Although tissue plasminogen activator (tPA) is an effective treatment for acute ischemic stroke and has been widely available since 1996, it is still underutilized. Low tPA treatment rates, only 3.4% to 5.2% in 2009, are troubling because evidence supports the efficacy of intravenous tPA (IV-tPA) in improving patient outcomes.  

To aggressively address the challenges of stroke treatment, Saint Luke’s Hospital, a tertiary care community hospital in Kansas City, Missouri, developed a dedicated stroke center in 1993. It subsequently expanded into a full-service Neuroscience Institute and regionally organized stroke referral network of >70 hospitals. Saint Luke’s Neuroscience Institute (SLNI) has developed over time a systems approach to all aspects of the stroke treatment continuum, including the following: extensive efforts to increase public and professional awareness and education; 24/7 access to stroke expertise and technology for patients living within 150 miles of the center; standardized order sets and care paths; interventional stroke reversal protocols to extend the treatment window up to 8 hours after onset; cutting-edge imaging; timely communication of outcomes to referring physicians and emergency medical service providers; development and support of the regional referral network; help for patients who are ineligible for standard care participate in clinical trials; and evidence-based practices for preventing complications and secondary stroke and for promoting early rehabilitation.  

The aim of such initiatives was to increase stroke awareness, improve access to coordinated care, and, ultimately, improve outcomes. Because of the incremental nature of these efforts, they potentially may be considered for implementation across other community hospitals.

Background and Purpose—Compare access and outcomes in a tertiary care community hospital (Saint Luke’s Neuroscience Institute) and its stroke network to hospitals in 3 national databases.

Methods—Retrospective analysis of ischemic stroke patients (2005, 2007, 2010) in Saint Luke’s (n=1576), Get With The Guidelines-Stroke (n=423 809), Premier (n=91 598), and Merci Registry (n=966). Study measures were use of computed tomography scans and tissue plasminogen activator (tPA), symptomatic intracranial hemorrhage, discharge disposition, discharge National Institutes of Health Stroke Scale scores, and 90-day modified Rankin Scores.

Results—Saint Luke’s increased access to care with higher tPA use than other hospitals (17.2% received intravenous tPA therapy compared with 5.8% at Get With The Guidelines–Stroke hospitals, \( P<0.001 \); 22.1% of Saint Luke’s patients received tPA by any route compared with 3.5% of Premier patients, \( P<0.001 \)). Use of intravenous tPA within 4.5 hours of onset was associated with more discharges to home (odds ratio, 2.123; 95% confidence interval, 1.394–3.246) and improved National Institutes of Health Stroke Scale scores (\( P=0.001 \). Saint Luke’s patients also were more likely than those in other hospitals to receive computed tomography scans (99.4% vs 58.6% at Premier hospitals). Embolectomy at Saint Luke’s was associated with better outcomes than peer hospitals, and treatment at Saint Luke’s was independently associated with more discharges to home (odds ratio, 3.92; 95% confidence interval, 1.84–8.32). In 2010, symptomatic intracranial hemorrhages after tPA therapy was similar for Saint Luke’s patients and Premier patients (2.2% vs 1.5%; \( P=0.590 \)).

Conclusions—Regionally coordinated stroke programs can substantially improve access and patient outcomes.

Key Words: guidelines ■ thrombolytic ■ tissue plasminogen activator ■ stroke
The purpose of this study was to compare the impact of these incremental improvements on access to stroke care and outcomes in SLNI and its stroke network with national benchmarks of peer hospitals based on Get With the Guidelines–Stroke (GWTG-Stroke), Premier Perspective (Premier), and the Mechanical Embolus Removal in Cerebral Ischemia (Merci) Registry datasets. The results of this project may help other community hospitals identify potential opportunities for improving stroke management.

Methods
This study was a retrospective analysis to evaluate access and effectiveness of SLNI’s stroke treatment compared with that of other stroke centers and hospitals. To the authors’ knowledge, this is the first benchmark evaluation of stroke treatment processes and outcomes using multiple databases. The study was approved by Saint Luke’s Health System Institutional Review Board.

Data Sources Assessed
The lack of a national stroke registry makes quality benchmarking analysis quite challenging. As a result, to adequately benchmark SLNI, a comparison was made with 3 datasets and each approach had to be different because of availability of data and uniqueness of the datasets. GWTG-Stroke is a registry of ≈800 hospitals coordinated by the American Heart Association (AHA) and American Stroke Association. GWTG-Stroke establishes metrics of quality that are subsequently used by The Joint Commission for accreditation of stroke hospitals as Primary Certified Stroke Centers. As a result, this database represents hospitals that have implemented high standards of care. GWTG-Stroke has been shown to improve the use of evidence-based stroke treatment. The data from the SLNI and GWTG-Stroke databases were analyzed for 2005, 2007, and 2010, to summarize patient demographics, treatments, care outcomes, including IV-tPA use, and disposition at discharge.

Premier is an administrative database of 600-plus community hospitals. Although not all variables relevant to stroke management were available for analysis in this database, these data serve as a relevant benchmark to the broad United States community hospital population. Data from the Premier database were available for 2007 and 2010 to contrast SLNI and United States community hospitals in the areas of patient characteristics, access to computed tomography (CT) scanning, use of ICA (either IV or intra-arterial), and discharge disposition. The data available in Premier are limited to acute admission data only and not the full electronic medical record.

The Merci Registry (2007, 2010) is a national prospective registry for facilities using the Merci Retriever evaluating clinical outcomes of mechanical embolectomy used in routine clinical practice. The now-closed registry captured a subset of 966 stroke patients who either were ineligible for or did not have success with treatment with IV-tPA. This study queried the Registry to compare SLNI’s aggregate process and outcomes data with similar leading centers that use mechanical embolectomy; symptomatic intracerebral hemorrhage (sICH) rate (2010 only); discharge disposition; and clinical outcomes. Because the definition of sICH changed with publication of the European Cooperative Acute Stroke Study (ECASS III) in 2009, data for sICH at SLNI were reported for 2010 only.

GWTG-Stroke was queried in November 2011 to determine patient demographics and treatment characteristics from participating stroke centers. The GWTG-Stroke Aggregate Data report was generated using the Outcome PMT system. Copy or distribution of the GWTG-Stroke Aggregate Data report is prohibited without the previous written consent of the AHA and Outcome Sciences, Inc.

Premier was a national benchmark to compare SLNI patients’ demographic and treatment characteristics with those of US community hospitals. International Classification of Diseases, ninth edition, clinical modification (ICD-9) codes (433.01, 433.11, 433.21, 433.31, 433.81, 433.91, 434.01, 434.11, and 434.91) were used to identify patients. The ICD-9 procedure code 99.10 identified patients treated with ICA. IV-tPA administered at an outside facility (ie, drip and ship) was identified with ICD-9 code V45.88. ICD-9 procedure code 99.74 was used to pinpoint patients who received a mechanical embolectomy procedure. Brain hemorrhage as a treatment complication was identified with ICD-9 codes of 431, 432.0, 432.1, and 432.9.

Merci Registry data were queried to examine patient demographic and treatment characteristics, and multivariate regression analyses were conducted to evaluate the impact of SLNI treatment on patient outcomes relative to other contributing sites.

Analysis Plan
SLNI patient-level data were analyzed between years and in aggregate. The AHA provided aggregate information for GWTG-Stroke. Premier had patient-level data for analysis. Concentric Medical conducted patient-level analyses using their Merci Registry and provided aggregated results with comparisons with SLNI. Continuous variables were compared using independent t tests and ANOVA with a Bonferroni post hoc test. Dichotomous variables were compared using χ² analysis. For the multivariate analyses conducted based on the Merci Registry, dependent variables included Modified Rankin Scale (mRS) at 90 days and whether the patient was discharged to their home. A good mRS outcome was defined as scores of 0, 1, or 2, as has been adopted by most trials of intra-arterial therapies. Logistic regression for both of these dependent variables was used to control for independent variables: age; gender; stroke severity using the National Institutes of Health Stroke Scale (NIHSS) score; and comorbidities. Linear regression was used to examine the independent variables associated with hospital length of stay. An α level of 0.05 was used as a threshold for statistical significance.

Results
The numbers of patients identified in the databases were: 1576 in SLNI; 423 809 in GWTG-Stroke; 91 598 in Premier; and 966 in Merci Registry. Table 1 summarizes the demographic characteristics of these stroke patients across databases. Patient ages, proportion of males, and comorbidities were largely similar across databases. It should be noted that the frequency of coronary artery disease in Premier is limited to acute admission data only.

Volume of stroke patients treated at SLNI increased 23% during the study period, from 447 in 2005 to 550 in 2010 (P<0.001). This increase can be explained partly by the number of patients who were transferred from other facilities in the regional network: 654 (41.4%) patients treated at SLNI were transferred across the 3 years and the volume of transfer patients increased by 17% (n=36) during this time period. Of the transferred patients from 2005 to 2010, 137 (20.9%) received IV-tPA at the originating outside hospital before transfer. The absolute number of patients receiving IV-tPA before transfer increased from 39 in 2005 to 70 in 2010.
Patients were transported a mean of 50.5 (SD±39.7) miles; 29 of the hospitals in the network were critical access facilities with 25 or fewer beds. Similar outcomes in terms of mRS scores at 90 days, NIHSS scores at discharge, length of stay, or discharge disposition were observed for transfer patients and original SLNI patients.

Important differences were noted in access to diagnostic testing and rates of stroke intervention between SLNI and the comparison databases (Table 2). Across all years of data, a CT scan of the head was obtained for 99.4% (1567) of SLNI patients and for 58.6% (53 629) of Premier patients (P<0.001). All patients in the Merci Registry had a CT scan, because this was a necessary criterion for inclusion in the registry. According to the GWTG-Stroke measure for diagnostic imaging within 25 minutes of arrival, SLNI data (excluding transfers) indicate 60.2% (n=480) of patients received a CT scan and GWTG-Stroke data showed 26.5% (112 210) of cases obtained a CT scan within this same timeframe (P<0.001).

The use of IV-tPA within 4.5 hours of stroke onset increased over time with both SLNI (13.6% [n=59] in 2005, 28.5% [n=135] in 2010; P<0.001) and GWTG-Stroke patients (4.0% [n=2441] in 2005, 6.8% [n=15 596] in 2010). However, a larger proportion of SLNI patients received IV-tPA in any year assessed compared with GWTG-Stroke (Table 2; P<0.001). A similar finding was noted when comparing Premier hospitals with SLNI across all years of data (use of any tPA defined as either IV-tPA or intra-arterial- tPA): 22.1% (n=333) of SLNI patients received tPA compared with 3.5% (n=3240) of Premier patients (P<0.001). Further, 10.9% (n=144) of SLNI patients had a mechanical embolectomy procedure compared with 0.3% (n=280) of Premier patients (P<0.001).

For SLNI, complete information about sICHs using the 2009 ECASS III definition was only available for 2010.9 Of the SLNI patients who were treated with IV-tPA alone, 2 of 92 (2.2%) had a sICH using this 2009 ECASS III definition. As expected, patients with a hemorrhage in the SLNI database were associated with worse outcomes than were patients without a hemorrhage, as measured by discharge to home, mRS at 90 days, and discharge NIHSS scores.

SLNI’s patient characteristics and stroke severity, as measured by baseline NIHSS scores, were not different from those in the Merci Registry. The strokes at all centers were quite severe, with baseline NIHSS mean scores of 18.8 (±7.7) for SLNI and 17.7 (±6.3) for other hospitals in the Merci Registry.
Registry. There were some statistical differences in how SLNI patients were treated compared with other Registry patients. For example, 41.7% (n=40) of SLNI patients received IV-tPA before embolectomy compared with 29.2% (n=254) of other Registry patients (P=0.014). The mean time from symptom onset to arterial puncture for the procedure was shorter at SLNI (5.6 [±4.1] hours vs 6.5 [±8.4] hours; P=0.047), the length of the procedure was shorter at SLNI (1.5 [±0.8] hours vs 1.9 [±0.9] hours P=0.001), and the length of stay was shorter at SLNI (7.9 [±4.4] days vs 10.8 [±8.7] days; P=0.001), as was the length of intensive care unit stay (4.0 [±3.7] days vs 6.7 [±6.2] days; P≤0.001). Mortality at 90 days was not different between SLNI and the Registry hospitals (35.4% [n=34] vs 36.2% [n=315]), and SLNI recorded a higher self-reported sICH hemorrhage rate (ECASS III definition) (15.1% [n=8] vs 6.1% [n=38]; P=0.021). Within the Merci Registry, significantly more patients treated at SLNI had good outcomes as assessed by mRS at 90 days, with scores of 0 to 2 (40.6% [n=39] vs 28.2% [n=245]; P=0.013), and discharge to home (17.7% [n=17] vs 11.9% [n=103]; P=0.031).

Baseline NIHSS score was inversely associated with whether SLNI patients were discharged to home: 6.3 (±6.1) for discharged compared with 14.4 (±8.5) for those not discharged to home (P<0.001).

Three analyses were conducted using SLNI patient data to examine the use of tPA-associated outcomes. Logistic regression analysis noted that the use of IV-tPA within 4.5 hours of stroke onset was associated with significantly more patients being discharged to home (odds ratio, 2.123; 95% confidence interval, 1.394–3.246), controlling for age and baseline NIHSS score. In addition, regression analysis noted there were significantly lower (improved) NIHSS scores at discharge in SLNI patients receiving IV-tPA within 4.5 hours, controlling for age and baseline NIHSS score (P=0.001).

Further analysis compared SLNI and Merci Registry patients who underwent mechanical embolectomy and assessed the relationship between setting, treatment, and patient discharge status. SLNI patients were found to be more likely to be discharged to home (odds ratio, 3.94; 95% confidence interval, 1.86–8.35) after controlling for baseline NIHSS score, post-procedure Thrombolysis in Cerebral Infarction score of 2b or 3, diabetes mellitus, and hypertension.

**Discussion**

Currently, health care systems around the globe are challenged with improving access and quality under significant cost constraints. New models of delivery will be necessary to meet these challenges. This study illustrates that incremental changes within an existing system can produce meaningful improvements in access and outcomes for cases of acute ischemic stroke, the leading cause of adult disability.

It is worth emphasizing that SLNI is a typical tertiary care community hospital that has been able to improve stroke management. In addition to the basic infrastructure requirements of 24/7 availability of neurologists, neurointerventionalists, timely CT scanning and laboratory reports, 30-minute response time for catheterization laboratory staff, and biplane technology, 4 major initiatives implemented over time drove the results reported for SLNI. Proactive focused education and communication for referring emergency department staffs and the emergency medical service personnel in the region were undertaken in 2006 by 2 designated stroke team nurses. An electronic feedback report on treatment and outcome for each stroke case goes back to the referring emergency department and emergency medical service squad. The transfer process was streamlined in 2007 with 1 telephone number and immediate access to the stroke neurologist with coordination by the transfer team nurse, including faxing of tPA order sets, dosing schedules, and transfer protocols to the referring facility once the decision was made to administer tPA before transfer. SLNI neurologists were not credentialed at the referring hospitals. Initiation of 24/7 coverage by a neuro-critical care nurse (Code Neuro Nurse) who is the first responder to stroke cases in the emergency department and who stays with the patient to coordinate care from the emergency department until the patient is in an intensive care unit bed was implemented. Expansion of standardized order sets and care paths based on the American Stroke Association Guidelines to ensure early rehabilitation, identification of stroke cause, prevention of complications, and institution of secondary prevention also was implemented. These were shared with network hospitals if they decided to keep the stroke patient at their facility.

This benchmarking analysis of SLNI is particularly important, because it emphasizes that a tertiary care community hospital with dedicated clinicians, technology, and standardized procedures, and without the support of neurology residents or stroke fellows, can successfully treat large numbers of acute ischemic stroke patients with good clinical outcomes. Overall, SLNI stroke patients had better outcomes than those treated at the other settings studied, including other community hospitals (Premier), stroke centers (GWTG-Stroke), and progressive stroke centers using state-of-the-art technology, such as mechanical embolectomy (Merci Registry). The outcomes reflect the quality of acute care and also the work that goes into the entire continuum of care, including early access to rehabilitation. This analysis supports the vision that stroke treatment in the United States can improve substantially by organizing care around a tertiary care center and a strong regional hospital network. SLNI increased the volume of patients by 23%, including a 17% increase in transfer patients.

Moreover, these results indicate a potential area of improvement across United States community hospitals, because guidelines have established all potential stroke patients should undergo diagnostic imaging to ensure accurate diagnosis. As shown, 99% of SLNI patients had CT imaging, which is critical to securing an accurate diagnosis of ischemic stroke, compared with 60% of patients treated in other United States community hospitals. Reasons for the low rates across other hospitals cannot be confirmed based on administrative data, but they may be attributable to factors such as late presentation, incorrect early diagnosis, and lack of technology/personnel.

With proper diagnosis, SLNI patients also were more likely to receive appropriate and timely stroke treatment. IV-tPA is the only Food and Drug Administration approved treatment for stroke, and administration of IV-tPA within 4.5 hours after the onset of stroke symptoms is the second metric of quality of care recommended for comprehensive stroke centers. Although not yet approved, tPA administered intra-arterially is commonly
used among advanced stroke centers up to 6 hours from the time symptoms present. National US data demonstrate that <5.5% of acute ischemic stroke patients receive thrombolytic therapy, consistent with the rates observed for the Premier community hospitals. Rates of IV-tPA treatment among GWTG-Stroke hospitals were similar, although they increased slightly in 2010 (6.8%). These figures are in sharp contrast to SLNI treatment rates, in which 22% of patients received tPA treatment during the study period and IV-tPA use increased from 13.6% to 28.5%. Although a direct causal effect cannot be established, it is reasonable that the community education, regional emergency medical service education and organization, and coordination of complex care on arrival helped contribute to this improvement in observed care delivery. It is possible that SLNI’s high tPA treatment rate is, at least partly, because it receives treated patients from referral hospitals, but these treatment decisions are made in consultation with the SLNI neurologist. It is difficult to fully quantify the exact magnitude of the regional stroke network with its multi focused efforts to emphasize the importance of stroke treatment in the community and coordinate care between institutions. However, it should be noted that SLNI accepts all acute stroke patients regardless of treatment status, stroke severity, and timing of onset of stroke symptoms.

Of note, there were no differences in NIHSS scores at discharge, length of stay, or mRS scores at 90 days between transfer and nontransfer patients, validating the safety and efficacy of the drip- and -ship option for stroke patients. Once patients have been transferred to SLNI for stroke treatment, they are never transferred back to the referring hospital for acute care, although they may be transferred to the referring facility or another facility for rehabilitation care. It is known that treatment with tPA may increase the risk of bleeding. However, no increased risk associated with tPA therapy was observed within this study. The 2.2% sICH rate for IV-tPA patients at SLNI was not statistically different from the rate in Premier (1.5%), and both were less than the 6.4% rate in the National Institute of Neurological Disorders and Stroke rt-PA Stroke Study Group (NINDS) trial. A higher bleeding rate with SLNI patients was noted in the Merci Registry; yet, according to all outcome measures, SLNI patients did well compared with those in other cohorts.

Overall, this study assessed these results and attempted to address the critical question of whether improvement in access and process translates into beneficial patient outcomes. Clinical trials have consistently demonstrated the efficacy of IV-tPA in improving stroke outcomes, and the tPA analysis in this study is compatible with trials assessing IV-tPA. The results in this analysis further confirm that within a defined, real-world setting, and controlling for other potentially confounding factors, IV-tPA treatment increases the likelihood of good patient outcomes (ie, discharge to home, lower stroke severity at discharge). If 30% of cases of ischemic stroke could be treated rather than the current rate of 2% to 5% reported in the literature, many more patients would have functional recovery and would return home normal or with less disability, translating to substantial savings in cost of care. The study further indicates that a subset of patients, namely those who are ineligible or who have not had success with IV-tPA therapy and are treated with mechanical embolectomy, may have improved likelihood of being discharged to home when treated at SLNI in comparison with other United States interventional stroke centers. Although the Merci Registry is defined by a specific stroke subpopulation, it also offers the opportunity to evaluate impact among a more severe and clinically challenging patient population. These results should be interpreted cautiously because they are based on small sample size and a specific subpopulation. Nonetheless, they do indicate that coordinated improvements in access, imaging, and treatment may collectively contribute to better outcomes for stroke patients.

There are several important limitations to this analysis. Because this study was focused on analyzing data from 2 registries and a retrospective analysis of hospital administrative data, there is the potential for selection bias because hospitals elected to participate in the registry, in GWTG-Stroke reporting, or in contributing to the hospital claims database. However, the large number of hospitals that report results to the GWTG-Stroke and the number of facilities included in Premier mitigate some of these concerns. Also, Premier data did not have NIHSS scores to control for stroke severity in a multivariate analysis of stroke outcomes, although the data did enable strong comparisons of treatment rates between SLNI and nationally representative community hospital data. In addition, hemorrhage rates were self-reported and the definition of sICH has changed from the original NINDS trial to the 2009 ECASS III definition. Because careful analysis and interpretation are required when examining such complications, the analysis was focused on areas with available detailed SLNI data. Because 3 years of data were not available for all databases, the analyses were segmented accordingly to offer a comprehensive analysis of access to stroke care and the related effectiveness of stroke outcomes at SLNI relative to peer community hospitals, Primary Certified Stroke Centers, and leading interventional stroke centers that use mechanical embolectomy treatment.

Conclusion
This analysis has demonstrated that a full-service, regional stroke management program can be effectively coordinated by tertiary care community hospitals, and that standardized systems of care can result in improved clinical outcomes for stroke victims. Decreased patient disability and shortened hospital and intensive care unit stays would have significant cost implications. The changes implemented by Saint Luke’s Hospital were introduced incrementally over time and represent initiatives that can be adopted by other tertiary care community hospitals. If stroke access and outcome results from a community hospital could be replicated across the globe, then the clinical and economic impacts could be substantial. Developing this model worldwide would enable stroke centers to establish the leadership and infrastructure to provide the most comprehensive and effective medical care to stroke patients.

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Analysis of a Coordinated Stroke Center and Regional Stroke Network on Access to Acute Therapy and Clinical Outcomes

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