ORIGINAL RESEARCH

Outcomes associated with endovascular treatment among patients with acute ischemic stroke in the USA

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ABSTRACT

Background Few studies have examined the trends in clinical and economic outcomes of patients with acute ischemic stroke (AIS) who receive endovascular therapy (ET) in the real-world setting.

Objective To evaluate characteristics and trends in clinical and economic outcomes among commercially insured patients with AIS undergoing ET between 2011 and 2017.

Methods Patients with AIS undergoing ET from January 1, 2011 to June 30, 2017 were identified from administrative claims contained in the IBM MarketScan Commercial and Medicare Supplemental databases. The Mann–Kendall trend test was performed to examine clinical and economic trends.

RESULTS

Between 2011 and 2017, 3411 patients (mean age 62.85±15 years) with a primary diagnosis of AIS underwent ET (coverage: Commercial 59%, n=2008; Medicare Supplemental 41%, n=1403). In the Commercial cohort, discharge to home increased significantly (from 29.54% to 39.18%, p<0.05). Length of stay declined significantly among the overall cohort (from 10.96 to 9.05 days, p<0.01) and the Medicare Supplemental cohort (from 10.03 to 8.43 days, p<0.05). All-cause 365-day readmission decreased significantly among the overall cohort (from 47.5% to 36.7%, p<0.05) and the Commercial cohort (from 51.54% to 36.43%, p<0.05) but remained unchanged in the Medicare Supplemental cohort. While index procedure cost did not change significantly ($93 955 to $87 906, p=0.8806), total cost significantly declined in the overall cohort (from $166 922 to $130 678, p<0.05).

Conclusions Although with some variation across the samples studied, outcomes including discharge to home, length of stay, readmission, and total cost associated with endovascular stroke therapy seemed to have improved between 2011 and 2017. Index admission cost remained unchanged.

INTRODUCTION

The annual economic burden of stroke in the USA is estimated at $34 billion.[1] Ischemic strokes account for about 87% of all strokes.[1] A major shift in acute ischemic stroke (AIS) treatment over the last few years has been the adoption of endovascular mechanical thrombectomy (ET) for treatment of large vessel occlusions following multiple clinical trials which have shown superior efficacy of the combination of ET with intravenous recombinant tissue plasminogen activator (rt-PA) over rt-PA alone.[2–5] The rate of large vessel strokes among patients with AIS is reported to be between 16% and 22%.[6–8]

A few studies including one by the authors of the current study have examined real-world outcomes among patients with AIS receiving ET.[9 10] In our earlier analysis of trends in outcomes associated with ET among patients with AIS using a nationally representative multi-hospital Premier Healthcare Database (PHD), we found a significant improvement in clinical and economic indicators including increase in discharge to home and a decline in mortality, length of stay (LOS), and admission (including 1-year repeat all-cause admission) costs during the 2011–2017 study period.[10] The decline in mortality was notable, with AIS patients receiving ET in 2017 having 44% lower odds of mortality compared with those who had ET in 2011 (OR 0.56; 95% CI 0.44 to 0.72). Not surprisingly, as mortality decreased, the odds of a patient being discharged to home increased over the study period. The LOS of patients with AIS decreased almost 23% and 1-year repeat admission costs declined by 21%.[10]

In continuation of earlier work,[10] we examined trends in outcomes associated with ET treatment among patients with AIS using a nationally representative administrative claims database in this study. The objective of the current study was to evaluate the characteristics of patients with primary (first-time) AIS undergoing ET, specifically to examine trends in discharge status, healthcare utilization, and costs among commercially insured AIS patients who underwent ET between 2011 and 2017 in the real-world setting using claims from the IBM Marketscan Commercial and Medicare Supplemental databases.

METHODS

Study design

A retrospective observational study design was used for this study. No institutional review board approval was required.

Data source

Claims data from January 1, 2011 to June 30, 2017 (Q3) of the IBM Marketscan Commercial and Medicare Supplemental databases (IBM Truven Health Analytics, Ann Arbor, MI) were analyzed.

The IBM MarketScan Commercial is a medical and prescription drug insurance claims database for more than 138 million individuals in the USA who are enrolled in employer-provided health insurance plans. The IBM MarketScan Medicare Supplemental database contains detailed information regarding healthcare services used by retirees with Medicare supplemental insurance paid by employers. The database includes information pertaining to inpatient admissions, outpatient services, prescription drugs, enrollment, and costs associated with the provision of healthcare services.

Study sample

The primary diagnosis of AIS was based on International Classification of Diseases, Ninth Edition (ICD-9) codes 433.xx, 434.xx, and 436.xx and equivalent ICD-10 codes. Patients with a first primary diagnosis of AIS in inpatient claims between January 1, 2011 and June 30, 2017 were identified. By definition, the index AIS was the first inpatient admission with a primary diagnosis of AIS. Eligible patients were required to be at least 18 years of age at the time of index admission. Patients who did not receive ET were excluded. Patients were required to be continuously enrolled for the 12-month pre-index baseline period. Those with a primary or secondary diagnosis of AIS (inpatient) within 12 months prior to the index date and patients with LOS ≤1 day were excluded. The ET procedure was defined based on ICD-9 procedure code 39.74 and equivalent ICD-10 codes; Current Procedural Terminology (CPT) codes 61645, 61650, and 61651; and Diagnosis-Related Group (DRG) codes 023 and 024.

Patient demographics and characteristics

Age and gender were collected at the index hospitalization. Based on the primary or secondary diagnosis code for medical services visits in the 12 month pre-index period, patients were classified as having the following comorbidities: atrial fibrillation, coronary artery disease, congestive heart failure, transient ischemic attack, hemorrhagic stroke, diabetes mellitus, gastrointestinal bleeding, hypertension, valve disease, chronic renal failure, cancer, chronic obstructive pulmonary disease, and comorbidities based on the Charlson Comorbidity Index (CCI). Anticoagulant use in the 90 days prior to the index date was also measured.

Hospital and provider characteristics

Hospital characteristics, including geographic region, metropolitan statistical area (MSA), and weekend admission were collected.

Healthcare and economic outcomes measurements

Trends in discharge status, healthcare use, and costs were evaluated. Study outcome measures included discharge status (home, long-term care, or other (which includes transfer to another facility, transfer to short-term hospital, or any other discharge status)), healthcare use (LOS for index AIS, 365day readmission (all-cause and AIS-related)), and payments for index AIS admission and total payment for index admission and readmission in the 365-day post-index follow-up period.

For the longitudinal outcomes (ie, all-cause 365-day readmission, AIS-related 365-day readmission, and the cost of index admission and readmission in the 365-day post-index period), we applied 365-day continuous enrollment criteria post-index admission discharge. Considering that these patients were followed for 1 year after enrollment, these outcomes are reported up to the last enrollment date (2016Q3).

Statistical analysis

All study variables were analyzed descriptively. The Mann–Kendall trend test, which is a non-parametric statistical test to assess monotonic upward or downward trends, was used to examine trends in the study outcomes. For sensitivity analysis we conducted multivariable modeling to examine the relationship between year of index AIS (independent variable of interest) and the study outcomes, controlling for baseline covariates. In all analyses, a two-sided $p<0.05$ was the threshold by which differences were considered to be statistically significant. All analyses were conducted using SAS for Windows, Version 9.4 (SAS Institute, Cary, North Carolina, USA).

RESULTS

Patient attrition

Patient attrition is presented in table 1. The final study population consisted of 3411 patients with a primary diagnosis of AIS who underwent ET and were identified in the IBM Commercial (n=2008) or the Medicare Supplemental (n=1403) databases.

Patient and provider characteristics

Patient and provider characteristics of the overall population from 2011 to 2017 are presented in table 2. The average age of the population was 62.85±14.94 years, with a majority of the population being male. Overall, 332 (9.73%) patients used anticoagulants within 90 days prior to their index admission date. A majority of the provider regions were located in the Northcentral and Southern regions. Most hospitals were located in a MSA region (overall=87.54%), and weekend admissions occurred in 25.74% of patients overall.

Study outcomes

Discharge status

Among patients with AIS treated with ET from 2011 to 2017, discharge to home increased significantly from 29.54% in 2011 to 39.18% in 2017 in the Commercial cohort (figure 1B; $p<0.05$); however, discharge to home was consistent among the overall (figure 1A) and Medicare cohorts (figure 1C). Discharge to long-term care was consistent among all patient cohorts.

Overall LOS

In the overall and Medicare supplemental cohorts, overall LOS decreased significantly from 2011 to 2017 (overall: from 10.96

Table 1 Cohort selection

Step	Criteria	Commercial (n)	Medicare Supplemental (n)
1	Inpatient episodes with discharge between 2011 and 2017Q3	11 704 481	4 206 057
2	All episodes with a primary diagnosis of AIS	107 526	139 837
3	Select index occurrence of the AIS	95 130	128 275
4	Exclude patients <18 years	94 669	128 275
5	Exclude patients with the diagnosis (primary or secondary) of AIS in inpatient setting in the baseline period of 12 months	90 728	123 451
6	Patients with LOS >1 day	87 960	119 327
7	Continuous enrollment in 365 days pre-index	63 267	97 259
8	Patients who underwent ET (final study sample)	2008	1403

AIS, acute ischemic stroke; LOS, length of stay; ET, endovascular treatment; Q, quarter.

to 9.05 days, p<0.01; Medicare Supplemental: from 10.03 to 8.43 days, p<0.05; figure 2). Although LOS decreased from 2011 to 2017 among the Commercial population (from 11.55 to 9.46 days), the trend was not significant (p=0.0509).

All-cause 365-day readmission

All-cause 365-day readmission decreased significantly from 2011 to 2016 in the overall (47.52% to 36.65%, p<0.05) and Commercial (51.54% to 36.43%, p<0.05) cohorts but remained unchanged among the Medicare Supplemental cohort (40.28% to 36.96%, p=0.8510) (online supplementary figure 1).

AIS-related 365-day readmission

From 2011 to 2016 there was no significant change in AIS-related 365-day readmission in the overall (31.68% to 25.79%, p=0.1885), Commercial (40.77% to 29.46%, p=0.1885), and the Medicare Supplemental (15.28% to 20.65%, p=0.1885) cohorts (online supplementary figure 2).

Index admission cost

There was no significant change in index admission cost over the 6-year period among all cohorts (overall: $93 955.58 to $87 906.07, p=0.8806; Commercial: $112 081.33 to $100 278.73, p=0.0509; and Medicare Supplemental: $65 506.55 to $69 633.48, p=0.6523), with no significant trend observed (online supplementary figure 3).

Index admission plus 365-day readmission cost

Index admission plus 365-day readmission cost significantly decreased from 2011 to 2016 in patients with AIS treated with

Table 2 Patient and provider characteristics of IBM overall cohort (n=3411)

Characteristic	2011 (11.37%) (n=388)	2012 (15.13%) (n=516)	2013 (12.52%) (n=427)	2014 (14.78%) (n=504)	2015 (12.69%) (n=433)	2016 (17.82%) (n=608)	2017 (15.68%) (n=535)	P value
Age (mean (SD)), years	61.70 (14.16)	61.43 (14.81)	63.43 (15.36)	62.98 (14.89)	62.57 (15.06)	63.48 (14.71)	63.99 (15.37)	0.0619
Age group								0.0155
18–49 years	19.59%	18.99%	19.91%	16.27%	18.71%	16.78%	16.45%	
50–59 years	23.45%	29.84%	18.74%	24.21%	23.79%	22.70%	24.49%	
60–69 years	28.09%	22.09%	24.36%	27.18%	24.48%	27.63%	24.86%	
70–79 years	16.75%	15.50%	19.44%	16.07%	16.86%	16.12%	13.46%	
≥80 years	12.11%	13.57%	17.56%	16.27%	16.17%	16.78%	20.75%	
Male gender	55.41%	59.11%	55.74%	52.98%	52.19%	53.13%	52.90%	0.3005
Provider region								<0.0001
Northeast	17.01%	20.74%	16.16%	15.67%	17.32%	15.95%	15.51%	
Northcentral	30.93%	29.84%	38.41%	33.73%	27.48%	29.93%	28.97%	
South	33.51%	27.33%	22.25%	29.96%	41.34%	41.94%	41.50%	
West	15.72%	20.35%	21.55%	18.45%	13.86%	12.17%	13.46%	
Unknown	2.84%	1.74%	1.64%	2.18%	0.00%	0.00%	0.56%	
MSA region	85.05%	86.63%	87.59%	88.89%	87.76%	88.89%	87.10%	0.5819
Weekend admission	25.00%	24.81%	26.23%	26.59%	23.79%	28.45%	24.49%	0.6448
Medicare Supplemental vs Commercial insurance	38.92%	36.05%	48.95%	42.66%	38.57%	42.60%	40.37%	0.0035
Atrial fibrillation	17.01%	16.09%	22.95%	20.44%	19.40%	20.89%	20.93%	0.1192
Coronary artery disease	18.30%	22.48%	22.01%	16.87%	20.55%	24.34%	19.44%	0.0472
Congestive heart failure	10.82%	14.53%	15.46%	15.67%	13.86%	17.76%	17.76%	0.0567
TIA	6.19%	5.23%	5.62%	4.96%	3.70%	2.47%	3.55%	0.0514
Hemorrhagic stroke	2.58%	0.78%	1.64%	3.17%	0.92%	1.48%	1.50%	0.0453
Diabetes mellitus	22.16%	24.03%	23.65%	25.00%	21.02%	23.03%	23.93%	0.8478
Gastrointestinal bleeding	2.32%	3.29%	5.85%	3.77%	3.46%	5.10%	4.86%	0.1224
Hypertension	52.58%	50.78%	56.91%	55.36%	59.12%	62.99%	61.12%	0.0003
Valve disease	12.89%	14.34%	15.22%	12.70%	13.63%	16.12%	14.02%	0.7010
Chronic renal failure	6.19%	6.78%	8.67%	8.13%	7.39%	8.55%	11.40%	0.0809
Dementia	2.32%	1.16%	2.11%	0.60%	0.69%	1.97%	3.18%	0.0167
Cancer	7.99%	8.91%	11.71%	8.93%	8.55%	11.18%	10.47%	0.3731
Chronic obstructive pulmonary disease	13.66%	18.02%	14.52%	15.67%	16.17%	19.41%	18.88%	0.1242
CCI score								0.3031
0	41.49%	38.37%	38.88%	38.89%	38.80%	35.20%	38.88%	
1	38.14%	37.21%	36.53%	35.32%	38.11%	37.99%	35.52%	
≥2	20.36%	24.42%	34.59%	25.79%	23.09%	26.81%	28.60%	
Anticoagulant use within 90 days prior to index date	7.47%	8.33%	10.30%	8.93%	10.16%	11.84%	10.28%	0.2953

CCI, Charlson Comorbidity Index;MSA, metropolitan statistical area; TIA, transient ischemic attack.

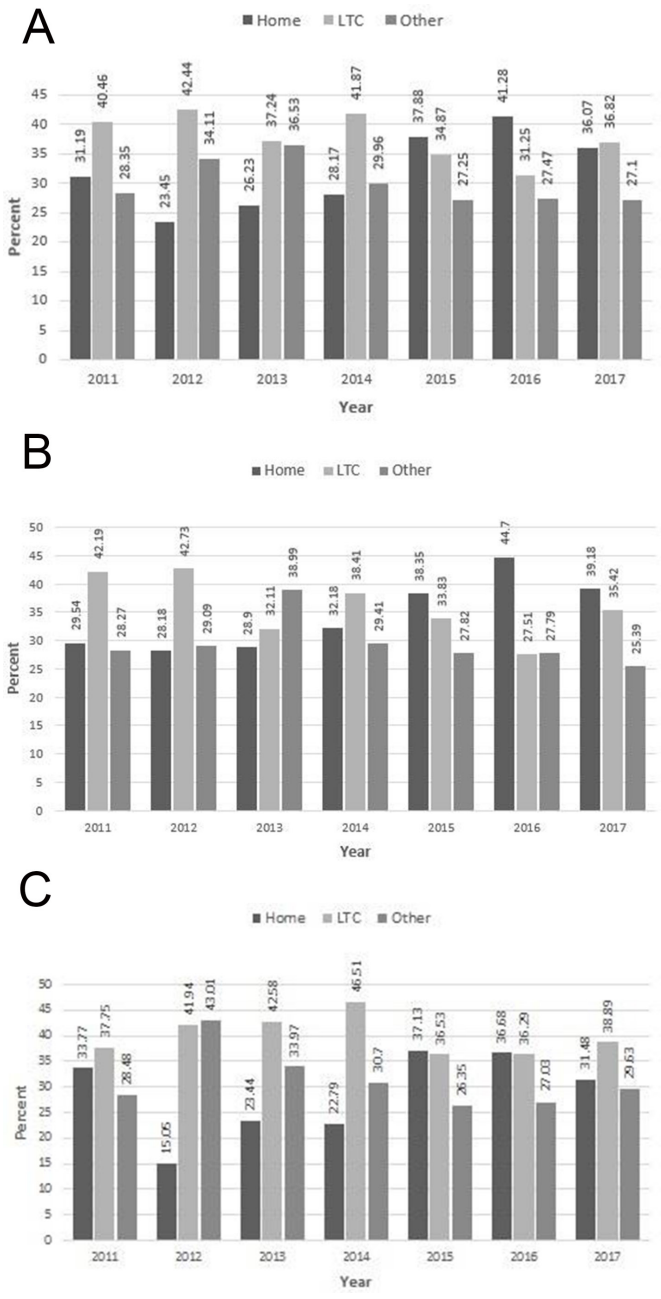

Figure 1 Discharge status in patients with acute ischemic stroke treated with endovascular therapy (ET) from 2011 to 2017 for the (A) overall, (B) commercial, and (C) Medicare Supplemental cohorts. *p<0.05, **p<0.01. LTC, long-term care.

ET in the overall ($166 921.62 to $130 678.06, p<0.05) and Commercial ($195 061.53 to $142 622.54, p<0.05) cohorts (online supplementary figure 2). Among the Medicare Supplemental cohort, although the cost decreased from $116 113.45 in 2011 to $113 929.82 in 2016, the trend was not significant (online supplementary figure 4).

Sensitivity analysis

The multivariable analysis of the overall cohort demonstrated that, for patients who were admitted in 2017, discharge to home was higher (OR 1.38, 95% CI 1.04 to 1.84), LOS was lower (OR 0.45, 95% CI: 0.44 to 0.46), all-cause 365-day readmission was lower (OR 0.24, 95% CI: 0.06 to 0.91), and total cost was lower

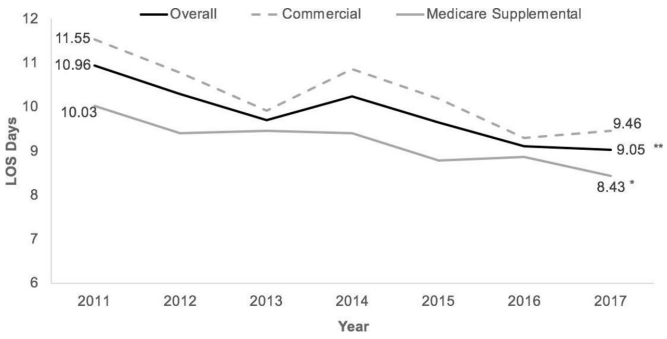

Figure 2 Length of stay (LOS) in patients with acute ischemic stroke treated with endovascular therapy from 2011 to 2017 for the overall, commercial, and Medicare Supplemental cohorts. *p<0.05, **p<0.01.

(OR 0.48, 95% CI: 0.39 to 0.58) than those admitted in 2011, taking into account all baseline covariates.

DISCUSSION

The treatment of AIS with ET has dramatically evolved over the past decade, culminating in the current standard of care of ET with or without use of rt-PA for large vessel strokes. The real-world clinical and economic outcomes of patients with AIS receiving ET is not well published. The current study is one of the first to evaluate in-hospital patient characteristics and trends in healthcare utilization and costs among patients with AIS treated with ET among a commercially insured population in the USA. The current study, although assessing similar outcomes to those in our earlier study using the PHD,[10] has some notable differences that primarily stem from the differential in the databases used across the two studies. The earlier study used a multi-hospital dataset while this study was based on an administrative claims database. Mortality information was not available in the current study, while we could assess mortality in our earlier work using the PHD. The underlying perspective of the two databases differs as well, with IBM MarketScan database having payer perspective while PHD is based on provider perspective. In IBM MarketScan, the cost is from the payer perspective (and includes out-of-pocket payment) while in PHD it is reflective of hospital cost.

We found significantly improving trends in clinical and economic outcomes over a 6-year period (2011 to 2017). There was a significant increase in the number of patients who were discharged to home (Commercial cohort), decline in overall LOS (overall and Medicare Supplemental cohorts), and decrease in all-cause 365-day readmission (overall and Commercial cohorts). However, we did not observe any significant changes in the 365-day AIS-related readmission rate and index admission cost in any of the cohorts studied. For 365-day AIS-related readmissions, while the rate for the Commercial cohort went from ~40% to ~29%, the rate for the Medicare Supplemental cohorts went from ~15% to ~20% during the study period. It is difficult to interpret this conflicting trend, but it may signify the differential in stroke outcomes by age. As per index admission cost being unchanged, it does seem to reflect that providers are able to effectively manage and treat patients with AIS undergoing thrombectomy, as indicated by improvements in outcomes, while at the same time holding costs consistent. Improvements in healthcare utilization did seem to translate into total cost savings. Total index admission plus 365-day readmission costs significantly declined (overall and Commercial cohorts) during the study period.

Despite the underlying differences in the database used, the results from this study align well with those from our earlier work using the PHD. Consistent with the previous study using the PHD,[10] we found an increase in discharge to home and a decline in LOS and cost during the 2011–2017 study period. Together, these studies reflect that outcomes associated with ET have improved among patients with AIS. Although it is difficult to comment on underlying factors influencing this change, the role of technological improvements in ET devices, together with changes in hospital patient management systems for stroke patients, could have played a role in these improvements. The use of CT angiography imaging, which helps predict recurrent stroke and clinical outcome, has been indicated to be a practical assessment tool for AIS patients.[11 12] Improvements in imaging techniques and change in protocols for imaging of AIS patients could also have contributed to the improvements in outcomes observed among patients with AIS undergoing thrombectomy treatment in our study. Improvements in workflow contributing to a decrease in time from symptoms to treatment could also explain the positive trend in AIS outcomes.

Large vessel strokes are associated with higher mortality, lower rate of discharge to home, and in general poorer outcomes compared with non-large vessel stroke.[13] Among patients with large vessel stroke, the use of ET along with rt-PA has been found to be associated with better outcomes including discharge to home compared with the use of rt-PA.[14] Although some outcomes like AIS readmission rate and index cost did not appear to have changed, others such as discharge status, LOS, all-cause readmission rate, and total cost showed improving trends in this study. As the healthcare delivery model transitions from traditional fee-for-service to value-based patient-centric care through acts like the Medicare Access and CHIP Reauthorization Act (MACRA),[14] assessment of outcomes including cost and readmissions will become increasingly critical.

Limitations of study

Most limitations in the current study are inherent to those associated with observational database analyses. This includes incomplete records across the claims data, possibility of miscoding and undercoding, and using a non-probability sample. The IBM Commercial and Medicare Supplemental databases reflect individuals with commercial insurance or those with supplemental commercial insurance in addition to being Medicare beneficiaries. Medicare supplemental insurance, as the name suggests, supplements the Medicare benefits. Therefore, the study results may not be generalizable to other patient populations, including the broader Medicare population. Although we could evaluate discharge to home or long-term care facility, mortality could not be studied as it is not available in the database. Considering the considerable mortality burden associated with large vessel strokes,[13] our assessment of discharge status is likely incomplete. However, it may be noted that, with the increase in discharge to home as seen in our study, it is potentially likely that mortality may have decreased during the study period in our sample, although we could not confirm this in our study. Lastly, the costs reported include paid amounts and may not be reflective of the hospital costs for ET.

CONCLUSIONS

We observed outcomes including discharge to home, LOS, all-cause readmission, and total cost to have improved significantly among patients with AIS treated with ET from 2011 to 2017; however, no significant change in AIS-related readmission rate and index admission cost was observed. As treatment protocols, hospital workflows, imaging techniques, and endovascular devices evolve, ongoing monitoring and retrospective evaluation should be conducted to further confirm these improving trends in outcomes among patients with AIS.

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Contributors AR, CC, IK, RK, NP, FC, and RK were involved in study design, results interpretation, and manuscript development. RK, NP, FC, and RK were involved in data analysis. EK was involved in results interpretation and manuscript development.

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Competing interests CC, EK, IK, and RKh are Johnson and Johnson employees. RKu is an employee of MuSigma Inc, which has a consulting agreement with Johnson and Johnson. NP and FC were Johnson and Johnson employees at the time of the conduct of the study. AR has a consulting agreement with Stryker Neurovascular.

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Provenance and peer review Not commissioned; externally peer reviewed.

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