Published in final edited form as:

Med Care. 2016 May ; 54(5): 423–425. doi:10.1097/MLR.0000000000000538.

Stroke Imaging: Quantity, But Is There Quality?

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Diagnostic tests are a routine part of clinical care, accounting for a substantial amount of clinical effort and costs. We commonly assess the quality of medical care by examining these processes of care rather than their outcomes. However, the evidence base for “good” medical care, even guideline-recommended care, is often less strong than we realize.¹ This is particularly true for diagnostic tests that only influence outcomes indirectly by changing decision making and management.² Thus, in routine clinical practice, fundamental questions go unasked or unanswered: Why do we test? Who should we test?

These questions, while not unasked, are largely unanswered for most diagnostic tests for stroke. Every year, millions of individuals worldwide suffer a stroke, 80-87% of which are ischemic. Clinical practice guidelines recommend several imaging tests for suspected or confirmed stroke and transient ischemic attack (TIA) including recommendations regarding axial brain imaging (e.g., computed tomography (CT) or magnetic resonance imaging (MRI)), vascular (intracranial and cervical) imaging, and echocardiography.³⁻⁵ However, these recommendations are based on modest and varying levels of evidence and expert opinion. Formal technology assessments of many recommended diagnostic tests for stroke are lacking.

The article by Ng and colleagues⁶ prompts us to re-examine the value of diagnostic tests for stroke. The investigators evaluated temporal trends in the use of selected diagnostic tests for ischemic and hemorrhagic stroke as well as transient ischemic attack (TIA) among 42,378 patients (median age, 73 years) discharged alive from 11 regional stroke centers between 2003 and 2012 in a province of Canada, a country with universal health care. Information from a stroke registry was linked to longitudinal, administrative data on diagnostic tests after discharge, readmissions, and surgical procedures. The study population consisted of ischemic stroke (54%), TIA (27%), and hemorrhagic stroke (19%). Trained neurology research nurses verified stroke diagnoses and type using chart abstraction and criteria.

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Dr. Levine has no conflict of interest. Dr. Burke has no conflict of interest.

The frequency of all diagnostic tests increased over time. In the combined ischemic and hemorrhagic stroke population, the frequency of any brain imaging (CT or MRI) increased from 96% in 2003 to 99% in 2012. In the subgroup with ischemic stroke/TIA, cervical vessel imaging increased from 62% to 88% and echocardiography from 52% to 70%. Increases in evidence-based treatments in patients with ischemic stroke/TIA were less uniform: antithrombotic therapy increased from 83% to 91% but the frequency of anticoagulation (68%) and carotid revascularization (1.5%) did not.

The study has several strengths. The longitudinal study has information on diagnostic testing as well as downstream surgical procedures and medication use because it combines registry and administrative data. The identification of strokes and inpatient diagnostic testing by chart abstraction is an additional strength compared to the common use of billing data in other studies. The number of cases was large.

The study has limitations. The study did not assess clinical outcomes. Causation cannot be inferred from observed associations. We are not given information on the type of brain imaging tests (e.g., intracranial vascular imaging, perfusion imaging, repeat CT scans for clinical change) performed by stroke type (hemorrhagic stroke, ischemic stroke, or TIA) or stroke severity. Although the number of brain scans per patient seems high (3.6 per patient from hospitalization to 90 days after stroke/TIA), it is unclear how intracranial imaging tests were counted and this information influences the perception of this apparently high scan count.

Ultimately, we care about the overuse of low value tests and treatments as well as the underuse of high value tests and treatments. The characteristics of a high value stroke diagnostic evaluation are clear — optimizing decision making for acute and secondary preventive treatments while minimizing radiation, contrast exposure, false positives, cost, and inconvenience. Developing an optimal stroke diagnostic algorithm and achieving these goals is likely feasible. Yet, the evidence base for diagnostic tests in general is often poor.⁷ Clinical practice guidelines often fail to quantify or clearly present the benefits and harms of tests⁸, provide incomplete or biased presentations⁸, and often rely on case-cohort studies of predictors of stroke.^{9, 10}

Our current evidence base for stroke diagnostic tests has three fundamental limitations. First, the absolute benefits and harms of diagnostic tests are often unknown. While the sensitivity and specificity of tests are typically known, how often tests lead to effective changes in management, treatment delays¹¹, or evaluations of incidental findings is rarely quantified. Second, the cost-effectiveness of diagnostic tests is often unknown. While neuroimaging is the fastest growing driver of hospital costs of stroke care in the United States¹², it is hard to quantify the value of this investment or compare the value of this investment to other potential investments without a better understanding of the absolute benefits and harms of the tests. Third, which patients to test and which test to use are often unknown. While MRI has higher sensitivity for the identification of stroke than CT, are there populations where the pre-test probability of stroke is sufficiently high that even a negative MRI is unlikely to alter secondary prevention decisions? Which stroke syndromes reliably localize to the posterior circulation and obviate carotid imaging? As a result, it is easy to default to maximally testing

all or most patients. Dual brain imaging and echocardiography in acute ischemic stroke are two good examples.

Brain imaging with CT or MRI is required for the rapid and accurate diagnosis and treatment of acute stroke, hemorrhagic or ischemic. There is no doubt that determining whether a stroke is ischemic or hemorrhagic strongly influences decision making for acute treatment (i.e. thrombolysis) as well as secondary prevention. Although head CT is typically the initial test because of its speed and availability, brain MRI has well-established advantages over CT in terms of increased sensitivity for ischemia and putative advantages in reclassifying stroke etiology and improving localization of an ischemic stroke to the anterior or posterior circulation. Yet, there is little evidence that these additional strengths of MRI lead to better patient outcomes¹³ and almost no evidence proving that dual brain imaging with CT and MRI has incremental utility over either test in isolation. Despite the lack of scientific evidence or clinical practice guidelines supporting its use, dual brain imaging with CT and MRI is performed routinely in many acute stroke patients at considerable costs in the United States¹² and Canada.⁶

Echocardiography can identify cardiac sources of stroke that lead to changes in management (e.g., intracardiac thrombus which is rare) and, more commonly, cardiac structural features that suggest a higher risk of cardioembolic stroke (e.g., left atrial enlargement, slow flow, valvular abnormalities) that may influence further tests or treatment decisions. Just as with dual brain imaging, it is unclear which patients require echocardiography. Does a patient with a prior indication for anticoagulation require echocardiography? Are their sub-populations where the risk of cardioembolism is sufficiently low (e.g. classic lacunar syndromes) to forego echocardiography? While it is likely that all ischemic stroke patients do not require dual brain imaging and echocardiography, we do not know which patients benefit from this testing.

The constant development of new medical technologies like perfusion imaging and long-term cardiac monitoring also presents major challenges for rational diagnostic testing in stroke. Recent randomized, controlled trials (RCTs) have shown that acute ischemic stroke patients with proximal artery occlusion benefit from endovascular therapy. Consequently, an additional role for vascular imaging is to identify the small subset of acute ischemic stroke patients that may be candidates for endovascular therapy. Many of these RCTs have relied on perfusion imaging combined with intracranial vascular imaging, yet the incremental utility of perfusion imaging remains uncertain.¹⁴ Similarly, recent RCTs have shown that long-term monitoring with 30-day or insertable cardiac monitors increases the detection of atrial fibrillation after ischemic stroke.^{15, 16} Yet, RCTs have not shown which ischemic stroke patients to select for intensive or insertable cardiac monitors.

In the absence of details on test indication and results, it is difficult to assess whether the imaging trends identified by Ng et al⁶ represent improvements in high value care. However, some reasonable inferences can be made. The near universal use of brain imaging (99%) for stroke/TIA in 2012 reflects high quality stroke care because all stroke/TIA patients warrant emergent brain imaging to assess for hemorrhage. Conversely, the marked increases in duplicative imaging among ischemic stroke/TIA patients suggest that substantial

inefficiencies exist. Increasingly, stroke patients are receiving two or more axial neuroimaging (CT and MRI) as well as two or more vascular (ultrasound, CT angiography, MR angiography) studies. Given the increased sensitivity of MRI for the detection of ischemia, two axial studies might be the right approach for ischemic stroke patients when substantial diagnostic uncertainty exists and MRIs are not immediately available. However, these situations should likely be the exception and not the rule in well-designed systems. For ischemic stroke patients where there is little diagnostic uncertainty, the added value of MRI is uncertain and likely modest.¹³

Similarly, some patients certainly merit two or more vascular studies. Cervical vessel imaging is indicated to identify high-grade carotid artery stenosis after ischemic stroke/TIA (why we test) in patients who are suspected to have anterior circulation ischemia and who are suitable candidates for revascularization (who we test). However, as 20% of strokes occur in the posterior circulation, and no specific secondary prevention strategies are known to be effective for intracranial stenosis, it seems likely that a considerable proportion of duplicative vascular imaging observed in this study represents low value care. Indeed, CTA and MRA have greater accuracy than ultrasound as initial or confirmatory testing for high-grade carotid stenosis, and, if anything, their increasing use as initial tests should reduce the need for duplicative imaging. The inefficiency of this increased vascular imaging is also suggested by the lack of concomitant increases in the proportion of patients undergoing carotid endarterectomy over time⁶, although it is possible that selection of appropriate candidates for carotid revascularization improved.

Rising and unsustainable health care costs demand a focus on the value of diagnostic testing particularly on high-technology expensive imaging. An increasingly asked question is: “Can we reduce health care costs by reducing imaging *and* without negatively impacting patient outcomes?”¹⁷ The introduction of constrained payment models with fixed-dollar payments for the care of patients or populations will incentivize health care systems and their clinicians to do fewer tests and spur scientists to demonstrate the value of more expensive diagnostic tests.

To develop a high-value testing approach for stroke, research is needed to better delineate the incremental utility and potential harms of diagnostic testing and to determine which patients are most likely to benefit from specific tests. When such data exist, the costs of diagnostic testing for stroke can be used to develop high-value diagnostic testing algorithms. In short, we need formal technology assessments and RCTs of diagnostic tests for acute stroke. Ten years ago, one author (DAL) submitted a grant to perform a formal technology assessment of dual brain imaging for stroke. The grant was unfunded and deemed futile because MRI had diffused. On the contrary, diffusion of a medical technology and its widespread use are strong justifications for doing formal technology assessments and updating those assessments in the context of new data and technology.¹⁸ This robust evidence will maximize clinical outcomes and improve the value of diagnostic testing in acute stroke.

Diagnostic testing in stroke, particularly neuroimaging, represents a critical opportunity to improve the value of stroke care. The quantification and elimination of redundant testing

would identify opportunities for cost savings. These cost savings could be spent on important things like improving access to physician care, ambulatory blood pressure monitors, and medications after stroke, particularly in high-risk minority groups, in order to optimize risk factor modification and prevention of recurrent stroke.¹⁹

Acknowledgments

Funding: Dr. Levine is supported by grant K23AG040278 from the National Institute of Aging. Dr. Burke is supported by NINDS K08 NS082597 and National Institute of Minority Health and Health Disparities R01 MD008879.

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