American Journal of Emergency Medicine 35 (2017) 1234–1239

Contents lists available at ScienceDirect

American Journal of Emergency Medicine

journal homepage: www.elsevier.com/locate/ajem

Original Contribution

Regional disparities in the quality of stroke care

Seth Seabury, PhD [a,*], Katalin Bognar, PhD [b], Yaping Xu, MD, MPH [c], Caroline Huber, MPH [b], S. Renee Commerford, PhD [c], Darren Tayama, MD [c]

[a] University of Southern California, Los Angeles, CA, United States
[b] Precision Health Economics, Los Angeles, CA, United States
[c] Genentech, San Francisco, CA, United States

ARTICLE INFO

Article history:
Received 8 November 2016
Received in revised form 17 March 2017
Accepted 18 March 2017

Keywords:
Stroke
Quality of care
Telemedicine

ABSTRACT

Background and purpose: There is widespread geographic variation in healthcare quality, but we often lack clear strategies for improving quality in underserved areas. This study characterized geographic disparities in stroke care quality to assess whether improved access to neurological services has the potential to bridge the care quality gap, particularly in terms of alteplase (rt-PA) administration.
Methods: This was a retrospective study using quality performance data from the 2015 Hospital Compare database linked to information on certification status from the Joint Commission and information on local access to neurological services from the Area Health Resources File. We used these data to compare stroke care quality according to geographic area, certification, and neurologist access.
Results: Non-metropolitan hospitals performed worse than metropolitan hospitals on all assessed stroke care quality measures. The most prevalent disparity occurred in the use of rt-PA for eligible patients (52.2% versus 82.7%, respectively). Certified stroke centers in every geographic designation provided higher quality of care, whereas large variation was observed among non-certified hospitals. Regression analyses suggested that improvements in hospital certification or access to neurologists were associated with absolute improvements of 44.9% and 21.3%, respectively, in the percentage of patients receiving rt-PA.
Conclusions: The large quality gap in stroke care between metropolitan and non-metropolitan areas could be at least partly addressed through improved procedural efforts by stroke center certification increasing the supply of neurological services, (i.e. through training and hiring new neurologists) or by adopting decision support systems such as telemedicine.

1. Introduction

While decades of research have demonstrated regional variation in the quality of healthcare in the United States, it is especially pronounced in stroke care [1]. Rural and underserved areas are associated with a higher prevalence of stroke, as well as worse care and patient outcomes [2,3]. In these areas it is challenging to provide prompt stroke treatment and clinical expertise that can prevent stroke-related disability and mortality [4].

A number of factors contribute to these geographic disparities. Prompt treatment with clot-dissolving thrombolytic drugs, such as alteplase (rt-PA), within 3 h of an acute ischemic stroke (AIS) can restore blood flow in the brain before substantial damage occurs [5,6]. While rt-PA administration is the standard of care for patients with AIS and is recommended by organizations such as the American Heart Association and American Stroke Association [7-9], fewer than 5% of patients who suffer from an AIS in the US receive rt-PA [10]. Even fewer patients living in regions with limited stroke-systems of care are administered rt-PA, which may be due to long distances these patients must travel to stroke centers [11-13].

Further, clinical expertise is essential to rapid diagnosis and treatment. Receiving care at a specialized stroke center, such as a Joint Commission (JC)-certified Primary Stroke Center (PSC), is associated with improved outcomes, as emergency physicians (EPs) often lack experience with rt-PA and are reluctant to use it [12]. Only 1% of individuals in rural areas, however, live within a 60-minute ground ambulance ride of a PSC [14].

Given the need for prompt evaluation and treatment, often including a neurological consult, there is concern that rt-PA is especially underused in rural or underserved urban areas. More generally, improving access to neurological services likely can improve the quality of care and outcomes for many patients with stroke, but it is unknown to what extent regional disparities in stroke care are related to disparities in access to neurological services [15]. In light of this, the objective of our study

* Corresponding author at: Keck School of Medicine of USC, GNH 1011, Los Angeles, CA 90089, United States.
E-mail address: seabury@usc.edu (S. Seabury).

http://dx.doi.org/10.1016/j.ajem.2017.03.046

was to document the quality gaps that exist in stroke care, particularly as measured by rt-PA administration, between metropolitan and non-metropolitan areas and quantify the extent to which these gaps are associated with disparities in access to neurological services. We also explored the impact of potential approaches to bridge these gaps.

2. Methods

Data based on 2013–2014 discharges were obtained from the fiscal year (FY) 2015 Hospital Compare, a database operated by the Centers for Medicare & Medicaid Services that provides information on hospital performance by measuring the percentage of patients within each hospital who meet a set of quality criteria [16,17]. The data are collected through the Hospital Inpatient Quality Reporting (Hospital IQR) program [18].

CMS began collecting data on eight stroke quality measures (STK-1 through STK-6, STK-8 and STK-10) in calendar year 2013 (the relevant data year for FY 2015) [19]. Hospitals reporting performance data on at least one stroke measure were assumed to provide stroke care to patients on at least a semi-regular basis and were included.

We used information from the US Department of Agriculture Rural–Urban Continuum Codes to classify hospitals (within the 50 states only) into different categories based on the size of metropolitan area or proximity to urban areas [20]. Specifically, we categorized hospitals as large-metropolitan, medium-metropolitan, small-metropolitan, or non-metropolitan based on continuum codes of 1, 2, 3 and 4–9, respectively. Geographic information was assigned to hospitals using Federal Information Processing Standard (FIPS) codes. Institutions were further characterized by their JC stroke center certification status, which is offered at multiple levels. Requirements for PSC and Comprehensive Stroke Center (CSC) status are described in Table I in the Online-only Supplement. The list of certified hospitals was obtained from the JC website [21].

Finally, to measure the level of access to neurological services in a given geographic area, we used the per-capita number of neurologists from the 2013 Area Health Resources Files (AHRF) [22]. Patients living in areas with a larger number of specialists per capita are more likely to receive specialist care, making the number of neurologists per capita a proxy variable for access to neurological stroke services [23]. One limitation to this measure is that many neurologists practice in an outpatient setting or do not provide acute stroke care regularly [24]. To test the sensitivity of our results, we also used the per-capita number of neurosurgeons to measure the level of access to acute neurological services. Physician data by specialty are based on counts from the American Medical Association Masterfile, while the population counts by county are based on 2013 estimates from the US Census Bureau.

To document the gap in care quality among hospitals according to geographic designation and JC certification, average performance levels on stroke measures were calculated. Mean differences in performance were tested for significance by paired *t*-tests.

The association between access to neurological services and quality of care was assessed using multivariable regression analysis, in which hospitals were stratified by access to neurological services and JC certification status after controlling for location, and for an indicator of volume as a sensitivity analysis. Additionally, to understand systematic differences in reporting that may bias our results, the qualitative level of stroke care was estimated as the probability of hospitals reporting stroke quality measures, controlling for location, access to neurological services, and certification level. In these analyses, counties were identified as having high access to neurologists if they were in the top 25% of all counties based on their per-capita number of neurologists, or low access for those in the bottom 25%.

To measure the clinical significance of different policies addressing gaps in care quality, we simulated the impact on patient outcomes under three hypothetical scenarios according to their association with rt-PA administration: an uncertified non-metropolitan hospital becoming certified; a low-access non-metropolitan hospital becoming high access (based on the number of neurologists per capita); and a non-metropolitan hospital adopting telemedicine. Changes in rt-PA administration rates informing the simulations above were estimated from the Hospital Compare data for the first two scenarios and from observational studies for the third scenario (Online-only Supplement Table II) [25-28]. The clinical relationship between rt-PA use and patient outcomes was obtained from a recent meta-analysis [29].

3. Results

Performance measures reported between April 1, 2013 and March 13, 2014 were examined for 4765 US institutions in the FY 2015 Hospital Compare dataset. A total of 2758 (57.9%) reported at least one stroke measure and were included in our analysis. Large metropolitan hospitals were about twice as likely to report a performance indicator for stroke as non-metropolitan hospitals (75.4% and 36.3%, respectively; Table 1), with a more pronounced difference in STK-4 reporting (32.6% vs. 2.3% among all hospitals, and 41.7% vs. 6.3% among hospitals reporting any STK measure; Online-only Supplement Table III).

Of the eight STK measures assessed, the reported performance of hospitals was lowest for STK-4, which measures administration of rt-PA in eligible patients (Table 2). On average, only 77.9% of eligible patients received rt-PA across all hospitals, whereas the reported performance for all other stroke quality measures was over 87%.

When examining hospitals by geographic area, performance on all eight stroke indicators was higher in metropolitan hospitals than non-metropolitan hospitals (Table 2; differences were statistically significant at 5%). The greatest disparity observed was for the administration of rt-PA. At large, medium and small metropolitan area hospitals, the average rt-PA administration rates were 82.7%, 77.2%, and 68.4%, respectively, and these rates were 30.5% (82.7% vs. 52.2%), 25.0% (77.2% vs. 52.2%), and 16.2% (68.4% vs. 52.2%) higher than the average rt-PA administration rate in non-metropolitan areas (Fig. 1). Aside from rt-PA use, quality gaps were also pronounced for access to stroke education (STK-8) and statin medication (STK-6), with between-group absolute differences of 9.1% and 9.6%, respectively.

Hospitals in different geographic areas were also analyzed by their level of stroke center certification (Fig. 1). We found a positive association between quality of stroke care and JC certification status, as evidenced by greater rt-PA administration among eligible patients at JC-certified hospitals, regardless of geographic area.

Although reported quality was higher at JC-certified hospitals in all areas, some treatment gaps were evident between rural and urban settings. In particular, the gap in rt-PA administration between a certified and non-certified hospital was 13.2% (86.2% vs. 73.0%) at large metropolitan area hospitals, compared with 44.9% (83.2% vs. 38.3%) in non-metropolitan areas.

The association between rt-PA administration and per-capita number of neurologists at the county level (i.e., low, moderate, and high access to neurological services) was also assessed for both certified and non-certified hospitals. We found the rate of neurologists per capita was associated with increased rt-PA administration, even after controlling for hospital location. The absolute difference in rt-PA use of 21.3% (70.4% vs. 49.1%) between low and high access non-certified hospitals equals approximately half of the gap between certified and non-

Table 1
Characteristics of institutions included in the analysis.

Location	Number of institutions	Number of institutions reporting ≥1 stroke performance measure, n (%)
Large metropolitan	1585	1195 (75.4%)
Medium metropolitan	814	561 (68.9%)
Small metropolitan	526	335 (63.7%)
Non-metropolitan	1840	667 (36.3%)
Total	4765	2758 (57.9%)

Table 2
Hospital performance data on various stroke quality metrics by geographic area.

Quality measure (description)	Large metropolitan	Medium metropolitan	Small metropolitan	Non-metropolitan	Total
STK-1: DVT prophylaxis (Proportion of ischemic or hemorrhagic stroke patients who received VTE prophylaxis or have documentation why no VTE prophylaxis was given on the day of or the day after hospital admission.)	94.26%	94.20%	92.65%	88.46%	92.67%
STK-2: Discharged on antithrombotic therapy (Proportion of ischemic stroke patients prescribed antithrombotic therapy at hospital discharge.)	98.85%	98.75%	98.68%	96.79%	98.33%
STK-3: Patients with AF receiving anticoagulation therapy (Proportion of ischemic stroke patients with atrial fibrillation/flutter who are prescribed anticoagulation therapy at hospital discharge)	96.11%	95.13%	94.46%	93.68%	95.42%
STK-4: Thrombolytic therapy administered (Proportion of acute ischemic stroke patients who arrive at this hospital within 2 h of time last known well for whom IV rt-PA was initiated at this hospital within 3 h of time last known well.)	82.73%	77.23%	68.38%	52.17%	77.90%
STK-5: Antithrombotic therapy by end of hospital day two (Proportion of ischemic stroke patients who had antithrombotic therapy administered by end of hospital day two (with the day of arrival being day 1))	98.02%	97.80%	97.67%	95.55%	97.36%
STK-6: Discharged on statin medication (Proportion of ischemic stroke patients with LDL greater than or equal to 100 mg/dL, or LDL not measured, or who were on a lipid-lowering medication prior to hospital arrival who are prescribed statin medication at hospital discharge.)	95.12%	93.62%	93.02%	85.55%	92.48%
STK-8: Stroke education (Ischemic or hemorrhagic stroke patients or their caregivers who were given educational materials during the hospital stay addressing all of the following: activation of emergency medical system, need for follow-up after discharge, medications prescribed at discharge, risk factors for stroke, and warning signs and symptoms of stroke)	89.29%	88.06%	86.31%	80.15%	87.01%
STK-10: Assessed for rehabilitation (Proportion of ischemic or hemorrhagic stroke patients assessed for or who received rehabilitation services during the hospital stay.)	97.05%	97.40%	96.81%	94.96%	96.60%

AF, atrial fibrillation; DVT, deep vein thrombosis; IV, intravenous; LDL, low-density lipoprotein; VTE, venous thromboembolism.

certified hospitals in non-metropolitan areas (Fig. 2). This gap remained after controlling for patient volume (Online-only Supplement Fig. I). Furthermore, sensitivity analyses using alternative measures of access based on neurosurgeons per capita yielded very similar results (Online-only Supplement Fig. II and III).

Our analysis also revealed that areas with greater access to neurological services were more likely to report the STK-4 measure, (Fig. 2). Certified hospitals with high access to neurological services reported STK-4 approximately 1.6 times (59.0% vs. 36.7%) more often than those in low-access areas. Among non-certified hospitals, those with high access were approximately 3.5 times (9.0% vs. 2.6%) more likely to report STK-4 than hospitals with low access to neurological care.

The three hypothetical scenarios we simulated were (i) an uncertified non-metropolitan hospital becoming certified; (ii) a low-access non-metropolitan hospital becoming high access; and (iii) a non-metropolitan hospital adopting telemedicine. These scenarios represent a 44.9%, 21.3%, and 22% (using the conservative rate of improvement in rt-PA administration) absolute improvement in rt-PA administration, respectively. The simulated drop in the number of dead or dependent patients, as measured by a Modified Rankin Score (mRS 2–6), for the three scenarios were 23, 11, and 11 out of 1000 stroke patients, respectively (Table 3).

4. Discussion

Our findings demonstrated a significant quality gap between metropolitan and non-metropolitan area hospitals at the national level, especially with the rate of rt-PA administration and provision of stroke education. The administration of rt-PA (STK-4) was reported for 52.2%

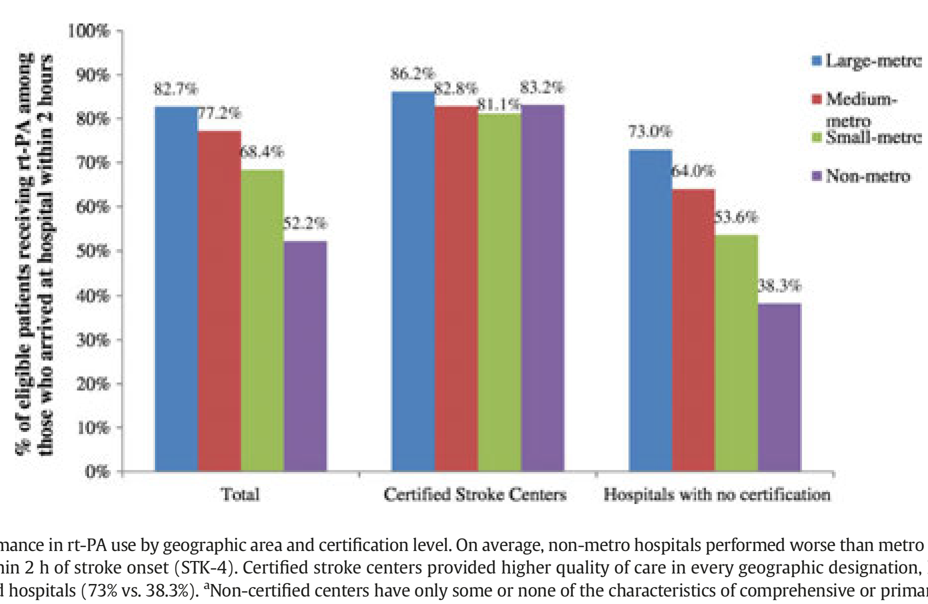

Fig. 1. Hospital quality performance in rt-PA use by geographic area and certification level. On average, non-metro hospitals performed worse than metro hospitals in the use of rt-PA for eligible patients arriving within 2 h of stroke onset (STK-4). Certified stroke centers provided higher quality of care in every geographic designation, however a large variation was observed among non-certified hospitals (73% vs. 38.3%). [a]Non-certified centers have only some or none of the characteristics of comprehensive or primary centers.

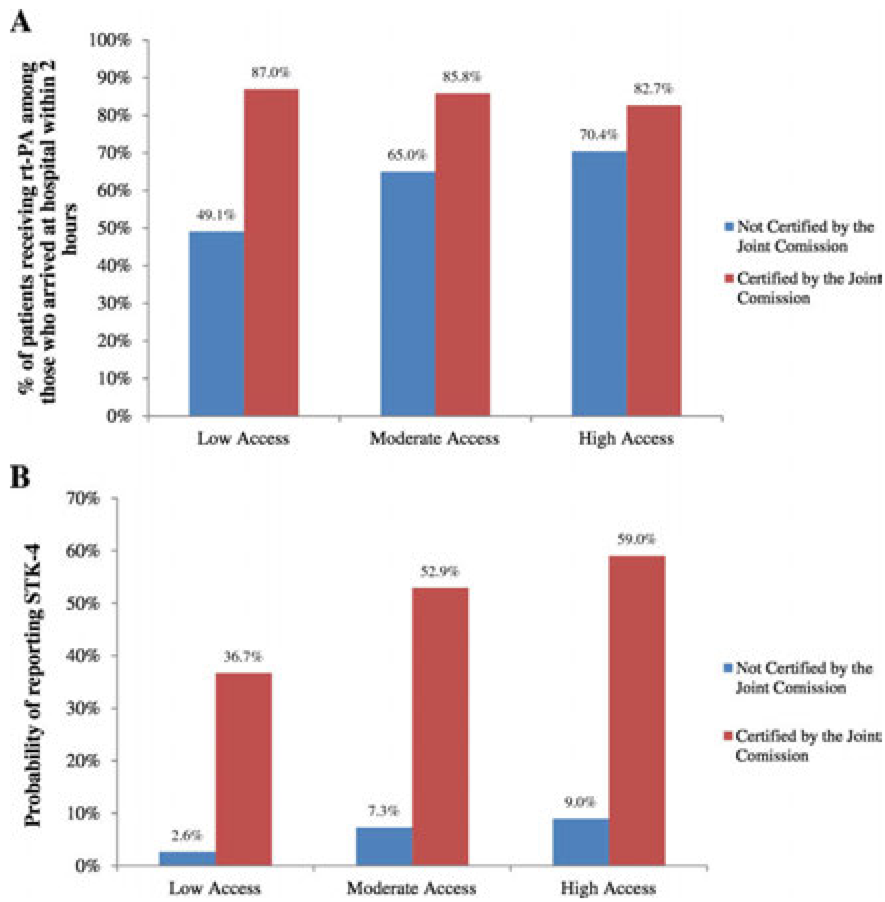

Fig. 2. Hospital quality performance assessed by rt-PA use (A) and the proportion hospitals reporting use of rt-PA (B), by level of access and JC certification. (A) A higher per-capita number of neurologists was associated with higher rt-PA use among eligible patients arriving at a hospital within 2 h of stroke onset (assessed by STK-4), after controlling for metropolitan and non-metropolitan hospital location. Performance difference for hospitals not certified by JC between areas with low versus high access to neurological services was 21.3% (70.4%–49.1%). (B) The association between hospitals reporting rt-PA use (assessed by STK-4 score) and per-capita number of neurologists showed a notable disparity in the probability of reporting STK-4 based on level of access, suggesting that hospitals in low-access areas are less likely to have the infrastructure to administer rt-PA. JC, Joint Commission; rt-PA, alteplase.

of patients in non-metropolitan area hospitals, compared with 82.7% of patients in large metropolitan area hospitals.

Since JC stroke center certification requires instituting care protocols, our results suggest that such certification may eliminate substantial care quality gaps based on geographic location [4,30].

Our analysis further showed that, for non-certified hospitals, the level of access to neurological services was positively associated with the quality of stroke care, which is most evident for rt-PA use. Indeed, the average quality gap for rt-PA use between low- and high-access non-certified hospitals was estimated to be 21.3% (Fig. 2). A previous report analyzing Medicare fee-for-service patients using claims data have shown geographic disparities in thrombolysis treatment [13]. Our findings agree with their conclusion; however, we analyze a broader population and rely on data reported by hospital. Although it is generally

Table 3
Simulation of rural hospital parameter changes on patient outcomes.

Outcome (per 1000 patients with stroke)	Changes undertaken by rural hospitals		
	Uncertified to certified (Change in rt-PA use: 44.9%)	Low- to high-access (Change in rt-PA use: 21.3%)	Adopts telemedicine[a] (Change in rt-PA use: 22%)
Number of patients with death or dependency as measured by a mRS 2–6	−23	−11	−11
Number of patients with death or dependency as measured by a mRS 3–6	−19	−9	−9
Number of patients who were dependent at the end of follow-up as indicated by a mRS 3–5	−22	−10	−11
Number of patients who were treated within 3 h but died or were dependent; randomized within 0–3 and 3–6 hour windows	−34	−16	−17
Number of patients who were treated between 3 and 6 h but died or were dependent; randomized within 0–3 and 3–6 hour windows	−4	−2	−2
Number of patients who were alive and independent (mRS 0–2) at end of follow-up; treated within 3 h	41	19	20
Number of patients who were alive and independent (mRS 0–2) at end of follow-up; treated between 3 and 6 h	8	4	4

mRS, Modified Rankin Score.
[a] Assumes conservative estimate of a 22% increase in rt-PA use with eligible patients.

recognized that increasing access to neurological services in underserved areas can improve stroke care quality [13], it may be challenging and also cost-prohibitive to find skilled professionals. With growing demand for treatment of other neurological disorders, such as Alzheimer's disease, training and hiring additional neurologists may not substantially close the gap in quality stroke care.

A possible solution to this issue of disparity in access to neurological services is to better leverage the time of stroke neurologists through telemedicine. Observational studies have demonstrated that introducing telemedicine has the potential to increase the rate of rt-PA use by an absolute difference of 2.2%–5.1% among patients with stroke (Online-only Supplement Table II) [25-28]. When combined with the observations of a recent study finding that approximately one in 10 patients were fully eligible for rt-PA treatment [31], there is potential for an increase in STK-4 performance of 22%–51% with the implementation of telemedicine.

The simulated impact of incorporating telemedicine improved patient outcomes by an amount that was comparable to our hypothetical scenario in which a rural hospital changed from low to high access for neurological services. While this is not conclusive, it is consistent with the idea that implementing telemedicine could bridge the quality gap between low- and high-access hospitals. Since hiring a full-time stroke neurologist may be impractical for many non-metropolitan hospitals, telemedicine could be a reasonable alternative to improve access to specialist services and provide higher quality care to their patients with stroke [32].

Telemedicine, however, is not the only solution to increasing access to neurological services for patients with stroke. Given the importance of distance-related obstacles to receiving rt-PA, mobile stroke units, ambulances equipped with CT scanners and on-board or remote neurological services have been utilized in other countries to reduce the time from stroke onset to treatment [30,33]. In the United States, initiatives like education programs and toolkits for Emergency Medical Service providers have been effective in reducing distance-related barriers for stroke care, as they enable these emergency workers to better identify stroke symptoms and provide care [34]. Additionally, the "drip and ship" method, in which patients are administered rt-PA in a local emergency room and transferred to a stroke center, can increase the rate of rt-PA use [35].

Our study has several limitations. First, the methodology used did not allow us to measure the causal impact of access to neurological services on stroke care quality. It is reasonable to assume that hospitals in low-access counties are different from hospitals in high-access counties in terms of characteristics beyond those measured in this study, which may affect the quality of care. Moreover, we cannot control for potential confounding differences in the patient population across hospitals, such as stroke severity, comorbidities, and measures of socioeconomic status. In addition, we were only able to measure disparities in quality of care for hospitals reporting STK measures and thus were unable to measure the potential impact of increased access to neurological services when hypothetically "turning" a hospital into a stroke-ready institution. Therefore, it is possible that the impact of access to neurological services on improving stroke care has been underestimated in this study.

The data generated from our analysis also have inherent limitations. We measured the level of access to neurological services as the per-capita number of neurologists in each county. In reality, neurologists with adequate skills to evaluate stroke patients are a small subset of all neurologists, although the per-capita number of all neurologists is likely positively correlated to the per-capita number of stroke neurologists (the requirement for it to serve as a proxy variable). However, sensitivity analyses confirmed that our results are robust for alternative measures of access.

We also assumed that hospitals reporting STK measures provided stroke care on a semi-regular basis; however, because of insufficient data we did not stratify hospitals by their volume of patients with stroke. Since Hospital Compare did not collect data on the STK measures prior to 2013, reporting in our data was low overall and disproportionally so in non-metro areas – particularly in terms of STK-4. Thus the sample of reporting hospitals may not be representative of all hospitals in a given location.However, we found that reporting errors are reasonably stable across locations (Online-only Supplement Table IV). Moreover, differences in measured performance may reflect differences in hospital coding and documentation, which maybe correlated with level of certification.

Furthermore, when identifying stroke centers, we relied exclusively on JC certification. Other certifying authorities exist, and these were not captured by the analysis. While JC certification ensures the highest standards of care [21], excluding other certifications may overestimate the impact of access to neurological services. Also, our dataset does not indicate how many non-certified hospitals in our sample currently use telemedicine, which could result in an overestimation of the impact of telemedicine in the simulation. Finally, it is unknown whether there currently is a sufficient supply of neurologists who would be willing to participate in the expansion of telemedicine beyond its current levels.

5. Conclusions

In our study, we found that the quality gap in stroke care between metropolitan and non-metropolitan areas is significant. These findings also suggest that adequate access to neurological services may improve rates of rt-PA use. However, given the current shortage of neurologists in the US [36], telemedicine – which has been demonstrated to be an effective method in the treatment of stroke [25-28] – could improve outcomes for rt-PA-eligible patients with stroke in under-resourced hospitals by facilitating access to neurological services.

Sources of support

The research reported in this manuscript and the medical writing support provided for this manuscript was supported by Genentech, Inc. through consulting fees paid to PHE.Genentech and PHE collaborated to conduct the study.Both Genentech and PHE participated in the interpretation of data, review, and approval of the manuscript.

Disclosures

Seth Seabury: Associate Professor of Research Emergency Medicine, Keck School of Medicine of USC, Consultant for Precision Health Economics.

Yaping Xu, S. Renee Commerford, Darren Tayama: Employees of Genentech, Inc. and hold stocks at Roche and Genentech.

Katalin Bognar, Caroline Huber: Employees of Precision Health Economics.

Acknowledgments

The authors take full responsibility for the content of the paper. They thank Marcia Reinhart and Leslie Grad for medical writing support and editorial assistance.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.ajem.2017.03.046.

References

[1] Skinner J. Causes and consequences of regional variations in health care. Handb Health Econ 2011;2:45–93.

[2] Liao Y, Greenlund KJ, Croft JB, Keenan NL, Giles WH. Factors explaining excess stroke prevalence in the US Stroke Belt. Stroke; A Journal of Cerebral Circulation 2009; 40(10):3336–41.

[3] Ovbiagele B, Goldstein LB, Higashida RT, Howard VJ, Johnston SC, Khavjou OA, et al. Forecasting the future of stroke in the United States: a policy statement from the American Heart Association and American Stroke Association. Stroke; A Journal of Cerebral Circulation 2013;44(8):2361–75 Epub 2013/05/24 10.1161/STR.0b013e31829734f2. (PubMed PMID: 23697546).

[4] Shultis W, Graff R, Chamie C, Hart C, Louangketh P, McNamara M, et al. Striking rural-urban disparities observed in acute stroke care capacity and services in the pacific northwest: implications and recommendations. Stroke; A Journal of Cerebral Circulation 2010;41(10):2278–82 Epub 2010/09/04 10.1161/STROKEAHA.110.594374. (PubMed PMID: 20813997).

[5] Audebert HJ, Kukla C, Clarmann von Claranau S, Kuhn J, Vatankhah B, Schenkel J, et al. Telemedicine for safe and extended use of thrombolysis in stroke: the Telemedic Pilot Project for Integrative Stroke Care (TEMPiS) in Bavaria. Stroke; A Journal of Cerebral Circulation 2005;36(2):287–91 Epub 2004/12/31 10.1161/01.STR.0000153015.57892.66. (PubMed PMID: 15625294).

[6] Graham GD. Tissue plasminogen activator for acute ischemic stroke in clinical practice a meta-analysis of safety data. Stroke; A Journal of Cerebral Circulation 2003; 34(12):2847–50.

[7] Jauch EC, Saver JL, Adams HP, Bruno A, Demaerschalk BM, Khatri P, et al. Guidelines for the early management of patients with acute ischemic stroke a guideline for healthcare professionals from the American Heart Association/American Stroke Association. Stroke; A Journal of Cerebral Circulation 2013;44(3):870–947.

[8] Disorders TNIoN, Group Sr-PSS. Tissue plasminogen activator for acute ischemic stroke. N Engl J Med 1995;333(24):1581–8. http://dx.doi.org/10.1056/NEJM199512143332401 (PubMed PMID: 7477192).

[9] Lansberg MG, O'Donnell MJ, Khatri P, Lang ES, Nguyen-Huynh MN, Schwartz NE, et al. Antithrombotic and thrombolytic therapy for ischemic stroke: antithrombotic therapy and prevention of thrombosis, 9th ed: American College of Chest Physicians Evidence-Based Clinical Practice Guidelines. Chest 2012;141(Suppl. 2):e601S–36S Epub 2012/02/15 10.1378/chest.11-2302. (PubMed PMID: 22315273; PubMed Central PMCID: PMCPmc3278065).

[10] Demaerschalk BM, Miley ML, Kiernan TE, Bobrow BJ, Corday DA, Wellik KE, et al. Stroke telemedicine. Mayo Clin Proc 2009;84(1):53–64 Epub 2009/01/06 10.1016/S0025-6196(11)60808-2. (PubMed PMID: 19121244; PubMed Central PMCID: PMC2664571).

[11] Eissa A, Krass I, Bajorek BV. Optimizing the management of acute ischaemic stroke: a review of the utilization of intravenous recombinant tissue plasminogen activator (tPA). J Clin Pharm Ther 2012;37(6):620–9 Epub 2012/06/20 10.1111/j.1365-2710.2012.01366.x. (PubMed PMID: 22708668).

[12] Eissa A, Krass I, Bajorek B. Barriers to the utilization of thrombolysis for acute ischaemic stroke. J Clin Pharm Ther 2012;37(4):399–409.

[13] Skolarus LE, Meurer WJ, Shanmugasundaram K, Adelman EE, Scott PA, Burke JF. Marked regional variation in acute stroke treatment among medicare beneficiaries. Stroke; A Journal of Cerebral Circulation 2015;46(7):1890–6 Epub 2015/06/04 10.1161/STROKEAHA.115.009163. (PubMed PMID: 26038520).

[14] Mullen MT, Wiebe DJ, Bowman A, Wolff CS, Albright KC, Roy J, et al. Disparities in accessibility of certified primary stroke centers. Stroke; A Journal of Cerebral Circulation 2014;45(11):3381–8.

[15] Kulcsar M, Gilchrist S, George MG. Improving stroke outcomes in rural areas through telestroke programs: an examination of barriers, facilitators, and state policies. Telemedicine Journal and E-health: The Official Journal of the American Telemedicine Association 2014;20(1):3–10 Epub 2013/11/30 10.1089/tmj.2013.0048. (PubMed PMID: 24286197).

[16] Centers for Medicare & Medicaid Services. Medicare.gov - hospital compare 2015 [cited 2015 5 October] Available from: https://www.medicare.gov/hospitalcompare/search.html.

[17] Centers for Medicare & Medicaid Services. HOSArchive_Revised_Flatfiles_20150122.zip; 2015.

[18] Centers for Medicare & Medicaid Services. Hospital inpatient quality reporting program 2015 [cited 2015 October 5] Available from: https://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-Instruments/HospitalQualityInits/HospitalRHQDAPU.html.

[19] QualityNet. Measure comparison (inpatient hospital quality measures) 2015 [cited 2015 October 5] Available from: https://www.qualitynet.org/dcs/ContentServer?c=Page&pagename=QnetPublic%2FPage%2FQnetTier3&cid=1138900297065.

[20] U.S. Department of Agriculture Economic Research Service. Rural-urban continuum codes overview 2013 [cited 2015 October 5]. Available from: http://www.ers.usda.gov/data-products/rural-urban-continuum-codes.aspx.

[21] The joint commission. Stroke certification programs; 2015(Epub January 30, 2015).

[22] Health Resources and Services Administration. 2014–2015 area health resources file. Fairfax, Virginia: U.S. Department of Health and Human Services; 2015.

[23] Wennberg JE, Fisher ES, Goodman DC, Skinner JS. Tracking the care of patients with severe chronic illness-the Dartmouth Atlas of health care 2008; 2008.

[24] Schneider SM, Goldstein LB, Adams JG, KL DeHart, Demchuk AM, Furlan AJ, et al. Improving the chain of recovery for acute stroke in your community: task force report. Bethesda: National Institute of Health; 2002.

[25] Audebert HJ, Kukla C, Vatankhah B, Gotzler B, Schenkel J, Hofer S, et al. Comparison of tissue plasminogen activator administration management between telestroke network hospitals and academic stroke centers: the telemedical pilot project for integrative stroke care in Bavaria/Germany. Stroke; A Journal of Cerebral Circulation 2006;37(7):1822–7 Epub 2006/06/10 10.1161/01.STR.0000226741.20629.b2. (PubMed PMID: 16763192).

[26] Audebert HJ, Schenkel J, Heuschmann PU, Bogdahn U, Haberl RL. Telemedic pilot project for integrative stroke care g. effects of the implementation of a telemedical stroke network: the Telemedic Pilot Project for Integrative Stroke Care (TEMPiS) in Bavaria, Germany. The Lancet Neurol 2006;5(9):742–8 Epub 2006/08/18 10.1016/S1474-4422(06)70527-0. (PubMed PMID: 16914402).

[27] Choi JY, Porche NA, Albright KC, Khaja AM, Ho VS, Grotta JC. Using telemedicine to facilitate thrombolytic therapy for patients with acute stroke. Joint Commission Journal on Quality and Patient Safety/Joint Commission Resources 2006;32(4): 199–205 Epub 2006/05/03. (PubMed PMID: 16649650).

[28] Pedragosa A, Alvarez-Sabin J, Molina CA, Sanclemente C, Martin MC, Alonso F, et al. Impact of a telemedicine system on acute stroke care in a community hospital. J Telemed Telecare 2009;15(5):260–3 Epub 2009/07/11 10.1258/jtt.2009.090102. (PubMed PMID: 19590033).

[29] Wardlaw JM, Murray V, Berge E, del Zoppo GJ. Thrombolysis for acute ischaemic stroke. Cochrane Database Syst Rev 2014;7:CD000213 Epub 2014/07/30 10.1002/14651858.CD000213.pub3. (PubMed PMID: 25072528; PubMed Central PMCID: PMC4153726).

[30] Leira EC, Hess DC, Torner JC, Adams Jr HP. Rural-urban differences in acute stroke management practices: a modifiable disparity. Arch Neurol 2008;65(7):887–91 Epub 2008/07/16 10.1001/archneur.65.7.887. (PubMed PMID: 18625855).

[31] Schwamm LH, Ali SF, Reeves MJ, Smith EE, Saver JL, Messe S, et al. Temporal trends in patient characteristics and treatment with intravenous thrombolysis among acute ischemic stroke patients at get with the guidelines-stroke hospitals. Circ Cardiovasc Qual Outcomes 2013;6(5):543–9 Epub 2013/09/21 10.1161/CIRCOUTCOMES.111.000303. (PubMed PMID: 24046398).

[32] Meyer BC, Demaerschalk BM. Telestroke network fundamentals. Journal of Stroke and Cerebrovascular Diseases: The Official Journal of National Stroke Association 2012;21(7):521–9 Epub 2012/08/14 10.1016/j.jstrokecerebrovasdis.2012.06.012. (PubMed PMID: 22885074).

[33] Parker SA, Bowry R, Wu T-C, Noser EA, Jackson K, Richardson L, et al. Establishing the first mobile stroke unit in the United States. Stroke; A Journal of Cerebral Circulation 2015;46(5):1384–91.

[34] Okon NJ, Fogle CC, McNamara MJ, Oser CS, Dietrich DW, Gohdes D, et al. Statewide efforts to narrow the rural–urban gap in acute stroke care. Am J Prev Med 2010; 39(4):329–33.

[35] Sheth KN, Smith EE, Grau-Sepulveda MV, Kleindorfer D, Fonarow GC, Schwamm LH. Drip and ship thrombolytic therapy for acute ischemic stroke use, temporal trends, and outcomes. Stroke; A Journal of Cerebral Circulation 2015;46(3):732–9.

[36] Dall TM, Storm MV, Chakrabarti R, Drogan O, Keran CM, Donofrio PD, et al. Supply and demand analysis of the current and future US neurology workforce. Neurology 2013;81(5):470–8 Epub 2013/04/19 10.1212/WNL.0b013e318294b1cf. (PubMed PMID: 23596071; PubMed Central PMCID: PMC3776531).