AAN Board approved a policy position statement on stroke care recommending the availability of telemedicine services as an alternative for hospitals lacking critical elements for stroke care.[39] It also endorses equitable reimbursement for care provided via telemedicine and the availability of telemedicine care similar to in-person on-call stroke-specific services. As a result of having a defined policy on stroke care that endorses telemedicine, the AAN will strongly advocate opportunities to find alignment of this position with pending legislation at the state and federal levels.

Several states have recently passed legislation acknowledging the role telemedicine provides in bridging coverage gaps. At the federal level, the 2010 Patient Protection and Affordable Care Act (ACA) contained provisions addressing health information technology.[40] The following provisions in the ACA specifically address telemedicine services and are closely monitored by the AAN:

- To find cost efficiencies for both programs, the new Center for Medicare and Medicaid Innovation (CMI) will examine new ways of delivering health care and paying health care providers. As a part of this charge, the CMI is mandated to study ways to improve the use of telemedicine services to treat behavioral health problems and stroke in medically underserved areas and facilities of the Indian Health Service.
- The ACA also directs the CMI to consider delivery models that use technology, such as patient-based remote monitoring systems, to coordinate care over time and across settings.
- Accountable Care Organizations will be able to fulfill the requirements to establish ways to promote evidence-based medicine and patient engagement, coordinate care, and report on quality and cost measures through the use of telemedicine, remote patient monitoring, and other such enabling technologies.

DISCUSSION Current challenges in neurologic practice include 1) the growing burden of neurologic disease in our aging population, 2) disparities in and variation of neurologic services, 3) a shortage of neurologists to satisfy increasing demand, 4) the need for rapid expert evaluation and management of high-impact conditions including stroke, 5) addressing liability issues, and 6) adequate reimbursement. Telemedicine has demonstrated clinical effectiveness in increasing access to neurologic expertise,

reducing patient and physician travel time, fostering communication and coordinated care, and improving physician productivity. As systems of care and technology evolve, the role of telemedicine in neurologic practice is uniquely positioned to add significant value with both improved outcomes and cost reduction as measurable goals.

GLOSSARY OF TERMS **eConsultation**—a nonvisit electronic consultation between a requesting physician and a specialist. The eConsultation is typically requested through an online portal. This portal allows the requesting physician to ask a specific question and to upload supporting medical records or other data required for the specialist to provide an opinion. One of the goals of eConsultations is to provide timely access to a specialist's opinion, when there is a clear and focused question requiring a specialist's expertise and when a face-to-face examination is not required.

Hub-and-spoke system—a structure of telemedicine in which a certified comprehensive stroke center, usually in a large urban area, serves as the primary stroke center (the hub). The spokes are located in remote areas, usually smaller regional rural or underserviced hospitals. The neurology specialists at the hub will consult with doctors and people with neurologic symptoms at the remote sites (spokes).

Retail medicine—acute health care that is delivered in nontraditional settings, typically in high-traffic retail outlets associated with pharmacies like Wal-Mart or CVS. These settings may be referred to as "retail clinics" or convenient care clinics. Services are rendered by nurse practitioners or physician assistants on a walk-in basis.

Store-and-forward—the practice of telemedicine in which the initial care provider stores images or medical information and forwards them via e-mail to a specialist for review. Store-and-forward consultations typically occur at the specialist's convenience when the patient is not present.

Telemedicine—medical practice at a distance, or not in person, using modern communications technology. Such technology includes videoconferencing systems (real-time, synchronous) or store-and-forward systems (asynchronous, see "store-and-forward"). Subcategories (for the purposes of this article) include **teleneurology**, **teleradiology**, **telestroke**, and **telerehabilitation**.

AUTHOR CONTRIBUTIONS

Lawrence R. Wechsler: drafting/revising the manuscript, study concept or design. Jack W. Tsao: drafting/revising the manuscript, study concept or design, analysis or interpretation of data, study supervision. Steven R. Levine: drafting/revising the manuscript, study concept or design, analysis or interpretation of data. Rebecca J. Swain-Eng: drafting/revising the manuscript. Robert J. Adams: drafting/revising the manuscript. Bart M. Demaerschalk: drafting/revising the manuscript. David C. Hess: drafting/revising the manuscript. Elena Moro: drafting/revising the manuscript. Lee H. Schwamm: drafting/revising the manuscript. Steve Steffensen: drafting/revising the manuscript. Barney J. Stern: drafting/revising the manuscript, study concept or design. Steven J. Zuckerman. drafting/revising the manuscript. Pratik Bhattcharya: drafting/revising the manuscript. Larry E. Davis: drafting/revising the manuscript, analysis or interpretation of data, contribution of vital reagents/tools/patients, acquisition of data. Ilana R. Yurkiewicz: drafting/revising the manuscript, analysis or interpretation of data. Aimee L. Alphonso: drafting/revising the manuscript.

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DISCLOSURE

L. Wechsler has served as a consultant for Abbott Vascular, Lunbeck, and Ferrer; is on the Data and Safety Monitoring Board for DIAS 3/4/J and the steering committee for CLOSURE, ACT I; and owns stock in Neurointerventional Therapeutics. J. Tsao has received funding from the Telemedicine and Advanced Technology Research Center, United States Army, to develop a military neurology telemedicine system. S. Levine has given expert review and testimony on medical legal cases and has received research funding from the NIH. R. Swain-Eng is a full-time employee of the American Academy of Neurology. R.J. Adams is cofounder of REACHCall Inc., a for-profit telemedicine platform provider. He is also a co-owner of the company with <5% of outstanding stock. He is employed by Medical University of South Carolina, which offers telestroke consultation for fair market value to hospitals in South Carolina. He also is a speaker for Genentech, which makes tPA, but owns no stock. B. Demaerschalk has received telemedicine research grant funding from the Arizona Department of Health Services. Dr. Hess is a cofounder of REACHCall Inc., a for-profit telemedicine platform provider. He is also a co-owner of the company with <5% of outstanding stock. He is employed by Georgia Health Sciences University, which offers telestroke consultation for fair market value to hospitals in Georgia. He also has research contracts with Athersys, Inc., and Lundbeck. E. Moro has received honoraria from Medtronic for consulting services and speaking. She has received research grant support from St. Jude Medical and educational grants from Medtronic and St. Jude Medical. L. Schwamm serves as a consultant to LifeImage, a teleradiology company, and on the International Steering Committee for the DIAS3/4 trial. His employer, The Massachusetts General Hospital, offers an array of telehealth services at fair market value to many area hospitals, including telestroke. He has also given expert review and testimony on medical legal cases and has received research funding from the NIH on thrombolysis and HRSA on telemedicine. S. Steffensen reports no disclosures. B. Stern has received research support from Remedy Pharmaceuticals per patient research costs and research grants from the NIH. He has also received compensation for expert witness testimony. S. Zuckerman and P. Bhattacharya report no disclosures. L. Davis is a part of the VA Teleneurology group for which the VA pays part of the research costs for the nursing staff. I. Yurkiewicz and A. Alphonso report no disclosures. The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Department of the Navy, the Department of Defense, or the Department of Veterans Affairs. Go to Neurology.org for full disclosures.

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