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Telestroke Adoption among Community Hospitals in North Carolina: a Cross-sectional Study

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Abstract

Objective—In this study, we identify community and hospital characteristics associated with adoption of telestroke among acute care hospitals in North Carolina (NC).

Methods—Our sample included 107 acute care hospitals located in NC. Our analytic dataset included variables from the AHA Annual Survey, AHA Health IT supplement, Healthcare Cost Report Information System (HCRIS), and the Centers for Disease Control and Prevention's WONDER online database. We supplemented our secondary sources with data on telestroke adoption (for which there is no national data source) and market-level variables developed for NC. We used the Consolidated Framework for Implementation Research and previous telehealth studies to guide our selection of variables to include in our model. We conducted a multivariate logistic regression to determine which variables were associated with telestroke adoption.

Results—Proportion of discharges that are Medicare (OR=1.93, $p<0.04$) and total operating margin (OR=2.89, $p=0.00$) were positively associated with telestroke adoption. Critical Access Hospital status was positively associated telestroke adoption, although not at $p<0.05$ (OR=5.61, $p=0.07$). Distance to the nearest hospital with a telestroke program (OR=0.91, $p=0.01$) and volume of ED visits (OR=0.98, $p<0.05$) were both negatively associated with telestroke adoption.

Conclusions—Our study is novel in its focus on telestroke adoption specifically, rather than telehealth adoption generally, and for including variables not included in previous telehealth analyses. Our findings suggest some hospitals may have neither the financial resources nor the ability to pool resources for acquiring needed technology, and differences in adoption may result in geographic inequities in access to telestroke services.

Key Terms

Stroke; Telemedicine; Telestroke; Medical Care; Hospitals; Emergency Health Services; Rural Health Services; Organizational Innovation

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INTRODUCTION

Telestroke involves synchronous audio and visual communication between individuals at an originating site (i.e., where the patient presents) and a distance site (i.e., where the clinical consultant is located). By providing remote access to stroke experts, telestroke reduces the time required to transport a patient prior to receiving care from a stroke specialist.(1) Without assistance from stroke specialists, emergency department (ED) physicians may be reluctant to prescribe tissue Plasminogen Activator (tPA—the gold standard for treatment of ischemic strokes(2,3)—because of its potential adverse side effects, including intracranial or other systemic hemorrhage.(4) By reducing transport time and “door-to-needle time” for tPA,(5) telestroke has potential to reduce stroke-related morbidity and mortality.(6–9) Therefore, the American Heart Association and American Stroke Association recommend the use of telestroke when an on-site assessment by a specialist is not available and when equipment approved by the Food and Drug Administration (FDA) (or equivalent organization) is used.(10)

Telestroke is a particularly promising approach for rural areas,(11) where the stroke mortality rate is approximately 20% higher than urban areas(12) and training, recruiting and supporting specialized stroke teams simply has not been feasible.(13). Reducing door-to-needle time for tPA administration in rural areas is critical given that only half the US population is estimated to reside within 60 minutes of a primary stroke center(6) and that tPA use is less common in small hospitals and hospitals located in rural locations.(14). By providing access to stroke experts who can manage tPA administration, telestroke services are helping rural hospitals to provide care comparable to hospitals with in-person stroke specialists.(15,16)

Acute care hospitals with an emergency department (ED) and CT scan capabilities, but without their own stroke specialists, are candidates for delivering telestroke to better meet the needs of their communities.(17) However telestroke services have not been widely adopted by acute care hospitals(18,19) and much remains unknown about why some hospitals adopt telestroke and others do not. Identifying the characteristics of hospitals that have adopted telestroke is an important first step toward identifying internal barriers (e.g. organizational, technical, and educational) and external barriers (e.g. economic, legal, and regulatory environment) to providing telestroke—a need that has been highlighted by previous research. (20) Our study helps address this gap in knowledge about telestroke adoption by identifying community and hospital characteristics associated with telestroke adoption among acute care hospitals in North Carolina. Our findings have the potential to impact legislative policy and health system development.

METHODS

Standard protocol approvals, registrations, and patient consents

This study did not use individual patient data and was reviewed by the Institutional Review Board at the University of North Carolina at Chapel Hill (IRB # 16-2890).

Data Sources and Sample

The study sample included 107 acute care hospitals located in the state of North Carolina (NC) that completed the American Hospital Association (AHA) annual survey in 2015. Acute care hospitals were defined as short-term hospitals that provide care in a range of areas including emergency medicine; therefore, hospitals that focus on long-term care or specialty care (e.g., cancer hospitals and substance use facilities) were not included. Situated in the nation's stroke belt, NC has a higher than national average rate of stroke mortality.(21) Additionally, NC is made up largely of rural counties (70 rural counties compared to 30 urban counties)(22) and therefore is an appropriate setting for examining telestroke adoption, which is of particular importance to rural hospitals. We focused on one state, rather than a national sample, in order to supplement our secondary data sources with data on telestroke adoption. For example, although the AHA Health IT supplement includes data on whether a hospital has a telehealth program, it does not indicate which specific telemedicine services are offered, and we are aware of no national data set that does so. Therefore, we developed a list of acute care hospitals that have adopted telestroke by administering a survey to representatives from telestroke distant sites within NC stroke networks. Distant sites are defined as primary medical centers, such as a primary or comprehensive stroke center, that provide telestroke consultation services via synchronous live video to other hospitals (i.e., originating sites) in the telestroke network. In addition to developing a list of hospitals providing telestroke services, we also were able to include in our analysis market-level variables developed for the state.

For our comparison group, we selected acute care hospitals with an emergency department and CT scanning capability but that were not participating in a telestroke network. We excluded government-owned hospitals because their telemedicine adoption decisions may be driven by a unique set of factors. By selecting these inclusion and exclusion criteria, our goal was to include only hospitals that would be likely candidates to adopt telestroke. Because of the small sample size, all hospitals that met our inclusion criteria were retained in the comparison group.

In addition to an indicator of telestroke adoption, our analytic dataset included variables on hospital characteristics from the 2015 AHA Annual Survey, 2015 AHA Health IT supplement, and 2015 Healthcare Cost Report Information System (HCRIS), and population characteristics from the Centers for Disease Control and Prevention's WONDER online database, covering the period 2012–2014.

Conceptual Framework and Measures

We used the Consolidated Framework for Implementation Research (CFIR) as our primary framework for identifying variables pertinent to telestroke adoption.(23). CFIR builds upon classic theories(24) to identify constructs associated with innovation adoption and implementation and has been applied to a range of innovations and care settings, including stroke care.(25) CFIR includes five domains, two of which in particular (outer setting and inner setting) are consistent with the previous call for identifying both internal and external barriers to telestroke adoption.(20,23) Both domains include multiple constructs. We

complemented CFIR constructs with constructs identified in previous telehealth studies. (26,27)

The outer setting refers to the economic, political, and social context of an organization.(23). Within the outer setting, hospitals in competitive markets may feel peer pressure to adopt technologies that their peer hospitals have adopted to maintain or increase their market share.(23) A recent study of telehealth adoption found evidence of peer pressure, with hospitals in more competitive markets being more likely to adopt telehealth programs.(26) To measure peer pressure, we examined two variables: distance in miles to another hospital with telestroke and distance in miles to a hospital with primary stroke center certification from The Joint Commission. We measured distance in straight miles rather than driving distance because previous studies(28) suggest that straight-line distance is a more appropriate measure for geographic areas, like NC, that have physical barriers such as mountains. Additionally, hospitals considering adopting telestroke may be influenced by their patients' needs.(23) Hospitals, for example, might prioritize the adoption of telestroke over other healthcare innovations if the hospital is located in a region of the country with a high prevalence of stroke. To measure patient needs, we examined the rate of stroke hospitalizations in the hospital's county, the percentage of patients within a hospital's market who reside in a rural area, and whether the hospital is classified as a critical access hospital (CAH). These measures build upon a previous study of telehealth adoption that found rural location of the hospital to be positively associated with telehealth adoption.(26) Finally, we expected affiliation with an integrated delivery system to be a potential factor associated with telestroke adoption. However, data sources for our sample indicated very little variation in this variable, with nearly 100% of hospitals in the sample belonging to a health system. Therefore, we did not use this variable in our model.

The inner setting of an organization refers to characteristics of the organization itself. Regarding hospital structure, we included the number of emergency room visits per year, which is a proxy for patient volume and particularly appropriate for stroke patients because most stroke patients would present at the hospital's ED. We expected ED visits to be positively associated with telestroke adoption. We also examined a hospital's available resources, which is likely to influence the hospital's ability to adopt telestroke. Measures of resources included total operating margin (i.e., profitability of the hospital), payer mix (e.g., the proportion of hospital days that are Medicare days), telehealth capacity, and teaching status. Although we found no studies of telehealth adoption that included hospital finances, we included them in our model to examine whether hospitals with greater profitability have more financial resources for investments in staffing, training, and technology to support telestroke adoption.(23) We also found no other studies examining whether telehealth capacity (i.e., having an existing telehealth service) influences adoption of another telehealth service.(26) However, based on interviews conducted with acute care hospital representatives (which are ongoing), we believed such a relationship might exist, with hospitals offering another telehealth service being more likely to adopt telestroke because they have telehealth experience and may be able to realize synergies within their existing telehealth infrastructure. Although a comprehensive list of telehealth services offered in the state was not available, we were able to access a list of hospitals with telepsychiatry. We deemed the presence of telepsychiatry as being a better indicator of telehealth capacity than

the composite telehealth variable in the AHA Health IT supplement because that variable does not delineate between types of telehealth and presumably includes telestroke services. Finally, we included the teaching status variable to be consistent with previous research that found teaching hospitals to be more likely to adopt telehealth,(26) perhaps because using innovative approaches aligns with the mission of teaching hospitals or because residents may serve as an additional resource to support telestroke services in originating sites. We defined teaching status as any hospital having at least one resident in the year 2015.

Statistical Analysis

First, we compared baseline characteristics for the outer and inner setting variables between hospitals that adopted telestroke and hospitals that had not adopted telestroke. Second, we conducted a multivariate logistic regression to determine which variables were associated with telestroke adoption. To deal with missing data, we used the complete case analysis method, as the amount of the missing data was low. For the 107 hospitals in the sample, we had complete data on the majority of variables and no more than 3% missing data on any variable. We tested for multicollinearity of variables that we thought might be highly correlated, such as rural location and critical access hospital, but did not find any problems related to multicollinearity. We also considered that there might be a clustering effect at the county-level, with hospitals in the same county being more similar as compared to hospitals across counties. We ran the analysis with clustered standard errors and without clustered standard errors and found that the standard errors for both models were similar, suggesting that there is not a clustering effect. Therefore, the final model was run with unclustered standard errors. We rescaled the emergency department visits variable since it had a larger range than the other variables and we wanted to reduce the likelihood of heteroskedasticity. We also conducted a Hosmer-Lemeshow goodness of fit test to determine if adding non-linear or interaction terms would improve model fit. Based on the results, we did not find that adding non-linear or interaction terms improved model fit.

RESULTS

From the sample of 107 hospitals in our dataset, the majority was located in a rural area (57.4%), had a telestroke program (60.7%), and were critical access hospitals (76.6%). Fewer hospitals had a tele-psychiatry program (33.6%) and were teaching hospitals (25.2%). The mean of straight-line distance to the nearest hospital with primary stroke center certification was 24.4 miles, with 75.7% of hospitals being less than 30 miles from the nearest stroke center. The mean of straight-line distance to nearest hospital with telestroke services was 17.7 miles, with 90.6% of hospitals being less than 30 miles from the nearest telestroke hospital. The mean age-adjusted stroke hospitalization rate defined for counties was 11.9 per 1,000 residents with the range of 6.4 to 16.3. The mean number of ER visits per hospital was 46,853 with a range of 2,624 and 225,864. The mean total operating margin was 0.047 (4.7%). See Table 1 for a summary of hospital characteristics.

Our logit model indicates that the distance to nearest telestroke program, number of ER visits, proportion of discharges that are Medicare, and total operating margin are significantly associated ($p < 0.05$) with the probability that a hospital has adopted telestroke.

As shown Table 2, holding all other variables constant, a one-mile increase in distance to the nearest hospital with a telestroke program is associated with a decrease of 0.09 in the odds that a hospital adopted telestroke, which suggests that hospitals farther from a hospital with telestroke have lower odds of adopting telestroke. Hospitals with a higher volume of ER visits also have lower odds of telestroke adoption. Hospitals with a higher proportion of discharges that are Medicare and a higher total operating margin have higher odds of telestroke adoption. Also, using a threshold of $p < 0.1$, being a CAH is positively and significantly associated telestroke adoption ($p = 0.07$). Although $p < 0.1$ is a liberal threshold, this relationship is worth noting due to the small sample size, the large effect size, and the potential policy implications of this finding.

DISCUSSION

Our study examined adoption of telestroke services among acute care hospitals in North Carolina. Contrary to our original hypotheses, we found that certain indicators of patients' needs for telestroke, such as rural hospital location and stroke hospitalization rate, were not associated with telestroke adoption. Additionally, we found that the hospital's capability for telehealth (i.e., presence of a telepsychiatry program) and teaching status were not associated with telestroke adoption. Consistent with our hypotheses, we found factors in the external environment (e.g., market competition and CAH status) and factors within the hospital (e.g., payer mix, patient volume, and hospital profitability) were associated with telestroke adoption. Below we outline the unique contribution of our findings.

Our findings about internal hospital characteristics suggest that more financially vulnerable hospitals (i.e., those with a lower total margin) may be less likely to adopt telestroke. Beginning a telestroke program requires a substantial investment in technology and staff time such as purchasing telecommunications equipment, hiring a telestroke coordinator, and providing staff training.⁽²⁹⁾ Hospitals that are struggling from a profitability perspective simply may not be able to justify that investment. To the best of our knowledge there is no other study that included hospital financial variables in an analysis of telestroke adoption, so this is a particularly notable finding. We also found that hospitals with a higher Medicare payer mix are more likely to adopt telestroke services suggesting that available resources for telestroke (e.g., reimbursement from Medicare) may affect adoption. Since Medicare payment rules for telemedicine are limited to certain hospital types, future studies could examine whether reimbursement restrictions affect telestroke adoption among certain hospitals. Furthermore, our finding that a higher volume of ED visits is negatively associated with telestroke adoption has potential workforce implications. For example, hospitals may need a critical mass of physicians or nursing staff to support telestroke, and higher-volume hospitals may have such a critical mass. Future studies could examine how hospital workforce, such as number of neurologists, emergency department physicians, and nursing staff, correlates with telestroke adoption.

In the external environment, market competition is an important consideration, as we found hospitals farther from telestroke hospitals to be less likely to adopt telestroke themselves. This finding supports previous research suggesting the competitive market pressure may be a driver of telehealth adoption.⁽²⁶⁾ Notably, this competitive pressure may run counter to a

community's need for the service. The finding that CAH designation is positively associated with telestroke adoption ($p=0.07$) is also noteworthy. Past studies have suggested that CAHs vary in their ability to adopt technological innovations due to differences in support and resources.(30) Some CAHs, for example, pool resources with other CAHs or use group purchasing for health information technology, which may assist with technology adoption such as telestroke.(30) It is also possible that integrated delivery systems have prioritized their affiliated CAHs for support needed to provide telestroke services. Our study did not find that rural hospitals—which have historically had more difficulty staffing neurological specialists—were more likely to adopt telestroke. Future studies could examine whether other measures of healthcare access—such as ratio of specialists to patients—affects telestroke adoption.

Although our study is an important step toward understanding telestroke adoption, the aim of developing a full profile of telestroke non-adopters warrants further research. For example, the profile of telestroke non-adopters could be a subset of small rural hospitals that do not meet the CAH criteria. However, developing a profile of non-adopters may require additional data sources, particularly related to hospital-level variables, such as existing telehealth infrastructure (e.g., other telehealth services and Internet capabilities). Another approach that may yield insight into a non-adopter profile is geographic or spatial analysis, which could reveal interrelationships between distance, community, and hospital characteristics.

Limitations

Our study has a few limitations. This study examines telestroke adoption among acute care hospitals in NC and therefore may have limited generalizability to other states. State laws and regulations supporting telemedicine—such as medical licensure, hospital credentialing, and reimbursement—vary widely, and may affect hospital adoption of telestroke.(31,32) Further research is needed to determine whether the factors associated with telestroke adoption identified in this study reflect telestroke adoption in hospitals located in other states. There are also limitations to the data sources that were used. As an example, the AHA annual survey has greater participation among larger hospitals (greater than 200 beds) than smaller hospitals.(33) However, in NC there are 110 non-government owned, acute care hospitals(34) and we were able to include 107—suggesting that non-response bias may not be a problem. Additionally, we were unable to collect data on whether the hospitals in our study offer telemedicine services in addition to telestroke and tele-psychiatry, such as tele-radiology, which may be associated with telestroke adoption. Finally, our study was cross-sectional; it is possible that a longitudinal model might capture dynamic effects of other variables that are influential in telestroke adoption. Nonetheless, this study represents a unique contribution to the literature by identifying factors associated with telestroke adoption specifically, as opposed to telehealth adoption in general.

CONCLUSIONS

Our study of telestroke adoption by acute care hospitals in North Carolina builds upon previous telehealth-adoption literature by focusing on telestroke in particular and including

variables that typically have not been included in telehealth analyses. Perhaps most notable are the positive associations between telestroke adoption and total operating margin and CAH status, which suggest some hospitals may have neither the financial resources nor the ability to pool resources for acquiring needed technology. Also, the negative association between telestroke adoption and distance to another hospital with telestroke services suggests geographic inequities in access to telestroke services.

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Table 1

Characteristics of Hospitals in the Sample (n=107)

	Adopters Mean (N=65)	Non adopters Mean (N=42)	All hospitals Mean (N=107)	P value ^a
Outer Setting Factors				
Distance to nearest telestroke program/miles	15.56	21.13	17.71	0.0026
Distance to nearest stroke center/miles	23.7	25.6	24.4	0.57
Percentage of residents living in urban area (market-level)	49.1	32.4	42.6	0.03 ^a
Stroke hospitalization rate (county-level) ^b	11.9	11.8	11.9	0.93
Inner Setting Factors				
Critical access hospital (%)	0.87	0.67	0.79	0.01
Total operating margin	0.08	-0.006	0.04	0.0005
Having a tele-psychiatry program	0.31	0.39	0.34	0.38
Teaching hospital	0.24	0.24	0.24	0.97
Proportion of discharges that are Medicare	0.39	0.41	0.4	0.47
ER visits (thousands)	48.8	43.5	46.8	0.52

^a 2-tailed T test;^b The stroke hospitalization rate is calculated over a two-year period (2012–2014) to ensure that there are a sufficient number of cases in each county in NC.

Table 2

Multivariable model for variables associated with adopting telestroke program (n=107)

	OR	95% CI	P value ^a
Outer Setting Factors			
Distance to nearest telestroke program/miles	0.91	0.84–0.97	0.01
Distance to nearest stroke center/miles	1.02	0.98–1.06	0.24
Percentage of residents living in urban area (market-level) ^b	1.01	0.99–1.03	0.29
Stroke hospitalization rate (county-level) ^b	1.06	0.82–1.38	0.65
Inner Setting Factors			
Critical access hospital	5.61	0.89–35.28	0.07
Total operating margin	2.89	1.40–5.94	0.00
Having a tele-psychiatry program	2.49	0.71–8.70	0.15
Teaching hospital	2.09	0.51–8.55	0.31
Proportion Medicare discharge	1.93	1.02–3.66	0.04
ER visit	0.98	0.97–1.00	0.04
Constant	0.03	0.00–2.76	0.13

Abbreviations: CI = confidence interval; OR = odds ratio;

^a 2-tailed T test;^b The stroke hospitalization rate is calculated over a two-year period (2012–2014) to ensure that there are a sufficient number of cases in each county in NC.