











ORIGINAL RESEARCH

Hospital Readmissions and Mortality Among Fee-for-Service Medicare Patients With Minor Stroke or Transient Ischemic Attack: Findings From the COMPASS Cluster-Randomized Pragmatic Trial

Cheryl D. Bushnell , MD, MHS; Anna M. Kucharska-Newton, PhD, MPH; Sara B. Jones, PhD, MPH; Matthew A. Psioda , PhD; Anna M. Johnson , PhD, MSPH; Laurie C. Daras, PhD, MS; Jacqueline R. Halladay , MD, MPH; Janet Prvu Bettger , ScD; Janet K. Freburger , PhD; Sabina B. Gesell , PhD; Sylvia W. Coleman, MPH, RN, BSN, CLNC; Mysha E. Sissine , MSPH; Fang Wen, MS; Gary P. Hunt , BA; Wayne D. Rosamond, PhD, MS; Pamela W. Duncan , PhD, PT

BACKGROUND: Mortality and hospital readmission rates may reflect the quality of acute and postacute stroke care. Our aim was to investigate if, compared with usual care (UC), the COMPASS-TC (Comprehensive Post-Acute Stroke Services Transitional Care) intervention (INV) resulted in lower all-cause and stroke-specific readmissions and mortality among patients with minor stroke and transient ischemic attack discharged from 40 diverse North Carolina hospitals from 2016 to 2018.

METHODS AND RESULTS: Using Medicare fee-for-service claims linked with COMPASS cluster-randomized trial data, we performed intention-to-treat analyses for 30-day, 90-day, and 1-year unplanned all-cause and stroke-specific readmissions and all-cause mortality between INV and UC groups, with 90-day unplanned all-cause readmissions as the primary outcome. Effect estimates were determined via mixed logistic or Cox proportional hazards regression models adjusted for age, sex, race, stroke severity, stroke diagnosis, and documented history of stroke. The final analysis cohort included 1069 INV and 1193 UC patients (median age 74 years, 80% White, 52% women, 40% with transient ischemic attack) with median length of hospital stay of 2 days. The risk of unplanned all-cause readmission was similar between INV versus UC at 30 (9.9% versus 8.7%) and 90 days (19.9% versus 18.9%), respectively. No significant differences between randomization groups were seen in 1-year all-cause readmissions, stroke-specific readmissions, or mortality.

CONCLUSIONS: In this pragmatic trial of patients with complex minor stroke/transient ischemic attack, there was no difference in the risk of readmission or mortality with COMPASS-TC relative to UC. Our study could not conclusively determine the reason for the lack of effectiveness of the INV.

REGISTRATION: URL: <https://www.clinicaltrials.gov>; Unique identifier: NCT02588664.

Key Words: mortality ■ patient readmission ■ stroke ■ subacute care ■ transient ischemic attack ■ transitional care

Approximately 795 000 people have a new or recurrent stroke in the United States each year.¹ Stroke is the fifth leading cause of death in the

United States, accounting for over 142 000 deaths each year. Mortality is 10.5% in the first 30 days post stroke and 21.2% within the first year.² Hospital

Correspondence to: Cheryl D. Bushnell, MD, MHS, Department of Neurology, Wake Forest School of Medicine, Medical Center Blvd, Winston-Salem, NC 27157. E-mail: cbushnel@wakehealth.edu

For Sources of Funding and Disclosures, see page 9.

© 2021 The Authors. Published on behalf of the American Heart Association, Inc., by Wiley. This is an open access article under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.

JAHA is available at: www.ahajournals.org/journal/jaha

CLINICAL PERSPECTIVE

What Is New?

- Here we present 30-day, 90-day, and 1-year all-cause and stroke-specific readmission rates and 1-year all-cause mortality among patients with stroke and transient ischemic attack discharged home from 40 diverse hospitals participating in the COMPASS (Comprehensive Post-Acute Stroke Services) study, one of the first large-scale pragmatic clinical trials of transitional care in the United States.
- The risk of all-cause readmission, stroke-specific readmission, and mortality was similar between intervention and usual care arms at all time points.
- Comparison of our findings with other stroke transitional care interventions is limited, as few studies have been conducted in the United States, and even fewer have included readmission as an outcome or stroke severity as a covariate.

What Are the Clinical Implications?

- In the overall cohort, patients with mild stroke and transient ischemic attack remained at a substantial risk of readmission within 1 year.
- Despite strong implementation monitoring, uptake of the intervention was low, suggesting that not all acute care hospitals are prepared to be the hub for transitional care.
- Further research should evaluate the best systems to manage extended transitional care.

Nonstandard Abbreviations and Acronyms

CMS	Centers for Medicare and Medicaid Services
COMPASS	Comprehensive Post-Acute Stroke Services
COMPASS-TC	Comprehensive Post-Acute Stroke Services Transitional Care
FFS	fee-for-service
INV	intervention
TC	transitional care
TIA	transient ischemic attack
UC	usual care

readmission rates are high in the first 30 days; in the United States between 2010 and 2015, 30-day all-cause readmission rates were 13.7% among patients with intracerebral hemorrhage and 12.4% among patients with ischemic stroke.³

Stroke and transient ischemic attack (TIA) are complex chronic conditions, and survivors report many unmet needs and high rates of comorbidity, leaving them vulnerable to complications, poor risk factor management, medication nonadherence, and residual disability.^{1,4-6} Coordination of transitional care (TC), which includes hand-offs from inpatient to outpatient providers and between primary care and specialty providers, is vital to the management of modifiable risk factors, reduction in adverse events, and improvement of patient well-being.⁷⁻⁹ However, in the United States, ~45% of all stroke patients and 65% of those under the age of 65 years receive no postacute care services, including inpatient or outpatient rehabilitation, ambulatory care visits, or other community services.¹⁰ Poor coordination of transitional and postacute care for complex patients, such as stroke patients, increases the risk of hospital readmission and costs the US healthcare system \$58 billion each year.^{7,11,12}

The Centers for Medicare and Medicaid Services (CMS), which oversees US public health insurance programs including Medicare (for people aged 65 and older and eligible younger people with disabilities) and Medicaid (for low-income Americans), implemented national policies and reimbursement models to improve access to and quality of TC.⁸ However, use of TC models remains low,⁹ and evidence of their effectiveness for reducing hospital readmissions and mortality has not been established.¹³⁻¹⁵ The latest update to the American Heart Association/American Stroke Association's Stroke Systems of Care Policy Statement recommends establishment of support systems to ensure appropriate follow-up, with appointments scheduled with primary care before discharge and with specialty care as needed to optimize secondary prevention and access to rehabilitation.¹⁶

A comprehensive TC approach to managing stroke patients discharged home from the hospital is critical given their comorbidities, risk for complications, and their need to navigate care in multiple, unintegrated healthcare settings. An early model of comprehensive TC in 1 tertiary comprehensive stroke service provided by an advanced practice provider and a nurse coordinator showed that 30-day readmissions could be reduced by nearly 50% for patients with stroke who attended the clinic.¹⁷ Building on this evidence, we designed the COMPASS-TC (Comprehensive Post-Acute Stroke Services Transitional Care) intervention, which included a postacute care pathway follow-up with the advanced practice provider and nurse coordinator in clinic within 7 to 14 days post discharge, an individualized electronic care plan, and referral to community services.¹⁸

Here we present 30-day, 90-day, and 1-year all-cause and stroke-specific readmission rates and 1-year all-cause mortality among patients with stroke and

TIA discharged home from 40 diverse North Carolina hospitals participating in the COMPASS study.

METHODS

Study Design and Population

The rationale, design, and primary results of the COMPASS study have been published.^{18,19} Briefly, COMPASS was a cluster-randomized trial of the effectiveness of the COMPASS-TC intervention (INV) compared with usual care (UC). All acute care hospitals in North Carolina were eligible and were invited to participate if they had an emergency department that treated patients with stroke and could identify patients with stroke and TIA concurrent with care. Among 95 eligible hospitals, 41 agreed to participate. These were randomized as 40 units because of shared staff for 2 hospitals.^{18–20} Randomization of hospital units to INV or UC was stratified by annual discharge volume of patients with stroke and primary stroke center certification status. Assignment was implemented centrally by a study statistician. Thirty-nine hospitals completed at least 12 months of participation between July 2016 and March 2018. One hospital enrolled no patients and was excluded from analyses. Hospitals enrolled 6024 adult patients with stroke and TIA discharged home from 2016 to 2018. COMPASS-TC involved patient-centered engagement before and after hospital discharge and assessed social and functional determinates of health to inform postacute care planning.¹⁸ Patient enrollment began after each hospital was randomized and their staff were trained. Details on COMPASS-TC, as well as staff training at INV and UC hospitals, have been published.^{18,19,21}

Institutional review board approval was granted through the Wake Forest Baptist Health central institutional review board or through local hospital institutional review boards. The study met criteria for a waiver of consent and Health Insurance Portability and Accountability Act authorization; therefore, eligible patients were enrolled at hospital discharge without consent. At 90 days post discharge, patients or their proxies provided verbal informed consent over the telephone for collection of outcomes.¹⁸ The trial was periodically reviewed by an independent Data and Safety Monitoring Board. The data that support the findings of this study are available from the corresponding author in accordance with the Patient-Centered Outcomes Research Institute Policy for Data Access and Sharing.

Data Linkages

Using indirect identifiers, we linked COMPASS data with CMS Medicare healthcare use claims for beneficiaries enrolled in traditional CMS Medicare fee-for-service programs during the years 2016 to 2019.

Participants enrolled in Medicare Advantage (MA) were not included owing to the inability to obtain individual-level claims for services provided under this healthcare financing program.²² Matching protocols are described next.

CMS Medicare Claims

We used sex, date of birth, and dates of admission and discharge from inpatient care available from both the COMPASS Study data and CMS Master Beneficiary Summary File and the Inpatient and Outpatient claims to perform a series of deterministic linkages.²³ The Master Beneficiary Summary File contains data on all Medicare enrollees each year (eg, age, sex, race, county, whether the beneficiary was dually enrolled in Medicaid, and other enrollment information).²⁴ We used the hospital's unique CMS Certification Number, equivalent to provider number found in Medicare inpatient claims, to limit all matching protocols to claims for services provided in hospitals enrolled in COMPASS. Linkages exact on the 4 unique identifiers were considered a match. In subsequent linkages, conducted using remaining records, dates of service between COMPASS and Medicare claims were allowed to vary in a graded pattern by ± 3 days and dates of birth were allowed to vary by 1 of the 3 date elements (day, month, year). Matches were reviewed by 2 investigators, using admission status, *International Classification of Diseases, Tenth Revision (ICD-10)* inpatient diagnostic codes, race, and zip code (as needed) as verification variables. Admission status was defined as inpatient admission or observation stay. A third reviewer adjudicated discrepancies.

Outcomes

The primary prespecified outcome of the COMPASS trial, as outlined on clinicaltrials.gov, was functional status; analyses of this outcome and other prespecified outcomes have been published.¹⁹ All outcomes reported here are key, prespecified secondary outcomes of the COMPASS trial.

1. *Thirty- and 90-day all-cause readmissions* were defined as an inpatient admission or admission under observation status to any acute care facility within 30 or 90 days of the discharge date of the index admission.²⁵ We excluded planned inpatient readmissions for procedures not associated with a recurrent stroke, including carotid endarterectomy, carotid stenting, percutaneous carotid stenting, intracranial and intervertebral stenting, patent foramen ovale closure, ablation, aortic or mitral valve replacement, and cranioplasty identified by *ICD-10* procedure codes in which acute stroke was not also listed as the primary discharge

diagnosis code (suggesting the readmission was because of recurrent stroke). Observation stays were identified from outpatient claims using the G0378 and G0379 Healthcare Common Procedure Coding System codes.

2. *Time to hospital readmission over 1 year* was defined as described except planned inpatient readmissions were included to be consistent with prior 1-year readmission methods and analyses.²⁵
3. *Time to stroke-related readmission* was defined as time to admission for stroke (inpatient or observation stay) to a nonfederal, acute care hospital. Readmissions for stroke were identified using the primary discharge diagnosis *ICD-10* codes associated with cerebral infarction (I63.0–I63.9), subarachnoid hemorrhage (I60.0–I60.9), and intracerebral hemorrhage (I61.0–I61.9).
4. *Time to death from any cause* included deaths recorded in the North Carolina State Death Index or Master Beneficiary Summary File that occurred within 1 year of index discharge.

Analysis Cohort

The analysis cohort included COMPASS patients linked with CMS Medicare enrollment data identified as having FFS Medicare coverage at baseline (N=2262, 1069 INV, 1193 UC), including those dually enrolled in FFS Medicare and Medicaid (n=313, 13.8%). For the analysis of incident 30- and 90-day readmissions, we excluded patients without continuous FFS coverage throughout the risk period (ie, 30 or 90 days from index discharge) and included those who died within the risk period (Figure). Individuals who died without a qualifying readmission were treated as not having had a readmission. Individuals readmitted before death were treated as having had a readmission.

Statistical Analysis

Intention-to-treat analyses compared readmission and mortality outcomes between the INV (N=1069) and UC (N=1193) groups. Binary end points (30- and 90-day readmission) were analyzed using mixed logistic regression models that included a hospital-specific random intercept, a hospital-level treatment variable, and patient-level baseline characteristics including diagnosis type (stroke versus TIA), National Institutes of Health Stroke Scale score (0, 1–4, >4), race (White versus people of color), age, sex, prior stroke, and prior TIA. Analyses of recurrent hospitalization end points (all cause and stroke specific) were based on cause-specific hazard models, which censored patients at the time of death or loss of coverage. Recurrent event analyses were performed using the Prentice, Williams, and Peterson model²⁶ and adjusted for

covariates listed previously. Correlation between event times within a hospital unit was accounted for using a robust sandwich estimator for the covariance of model parameter estimates. One-year mortality was analyzed using the approach of Wei et al, which specifies a Cox proportional hazards model for the marginal distribution for the event times and accounts for correlation between event times within a hospital unit using a robust sandwich estimator for covariance of model parameter estimates.²⁷

To account for missing data in covariates (ranging from 0.04%–7.5%; Table 1), we used multiple imputation by chained equations to impute 100 complete data sets. These were then analyzed as described, and results were combined using standard methods.²⁸ *P* values were evaluated against a significance level of 5%. Sensitivity analyses were performed to evaluate the robustness of findings to the multiple imputation procedure and covariate adjustment set, details of which have been published.²⁹

Additional details of the prespecified statistical methods can be found in the Statistical Analysis Plan on clinicaltrials.gov.

RESULTS

The final analysis cohort included 1069 patients from 19 INV hospitals and 1193 patients from 20 UC hospitals (Figure). Hospital characteristics were similar between study arms (Table 2), although more patients from metropolitan areas were enrolled at UC hospitals (1010 of 1193 or 84.7% versus 590 of 1069 or 55.2% in INV), and more patients from rural areas were enrolled at INV hospitals (124 of 1069 or 11.6% versus 8 of 1193 or 0.7% in UC). With regard to patient characteristics (Table 1), there was a smaller proportion of women in the INV arm (49.1% versus 54.7% in UC), and there were more White patients in the INV arm (85.7% versus 76.6% in UC). There were no notable differences in stroke diagnoses, stroke severity, comorbidities, or referrals to rehabilitation between groups.

In intention-to-treat analysis, 19.9% of INV and 18.9% of UC patients experienced at least 1 all-cause readmission at 90 days, with an odds ratio (OR) of 1.10 (95% CI, 0.85–1.41), after adjustment for age, sex, race, stroke severity, stroke diagnosis, history of stroke, and history of TIA (Table 3). We observed no differences in the proportion and adjusted ORs of 30-day (9.9% in INV versus 8.7% in UC; OR, 1.20; 95% CI, 0.83–1.74) or 1-year all-cause readmissions (45.5% INV versus 43.2% UC; OR, 1.06; 95% CI, 0.95–1.77) between groups.

We found that 3.6% of INV and 2.0% of UC patients were readmitted with a primary stroke diagnosis at 90 days, and 1.5% versus 1.4% at 30 days, respectively. Within 1 year, 6.2% of INV patients and 5.2% of

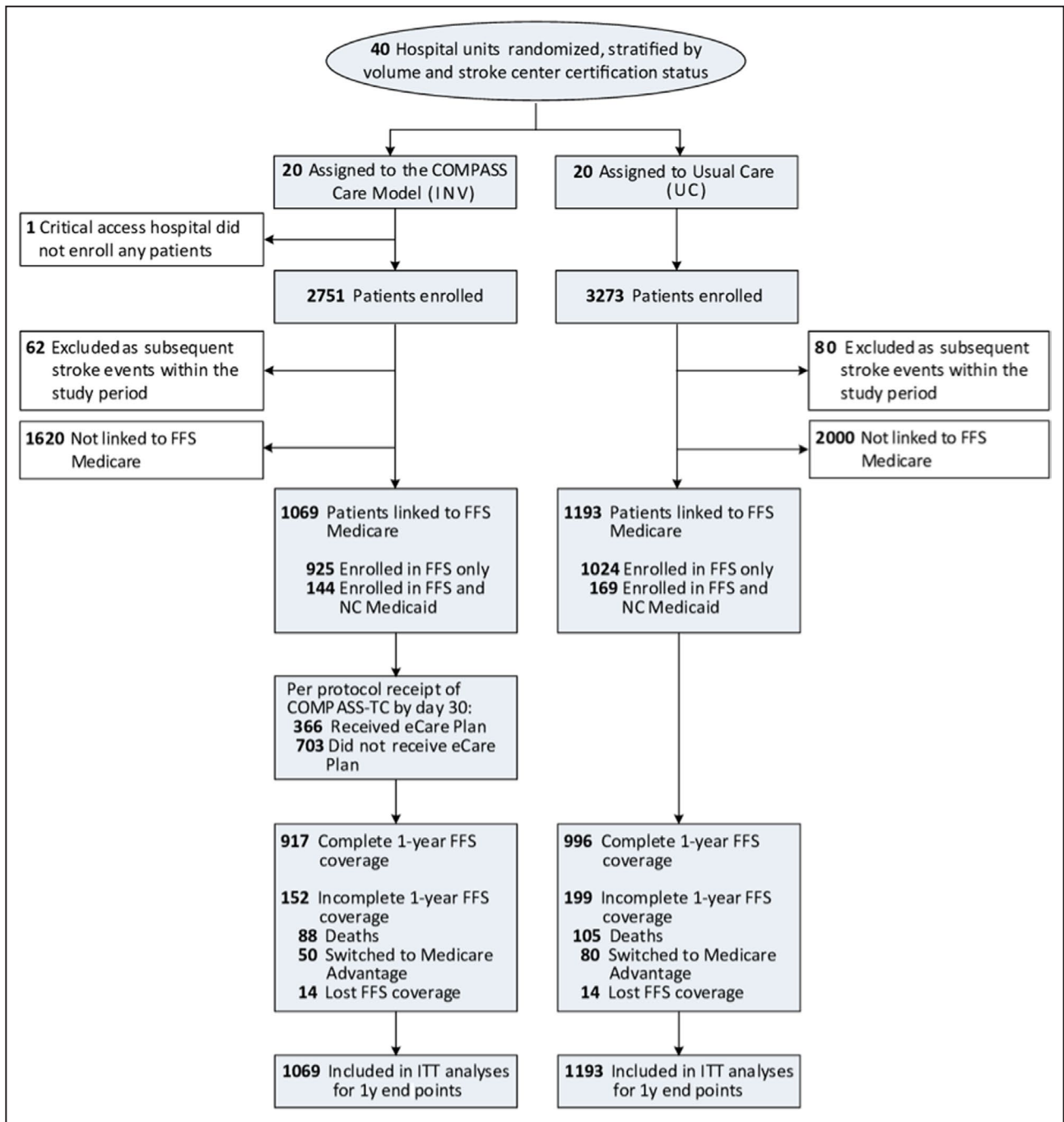


Figure. Flow of COMPASS patients included and excluded from analysis of FFS Medicare claims. COMPASS indicates Comprehensive Post-Acute Stroke Services; COMPASS-TC, Comprehensive Post-Acute Stroke Services Transitional Care; eCare Plan, electronic care plan; FFS, fee-for-service; INV, intervention; ITT, intention-to-treat; NC, North Carolina; and UC, usual care.

UC patients experienced a recurrent stroke (adjusted OR, 1.26; 95% CI, 0.90–1.77); differences were not statistically significant.

There were no differences between randomization groups in the risk of 1-year mortality (8.5% INV versus 8.8% UC; OR, 0.93; 95% CI, 0.68–1.26).

As is shown in Table 4, the most common diagnoses for initial 90-day readmission were cerebrovascular (21% UC versus 28% INV) followed by circulatory–cardiopulmonary (8% UC versus 10% INV). There were no major differences in reasons for all-cause readmissions.

Table 1. Baseline Patient Characteristics of Medicare FFS COMPASS Patients, by Study Arm

Patient characteristic	Intervention (N=1069)	Usual care (N=1193)
Age, y, mean (SD)	74.9 (10.2)	73.9 (10.5)
Female sex, n (%)	525 (49.1)	652 (54.7)
White race, n (%)	912 (85.7)	905 (76.6)
Missing	5	11
Urban-rural classification of patient residence, n (%)		
Metropolitan (population ≥50 000)	584 (54.7)	937 (78.5)
Micropolitan (population 10 000–49 999)	303 (28.4)	179 (15.0)
Small town or rural (population <10 000)	181 (17.0)	77 (6.5)
Missing	1	0
Stroke diagnosis, n (%)		
Stroke	648 (60.6)	702 (58.8)
TIA	421 (39.4)	491 (41.2)
Aphasia at presentation, n (%)	236 (22.1)	305 (25.6)
National Institute of Health Stroke Scale score, n (%)		
0	417 (39.3)	436 (37.9)
1–4	494 (46.6)	552 (47.9)
5–15	135 (12.7)	142 (12.3)
16–42	15 (1.5)	22 (1.9)
Missing	8	41
Medical history and comorbidity, n (%)*		
Hypertension	849 (79.4)	945 (79.2)
Diabetes	363 (34.0)	419 (35.1)
Prior stroke	229 (21.4)	276 (23.1)
Prior TIA	131 (12.3)	148 (12.4)
Atrial fibrillation or flutter	204 (19.1)	215 (18.0)
Heart failure	99 (9.3)	131 (11.0)
Coronary artery disease	267 (25.0)	280 (23.5)
Depression	97 (9.1)	149 (12.5)
Smoking in past year	143 (13.4)	178 (14.9)
Body mass index (kg/m ²), median (IQR)	27.7 (24.2–31.3)	27.0 (23.7–31.2)
Missing	112	57
Admission status, n (%)		
Inpatient	835 (78.1)	943 (79.0)
Emergency department	27 (2.5)	52 (4.4)
Observation status	206 (19.3)	198 (16.6)
Unknown	1 (0.1)	0 (0.0)
Hospital length of stay, median (IQR) [†]	2 (1–3)	2 (1–3)
Ambulatory status at discharge, n (%)		
Ambulate independently	983 (93.8)	1104 (93.8)
With assistance	22 (2.1)	20 (1.7)
Unable to ambulate	43 (4.1)	53 (4.5)
Missing	21	16

(Continued)

Table 1. (Continued)

Patient characteristic	Intervention (N=1069)	Usual care (N=1193)
Rehabilitation needed at discharge, n (%)	463 (47.0)	459 (40.2)
Missing	83	52
Home health referral at discharge, n (%)		
Occupational therapy	139 (14.1)	154 (13.5)
Physical therapy	286 (29.0)	299 (26.2)
Speech therapy	78 (7.9)	62 (5.4)

COMPASS indicates Comprehensive Post-Acute Stroke Services; FFS, fee-for-service; IQR, interquartile range; and TIA, transient ischemic attack.

*Abstracted from medical record by hospital nursing staff.

[†]Defined among patients with inpatient admission.

DISCUSSION

In this claims-based analysis of the COMPASS trial, we found the risk of all-cause readmission, stroke-specific readmission, and mortality similar between COMPASS-TC and usual care at all time points. Yet, in the overall cohort we note that patients with stroke and TIA discharged home are vulnerable because they are at a substantial risk of readmission within 1 year.

Comparison with other stroke TC interventions is limited because few studies were performed in the United States and even fewer included readmission as an outcome. The most common outcomes are physical function, disability, and quality of life.^{15,30} However, the Cochrane Collaboration review of all early supported discharge trials showed that of the 7 trials (918 patients) with data on hospital readmissions, rates were similar in early supported discharge (31%) and the UC (28%) groups.³¹ TC interventions to prevent readmissions have also shown mixed results when implemented for other high-risk conditions, such as chronic obstructive pulmonary disease,³² congestive heart failure,³³ and high-risk older adults.^{34,35}

Despite the low severity of patients in this study (mean initial National Institutes of Health Stroke Scale score=1 and one third of the patients had TIA), about 9%, 20%, and 45% were readmitted within 30 days, 90 days, and 1 year, respectively. According to data from the nationally representative National (Nationwide) Inpatient Sample, the largest all-payer inpatient care database in the United States, the 30-day all-cause readmission rate for stroke was 12.1% based on data from 2013.³⁶ A study of 2013 to 2014 Medicare FFS patients with ischemic stroke discharged to home health services experienced a 30-day readmission rate of 8.8% and a 90-day readmission rate of 18.2%.³⁷ Our 1-year readmission rates are consistent with the Swedish Stroke Register, which reported that ~44% of patients with ischemic stroke were readmitted in the first year.³⁸ Similarly, a claims-based study from Taiwan that explored the

Table 2. Hospital Characteristics of Medicare FFS COMPASS Patients, by Study Arm

Hospital characteristic	Intervention (N=1069)	Usual care (N=1193)
No. of hospital units	19	20
Joint Commission Primary Certified Stroke Center, n (%)	867 (81.1)	908 (76.1)
Any academic affiliation, n (%)*	276 (25.8)	518 (43.4)
Hospital geographic location, n (%)		
Central piedmont	530 (49.6)	536 (44.9)
Western	384 (35.9)	230 (19.3)
Eastern	155 (14.5)	427 (35.8)
Urban-rural classification of hospital, n (%)		
Metropolitan (population ≥50 000)	590 (55.2)	1010 (84.7)
Micropolitan (population 10 000–49 999)	355 (33.2)	175 (14.7)
Small town or rural (population <10 000)	124 (11.6)	8 (0.7)
Annual stroke discharge volume, n (%)		
<100 patients	83 (7.8)	65 (5.5)
100–299 patients	349 (32.7)	550 (46.1)
300+ patients	637 (59.6)	578 (48.4)

COMPASS indicates Comprehensive Post-Acute Stroke Services; and FFS, fee-for-service.
 *Includes limited, graduate, and major (vs none).

relationship between initial stroke severity and risk of readmission found that 34% of patients with mild stroke were readmitted 1 year after discharge.³⁸

Overall in intention-to-treat analyses, we found no differences in readmission rates, both all-cause and owing to recurrent stroke, and no difference in 1-year mortality between INV and the UC arms. These findings were not surprising given that only 34% of Medicare FFS patients in the INV arm attended the follow-up clinic visit to receive the comprehensive electronic care plan within 1 month of hospital discharge.¹⁹ This low uptake was in spite of phone contact with patients 2 days after discharge to confirm appointments, consistent central implementation monitoring, regular contact with providers at each INV hospital, with quality reports on key metrics, and site-specific support from the clinical coordinating center.³⁹ In line with the COMPASS study’s highly pragmatic design, COMPASS-TC was integrated into patient care

without additional staff resources provided to hospitals.^{18,21} Similar to the CMS Community-based Care Transitions Program—another real-world transitional care study—only half of hospitals staffed follow-up clinics adequately for uninterrupted delivery of the intervention.⁴⁰ Indeed, despite this low rate of uptake, receipt of COMPASS-TC (35%) was higher than TC management among Medicare beneficiaries nationwide for any condition (7% in 2015).¹³ In addition, our baseline hospital survey described significant hospital variation in meeting TC management requirements before study launch.⁴¹

In quantitative and qualitative implementation analyses, we noted multiple factors that characterized successful hospital implementation and delivery of the intervention, which included organizational readiness at the hospital level and consistent buy-in from billing providers and nurses who treated the INV as their standard of care rather than a research study.^{39,42} These

Table 3. Risk of Unplanned All-Cause Readmissions, Stroke-Specific Readmissions, and Mortality Following Discharge Home

Outcome	No. (%) experiencing the event*		Estimand	Treatment effect† (95% CI)
	Intervention	Usual care		
30 d all-cause unplanned readmissions†	105 (9.9)	103 (8.7)	Odds ratio	1.20 (0.83–1.74)
90 d all-cause unplanned readmissions†	210 (19.9)	222 (18.9)	Odds ratio	1.10 (0.85–1.41)
1-y all-cause readmissions	485 (45.4)	516 (43.3)	Hazard ratio from recurrent events model	1.06 (0.95–1.77)
1-y stroke readmission	67 (6.3)	62 (5.2)	Hazard ratio from recurrent events model	1.26 (0.90–1.77)
1-y mortality	91 (8.5)	105 (8.8)	Hazard ratio	0.93 (0.68–1.26)

Models adjusted for age (quadratic), sex, race, stroke severity, stroke diagnosis, history of stroke, history of transient ischemic attack.

*N (%) shown represent the number of patients with at least 1 qualifying event over follow-up.

†N=10 excluded because of loss of coverage within the 30-d risk period.

‡N=32 excluded because of loss of coverage within the 90-d risk period.

Table 4. Causes of 90-Day Readmission by *International Classification of Diseases, Tenth Revision (ICD-10)* Diagnosis Group

	Intervention (N=210)		Usual care (N=222)	
	n	%	n	%
Circulatory system				
Cerebrovascular	58	27.6	46	20.7
Heart/lung disease	21	10.0	18	8.1
Hypertension	11	5.2	10	4.5
Digestive system				
Injury	10	4.8	16	7.2
Genitourinary system/ kidney disease	10	4.8	15	6.8
Respiratory system				
Infections	10	4.8	13	5.9
Endocrine/nutritional/ metabolic	8	3.8	10	4.5
Nervous system				
Other	44	21.0	65	29.3

findings are a critical contribution of our trial overall and suggest that not all acute care hospitals are prepared to be the hub for TC.

The importance of timing of readmission was best illustrated in a large claims database analysis of all-cause risk-standardized readmission rates for patients discharged with acute myocardial infarction, heart failure, and pneumonia.⁴³ Hospital-level variation in readmissions was highest in the first 5 to 7 days, suggesting that quality of the discharge and early follow-up attributable to the hospital is likely related to these early readmissions. The study also noted that, with adjustment for location and median household income, there was essentially no variation between hospital readmission rates between 7 and 90 days post discharge. Recognizing the importance of these patient characteristics and the timing of readmission, we chose 90-day readmission rate as our primary claims-based outcome. As described in our publication of the primary, non-claims-based outcomes from this trial, the focal point of the intervention was a care plan generated from a functional assessment that incorporated geodemographic (eg, transportation challenges) and income factors (eg, access to medications).¹⁹ The assessment, therefore, provided insight into the social and functional determinants specific to the patient with stroke and caregiver and allowed creation of an individualized care plan that would provide referrals to address these factors (eg, sources for free medications or transportation services). Ultimately, this study could not conclusively determine if the lack of effectiveness of the intervention was attributable to the characteristics of the intervention itself or its inadequate implementation.

The most common risks for preventable all-cause readmission within 30 days after discharge from the acute stroke hospital stay have been well documented, and our findings were similar.²⁵ Shown in Table 4, in this cohort of patients with mild stroke or TIA, the reasons for readmission were most commonly cerebrovascular, followed by cardiopulmonary circulatory diagnoses, with a nonsignificant trend for more frequent *ICD-10* codes representing these conditions in the INV arm compared with UC. The reasons for readmission vary across studies, but recurrent stroke is often one of the most common readmission diagnoses and was in our study as well.^{17,36,38,44}

Given the many negative trials of TC interventions to reduce readmissions, as well as the finding that many poststroke readmissions may be preventable, it may be time to look at causes of readmissions through a different lens.³⁶ A systematic review identified multiple root causes of readmissions. These included organizational—integrated care (lack of resources for outpatient care, coordination and communication problems); organizational—hospital department level (poor clinical care before discharge at the patient level); human behavior—care provider (lack of skills and knowledge leading to poor clinical decision-making); human behavior—informal caregiver (inadequate support); patient—self-management (incorrect behavior such as nonadherence, misuse of medication, etc); and patient—disease (unexpected complications related to disease progression, comorbidity, or severity of illness). Consideration of these categories provides a contextual framework for hospital readmission analyses and may encourage investigators to consider factors beyond hospital characteristics in identifying root causes of readmissions (eg, electronic health record capture of patient-reported outcomes) to develop truly effective preventive strategies.

Hospital readmission rates are a priority for health systems because this metric is used to evaluate value-based programs and align payment with quality. It has continued despite changes in health care administrations. Given the dramatic impact that the Hospital Readmission Reduction Program has had on the hospitals' approach to 30-day readmissions,⁴⁵ changing the focus to postacute care extending well beyond 30 days and incentivizing health systems to promote more patient-centered outcomes is important.

Despite the clear challenges with delivery of the intervention, this analysis of the readmissions and mortality outcomes in the COMPASS study has important strengths. First, this analysis included all in the COMPASS study who were successfully matched with their CMS Medicare claims data; therefore, patients who were lost to follow-up for the nonclaims 90-day outcomes in the COMPASS study could be included in this analysis without missing data.¹⁹

Second, we supplemented claims data with key clinical characteristics—including initial stroke severity—collected as part of the trial at hospital discharge and at 90 days. Stroke severity is commonly missing from claims-only analyses and a major limitation when estimating outcomes.^{25,36} Finally, although this analysis cohort was not as large as other claims-based cohorts, our sample size was larger than any other randomized controlled trials of interventions for TC.^{15,30}

This study had limitations. First, about 50% of the patients enrolled in COMPASS had private insurance, were enrolled in Medicaid or MA (Medicare benefits through a private-sector insurer), or lacked insurance entirely and could not be included in this analysis that leveraged only Medicare FFS claims. Limiting analyses to Medicare FFS patients, with the exclusion of patients with other insurance types, reduced our generalizability to older adults with FFS insurance. Approximately 98% of US individuals aged ≥ 65 years receive either Medicare fee-for-service (FFS) or MA insurance. The latter was developed to provide Medicare beneficiaries with a choice of potentially cost-saving health insurance in addition to the traditional FFS programs. However, MA plans began submitting to CMS Medicare encounter data only in 2012,⁴⁶ and those data were not available for research purposes at the time of this study. During the time of the COMPASS study (2016–2018), approximately two thirds of Medicare beneficiaries were enrolled in Medicare FFS and one third in MA.⁴⁷ There may be concerns regarding differences in patients with FFS versus MA. Compared with FFS, enrollment in MA initially favored healthier beneficiaries,⁴⁸ leading to differences in outcomes such as mortality, which has been greater among FFS beneficiaries.⁴⁹ However, national survey data suggest that FFS and MA beneficiaries are now similar in terms of demographic and comorbidity characteristics but differ in their experiences with the health care system.⁵⁰ Therefore, we believe our results may be generalizable to the MA population. Finally, given the challenges we experienced in encouraging patients to attend the follow-up clinic visit within the target of 14 days post discharge, the intervention may not have been delivered prior to readmission.

CONCLUSIONS

In conclusion, a pragmatic trial of a comprehensive TC intervention for patients after minor stroke or TIA did not reveal a significant reduction in readmissions or mortality. Further research might lead to more definitive outcomes if the root causes of readmissions were identified and reported, TC models were intently focused on the complexity of all strokes, including minor stroke and TIA, and extended beyond 90 days post discharge. Further research should evaluate the best systems to manage extended transitional care.

ARTICLE INFORMATION

Received August 4, 2021; accepted October 11, 2021.

Affiliations

Department of Neurology, Wake Forest Baptist Health, Winston-Salem, NC (C.D.B., S.W.C., M.E.S., P.W.D.); Department of Epidemiology, College of Public Health, University of Kentucky, Lexington, KY (A.M.K.-N.); Department of Epidemiology, Gillings School of Global Public Health (A.M.K.-N., S.B.J., A.M.J., F.W., W.D.R.); Department of Biostatistics, Gillings School of Global Public Health (M.A.P.); and Cecil G Sheps Center for Health Services Research (G.P.H.), University of North Carolina at Chapel Hill, NC; Insight Policy Research, Arlington, VA (L.C.D.); Department of Family Medicine, University of North Carolina School of Medicine, Chapel Hill, NC (J.R.H.); Duke University School of Medicine, Durham, NC (J.P.B.); Department of Physical Therapy, School of Health and Rehabilitation Sciences, University of Pittsburgh, PA (J.K.F.); and Division of Public Health Sciences, Department of Social Sciences and Health Policy, Wake Forest School of Medicine, Winston-Salem, NC (S.B.G.).

Acknowledgments

All statements in this presentation, including its findings and conclusions, are solely those of the authors and do not necessarily represent the views of the Patient-Centered Outcomes Research Institute, its Board of Governors, or Methodology Committee.

Sources of Funding

This research was supported through a Patient-Centered Outcomes Research Institute Project Program Award (PCS-1403-14532).

Disclosures

Drs Duncan and Bushnell have ownership interest in Care Directions. The remaining authors have no disclosures to report.

REFERENCES

1. Benjamin EJ, Muntner P, Alonso A, Bittencourt MS, Callaway CW, Carson AP, Chamberlain AM, Chang AR, Cheng S, Das SR, American Heart Association Council on Epidemiology and Prevention Statistics Committee and Stroke Statistics Subcommittee, et al. Heart disease and stroke statistics-2019 update: a report from the American Heart Association. *Circulation*. 2019;139:e56–e528. doi: 10.1161/CIR.0000000000000659
2. Koton S, Schneider AL, Rosamond WD, Shahar E, Sang Y, Gottesman RF, Coresh J. Stroke incidence and mortality trends in US communities, 1987 to 2011. *JAMA*. 2014;312:259–268. doi: 10.1001/jama.2014.7692
3. Bambhroliya AB, Donnelly JP, Thomas EJ, Tyson JE, Miller CC, McCullough LD, Savitz SI, Vahidy FS. Estimates and temporal trend for US nationwide 30-day hospital readmission among patients with ischemic and hemorrhagic stroke. *JAMA Netw Open*. 2018;1:e181190. doi: 10.1001/jamanetworkopen.2018.1190
4. Brott TG, Halperin JL, Abbara S, Bacharach JM, Barr JD, Bush RL, Cates CU, Creager MA, Fowler SB, Friday G, et al. 2011 ASA/ACCF/AHA/AANN/AANS/ACR/ASNR/CNS/SAIP/SCAI/SIR/SNIS/SVM/SVS guideline on the management of patients with extracranial carotid and vertebral artery disease: executive summary. *Circulation*. 2011;124:489–532. doi: 10.1161/CIR.0b013e31820d8d78
5. Bushnell CD, Zimmer LO, Pan W, Olson DM, Zhao X, Meteleva T, Schwamm L, Ovbiagele B, Williams L, Labresh KA, et al. Persistence with stroke prevention medications 3 months after hospitalization. *Arch Neurol*. 2010;67:1456–1463. doi: 10.1001/archneurol.2010.190
6. Hughes AK, Woodward AT, Fritz MC, Swierenga SJ, Freddolino PP, Reeves MJ. Unmet needs of US acute stroke survivors enrolled in a transitional care intervention trial. *J Stroke Cerebrovasc Dis*. 2020;29:104462. doi: 10.1016/j.jstrokecerebrovasdis.2019.104462
7. Broderick JP, Abir M. Transitions of care for stroke patients: opportunities to improve outcomes. *Circ Cardiovasc Qual Outcomes*. 2015;8:S190–S192. doi: 10.1161/CIRCOUTCOMES.115.002288
8. Centers for Medicare and Medicaid Services. Transitional care management services fact sheet 2021. February 15, 2021. Available at: <https://www.cms.gov/outreach-and-education/medicare-learning-netwo>

- rk-mln/mlnproducts/downloads/transitional-care-management-services-fact-sheet-icn908628.pdf. Accessed February 15, 2021.
9. Agarwal SD, Barnett ML, Souza J, Landon BE. Adoption of Medicare's transitional care management and chronic care management codes in primary care. *JAMA*. 2018;320:2596–2597. doi: 10.1001/jama.2018.16116
 10. Prvu Bettger J, McCoy L, Smith EE, Fonarow GC, Schwamm LH, Peterson ED. Contemporary trends and predictors of postacute service use and routine discharge home after stroke. *J Am Heart Assoc*. 2015;4:e001038. doi: 10.1161/JAHA.114.001038
 11. Grabowski DC, Huckfeldt PJ, Sood N, Escarce JJ, Newhouse JP. Medicare postacute care payment reforms have potential to improve efficiency of care, but may need changes to cut costs. *Health Aff (Millwood)*. 2012;31:1941–1950. doi: 10.1377/hlthaff.2012.0351
 12. Buntin MB, Colla CH, Deb P, Sood N, Escarce JJ. Medicare spending and outcomes after postacute care for stroke and hip fracture. *Med Care*. 2010;48:776–784. doi: 10.1097/MLR.0b013e3181e359df
 13. Bindman AB, Cox DF. Changes in health care costs and mortality associated with transitional care management services after a discharge among Medicare beneficiaries. *JAMA Intern Med*. 2018;178:1165–1171. doi: 10.1001/jamainternmed.2018.2572
 14. Olson D, Grissom JL, Dombrowski K. The evidence base for nursing care and monitoring of patients during therapeutic temperature management. *Ther Hypothermia Temp Manag*. 2011;1:209–217. doi: 10.1089/ther.2011.0014
 15. Pühr MI, Thompson HJ. The use of transitional care models in patients with stroke. *J Neurosci Nurs*. 2015;47:223–234. doi: 10.1097/JNN.0000000000000143
 16. Adeoye O, Nyström KV, Yavagal DR, Luciano J, Nogueira RG, Zorowitz RD, Khalessi AA, Bushnell C, Barsan WG, Panagos P, et al. Recommendations for the establishment of stroke systems of care: a 2019 update. *Stroke*. 2019;50:e187–e210. doi: 10.1161/STR.000000000000173
 17. Condon C, Lycan S, Duncan P, Bushnell C. Reducing readmissions after stroke with a structured nurse practitioner/registered nurse transitional stroke program. *Stroke*. 2016;47:1599–1604. doi: 10.1161/STROKEAHA.115.012524
 18. Duncan PW, Bushnell CD, Rosamond WD, Jones Berkeley SB, Gesell SB, D'Agostino RB Jr, Ambrosius WT, Barton-Percival B, Bettger JP, Coleman SW, et al. The Comprehensive Post-Acute Stroke Services (COMPASS) study: design and methods for a cluster-randomized pragmatic trial. *BMC Neurol*. 2017;17:133. doi: 10.1186/s12883-017-0907-1
 19. Duncan PW, Bushnell CD, Jones SB, Psioda MA, Gesell SB, D'Agostino RB Jr, Sissine ME, Coleman SW, Johnson AM, Barton-Percival BF, et al. Randomized pragmatic trial of stroke transitional care: the COMPASS study. *Circ Cardiovasc Qual Outcomes*. 2020;13:e006285. doi: 10.1161/CIRCOUTCOMES.119.006285
 20. Johnson AM, Jones SB, Duncan PW, Bushnell CD, Coleman SW, Mettam LH, Kucharska-Newton AM, Sissine ME, Rosamond WD. Hospital recruitment for a pragmatic cluster-randomized clinical trial: lessons learned from the COMPASS study. *Trials*. 2018;19:74. doi: 10.1186/s13063-017-2434-1
 21. Bushnell CD, Duncan PW, Lycan SL, Condon CN, Pastva AM, Lutz BJ, Halladay JR, Cummings DM, Arnan MK, Jones SB, et al. A person-centered approach to poststroke care: the COMprehensive Post-Acute Stroke Services Model. *J Am Geriatr Soc*. 2018;66:1025–1030. doi: 10.1111/jgs.15322
 22. McGuire TG, Newhouse JP, Sinaiko AD. An economic history of Medicare part C. *Milbank Q*. 2011;89:289–332. doi: 10.1111/j.1468-0009.2011.00629.x
 23. Hammill BG, Curtis LH, Qualls LG, Hastings SN, Wang V, Maciejewski ML. Linkage of laboratory results to Medicare fee-for-service claims. *Med Care*. 2015;53:974–979. doi: 10.1097/MLR.0000000000000420
 24. Centers for Medicare and Medicaid Services (CMS). Master beneficiary summary file (MBSF) LDS. 2020. Available at: <https://www.cms.gov/Research-Statistics-Data-and-Systems/Files-for-Order/LimitedDataSets/MBSF-LDS>. Accessed July 1, 2021.
 25. Lichtman JH, Leifheit-Limson EC, Jones SB, Wang Y, Goldstein LB. Preventable readmissions within 30 days of ischemic stroke among Medicare beneficiaries. *Stroke*. 2013;44:3429–3435. doi: 10.1161/STROKEAHA.113.003165
 26. Prentice RL, Williams BJ, Peterson AV. On the regression analysis of multivariate failure time data. *Biometrika*. 1981;68:373–379. doi: 10.1093/biomet/68.2.373
 27. Wei LJ, Lin DY, Weissfeld L. Regression analysis of multivariate incomplete failure time data by modeling marginal distributions. *J Am Stat Assoc*. 1989;84:1065–1073. doi: 10.1080/01621459.1989.10478873
 28. van Buuren S. Multiple imputation of discrete and continuous data by fully conditional specification. *Stat Methods Med Res*. 2007;16:219–242. doi: 10.1177/0962280206074463
 29. Psioda MA, Jones SB, Xenakis JG, D'Agostino RB. Methodological challenges and statistical approaches in the COMprehensive Post-Acute Stroke Services Study. *Med Care*. 2021;59:s355–s363. doi: 10.1097/MLR.0000000000001580
 30. Reeves MJ, Fritz MC, Woodward AT, Hughes AK, Coursaris CK, Swierenga SJ, Nasiri M, Freddolino PP. Michigan stroke transitions trial. *Circ Cardiovasc Qual Outcomes*. 2019;12:e005493. doi: 10.1161/CIRCOUTCOMES.119.005493
 31. Fearon P, Langhorne P. Services for reducing duration of hospital care for acute stroke patients. *Cochrane Database Syst Rev*. 2012;Cd000443. doi: 10.1002/14651858
 32. Aboumatar H, Naqibuddin M, Chung S, Chaudhry H, Kim SW, Saunders J, Bone L, Gurses AP, Knowlton A, Pronovost P, et al. Effect of a hospital-initiated program combining transitional care and long-term self-management support on outcomes of patients hospitalized with chronic obstructive pulmonary disease: a randomized clinical trial. *JAMA*. 2019;322:1371–1380. doi: 10.1001/jama.2019.11982
 33. Van Spall HGC, Lee SF, Xie F, Oz UE, Perez R, Mitoff PR, Maingi M, Tjandrawidjaja MC, Heffernan M, Zia MI, et al. Effect of patient-centered transitional care services on clinical outcomes in patients hospitalized for heart failure: the PACT-HF randomized clinical trial. *JAMA*. 2019;321:753–761. doi: 10.1001/jama.2019.0710
 34. Finlayson K, Chang AM, Courtney MD, Edwards HE, Parker AW, Hamilton K, Pham TDX, O'Brien J. Transitional care interventions reduce unplanned hospital readmissions in high-risk older adults. *BMC Health Serv Res*. 2018;18:956. doi: 10.1186/s12913-018-3771-9
 35. Federman AD, Soones T, DeCherrie LV, Leff B, Siu AL. Association of a bundled hospital-at-home and 30-day postacute transitional care program with clinical outcomes and patient experiences. *JAMA Intern Med*. 2018;178:1033–1040. doi: 10.1001/jamainternmed.2018.2562
 36. Vahidy FS, Donnelly JP, McCullough LD, Tyson JE, Miller CC, Boehme AK, Savitz SI, Albright KC. Nationwide estimates of 30-day readmission in patients with ischemic stroke. *Stroke*. 2017;48:1386–1388. doi: 10.1161/STROKEAHA.116.016085
 37. Middleton A, Kuo YF, Graham JE, Karmarkar A, Lin YL, Goodwin JS, Haas A, Ottenbacher KJ. Readmission patterns over 90-day episodes of care among Medicare fee-for-service beneficiaries discharged to post-acute care. *J Am Med Dir Assoc*. 2018;19:896–901. doi: 10.1016/j.jamda.2018.03.006
 38. Sennfält S, Petersson J, Ullberg T, Norrving B. Patterns in hospital readmissions after ischaemic stroke—an observational study from the Swedish stroke register (Riksstroke). *Eur Stroke J*. 2020;5:286–296. doi: 10.1177/2396987320925205
 39. Gesell SB, Bushnell CD, Jones SB, Coleman SW, Levy SM, Xenakis JG, Lutz BJ, Bettger JP, Freburger J, Halladay JR, et al. Implementation of a billable transitional care model for stroke patients: the COMPASS study. *BMC Health Serv Res*. 2019;19:978. doi: 10.1186/s12913-019-4771-0
 40. Centers for Medicare and Medicaid Services (CMS). CCTP final evaluation report: evaluation of the community-based care transitions program. 2017. Available at: <https://downloads.cms.gov/files/cmml/cctp-final-eval-rpt.pdf>. Accessed July 1, 2021.
 41. Bettger JP, Jones SB, Kucharska-Newton AM, Freburger JK, Coleman SW, Mettam LH, Sissine ME, Gesell SB, Bushnell CD, Duncan PW, et al. Meeting Medicare requirements for transitional care: do stroke care and policy align? *Neurology*. 2019;92:427–434. doi: 10.1212/WNL.00000000000006921
 42. Lutz BJ, Reimold AE, Coleman SW, Guzik AK, Russell LP, Radman MD, Johnson AM, Duncan PW, Bushnell CD, Rosamond WD, et al. Implementation of a transitional care model for stroke: perspectives from frontline clinicians, administrators, and COMPASS-TC implementation staff. *Gerontologist*. 2020;60:1071–1084. doi: 10.1093/geront/gnaa029
 43. Chin DL, Bang H, Manickam RN, Romano PS. Rethinking thirty-day hospital readmissions: shorter intervals might be better indicators of quality of care. *Health Aff (Millwood)*. 2016;35:1867–1875. doi: 10.1377/hlthaff.2016.0205

-
44. Rao A, Barrow E, Vuik S, Darzi A, Aylin P. Systematic review of hospital readmissions in stroke patients. *Stroke Res Treat*. 2016;2016:9325368. doi: 10.1155/2016/9325368
 45. Bradley EH, Curry L, Horwitz LI, Sipsma H, Thompson JW, Elma M, Walsh MN, Krumholz HM. Contemporary evidence about hospital strategies for reducing 30-day readmissions: a national study. *J Am Coll Cardiol*. 2012;60:607–614. doi: 10.1016/j.jacc.2012.03.067
 46. Creighton S, Duddy-Tenbrunsel R, Michel J. The promise and pitfalls of Medicare Advantage encounter data. 2019. Available at: <https://www.healthaffairs.org/doi/10.1377/hblog20190221.696651/full/2021>. Accessed July 12, 2021.
 47. Freed M, Damico A, Neuman T. A dozen facts about Medicare advantage in 2020. 2021. Available at: <https://www.kff.org/medicare/issue-brief/a-dozen-facts-about-medicare-advantage-in-2020/>. Accessed July 12, 2021.
 48. Greenwald LM, Levy JM, Ingber MJ. Favorable selection in the Medicare+Choice program: new evidence. *Health Care Financ Rev*. 2000;21:127–134.
 49. Krumholz HM, Nuti SV, Downing NS, Normand SL, Wang Y. Mortality, hospitalizations, and expenditures for the medicare population aged 65 years or older, 1999–2013. *JAMA*. 2015;314:355–365. doi: 10.1001/jama.2015.8035
 50. Landon BE, Zaslavsky AM, Bernard SL, Cioffi MJ, Cleary PD. Comparison of performance of traditional Medicare vs Medicare managed care. *JAMA*. 2004;291:1744–1752. doi: 10.1001/jama.291.14.1744