Innovations in Care

Electronic Stroke CarePath
Integrated Approach to Stroke Care

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Abstract—We describe the development, implementation, and outcomes of the first 2 years of the Electronic Stroke CarePath, an initiative developed for management of ischemic stroke patients in an effort to improve efficiency and quality of care for patients. The CarePath consists of care pathways for ischemic stroke that are integrated within the electronic health record. Patient-reported outcomes are collected using an external software platform. Documentation tools, order sets, and clinical decision support were designed to improve efficiency, optimize process measure adherence, and produce clinical data as a byproduct of care that are available for future analyses. Inpatient mortality and length of stay were compared before and after CarePath implementation in ischemic stroke patients after adjustment for case-mix. Postdischarge functional outcomes of patients with ischemic stroke were compared between the first 3 months of rollout and remainder of the study period. From January 2011 to December 2012, there were 1106 patients with ischemic stroke on the CarePath. There was a decline in inpatient mortality in patients with ischemic stroke, but not in control patients with intracerebral or subarachnoid hemorrhage. Completion rate of patient-reported questionnaires at postdischarge stroke follow-up was 72.9%. There was a trend toward improved functional outcomes at follow-up with CarePath implementation. Implementation of the Electronic Stroke CarePath is feasible and may be associated with a benefit in multiple different outcomes after ischemic stroke. This approach may be an important strategy for optimizing stroke care in the future. (Circ Cardiovasc Qual Outcomes. 2015;8:S179-S189. DOI: 10.1161/CIRCOUTCOMES.115.001808.)

Key Words: clinical pathways | medical informatics | quality of health care | stroke

Goals and Vision of the Program
Improvements in efficiency, quality, and coordination of care are essential for healthcare institutions to adapt successfully in an era of decreasing reimbursement. Heart disease and stroke, which are leading causes of morbidity, mortality, and healthcare costs in the United States, are often among the first diseases to be involved in healthcare innovations and policy changes.1,2 They were among the first to have disease-specific process and outcome measures publically reported by the Center for Medicare and Medicaid services (CMS) and to have society supported quality registries. Regional and national systems of care are more advanced in stroke and myocardial infarction than in most other diseases. Solutions developed to improve delivery of care for patients with heart disease, and stroke can serve as models for the treatment of other conditions.

One important strategy to improve the efficiency and quality of healthcare is standardization of care. This is often done by implementing evidence-based protocols that incorporate guidelines into care algorithms. Evidence-based protocols can improve quality by providing guidance on indications for tests or interventions. A related method is the use of care paths, also referred to as critical pathways or care pathways. These are management plans that additionally provide the sequence and timing of actions necessary to meet the goals of care with optimal efficiency.3 Other features that differentiate care paths from evidence-based protocols include a detailed focus on processes of care, inclusion of multiple disciplines, specification of the documentation forms to be used, and inclusion of data collection to allow assessment of status and progress toward goals.

A second important strategy is the use of health information technology (HIT), which has the potential to transform the practice of medicine through clinical decision support, greater reuse of information, and improved efficiency of care.4 Reinforcing the importance of HIT in healthcare, CMS
implemented the Medicare and Medicaid EHR Incentive Program in 2011, which provides financial incentives to hospitals and healthcare providers, who meet various criteria for implementation and meaningful use of the electronic health records. Failure to meet criteria for meaningful use by 2015 will result in reduced CMS reimbursement. A third strategy is the systematic assessment of patient outcomes, which is necessary to understand overall performance, and is a critical part of the value equation. Outcomes traditionally available using administrative data sets, such as mortality and readmission, lack information about aspects of health important to the patient. Patient-reported outcomes (PROs) have the advantage of providing information on the patient’s symptoms and health status from the patient’s point of view, thus giving healthcare providers and regulators more complete information for making optimal decisions. Recognizing the importance of patient viewpoints, the collection of PROs as part of routine care has been recommended by the American Heart Association/American Stroke Association. 

In an effort to optimize patient care and efficiency, Cleveland Clinic incorporated these 3 strategies into the Electronic CarePath initiative. It consists of technologically enabled care pathways that include systematically collected both physician- and patient-reported data. To do this, we augmented the functionality of our electronic health record (EHR) and used an external software platform for the collection of patient-entered data. The Electronic CarePath concept was initiated and piloted for patients with ischemic stroke, focusing on care during the acute hospitalization and outpatient follow-up. This article discusses the development and implementation of this Electronic CarePath. Specific objectives of this pilot initiative were to (1) improve the efficiency of documentation that meet requirements for Joint Commission Primary Stroke Center Certification, (2) aid adherence to the institution’s generally accepted principles of care, including national stroke quality indicators, (3) produce structured electronic clinical data elements as a byproduct of care to be available for analysis and reporting, and (4) obtain patient-centered outcomes of care for patients on the Stroke CarePath, all with the ultimate goal to (5) improve outcomes after ischemic stroke. The study was approved by the Institutional Review Board.

Local Challenges in Implementation
Identification of resources for the technical components of the Electronic CarePath was the most significant challenge. The technical component involved integrating the clinical content within the EHR-based clinical workflow. Although Cleveland Clinic has a fully implemented electronic health record (Epic, Epic Systems, Verona, WI) for both inpatient and ambulatory settings, the customization of the Epic EHR necessary for this project required additional programming resources that were not internally available. For this, 3 Epic programming contractors were hired for =1 year, funded through a foundation grant. Another substantial challenge of this project was determining an approach to incorporate clinical protocols into the electronic workflow of the EHR. This required exploration of the EHR capabilities at our institution. In some cases, capabilities existed but Information Technology policies prevented us from using them for this project. Development of the approach comprised a significant portion of the entire effort. In addition, coordination and communication of CarePath efforts across many different operational areas within the institution was a struggle, which was ameliorated by assigning a project manager part-time to help with these efforts.

Design of the Initiative
Approach to CarePath Development
CarePath conceptualization and development was led by the Knowledge Program (KP), a joint collaboration between the Neurological Institute (NI) and the Information Technology Division (ITD) that is composed of software engineers and clinical personnel. The goals of the KP were to develop HIT tools to optimize patient care and outcomes, including a system to collect PROs and to facilitate the use of electronically derived clinical data for clinical care and research. The clinical content of the Electronic Stroke CarePath was written by a vascular neurologist, who also directed the KP. General processes of stroke care had been previously defined under national guidelines and in the requirements for Joint Commission Primary Stroke Center certification. These were further detailed and categorized into the following components: clinical workflows, internally derived and external quality metrics, order sets, documentation, and follow-up care. The clinical content was reviewed with members of the clinical stroke team during regularly scheduled meetings and modified based on feedback.

An approach to translate the clinical content into electronic workflow was then developed for each piece. The Programming Team, consisting of Epic consultants, KP software engineers, and the KP director met regularly to discuss different potential approaches to the implementation of clinical content. This was brought forward to a larger Stroke CarePath Team for review, composed of stroke team members, Epic contractors, and members of the nursing staff, nursing informatics, quality program, and the KP. A neurology resident was an important part of the team, providing input on resident workflow and the proposed documentation templates. The final approach is described below.

Description of the Electronic Stroke CarePath
The Stroke CarePath design supports the workflow associated with the acute evaluation of patients with stroke and subsequent hospital course and follow-up (Figure 1; Table 1). The Stroke CarePath has a modified view of the inpatient EHR screens, which includes a navigation panel organized into different phases of hospital admission: hyperacute, admission, hospital course, and discharge (Figure 2). Relevant documentation tools, order sets, and clinical aids for each phase of the hospitalization can be accessed through links on this panel. Stroke providers can access the Electronic Stroke CarePath using a specific login context.

The CarePath documentation tools are designed to improve the efficiency of collecting necessary clinical information for stroke care. Selected clinical data that are of significance for secondary uses are entered in a structured format into flowsheets that are easily accessible from the navigation
panel and formatted for improved user experience. These elements include past medical history, National Institutes of Health Stroke Scale (NIHSS, a scale of stroke severity), stroke mechanism, and key time metrics. To avoid the need for redundant entry, information from these flowsheets automatically populates the standardized stroke-specific clinical note templates for the history and physical, consult note, and progress note. The remaining clinical information is then entered as free text into these templates, which are accessible through the navigational panel.

**Hyperacute Evaluation**

In the Hyperacute section, a Key Metrics form is completed at the time of each patient’s initial presentation and consists of elements relevant to the acute evaluation, such as time patient was last known well and time of arrival (Figure 2). Based on this information, time intervals are automatically calculated on the form. In addition, context-driven questions reduce unnecessary data entry. For example, a checklist of intravenous tissue-type plasminogen activator eligibility criteria is displayed only if previous responses indicate that the patient arrived within the time window for intravenous tissue-type plasminogen activator. This eligibility criteria checklist dually serves to remind providers, many of whom are trainees, of the guidelines for intravenous tissue-type plasminogen activator administration and provide a way to easily document such information as required for Primary Stroke Center and Comprehensive Stroke Center certification. Because the data are entered in a structured format, they can be electronically extracted for further use.

**Admission**

The Admission section has a link to ischemic and post–tissue-type plasminogen activator stroke admission order sets. Select orders, such as dysphagia screening, are preselected to optimize adherence to standard care processes. The CarePath also contains an order for a postdischarge follow-up appointment, designed to streamline the process of scheduling appointments. The follow-up order is routed to the scheduling office through the EHR-based messaging system (Epic Inbox), who then schedules the appointment using information contained in the order.

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**Figure 1.** Stroke CarePath workflow algorithm. Electronic documentation tools were designed to support each point of care in the workflow algorithm. tPA indicates tissue-type plasminogen activator.
Table 1. Description of Stroke Navigation Panel and Intended Impact

<table>
<thead>
<tr>
<th>Phase of Hospitalization</th>
<th>Item</th>
<th>Description</th>
<th>Intended Impact</th>
<th>Data Available for Future Use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hyperacute Evaluation</td>
<td>Dosing weight*</td>
<td>Quick access to EHR area to enter/update patient weight for use in automated calculation of tPA dosing</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Key Metrics*</td>
<td>Standard method for documentation of acute stroke time metrics and tPA eligibility</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Acute stroke results</td>
<td>Link for quick access to EHR-based data used to determine eligibility for intravenous tPA, including: vital signs, CT report, and laboratory values</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Admission</td>
<td>Acute intervention*</td>
<td>Tool to document eligibility for acute endovascular intervention</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>History*</td>
<td>Documentation tool for medical history. Allows documentation of pertinent absence of conditions, such as stroke risk factors.</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stroke order sets</td>
<td>Stroke-specific order sets. Orders that should be performed on all stroke patients are preselected (such as dysphagia screening and ECG)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Initial NIHSS and premorbid Rankin Scores*</td>
<td>Tool for documentation of initial stroke impairment and functional status</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>History and Physical</td>
<td>Standardized clinical template for documentation of stroke history and physical. Data entered in other stroke-related forms autopopulate here (time metrics, tPA eligibility, medical history, and initial NIHSS). Includes Stroke 8 checklist of items to be assessed daily</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Daily orders</td>
<td>Includes frequently placed hospital orders, includes Stroke 8 items, such as blood pressure, diet, physical and occupational therapy</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Hospital Course</td>
<td>Daily NIHSS</td>
<td>Tool for structured documentation of NIHSS. Automatically calculates score</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stroke mechanism</td>
<td>Tool for structured entry of stroke mechanism, using a modified version of the TOAST criteria. Information is entered once and autopopulates subsequent notes</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Medical events</td>
<td>Tool for structured entry of medical events occurring during admission (–eg, gastrointestinal bleeding, recurrent stroke)</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Research studies</td>
<td>Provides link to internal website that houses research study eligibility criteria, protocol overviews, and informed consent documents</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NIHSS report</td>
<td>Graphical and tabular display of NIHSS scores completed over the admission</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Progress note</td>
<td>Standardized clinical template for documentation of daily progress notes, including the Stroke 8 checklist. There is autopopulation of clinical data completed on the electronic forms found in the Hospital Course section of the navigation panel (stroke mechanism and daily NIHSS) and laboratory values, vital signs, and medications</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Stroke Discharge</td>
<td>Discharge instructions</td>
<td>Individualized clinical template that includes stroke mechanism, admission and discharge NIHSS, HbgA1c, weight, BP, LDL levels, and follow-up appointment</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Discharge NIHSS/Rankin</td>
<td>Tool to record final NIHSS and Rankin score before hospital discharge</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Discharge checklist</td>
<td>List of process measures that should be completed before hospital discharge</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stroke discharge medication orderset</td>
<td>Abbreviated set of orders frequently used when preparing for hospital discharge, such as BP and statin medications, follow-up appointment</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

BP indicates blood pressure; EHR, electronic health record; HbgA1c, hemoglobin A1c; LDL, low-density lipoprotein; NIHSS, National Institutes of Health Stroke Scale; TOAST, Trials of Org 10172 in Acute Stroke Treatment; and tPA, tissue-type plasminogen activator.

*Data autopopulate clinical documentation templates.
There are several forms in this section for the structured entry of selected clinical elements, allowing them to be easily extracted from the EHR for other uses. Using the History form, providers can record a medical history using Intelligent Medical Objects (IMO) terminology (Chicago, IL) in a format that allows providers to indicate pertinent negatives for vascular risk factors and prespecified comorbid conditions (Figure I in the Data Supplement). The history information is stored within the EHR at the patient level and integrates with the standard history tools available in Epic, making the data available to all EHR users. The Initial NIHSS form is used to document the admission NIHSS and the premorbid modified Rankin Scale score (a measure of activities of daily living).

**Hospital Course**

The Daily NIHSS form in this section is completed each day by a member of the stroke team. The total NIHSS score is then automatically calculated and stored in a structured format. The stroke mechanism is entered by the attending physician once during the hospitalization through the Stroke Mechanism form, which is a modified version of the TOAST (Trials of Org 10172 in Acute Stroke Treatment) criteria,8 that allows a more detailed subgrouping of stroke mechanism subtypes.

The daily stroke progress note template contains autopopulated data from the Daily NIHSS form and Stroke Mechanism form and the Stroke 8. This is a checklist of 8 items that are assessed daily on patients hospitalized with stroke (Table I in the Data Supplement) and includes antithrombotic and statin therapy, blood pressure and glycemic control, venous thromboembolism prophylaxis, temperature, fluids and nutrition, and mobility and therapy orders. Data from the EHR autopopulate within the Stroke 8 section of the template, allowing providers to quickly assess the status of these items, saving providers time and reducing errors of recall.9

**Discharge**

The Discharge Checklist located in this section consists of a mixture of national stroke performance measures and internally derived process measures that should be completed before discharge (Figure II in the Data Supplement). It is designed to be autopopulated with data from the EHR so the provider is able to quickly see the status of these measures and identify the ones that still require action. To assist with completion of the noncompleted measures, the discharge order set is available in this section of the navigation panel for entering orders for statin and blood pressure (BP) medications, and a physical therapy evaluation. In addition, there is a patient Discharge Instructions in this section, which autopopulate with the patient’s scheduled follow-up appointment information and their values for the stroke vascular risk factors:
cholesterol, hemoglobin A1c levels, BP, and weight. The “Discharge Summary” available in this section autopopulates with the initial and discharge NIHSS and stroke mechanism.

**Nursing Documentation**

Nursing documentation at Cleveland Clinic is primarily entered through flowsheets. Stroke-specific additions to the neurological flowsheets were developed that included a 5-item dysphagia screen and neurological checks.

**Outpatient Follow-Up**

Standardized clinical templates are also used at the time of the postdischarge follow-up appointment, which typically occur 30 to 50 days after hospital discharge.

**Patient-Reported Outcomes**

The collection of PROs was an important component to the Stroke CarePath. These data were collected in the ambulatory setting through a separate Information Technology platform previously developed by the KP for broad use across the Cleveland Clinic enterprise. The system receives data feeds from scheduling, and the EHR among other sources. This allows the delivery of customized questionnaires to the patient based on clinical, demographic, and scheduling information. Patients complete web-based questionnaires using either a wireless tablet or a computer kiosk in the waiting room or computer at home before their appointment via Cleveland Clinic’s patient portal to the EHR (MyChart, Epic Systems). The patient responses are immediately available to the provider through a link in the Epic navigator panel.

Three scales are completed by the stroke patient: a generic health-related quality of life measure (EuroQol EQ-5D), a patient depression screen (Patient Health Questionnaire 9), and a measure of physical function (Stroke Impact Scale-16). Providers also enter information into the KP, including the date of the patient’s last stroke event and stroke mechanism, to aid in the interpretation of patient-reported health status information and complete an NIHSS and modified Rankin Scale. The PRO data, in addition to being available at the point of care, can be also used in aggregate for quality and research activities.

**Implementation of the Initiative**

**Electronic Health Record–Based CarePath**

Electronic Stroke CarePath planning and development occurred January through September 2010. Training of stroke team members took place in September through meetings with stroke attending physicians, neurology residents, and nursing staff. The Stroke CarePath was implemented in late September 2010. The CarePath development team made modifications over the first 3 months.

Between January 1, 2011 and December 31, 2012, the Stroke CarePath was used to document care of 3377 unique cerebrovascular patients, including 1106 admissions for ischemic stroke with the following principal discharge diagnosis *International Classification of Diseases, Ninth Revision*, Clinical Modification codes: 433.x1, 434.x11, 433.10, 433.91, 434.00, and 436. Mean age was 66.2 years (SD, 15.2), 46.1% were women. NIHSS on admission was 8.2 (SD, 8.1) and available in 98% cases (1085/1106; Table 2). Neurological worsening, defined as increase in NIHSS by 4 or more points at discharge compared with the admission NIHSS, occurred
in 8.6% (n=93) patients, whereas improvement occurred in 19.3% (n=209) cases. Mean length of stay was 6.2 (SD, 6.0), 6.6% patients died during the admission.

Follow-Up and Collection of PROs
Patient-reported data collection process had been previously implemented in the cerebrovascular ambulatory clinics, beginning September 2007, as part of a broader rollout of patient-entered data to the outpatient areas of the Neurological Institute.

Follow-up appointment with a Cleveland Clinic neurologist was completed in patients who were discharged alive and who were not in hospice care, readmitted, or died within 30 days. Follow-up rates ranged from 65.1% in patients discharged home to 49.1% discharged to subacute nursing facility or long-term acute care facility. Median days from discharge to follow-up visit was 36 [interquartile range, 28–50]. Completion rate of patient-reported questionnaires for all patients with ischemic stroke seen in the stroke clinic during this period was 72.9%, =16.1% were completed through the MyChart patient portal. Providers reviewed patient responses and completed provider-entered data, even when patient responses were not available, in 89.1% of visits. Correlations between admission NIHSS and functional status at the time of follow-up were assessed using Pearson correlation coefficient for all outcomes except modified Rankin Scale for which Spearman was calculated. As expected, patients with higher NIHSS scores on hospital admission had worse outcomes at follow-up; admission NIHSS was associated with higher NIHSS (r=0.685; P=0.0001), higher modified Rankin Scale score (r=0.604; P=0.0001), and lower SIS16 scores (r=-0.482; P<0.0001), reflecting worse impairment, more functional limitations, and worse physical functioning, respectively (Figure 3).

Evaluation of Impact of the Stroke CarePath
Analysis
We compared the inpatient mortality and length of stay (LOS) of patients with ischemic stroke in the 3 years before (2008–2010) and 3 years after implementation (2011–2013) of the Stroke CarePath after adjustment using administrative variables that were available at all times. To evaluate the impact of any changes in hospital operations that may have occurred over time, we also compared changes in inpatient mortality and length of stay in 2 control populations consisting of patients admitted with a principal diagnosis of intracerebral hemorrhage (International Classification of Diseases, Ninth Revision: 431.xx) and those with subarachnoid hemorrhage (International Classification of Diseases, Ninth Revision: 430.xx). These represented populations that were not the target of the CarePath but that would have been affected by changes in hospital practices. Expected in-hospital death and LOS were calculated for each patient based on All Patient Refined Diagnostic Related Groups (see Methods in the Data Supplement, Tables II and III in the Data Supplement) using the routinely applied method for case-mix adjustment within our institution. Logistic regression models were used to assess the association between observed in-hospital mortality and CarePath implementation, adjusted by expected mortality. χ² tests were used to evaluate the relationship of CarePath implementation with LOS in 3 categories: observed LOS less than expected LOS, equal to expected (within 1 day time window), and more than expected.

The expected mortality estimates that we used in our study did not account for overall improvements in ischemic stroke mortality over time. Thus, we performed a sensitivity analysis to estimate the magnitude an effect of calendar year (independent of CarePath) would have to be to negate the effect of the CarePath on ischemic stroke mortality and LOS. We reduced the expected mortality and LOS per calendar year until we identified the point at which the effect of the CarePath was no longer significant.

Changes over time in the functional outcomes at follow-up were assessed for the following measures: NIHSS, modified Rankin Scale, Stroke Impact Scale-16, and Patient Health Questionnaire 9, using general linear models adjusting for admission NIHSS, age, and sex. Because admission NIHSS was not available in a structured format before CarePath implementation, the first 3 months of implementation (when providers were still getting accustomed to using the CarePath) was used as the baseline comparator to the remainder of the study period. To further explore patterns over time, the 4 outcome measures were graphed for each quarter over the course of the study after adjustment for baseline NIHSS. Adherence to performance measures pre and post implementation of the CarePath was also assessed.

Findings
There was a significant reduction in observed/expected inpatient mortality after implementation of the Stroke CarePath in patients with ischemic stroke (odds ratio, 0.59; 95% confidence interval, 0.42–0.83), but not in the control patients with intracerebral hemorrhage (odds ratio, 0.90; 95% confidence interval, 0.59–1.38) or subarachnoid hemorrhage (odds ratio, 1.05; 95% confidence interval, 0.67–1.65; Table 3). Similarly, there was a significant increase in the proportion of ischemic stroke patients with LOS equal or less than expected LOS after CarePath implementation (P=0.047), but there was no significant difference in patients with intracerebral hemorrhage (P=0.117) or subarachnoid hemorrhage (P=0.943). These findings support a beneficial association between the CarePath and inpatient mortality and LOS that are unlikely to be because of general changes in hospital practices. In the sensitivity analysis, we found that an annual reduction in stroke mortality of 5% or higher would be necessary to negate the effect of the CarePath, supporting the impact of CarePath on mortality. In contrast, in the LOS analysis, we estimated that a change of only 0.64% would be required, which could be consistent with a secular trend.

Compared with the patients admitted within the first 3 months of the CarePath (when active modification were taking place), there were no significant differences in physical impairment (NIHSS; P=0.059), abilities to perform activities of daily living (modified Rankin Scale; P=0.079) and physical function (Stroke Impact Scale-16; P=0.084) at follow-up after adjustment (Table 4). There were also no difference over time in depressive symptoms (Patient Health Questionnaire 9; P=0.943). The greatest differences in functional outcomes
seemed to occur in the second quarter of implementation (first quarter after completion of CarePath modifications), although there was variability across quarters and by outcome measure (Figure III in the Data Supplement).

There was no change in adherence to national stroke performance measures pre and post CarePath implementation. The stroke core measure composite, which is an aggregate adherence rate combining all 8 core measures, was 95.6% both in the 3 years before implementation (2008–2010) and in the 2 years after implementation (2011–2012).

**Success of the Initiative**

**Efficiency of Electronic Documentation**

The greatest perceived impact of the Stroke CarePath was the improved efficiency of the providers’ EHR-based work. Several CarePath features contributed to this. The documentation approach of initial information entry into structured entry forms with subsequent autopopulation of these elements into a clinical note template allowed clinicians to enter information only once while providing them the features available with structured data, such as longitudinal display of NIHSS over time. The navigation panel provided quick access to most of the EHR-based functions needed to manage patients with stroke.

**Adherence to Generally Accepted Principles of Care**

The format of the Electronic Stroke CarePath reminded clinicians of the generally accepted standards of stroke care. For instance, the Stroke 8 checklist, which is integrated within the daily progress note and autopopulated with data from the EHR, prompts providers to review these 8 items daily. Order sets remind users of stroke processes of care and steer providers toward standard options.

The follow-up appointment order significantly reduced the time it took providers to arrange postdischarge appointments. Before implementing the follow-up order, making postdischarge appointments was time consuming, requiring team members to call the appointment line that often placed callers on hold. The success of the follow-up order has led to its implementation for hospital admissions across the enterprise.

As we expected, there was no significant changes in the institution’s previously high adherence rates to national stroke

![Figure 3. Functional outcomes at follow-up stratified by admission severity of impairment (National Institute of Health Stroke Scale [NIHSS]).](image-url)

A. NIHSS, higher scores indicate greater impairment; B. modified Rankin Scale, higher scores indicate more functional limitations; C. Stroke Impact Scale 16, higher scores indicate better physical function; D. Patient Health Questionnaire-9, high scores indicate more depressive symptoms. Data points are unadjusted. Upper edge of box=75th percentile; lower edge of box=25th percentile; +=mean; horizontal bar within box=median; upper whisker=maximum observed value(s) within 1.5 interquartile range (IQR) above 75th percentile; and lower whisker=minimum observed value(s) within 1.5 IQR below 25th percentile.
performance measures—after CarePath implementation, stroke coordinators had routinely monitored the charts of all strokes patients in real time to ensure completion of process measures.

Availability of Electronic Clinical Data for Quality and Research Purposes

The structured collection of selected data elements as part of the clinical workflow allows us to leverage the data captured in the course of care delivery for secondary uses, such as quality or research. The availability of the NIHSS, stroke mechanism, and acute stroke times is particularly useful for understanding the patient population seen at our hospital (Table 2).

Assessment of Patient-Centered Outcomes

Outcomes information was systematically collected from patients and providers at the time of hospital follow-up with completion rates above 75%. PROs provide an important view of patient health status that is often not captured by providers and allows assessment of the impact of care using outcomes that matter to patients. Some reasons for patients did not complete PRO questionnaires at the time of follow-up include: patients came late for their appointment, a tablet was not given to patients by front-desk personnel, and patients unable to complete because of functional limitations.

Implementation of the Stroke CarePath in patients with ischemic stroke was associated with a reduction in in-hospital mortality and length of stay. These findings cannot be considered conclusive given the observational design, use of an internally derived case-mix adjustment method, and lack of adjustment for initial severity of impairment. However, a plausible explanation for the better outcomes is improvement in functional outcomes.

Table 3. Inpatient Mortality and LOS for Patients With Stroke Before and After CarePath Implementation

<table>
<thead>
<tr>
<th>Stroke Subtype</th>
<th>Observed Inpatient Mortality Rate</th>
<th>Observed Rate/Expected Rate (95% CI)</th>
<th>Odds Ratio for Inpatient Mortality after CarePath Implementation (2011–2013)†</th>
<th>Observed LOS, Mean (SD)</th>
<th>Percentage of Patients With LOS Less Than Expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before CarePath, %</td>
<td>After CarePath, %</td>
<td>Before CarePath, %</td>
<td>After CarePath, %</td>
<td>Before CarePath (2008–2010)</td>
<td>After CarePath (2011–2013),</td>
</tr>
<tr>
<td>Ischemic stroke (n=2685)*</td>
<td>7.2</td>
<td>6.6</td>
<td>0.604 (0.570–0.638)</td>
<td>0.459 (0.436–0.482)</td>
<td>0.589 (0.547–0.638)</td>
</tr>
<tr>
<td>Intracerebral hemorrhage (n=666)*</td>
<td>21.7</td>
<td>22.5</td>
<td>0.645 (0.563–0.727)</td>
<td>0.609 (0.552–0.666)</td>
<td>0.904 (0.591–1.382)</td>
</tr>
<tr>
<td>Subarachnoid hemorrhage (n=607)*</td>
<td>15.0</td>
<td>18.1</td>
<td>0.592 (0.527–0.657)</td>
<td>0.618 (0.547–0.689)</td>
<td>1.050 (0.670–1.646)</td>
</tr>
</tbody>
</table>

CI indicates confidence interval; and LOS, length of stay.
*Total number patients hospitalized from 2008 to 2013.
†Adjusted for expected mortality.
‡χ² tests between CarePath implementation and LOS in three categories: observed LOS less than expected LOS, equal to expected and more than expected.

Challenges

Despite the overall success of the Stroke CarePath, we experienced some challenges in its implementation and not all features worked as planned. An anatomic diagram built within Epic and designed for providers to record the location of the stroke in a structured format did not function despite extensive efforts and resources put into this feature. Some of the items in the discharge checklist did not autopopulate correctly and so it was not uniformly used. There was suboptimal completion of some structured elements, such as time patients last experienced some challenges in its implementation and not all features worked as planned. An anatomic diagram built within Epic and designed for providers to record the location of the stroke in a structured format did not function despite extensive efforts and resources put into this feature. Some of the items in the discharge checklist did not autopopulate correctly and so it was not uniformly used. There was suboptimal completion of some structured elements, such as time patients last

Table 4. Functional Status at Follow-Up for Patients With Ischemic Stroke at the Beginning of CarePath Implementation Compared With That at Later

<table>
<thead>
<tr>
<th>Functional Outcome Measure</th>
<th>Mean Scores</th>
<th>Follow-Up Dates, January to March, 2011</th>
<th>Follow-Up Dates, April 2011 to March</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>NIHSS</td>
<td>3.9</td>
<td>2.7</td>
<td>0.059</td>
<td></td>
</tr>
<tr>
<td>Modified Rankin Scale</td>
<td>2.6</td>
<td>2.2</td>
<td>0.079</td>
<td></td>
</tr>
<tr>
<td>Stroke Impact Scale-16</td>
<td>67.8</td>
<td>76.0</td>
<td>0.084</td>
<td></td>
</tr>
<tr>
<td>Patient Health Questionnaire 9</td>
<td>6.8</td>
<td>6.7</td>
<td>0.943</td>
<td></td>
</tr>
</tbody>
</table>

Adjusted for admission NIHSS (continuous), age (continuous), and sex using general linear models. NIHSS indicates National Institutes of Health Stroke Scale.
retrospect, involved extraction of structured data from the EHR. It was assumed that the KP had full access to all CarePath data through previously constructed feeds from the Epic data repository. However, this was found not to be the case and alternative methods were required to extract the data. Several iterations of extraction were required, and extensive validation of the electronic data through manual review was necessary. This resulted in significant delays in availability of clinical data for use in operational and quality activities.

Summary of the Experience, Future Directions, and Challenges

An innovative aspect of this healthcare initiative is the integration of 3 different strategies to optimize the efficiency and organization of care: implementation of a standardized care path, use of HIT to integrate the pathways into clinical workflows, and the systematic collection of patient-reported information to inform our delivery of care. We think this type of integrated approach is a future model for healthcare delivery, aiming to improve patient care, efficiency, and reduce cost of care.

This approach can also be considered part of the framework of a learning health system at a local level. A concept promoted by CMS and the Institute of Medicine, a learning health system uses clinically derived data to identify best practices and generate new knowledge. The information is then integrated back into the care delivery process to improve patient care and ultimately patient health. We are optimistic that the Electronic CarePath infrastructure, which produces electronic clinical data as a byproduct of care, can be used to determine the management practices that optimize outcomes of patients with stroke.

Through the systems already in place to collect PROs, the Stroke CarePath is able to measure outcomes that matter to patients, including physical function and health-related quality of life. Improvement in these types of outcomes is the core goal of medicine, and measurement of these outcomes will increasingly become an important part of healthcare delivery.

Implementation of the Stroke CarePath in patients with ischemic stroke was associated with a reduction in in-hospital mortality and LOS. More evidence is needed on the impact and the return on investment of this integrated approach to care as well as each of its 3 separate components. A Cochrane review of in-hospital pathways for stroke found evidence to be inconclusive, however, it is encouraging that subsequent reports have demonstrated benefit. Although seemingly logical, evidence of the value of HIT and of the benefit of integrating PROs within clinical care is currently limited. Both these strategies involve complex interventions, making evaluation methodologically challenging.

The Electronic Stroke CarePath capitalized on the presence of an EHR with an integrated scheduling system, including both inpatient and ambulatory settings. In addition to this pre-existing infrastructure, the Stroke CarePath required extensive resource investment. Although expensive as a standalone initiative, the Stroke CarePath is an early step of a long-term strategy to use standardized processes and HIT to reshape the way the organization delivers healthcare. Similar CarePaths are being developed for conditions across the Cleveland Clinic enterprise.

A second iteration of the Stroke CarePath is also currently underway. A high priority item for this second version will be implementation of a reporting dashboard for quality metrics. A significant part of our current effort was the identification of the approach for integrating the clinical CarePath into the electronic workflow. This work can inform other hospitals who can use this approach as they develop and implement similar initiatives in their own EHR systems. Hospitals may wish to implement specific pieces rather than the entire initiative. As EHR functionality improves, the implementation of such initiatives will become progressively easier to accomplish.

In conclusion, implementation of an Electronic Stroke CarePath is associated with improved outcomes after ischemic stroke. We believe that the 3 strategies used in the Stroke CarePath—care paths, HIT, and the systematic collection of provider and PRO measures—will be important foundations for successful healthcare systems in the future. Our preliminary experience with combining these 3 strategies will be useful to others as they embark on related initiatives.

Acknowledgments

We thank the Cleveland Clinic neurology residents, the stroke team, and the Clinical Systems Office for their assistance in the development and ongoing implementation of the Electronic Stroke CarePath. We also thank Srividya Ramachandran, PhD, for her editorial assistance with this article.

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Disclosures

None.

References


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Irene L. Katzan, Youran Fan, Micheal Speck, Johanna Morton, Lauren Fromwiller, John Urchek, Ken Uchino, Sandra D. Griffith and Michael Modic

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SUPPLEMENTAL MATERIAL

Supplemental Methods

Method for Adjustment of Case-Mix

Adjustment for case-mix was based on 3M APR-DRGs system (described below) and was performed by calculating the ratio of “observed” to “expected” outcomes for inpatient mortality and length of stay (LOS).

Determination of Observed Values:
The observed value for the Cleveland Clinic cohort was obtained by directly calculating the value for each patient in the cohort.

Determination of Expected Values:

Data sources

The “Expected” values were determined using 3 external datasets:

(1) 2009 Medicare Provider Analysis and Review (MEDPAR) file – The MEDPAR file contains data from claims for services for 100% of Medicare beneficiaries admitted to Medicare certified inpatient hospitals, representing over 14,750,000 admissions in 2009.¹

(2) 2009 Premier Perspectives comparative database² - This consists of over 16 million U.S. hospital discharges in more than 400 hospitals in the U. S. Participating hospitals represent all regions of the United States and are predominantly small-to-midsize nonteaching facilities that serve largely urban patient populations³.
(3) **2009 Solucient dataset** – This dataset consists of over 6 million acute hospital encounters and contains administrative data from multiple sources. Solucient LLC has been incorporated within Truven Healthcare.

For the purposes of this study, we focused on patients who had a primary diagnosis code of ischemic stroke, intracerebral hemorrhage or subarachnoid hemorrhage.

**Case-Mix Adjustment**

The 3M ™ APR DRG Classification System was used to categorize each patient admission for each of the 3 external datasets and the study cohort. The APR-DRG system is a common method of risk adjustment used by hospital systems, and Medicaid programs and state and federal agencies. The system uses age, pre-existing medical conditions, and discharge administrative and procedural codes to categorize patients into groups that have similar characteristics and severity of illness. In addition to the APR-DRG, each patient is assigned a Severity of Illness subclass and Risk of Mortality subclass, which each have 4 levels; minor, moderate, major or extreme.

**Calculation of Observed vs. Expected Mortality:**

The Premiere dataset was used to define the expected risk of inpatient mortality for each patient in the study cohort. This was done by calculating the average mortality rate in the Premiere dataset for each combination of APR-DRG and Risk of Mortality subclass. Each patient in the study cohort was then assigned an “expected inpatient mortality rate” based on these average Premiere values for the corresponding combination of APR-DRG and Risk of
Mortality subclass. The overall observed: expected mortality rate was then calculated by calculating average observed mortality vs. average expected mortality rate for patients in defined subgroups (Supplemental Table 2).

*Calculation of Observed vs. Expected LOS:*

Observed lengths of stay from all 3 external datasets were used to define the expected LOS in our study cohort. To do this, the average LOS was determined separately in each of the external datasets for each combination of APR-DRG and Severity of Illness Subclass (see Supplemental Table 3). This resulted in 3 values for each combination of APR-DRG and Severity of Illness subclass. The smallest of the 3 LOS value for the each APR-DRG and Severity of Illness subclass combination was defined as the expected LOS for our study cohort. This method was selected to set the most aggressive target for our internal performance improvement. Each patient in the study cohort was then assigned an “expected LOS” based on their APR-DRG and Severity of Illness subclass. The overall observed to target LOS was then calculated for the predefined subgroups.

These calculations were completed for ischemic stroke patient cohort and 2 control groups — patients with intracerebral hemorrhage and subarachnoid hemorrhage — both before and after implementation of the stroke CarePath. The process was completed for both outcome variables inpatient mortality and LOS.
**Supplemental Table 1: The Stroke 8 Checklist**

<table>
<thead>
<tr>
<th><strong>Stroke Prevention</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Antithrombotic Therapy</td>
</tr>
<tr>
<td>2. Statin Therapy</td>
</tr>
<tr>
<td>3. Blood Pressure Control</td>
</tr>
<tr>
<td>4. Glycemic Control</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Prevention of Complications</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Venous Thromboembolism Prophylaxis</td>
</tr>
<tr>
<td>2. Temperature</td>
</tr>
<tr>
<td>3. Fluids and Nutrition</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Recovery and Disposition</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mobility and Therapy</td>
</tr>
</tbody>
</table>
Supplemental Table 2: Calculation of Observed: Expected Inpatient Mortality Ratio

**Sample Data**

<table>
<thead>
<tr>
<th>Study Cohort</th>
<th>APR DRG</th>
<th>Risk of Mortality Subclass</th>
<th>Patient Expired?</th>
<th>Expected Mortality Rate (derived from Premier dataset)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient 1</td>
<td>045</td>
<td>1</td>
<td>No</td>
<td>0.005</td>
</tr>
<tr>
<td>Patient 2</td>
<td>045</td>
<td>3</td>
<td>No</td>
<td>0.148</td>
</tr>
<tr>
<td>Patient 3</td>
<td>045</td>
<td>4</td>
<td>Yes</td>
<td>0.501</td>
</tr>
<tr>
<td>Patient 4</td>
<td>045</td>
<td>2</td>
<td>No</td>
<td>0.033</td>
</tr>
<tr>
<td>Patient 5</td>
<td>045</td>
<td>2</td>
<td>No</td>
<td>0.033</td>
</tr>
<tr>
<td>Patient 6</td>
<td>045</td>
<td>1</td>
<td>No</td>
<td>0.005</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Observed Mortalities</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected Mortality (sum) in this 6 patient sample</td>
<td>0.725</td>
</tr>
<tr>
<td>Observed : Expected mortality in this 6 patient sample</td>
<td>1.38</td>
</tr>
</tbody>
</table>

The “Patient Expired” column gives us the observed number of deaths. The sum of the expected mortality rate column gives us the total number of expected deaths. Dividing the two values gives us the Observed:Expected ratio.
Supplemental Table 3: Calculation of Expected LOS

*Numbers below are for Illustration purposes only and not actual study data.*

<table>
<thead>
<tr>
<th>APR DRG</th>
<th>Severity of Illness subclass</th>
<th>Average LOS Premier</th>
<th>Average LOS Solucient</th>
<th>Average LOS MEDPAR</th>
<th>“Expected” LOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>045</td>
<td>1</td>
<td>3.54</td>
<td>3.12*</td>
<td>4.03</td>
<td>3.12</td>
</tr>
<tr>
<td>045</td>
<td>2</td>
<td>4.20*</td>
<td>4.65</td>
<td>5.11</td>
<td>4.20</td>
</tr>
<tr>
<td>045</td>
<td>3</td>
<td>7.43</td>
<td>6.76</td>
<td>6.54*</td>
<td>6.54</td>
</tr>
<tr>
<td>045</td>
<td>4</td>
<td>11.3*</td>
<td>11.76</td>
<td>12.01</td>
<td>11.3</td>
</tr>
</tbody>
</table>

*smallest LOS among 3 datasets chosen as “expected LOS” for study cohort.

Note: Average LOS for each dataset is not actual study data and numbers shown are for the purposes of illustration. “Expected” LOS are the actual values used in calculations.
Figure 1 Legend: The History form allows providers to record pertinent positives and negatives for vascular risk factors and selected conditions that may impact management or outcomes of patients with stroke. Data is synchronized with Epic’s standard History feature, avoiding duplicate entry. Providers can also enter additional diagnoses not on this list.
Figure 2 Legend: The discharge checklist consists of process measures that should be completed prior to hospital discharge and is auto-populated with electronically-derived data from the EHR.
Figure 3 Legend: Adjusted for Admission NIHSS

NIHSS = National Institutes of Health Stroke Scale, SIS-16 = Stroke Impact Scale 16, PHQ9= Patient Health Questionnaire 9, Q= quarter
Supplemental References:


4. Hall BL, Hirbe M, Waterman B, Boslaugh S, Dunagan WC. Comparison of mortality risk adjustment using a clinical data algorithm (American College of Surgeons National Surgical Quality Improvement Program) and an administrative data algorithm (Solucient) at the case level within a single institution. *J Am Coll Surg.* 2007;205:767-777

