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Posterior Versus Anterior Circulation Strokes: Comparison of Treatment Costs, and Outcomes for Medicare Patients

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POSTERIOR VERSUS ANTERIOR CIRCULATION STROKES: COMPARISON OF TREATMENT COSTS, AND OUTCOMES FOR MEDICARE PATIENTS

by

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This study used a 5% sample of Medicare billing records from 2012 to identify cost differences between posterior circulation (PCS) and anterior circulation strokes (ACS). We examined ICD-9 codes related to these stroke types at hospital admission, records for six months post stroke, or until death, and identified mean payment and charges by type of care received. The Charlson Comorbidity Score was used to control for the effects of comorbid conditions on cost, survival, and the use of tPA during the Index admission. We identified 105 PCS and a comparison group of 5230 subjects with ACS and compared mean Medicare payment data from initial hospital admission, physician hospital payments, inpatient rehabilitation, outpatient rehabilitation, physician office visits, home healthcare, DME, nursing home care, hospital readmissions, and hospice care. As hypothesized, PCS have greater costs than ACS during early recovery from an ischemic stroke.

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INTRODUCTION

Background and Problem Statement

Stroke is a growing threat to an aging population and has a significant effect on individuals, their families, and society. In 2010 it was the second leading cause of death globally and the fourth leading cause of mortality in the United States, killing an estimated 129,000 Americans each year (Mozaffarian, et al., 2015). The Heart Disease and Stroke Statistics 2014 Update from the American Heart Association reported that there are 795,000 strokes in the US each year, with 610,000 as the first stroke event and 185,000 as stroke reoccurrence (Go, et al., 2013), thus making stroke the leading cause of long term disability in the United States (CDC, 2012). In 2003, Framingham researchers estimated 6% of ischemic stroke survivors required total care in activities of daily living, six months post stroke; of those 50% had a form of hemiparesis, 30% were unable to walk without assistance, 19% were left with aphasia, 35% had symptoms of depression, and 26% were in a nursing home six months post stroke (Kelly-Hayes, et al., 2003). The CDC estimates, each year approximately 50% of older stroke survivors are left to cope with a moderate or severe disability costing $36.5 billion annually (CDC, 2014). Overall cost estimates of stroke vary, with annual direct costs ranging from $18.8 billion ($19.6 in 2015) (Ma, Chain, & Carruthers, 2014) to $28.3 billion ($29.5 in 2015) (Heidenreich, et al., Forecasting the future of cardiovascular disease in the United States: A policy statement from the American Heart Association, 2011) and annual indirect cost from $15.5 billion ($16.2 in 2015) (Ma, Chain, & Carruthers, 2014) to $25.6 billion

($26.7 in 2015) (Heidenreich, et al., Forecasting the future of cardiovascular disease in the United States: A policy statement from the American Heart Association, 2011), (Coin News Media Group LLC, 2008-2014).

Current trends in health care have focused on the use of evidence based practice to improve patient outcomes, hospital quality, and lower treatment costs (Tsai, Orav, & Jha, 2015), (Esposito, Selker, & Salem, 2015), (Leonhardt & Benesch, 2015). Understanding the costs associated with stroke can have a direct effect on the timing and type of resources that are used to treat patients following a stroke. Recent studies have reported on the cost of stroke and stroke outcomes by examining ICD-9 codes associated with stroke type: ischemic, hemorrhagic, or other (Heidenreich, et al., 2011), (Lakshminarayan, et al., 2014), (Greenhalgh, Howick, & Maskrey, 2014). Unfortunately, using ICD-9 codes to research stroke by type restricts our ability to understand the level of deficit associated with each form of stroke. Anecdotal evidence from clinicians indicates that resource requirements for stroke rehabilitation are more closely related to a specific artery or area of the brain involved in a stroke, rather than to stroke type. Mittmann et al., (2012) stated that it is important to study the economic bearing of stroke treatment in particular, to explore the costs associated with stroke severity as a critical basis for choosing the best treatment approach (Mittmann, et al., 2012). The authors state that if treatment interventions lessen the severity of stroke, outcomes will improve, in turn lessoning the costs associated with the condition (Mittmann, et al., 2012). The use of standard stroke diagnosis ICD-9 codes to define stroke may obscure resource use and cost differences for stroke care associated with stroke location. However, this can occur with ICD-9 codes related to the anterior and posterior cerebral circulation strokes.

Studies are needed to examine rehabilitation resource use and cost of care for patients categorized by the location of a stroke in the brain, and this study is designed to fill that research gap. The proposed study will use ICD-9 codes for strokes affecting the anterior or posterior cerebral circulation to identify the costs and outcomes for stroke patients based on this definition. who are identified in a 5% sample of Medicare billing records. The study will measure the following stroke-related outcomes: 1) cost of initial hospital admission and associated physician costs, 2) cost of inpatient rehabilitation, 3) cost of outpatient rehabilitation therapy, and 4) total cost of care over 6 months post stroke.

Research Questions and Hypotheses

This study will attempt to answer the following questions: 1) What is the cost burden of an anterior circulation stroke compared to a posterior circulation stroke? 2) How do the stroke outcomes differ, and what are the clinical and cost implications? To address those questions, we will examine a 5% Medicare sample of initial hospital admission, the cost of inpatient rehabilitation, the cost of outpatient rehabilitation therapy, and the overall cost of care over six months post stroke.

We hypothesize that posterior circulation strokes will incur higher aggregate costs then anterior territory strokes due to the effects on vision systems, balance, and the multiple syndromes (Table 5 and 6) that are associated with infarction in the posterior area of the brain. Additionally, research shows that patients with a posterior circulation stroke can exhibit middle cerebral artery like symptoms including aphasia, visuospatial neglect, and hemiparesis (Maulaz, Bezerra, & Bogousslavsky, 2005). Multiple studies have shown a higher frequency of cardiovascular risk factors in patients with posterior strokes, increasing the chances of having a secondary event (Abdul-Ghaffar, El-Sonbaty, el-Din Abdul-Baky, Marafie, & Al-Said, 1997) (Glass, et al., 2002). Posterior area cerebral strokes are not well characterized to date. Research has shown that CT imaging is limited in detecting acute posterior circulation strokes; although posterior circulation ischemia has been thought to have a lower recurrence rate than anterior circulation ischaemia, recent data indicates that the risks are the same if not higher for posterior events (Merwick & Werring, 2014). Because posterior circulation stroke diagnostic and treatment strategies are less common, we hypothesize that they will have a greater total cost of treatment 6 months post stroke.

Importance of the Study

Understanding the cost impact of strokes in the United States is important because it enables researchers and clinicians to know which resources will have the most impact on recovery management. This study will determine whether there is a significant cost difference in the overall treatment and outcome of Medicare patients who have had a stroke by comparing ICD9 codes related to the anterior versus posterior circulation of the brain. Knowing the factors that affect the need for resources and cost of care for stroke after hospital discharge will help clinicians better advise patients and families about (a) prognosis and (b) access to resources needed to optimize outcomes and control cost of care.

Limitations

The study is limited by the reliability of ICD-9 code data. IDC-9 data entry is performed by a medical records coding specialist based on information the attending physician has included in the discharge summary. Thus, the coding is limited to specific medical events that occurred during a patient's hospital stay, which the physician considered important enough to include in the summary statement. The coding is not always specific to stroke type because the discharge summary only provides general information. Additionally, ICD-9 codes are limited in nature and often do not capture a specific stroke type, the artery related to the stroke, or the level of deficits following a stroke. Another limitation is that Medicare data are typically associated with beneficiaries older than 65 who have decreased their work productivity or who have retired. This makes it difficult for researchers to account for lost productivity and its effect on the indirect cost related to stroke. This study only examines the direct cost associated with charges and payments six months post stroke. Younger Medicare beneficiaries generally have severe chronic illnesses that may mask stroke effects or the post-stroke care process. Thus, this study will be limited to individuals over age 65.

REVIEW OF THE LITERATURE

Anatomy of Cerebral Circulation

Treating patients who have had a stroke requires an extensive detailed knowledge of brain anatomy, clinical correlations, burden of disease, prognosis for outcome, and risk of stroke recurrence or mortality (Piechowski-jozwiak & Bogousslavsky, 2009). Understanding brain anatomy and its blood supply is important for researchers who are investigating the associations between stroke type and the indirect and direct costs of stroke. Cerebral circulation can be correlated to specific areas of the brain and its associated function. See table 4 and 5 for a detailed description of brain arterial supply and deficits associated with stroke in each area. Continuous oxygenated blood to the brain is supplied by three major arteries that originate from the arch of the aorta, first from the brachiocephalic, then the left common carotid and the final arterial branch, the left subclavian (Jacobson & Marcus, 2011).

Originating from the heart, oxygenated blood first travels through the brachiocephalic artery which divides into the right subclavian and right common carotid artery (Jacobson & Marcus, 2011). The branches of the right common cardioid artery are the right external carotid supplying the head and neck and the internal carotid supplying the brain (Jacobson & Marcus, 2011). The right subclavian supplies the vertebral artery which is responsible for delivering blood to the head and neck and the posterior portion of the brain (Jacobson & Marcus, 2011). The left common carotid artery divides into the left external carotid which supplies the head and neck and the left internal carotid which supplies the brain (Jacobson & Marcus, 2011). The left subclavian gives rise to the left vertebral and supplies the head and neck and the posterior portion of the brain (Jacobson & Marcus, 2011).

The anterior cerebral circulation of the brain is comprised of the internal carotid, middle cerebral, anterior communicating, and anterior cerebral arteries and is responsible for supplying 75% of the blood to the brain (Jacobson & Marcus, 2011). Anterior circulation is responsible for supplying the basal ganglia, anterior diencephalon, the anterior two-thirds of the medial surfaces of the cerebral hemisphere including the corpus callosum, and the orbital frontal surfaces of the cerebral hemispheres (Jacobson & Marcus, 2011). Generally speaking, a cerebrovascular event in the anterior circulation of the brain commonly results in sensory loss and/or weakness or paralysis of the face, and/or contralateral limbs, language difficulties, and visual disturbance (Rovira, Grive, & Alvarez-Sabin, 2005).

The posterior cerebral circulation of the brain is supplied by the vertebral, basilar, posterior communicating, and posterior cerebral arteries and is responsible for supplying 25% of blood to the brain (Jacobson & Marcus, 2011). The posterior circulation brings blood to the upper cervical spinal cord, cerebellum, brain stem, most of the diencephalon, and the inferior and posterior surfaces of the temporal and occipital lobes of the brain (Jacobson & Marcus, 2011). A stroke affecting the posterior circulation of the brain commonly presents with the following symptoms: nausea, vomiting, ataxia, vertigo, visual disturbance, weakness, sensory loss, and dysarthria (Stein, Harvey, Winstein, Zorowitz, & Wittenberg, 2014).

Anterior Cerebral Circulation Strokes

Kumrali, Topcuoglu, & Onal (2009) defined anterior circulation as the cerebral areas supplied by the branches of the internal carotid arteries (Kumral, Topcuoglu, & Onal, 2009). These arteries, the interior carotid artery, anterior cerebral artery, anterior communicating artery, and middle cerebral artery, are responsible for supplying the majority of blood to both cerebral hemispheres excluding the occipital and medial temporal lobes (Kumral, Topcuoglu, & Onal, 2009). The most common anterior circulation stroke is the ischemic stroke with 8% to 12% resulting in death and an estimated stroke five year survival rate of 40% (San Luis, Staff, Fortunato, & McCullough, 2013). It has been estimated that 70% to 87% of all cerebral vascular accidents are ischemic, with cerebral artery occlusions of the terminal internal carotid artery and the proximal middle cerebral artery representing 30% to 40% (González, et al., 2013). These anterior circulation strokes have the poorest outcomes (González, et al., 2013) Anterior circulation strokes are predominantly in middle cerebral artery brain territory (Rovira, Grive, & Alvarez-Sabin, 2005). A 1990 study examining the causes of anterior circulation stroke in 159 patients found that 48% had hypertension, 14% had diabetes mellitus, 26% smoked, and 9% had hypercholesterolemia (Bogousslavsky, Melle, Regli, & Kappenberger, 1990). Similar findings were noted in a recent study with 220 patients (Mattioni et al., 2014).

Researchers have divided middle cerebral artery infarcts into two types: large and limited (Heinsius, Bogousslavsky, & Van Melle, 1998), (Rovira, Grive, & Alvarez-Sabin, 2005) . Total anterior circulation infarcts (TACI) is a clinical syndrome caused by ischemia in both the deep and superficial territories of the middle cerebral artery, resulting in higher cerebral dysfunctions such as dysphasia, dyscalculia, visuospatial disorder, homonymous visual field defect, and ipsilateral motor and/or sensory deficit of at least two areas of the face, arm, and leg (Rovira, Grive, & Alvarez-Sabin, 2005). San Luis et al. (2013) found that 34% of patients who failed their first swallow study within three days of stroke were discharged to palliative care (San Luis, Staff, Fortunato, & McCullough, 2013).

The last 10 years have seen a greater research focus on larger artery steno-occlusive disease, the most common stroke subtype worldwide (Mattioni et al., 2014). Studies show that intracranial large artery steno-occlusive disease, also called, intracranial disease is disproportionally higher in Asian, African-American, and Hispanic populations (Man & Fu, 2014). In their study, Mattion et al. (2014) highlighted the Northern Manhattan Stroke Study from 1993 to 1997, which found that intracranial disease related strokes comprised 9% of all ischemic strokes among whites, 17% among African-Americans, and 15% among Hispanics (Mattioni et al., 2014). Notably, intracranial disease has had a significant effect on the Chinese population accounting for 33% to 50% of all strokes and 50% of TIAs, making it the most common vascular lesion for Asian stroke patients (Man & Fu, 2014) (Mattioni et al., 2014).

Large stroke types cover at least two of the three middle cerebral artery territories-- deep, superficial anterior, and superficial posterior -- and thus are known to have poor outcomes with a higher mortality rate (Rovira, Grive, & Alvarez-Sabin, 2005). These middle cerebral artery strokes are associated with cardioembolism, internal carotid artery occlusion, and dissection (Rovira, Grive, & Alvarez-Sabin, 2005). Rovira et al. (2005) found that complete middle cerebral artery strokes have an 80% mortality rate caused by increased cranial pressure that typically builds within the first 2 to 3 days post stroke; leading to10% of all strokes (Rovira, Grive, & Alvarez-Sabin, 2005). Limited infarcts in the middle cerebral artery effect one of the three territories and typically have better outcomes than those seen with large middle cerebral artery infarction (Rovira, Grive, & Alvarez-Sabin, 2005).

In contrast, the anterior cerebral artery stroke is considered to be rare, making up .06% to 3% of acute ischemic strokes in the anterior cerebral circulation of the brain (Freitas, Christoph, & Bogousslavsky, 2009) (Nagamine et al., 2014). Strokes in the anterior cerebral artery commonly present with complex physical and cognitive deficits that usually require comprehensive neurological rehabilitation and care (Stein, Harvey, Winstein, Zorowitz, & Wittenberg, 2014). Nagamine et al. (2014) reported that for years researchers believed that large artery atherosclerosis was a frequent cause for isolated anterior cerebral artery territory infarction. However, a growing body of evidence suggests that anterior cerebral strokes may be due to arterial dissension (Nagamine et al., 2014). Nagamine et al. (2014) retrospectively evaluated the records of 2,315 patients with acute cerebral function to determine the etiologic and clinical characteristics of patients with isolated anterior cerebral artery territory infarction due to arterial dissension. The researchers found that 1.5% of the patients had an isolated anterior cerebral artery stroke with atrial dissention occurring in 32% of all cases (Nagamine et al., 2014). They also reported that embolisms occur less frequently in anterior cerebral artery circulation territory then in middle cerebral artery territory (Nagamine et al., 2014).

Patients with unilateral anterior cerebral artery strokes often present with contralateral hemiplegia that is typically more severe in the leg and shoulder than in the arm, hand, and face (Stein, Harvey, Winstein, Zorowitz, & Wittenberg, 2014). Anterior cerebral artery infarcts result in minimal sensory loss with apraxia that is limited to the left side (Stein, Harvey, Winstein, Zorowitz, & Wittenberg, 2014). This is because the anterior cerebral artery supplies the anterior corpus callosum, a major motor pathway between the frontal lobes of the brain (Türe, Yasargil, & Krisht, 1996). Notably, because the left motor cortex is adjacent to the Broca's Area, anterior cerebral artery strokes do not affect motor movement on commands in the right upper extremity, and patients usually have increased movement function of the left upper extremity given visual cue (Stein, Harvey, Winstein, Zorowitz, & Wittenberg, 2014). Visual issues are also associated with this stroke, as well as paratonia and reflect impairment (Stein, Harvey, Winstein, Zorowitz, & Wittenberg, 2014). Patients may present with aphasia and are often impulsive, affecting the level of care needed to return the community.

Posterior Cerebral Circulation Strokes

Posterior circulation strokes are defined by an infarction that is located in the vascular territory supplied by the vertebrobasilar arterial system (Nouh, Remke, & Ruland, 2014), as indicated in Table 5. The posterior circulation of the brain consists of the occipital and temporal lobes, superior cerebellum, rostral brain stem, and spinal cord (Piechowski-jozwiak & Bogousslavsky, 2009), (Merwick & Werring, 2014). Brain structures, functions, and syndromes / injuries associated with the posterior circulation are considered neurologically complex and may have a significant impact on the cost of healthcare associated with impairments to this area of the brain (Piechowski-jozwiak & Bogousslavsky, 2009).

Posterior circulation stroke make up an estimated 20% of all strokes, yet researchers admit that it has received significantly less attention than the anterior or carotid stroke types (Gulli, Marquardt, Rothwell, & Markus, 2013). 20% to 25% of ischemic strokes are posterior with an estimated 4% mortality rate, with a large percentage being embolic both cardiac and arterial origin (Merwick A. , 2014) (Labropoulos, Nandivada, & Bekelis, 2011) (Caplan, Wityk, Pazdera, & Chang, 2005). Researchers have found that posterior circulation stroke outcomes are directly related to the location and stroke type with increased morbidity and mortality from an embolic stroke in the basilar artery territory (Labropoulos, Nandivada, & Bekelis, 2011). Piechowski-jozwiak & Bogousslavsky (2009) states that 21.9% of younger males, and 20% of younger females who experience a posterior circulation stroke recover completely, with no deficit. Furthermore, 71.9% of young males and 73.3% of young females had only minor deficits (Piechowski-jozwiak & Bogousslavsky, 2009). Research shows that of these individuals 6.3% of males and 6.7% of females exhibited severe deficits (Piechowski-jozwiak & Bogousslavsky, 2009).

Caplan et al (2005) reported that the majority of the early literature related to the posterior arterial supply of the brain found that atherosclerotic lesions are overwhelmingly located in the posterior blood circulation of the brain, specifically the intracranial vertebral arteries and the basilar artery. Studies show that vertebrobasilar stenosis is a major predictor of recurrent posterior circulation strokes, notably within the first month (Gulli, Marquardt, Rothwell, & Markus, 2013). Gulli et al (2013) found that having vertebrobasilar stenosis made patients 24.6% more likely to have a second stroke within 90 days of the first, versus a 7.2% chance of having a secondary event for those who don't have stenosis.

Labropoulos, Nandivada, and Bekelis (2011) conducted a systematic review examining the prevalence and mechanisms of posterior circulation strokes and found that males with an average age of 65 made up 60% of all patients with posterior circulation strokes. Moreover, 61% had hypertension making it the most common risk factor, with smoking second at 36%. Although atrial fibrillation was a risk factor, it varied greatly in multiple studies (Labropoulos, Nandivada, & Bekelis, 2011). Additionally, the study showed that the most common site, 43%, of these stroke types occurred in the brainstem (Labropoulos, Nandivada, & Bekelis, 2011).

The brainstem can be divided into three main components, the midbrain, pons, and medulla. Isolated midbrain infarction is extremely rare and little research has occurred in this area of neurology (Gilberti et al., 2014). Gilberti et al. (2014) found that midbrain strokes occur in .6% to 2.3% of all ischemic strokes with the range discrepancy resulting in the lack of MRIs used to diagnose patients. Typical symptoms of a midbrain stroke include ocular motor disturbances and ataxia, and in most cases research suggests a good functional prognosis in relation to age and other contributing risk factors. The most common cause of pure midbrain stroke is small vessel disease with impairments including gate impairment and diplopia (Gilberti et al., 2014).

Strokes affecting the pons account for roughly 7% of all ischemic infarctions and are known to be progressive in nature, typically having positive outcomes if the lesion is not bilateral (Oh et al., 2012) (Varsou, Stringer, Fernandes, Schwarzbauer, & MacLeod, 2014). Lucunar syndromes are typically seen with unilateral pontine strokes resulting in pure motor strokes, as well as ataxic hemiparesis or dysarthria of the hand (Oh et al., 2012). General progressive motor weakness and overall functional disability is common (Oh et al., 2012). Research shows that roughly 26% of patients with a pontine stroke present with progressive motor weakness (Oh et al., 2012). Patients with basil artery branch disease have a greater chance of having a decrease in functional outcomes than those with a lucunar syndrome presentation (Oh et al., 2012). It is generally hypothesized that hypertension is the largest contributor to pontine related strokes (Oh, et al., 2012).

The medulla can be classified into three parts: (1) the anterior portion, which consists of the corticospinal tract; (2) the tegmentum, which contains the olivary complex, cranial nerve nuclei VII through XII, reticular formation and ascending/descending fiber tracts; and the (3) posterior portion, which contains the ascending fiber tracts nuclei gracilis and the cuneatus (Balucani & Barlinn, 2012). The medulla receives blood by the vertebral artery and the posterior inferior cerebral artery (Balucani & Barlinn, 2012). There are three basic unilateral medullary stroke syndromes: (1) the lateral medullary Wallenberg’s syndrome, which is the most common, making up 2% of ischemic strokes, (2) the medial medullary syndrome known as Dejerine’s syndrome, and (3) the extremely rare hemimedulary syndrome, which involves both the lateral and medial aspects of the medulla. (Balucani & Barlinn, 2012) (Krasnianski, Neudecker, Schluter, & Zierz, 2003). The syndromes may be overlapping, making it difficult to pinpoint the exact location and cause of lesion (Balami, Chen, & Buchan, 2013). The Wallenberg’s syndrome presents with ipsilateral paralysis of the soft-palate, pharynx, and larynx with dysphagia, dysarthria, dysphonia, ipsilateral anesthesia of the face for pain and temperature sensation, ipsilateral Horner’s syndrome, and ipsilateral cerebellar hemiataxia, as well as contralateral loss of pain and temperature sensation on the limbs and trunk (Krasnianski, Neudecker, Schluter, & Zierz, 2003). Medullary syndromes containing both lateral and medial part of the medulla contain all of the symptoms related to the Wallenberg's syndrome including contralateral hemiparesis (Krasnianski, Neudecker, Schluter, & Zierz, 2003). Diagnosing medullary strokes requires the use of MRI and often a combination of syndromes is present.

The posterior cerebral artery supplies parts of the midbrain, thalamus, medial surface of the temporal lobe, and medial surface of the occipital lobe (Jacobson & Marcus, 2011). Posterior cerebral artery strokes make up 5% to 10% of all strokes, and researchers state that number may be low as a result of the inclusion criteria in several definitions of the brain territory supplied by the artery (Ng, Stein, Salles, & Black-Schaffer, 2005). Posterior cerebral artery stroke symptoms include dysphasia, sensorimotor balance and visual deficits, and other neuropsychological deficits (Ng, Stein, Salles, & Black-Schaffer, 2005) (Park, Yoon, & Rhee, 2011). Visual deficits can include hallucinations, optic apraxia, optic ataxia, simultagnosia, achromotopia, palinopsia, prosopagnosia, aphasia, alexia, and acalculia (Ng, Stein, Salles, & Black-Schaffer, 2005). Patients often present with generalized confusion or hallucinations that can be easily misdiagnosed, especially in patients with dementia (Ng, Stein, Salles, & Black-Schaffer, 2005).

There has been an increased focus on the discovery that a posterior cerebral artery stroke can mimic the symptoms of a middle cerebral artery stroke syndrome involving unilateral hemiparesis hemisensory loss, hemianopia, hemispatial neglect, and aphasia (Maulaz, Bezerra, & Bogousslavsky, 2005), (Ng, Stein, Salles, & Black-Schaffer, 2005).

Celebisoy et al (2011) states that 30% of all strokes, and 70% of all strokes involving the posterior cerebral artery have hemianopsia (Celebisoy, Celebisoy, Bayam, & Kose, 2011). It has been theorized that the wide variety of symptoms are due to the multiple brain areas that the posterior cerebral artery supplies in conjunction with other anterior circulation arteries (Stein, Harvey, Winstein, Zorowitz, & Wittenberg, 2014). These areas include the thalamic nuclei, limbic system, posterior limb of the internal capsule, cerebral peduncles, and the mesencephalon (Stein, Harvey, Winstein, Zorowitz, & Wittenberg, 2014). The artery also supplies crucial areas of the parietal, temporal and occipital lobes (Stein, Harvey, Winstein, Zorowitz, & Wittenberg, 2014).

Isolated strokes in the cerebellum account for 2% to 3% of all ischemic strokes and exhibit generalized mild symptoms often including nausea, dizziness, or headache (Bultmann, et al., 2014). Research shows that ataxia is present in 40% of cerebellum strokes and it has been discovered that there is a correlation between ataxia type and the level of the cerebellum that is affected (Bultmann, et al., 2014). When the superior cerebral artery, which supplies the superior cerebellum, is affected by a stroke the patient typically presents with limb ataxia as well as gait ataxia (Bultmann, et al., 2014). When a stroke involves the posterior inferior cerebral artery, which supplies the inferior parts of the cerebellum, the patient exhibits gate and postural instability along with nystagmus and vertigo (Bultmann, et al., 2014). Cerebellum strokes related to the superior cerebral artery have poorer outcomes than those related to the posterior inferior cerebral artery (Bultmann, et al., 2014). Research shows that cerebellum motor recovery in the first three months following a stroke is high, frequently with spontaneous recovery (Bultmann, et al., 2014). Marquer, Barbieri, & Pe´renuou (2014) conducted a systematic review of cerebellar ataxia and found strong evidence that rehabilitation can improve postural, gait, and balance associated with cerebellar ataxia. However, 84% of patients with cerebellar ataxia were reported to have at least one fall within the first year of their stroke, suggesting that injury associated with this stroke may have a significant outcome on long-term direct and indirect cost (Marquer, Barbieri, & Pe´rennou, 2014).

The Cost of Stroke

It is important for researchers to understand the economic burden of stroke on society in order to make qualified recommendations for evidence based interventions that are both cost effective and beneficial to stroke patients. Today, stroke is one of the most catastrophic neurological conditions (Mozaffarian, et al., 2015). Globally, it is responsible for approximately 5.5 million deaths each year and an estimated 44 million disability adjusted life years lost (Mukherjee & Patil, 2011). The World Health Organization states that stroke is one of the leading causes of death and long-term disability worldwide and has warned researchers that an aging population and the increasing incidence of comorbidities contributing to stroke risk will have a direct effect on the number of disabled people and the overall treatment cost (Patel, et al., 2014). Strong, Mathers, & Bonita (2007) estimate that stroke accounts for 9.7% of all deaths worldwide and could reach almost 8 million by 2030.

The global economic effect of stroke is significant. A number of studies have examined the direct and indirect cost associated with stroke and have found high costs of inpatient stays, outpatient visits, rehabilitation, medications, long-term care, and the overall “burden of care” cost (Joo, George, Fang, & Wang, 2014). A comprehensive

2010 study that estimated the annual direct cost of neurological disorders of 30 European countries found that the cost of stroke reached € 64.1 billion in 2010 (Olesen, Gustavsson, Svensson, Wittchen, & Jönsson, 2012). Additionally, the study found that European countries spend a total of €798 billion on brain related health disorders, of which 37% was direct healthcare cost, 23% was direct nonmedical cost, and 40% was indirect cost (Olesen, Gustavsson, Svensson, Wittchen, & Jönsson, 2012).

Stroke is one of the leading causes of morbidity and mortality in the United States (Taylor, et al., 1996). According to The American Heart Association's heart disease and stroke statistical update for 2014, stroke is the number four cause of death in the United States, killing more than 129,000 people each year (Go, et al., 2013). The AHA estimates that stroke kills someone in the United States about every four minutes, and almost 800,000 US citizens have a stroke each year (Go, et al., 2013). Stroke is related to one out of every 19 deaths and is a leading cause of long term disability in the US (Go, et al., 2013). Stroke is the leading preventable cause of disability for African-Americans and Latinos Americans, who have almost twice the risk of first time strokes and a significantly higher death rate than Caucasian Americans (Go, et al., 2013).

The United States spends more on healthcare per person than any other nation (Burke, 2014), thus the need to determine effective health care spending that can help achieve optimal stroke outcomes. The majority of studies have focused on acute care in-hospital costs, and many investigations have examined the costs associated with a type of stroke, e.g., strokes due to ischemia (clots), hemorrhage (bleeds), or transient ischemic attacks (temporary clots). Patel et al., (2014) noted that ischemic strokes, hemorrhagic strokes, and major bleed events totaled $2.44 billion in annual stroke related Medicare costs in 2011.

Current literature on the cost of stroke has established two types of expenses associated with a stroke event: direct versus indirect costs (Joo, George, Fang, & Wang, 2014), (Brown, Boden-Albala, Langa, & Lisabeth, 2006), (Demaerschalk, Hwang, & Leung, 2010), (Mittmann, et al., 2012). Although there seems to be some differences in the definition and time frame of a patient's short term and long term direct cost following a stroke, the short term direct cost is typically 30 days after a stroke and can range up to 4 years post stroke. Tylor et al. (1996) defines indirect costs as the total lost revenue as a result of premature mortality and the reduced productivity following a stroke (Taylor, et al., 1996).

A 2010 systematic review by Demaerschalk, Hwang & Leung (2010) examining the cost of ischemic strokes in the US found that most studies focused on the short term acute hospital costs of stroke. When adjusted for 2014 dollars, the cost ranged from $8,822.28 to $25,364.06 with an acute care length of stay ranging from 4.6 to 12.4 days (Demaerschalk, Hwang, & Leung, 2010), (Coin News Media Group LLC, 2008-2014). The study highlights a report from Demaerschalk and Durocher (2007) which stated that one-third of the total cost of ischemic stroke treatment accounts for early critical care, with other costs arising from 19% medical surgical care, 19% radiology, 8% rehabilitation, 7% pharmacy, and 7% lab work (Demaerschalk & Durocher, 2007) (Demaerschalk, Hwang, & Leung, 2010). Similarly, Diringer et al. (1999) found that 50% of acute ischemic stroke costs were related to "room charges" being 34% for general beds and 16% ICU beds, as well as 16% for radiology, 7% for rehabilitation, 5% for pharmacy and 5% lab work (Diringer et al., 1999).

Demaerschalk, Hwang & Leung (2010) also examined the literature related to the direct long-term costs associated with ischemic stroke. Defined as more than thirty days following a stroke, long-term Medicare costs were found to increase 3.4 times during the 12 months following a stroke, with costs being the most significant during the first three months of recovery (Demaerschalk, Hwang, & Leung, 2010). Thus, direct costs of ischemic stroke per person in the first year (1990), adjusted to 2014 dollars, can reach $32,404.97 on average and depends on age (Demaerschalk, Hwang, & Leung, 2010) (Coin News Media Group LLC, 2008-2014). Total Medicare benefits paid out in the first years following an ischemic stroke were found to total $58,279.82, adjusted for 2014 dollars, (Demaerschalk, Hwang, & Leung, 2010) (Coin News Media Group LLC, 2008-2014).

More recently, Joo, George, Fang, & Wang, (2014) conducted a literature review of indirect costs associated with stroke from 1990 to 2012 and selected 31 articles, with 6 studies that where related to the direct and indirect cost of stroke in the United States. The earliest study included in the review was conducted by Wiebers, Torner, & Meissner (1992) examining the cost of unruptured intracranial aneurysms, and subarachnoid hemorrhages. The study examined survey data from 1979 to 1989 looking at hospitalization disability and lost income from morbidity and mortality (Wiebers, Torner, & Meissner, 1992), resulting in an estimated lifetime cost of intracranial aneurysms of $522 million, and $1.76 billion for patients with subarachnoid aneurysms; in 2014 dollars that equates to $2.97 billion (Coin News Media Group LLC, 2008-2014) (Wiebers, Torner, & Meissner, 1992).

After developing a model of lifetime cost of incident strokes occurring in 1990, Taylor et al. (1996) examined the estimated lifetime direct and indirect costs associated with the three major types of stroke: subdural hemorrhage, intracranial hemorrhage, and ischemic stroke. The researchers found that the estimated lifetime cost, in the year 1990, following a subarachnoid hemorrhage was $228,000 ($412,975 in 2014 dollars); following intracranial hemorrhages the cost estimate was $124,000 ($224,600 in 2014 dollars); $91,000 ($164,828 in 2014 dollars) for ischemic stroke; and an average of a little over $100,000 ($181,129.30 in 2014 dollars) was estimated for all stroke subtypes (Taylor et al., 1996) (Coin News Media Group LLC, 2008-2014). Importantly, the study found that indirect costs accounted for 58% of lifetime costs, with acute care costs in the two years following a stroke accounting for 45%, long-term ambulatory care accounting for 35%, and nursing home costs accounting for 17.5% of aggregate lifetime costs (Taylor et al., 1996). The authors concluded that lifetime cost of stroke varies widely by stroke type, and the cost burden is significant two years post stroke (Taylor et al., 1996).

Fox et al. (1996) found that the estimated cost of lost productivity in California due to cardiovascular disease mortality in 1991 had a $5.3 billion impact on society (Fox, Gazzaninga, & Max, 1996). That equates to $9.2 billion in 2014 dollars (Fox, Gazzaninga, & Max, 1996). Hickenbottom et al. (2002) used data from the Asset and Health Dynamics (AHEAD) study to determine the cost associated with informal caregiving for individuals who had a stroke (Hickenbottom, et al., 2002). After adjusting for comorbidity conditions, potential caregiver networks, and socio-demographics, those researchers found that in 1999 the caregiver cost of stroke could range from $3500-$8200 per year (Hickenbottom, et al., 2002). More importantly, using the AHEAD sample, the authors estimated that the United States spent $6.1 billion an annually for stroke or related informal caregiving in 2002 (Hickenbottom, et al., 2002). Additionally, the authors stated that 80% of stroke survivors return to the community, and most care is provided by unpaid informal caregivers with 60% to 80% being female with an average age of 63 years old (Hickenbottom, et al., 2002). 62% to 78% are spouses, and 25% are adult children, making it difficult to estimate the cost related to lost income (Hickenbottom, et al., 2002). It was also reported that 34% to 52% of stroke caregivers are depressed, further affecting the health of the caregiver and increasing overall cost (Hickenbottom, et al., 2002).

Brown et al.(2006) found that the indirect and direct cost of ischemic strokes in the United States affecting Non-Hispanic Whites, Hispanics and African-Americans from 2005 to 2050 would most likely exceed $2.3 trillion (in 2014 dollars), with the highest costs associated with Hispanics and African Americans (Brown, Boden-Albala, Langa, & Lisabeth, 2006). The study stated that the higher costs associated with the two groups were related to a higher prevalence of stroke, and an anticipated increase of earning potential by 2050 (Brown, Boden-Albala, Langa, & Lisabeth, 2006). Additionally, the authors discovered that persons from the age of 45 to 65 made up half of the total costs in the study and was 10 times larger than for those 85 or older who accounted for only 10% of the cost (Brown, Boden-Albala, Langa, & Lisabeth, 2006). It was noted that the younger group had a far greater percentage of lost earnings following a stroke, which greatly contributed to the difference in cost (Brown, Boden-Albala, Langa, & Lisabeth, 2006). Though the study did not discuss specific variables associated with the higher prevalence of stroke in Hispanics and African Americans populations, the authors suggested that the two groups have a higher prevalence of stroke related risk factors (Brown, Boden-Albala, Langa, & Lisabeth, 2006). The authors concluded that there is a significant cost associated with the long-term care of those who have had a stroke (Brown, Boden-Albala, Langa, & Lisabeth, 2006).

Heidenreich et al. (2011) conducted a prevalence-based study and found that annual indirect costs of stroke would increase from $27 billion in 2010 to $47 billion in 2030 with stroke having the largest relative real annual medical cost increase over 20 years by an estimated 238% (Heidenreich, et al., 2011). This increase is said to be caused in part by a population where adolescent and adult obesity will grow from 5% to 15% by 2035 (Heidenreich, et al., 2011). The authors cautioned that costs may be driven by a shortage of physicians which affects the ability to diagnose and prevent strokes, as well as by a shortfall of skilled caretakers to accommodate the needs of stroke survivors in the future (Heidenreich, et al., 2011).

The Joo et al. (2014) literature review concluded that the indirect costs of stroke varied widely ranging from 3% to 71% of the total cost of that event, depending on the study length, methods, study design, types of stroke, and cost components (Joo, George, Fang, & Wang, 2014). The authors were able to calculate that the average indirect cost was 32% of the total cost of stroke and will increase significantly as the population ages, diagnostic techniques improve, and stroke treatment evolves improving the survivability of those who have had a stroke (Joo, George, Fang, & Wang, 2014).

Use of Medicare Data in Stroke Research

The use of administrative data from large sources, like Medicare, is an essential tool for studies to establish the cost estimates related to the disease process (Riley, 2009). Medicare claims data sets have been used for more than 20 years in cost and outcomes research and have evolved into an extremely useful research tool (Iezzoni, 1997) (Mitchell, et al., 1994). Limitations related to administrative data include Medicare coding generalizations, patient diagnosis complexity limiting specifics, all beneficiary coverage limitations or restrictions, and a lack of long-term coverage continuity (Riley, 2009).

First utilized in the 1980s, administrative retrospective data has become a useful way to analyze practice variation, identify differences in the way medicine is accessed and delivered among ethnic groups, measure the quality of care delivered, determine the incidence of specifics diseases, and examine long-term outcome trends and costs (Mitchell, et al., 1994). In short, administrative data are a cost effective way for researchers to identify the direct cost differences associated with stroke care (Mitchell, et al., 1994). Currently Medicare beneficiary claims are made available through non-identifiable patient codes (Mitchell, et al., 1994). The data used in this research will include all Medicare Part A hospital events, Medicare Part B supplemental insurance provider files, nursing home files, home health services files, outpatient visit files, and durable medical equipment files (Mitchell, et al., 1994). These files contain the initial Part A: hospitalization diagnosis, procedures, dates, costs excluding clinician charges payments, and discharge destination (Mitchell et al., 1994). The Medicare Part B supplemental insurance provider files include clinician and specialty charges and payments and their associated diagnostic and procedure codes with dates of service, (Mitchell et al., 1994). Patient demographic information including age group, race, gender, and ZIP Code are all included in the demographic file, as well as the month and year of beneficiary death (Mitchell, et al., 1994). Medicare part D, prescription drug coverage, data will not be included in the study.

The centers for Medicare and Medicaid services (CMS) has required that all Medicare health care providers submit standardized diagnosis and payment codes to receive payment (Centers for Medicare & Medicaid Services, 2014). All Medicare outpatient clinical visits are coded with healthcare common procedure coding systems (HCPCS) (Centers for Medicare & Medicaid Services, 2014). Hospitalization events and procedures are coded using the international classification of diseases ninth revision clinical modification ICD9 (Centers for Medicare & Medicaid Services, 2014).

METHODS

This objective of this study is to examine rehabilitation resource use and cost of care for patients with stroke type defined by location in the brain. The study is a retrospective analysis of archival data from Medicare billing records. We will use the ICD-9 codes relevant to strokes affecting the anterior and posterior cerebral circulation and will identify the costs and outcomes for patients based on this definition. The Limited Data set that includes a 5% sample of Medicare billing records for 2012 will be used to identify: 1) cost of initial hospital admission, 2) cost of inpatient rehabilitation,3) cost of outpatient rehabilitation therapy, and 4) total cost of care over 6 months post stroke.

Research Questions and Hypotheses

This study will answer the following research questions:

1. What is the cost burden of an anterior circulation stroke (ACS) compared to a posterior circulation stroke (PCS)?
2. How are the rehabilitation needs different for ACS and PCS over the six months post-stroke?

Medicare billing data will be used to determine the difference in costs associated with anterior versus posterior brain circulation strokes, based on measures of the cost of the initial hospital stay, the cost of inpatient and outpatient rehabilitation, and a 6 month post stroke total cost analysis.

Cost will be measured from the perspective of society, and include costs reported as paid by Medicaid as well as patients' share of costs of care. Throughout the analysis, adjustments will be made to the cost of stroke data to reflect 2014 dollars. This will be achieved by using *The US Medical Care Services Inflation Calculator* from the US Bureau of Labor and Statistics.

Data will be extracted from Medicare bills for hospitalizations for stroke during the first half of 2012 to ensure that all stroke cases will have a minimum of six months follow up whenever possible.

The initial (Index) admission for persons with stroke will be identified as either ACS or PCS based on the recorded principal diagnosis, as indicated in Table 2 in the Appendix.

Table 1 List of ICD-9 codes used to extract Medicare patients

ICD-9 Codes Posterior Circulation Stroke		ICD-9 Codes Anterior Circulation Stroke	
433.00	Occlusion and stenosis of basilar artery without mention of cerebral infarction	434.00	Cerebral thrombosis without mention of cerebral infarction.
433.01	Occlusion and stenosis of basilar artery with cerebral infarction.	434.01	Cerebral thrombosis with cerebral infarction
433.21	Occlusion and stenosis of vertebral artery with cerebral infarction.	434.11	Cerebral embolism with cerebral infarction.
433.31	Occlusion and stenosis of multiple and bilateral precerebral arteries with cerebral infarction.	434.91	Cerebral artery occlusion, unspecified with cerebral infarction.
433.91	Occlusion and stenosis of unspecified precerebral artery with cerebral infarction.		

Cost Data Construction

All medical care bills for patients who are discharged from their Index hospital admission with an ACS or PCS primary diagnosis code will be extracted for six months after the date of hospital admission for stroke. This will provide a uniform time window for cost calculations. However, resource uses for post hospital rehabilitation will vary for two reasons: patients who die before the six month end date will have truncated follow up time, and patients with very long Index admission stays will have a shorter time for post-hospital follow up. However, the alternative is to use a six month post-hospital timeframe to compare costs for rehabilitation. This would lead to unequal overall time periods and make total cost comparisons invalid.

Costs will be aggregated by type of medical care resource used. The following cost categories will be included: 1) Index hospital, 2) Inpatient rehabilitation, 3) Outpatient use of physical, occupational and speech therapy, 4) Medical office visits, 5) Nursing home stays, 6) Acute care hospital admissions (readmissions post stroke), 7) hospice care.

We will not include the cost of prescription medications that are filled in a pharmacy because the Medicare LDS data set does not include pharmacy records. Physical, occupational, and speech therapy visits will be identified by CPT codes and/or by revenue codes. The codes used for the identification are provided in the Appendix.

For each cost component per patient, data will be aggregated and presented by component as well as total cost. Cost differences will be described by mean and median cost and compared using a t-test or non-parametric statistics as appropriate. Overall cost will be compared for the two groups using multivariable statistical modeling controlling for age, sex, race, and presence of comorbid conditions as measured by the Charleston score. The multivariable cost models will use a transformation function because the cost data are not normally distributed. A statistical difference of $p < 0.05$ will be considered significant for hypothesis testing.

Study Population

Medicare is the primary insurance payer of all strokes in the United States, and Medicare's payment policy is standardized across the US. Thus, Medicare billing data are an excellent source to assess the difference in costs associated with anterior versus posterior brain circulation strokes. We used a 5% sample of all Medicare billing data for 2012 for this study. We measured cost from the perspective of Medicare, using payments as recorded in the data. However, because Medicare payments are limited, we also reported total charges for services. While few patients pay what providers charge, a summary of charges is a reasonable indicator of the amount of resources used for providing the care. Both cost and charges are reported in 2012 currency because our time horizon for the study was six months after the date of the stroke admission. All patients having a stroke with any ICD-9 diagnosis code of 433 with 4^{th} and 5^{th} digits of 01, 21, 31, 91 were classified as having a posterior stroke Index admission. Patients with no posterior stroke codes and with a primary diagnosis code of 434 and 4^{th} and 5^{th} digits of 01, 11, or 91 were selected as the comparison group. Cost and charge data were extracted from Medicare bills for hospitalizations for stroke during the first half of 2012. This assured that all stroke cases had a minimum of six months of follow up possible. Only the first admission was used as an Index admission for patients who had more than one stroke admission over the 183 day time horizon of the study. Any subsequent admission for any condition, including re-stroke, was counted as a readmission.

ARTICLE MANUSCRIPT

Posterior Versus Anterior Circulation Strokes: Comparison of Treatment Costs for Medicare Patients

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ABSTRACT

Background and Purpose: Few studies have examined the differences in the resources used and costs of care between anterior circulation strokes (ACS) and posterior circulation strokes (PCS). The purpose of the study was to identify cost differences between these stroke types using archival Medicare billing data.

Methods: Specific ICD-9 codes related to acute ischemic PCS and ACS hospital admissions were identified in a 5% sample of Medicare billing records for the first half of 2012. All records for six months post stroke, or until death, were used to identify mean payment and charges by type of care received. The Charlson Comorbidity Score was used to control for the effects of comorbid conditions on cost and survival.

Results: Data for a total of 5335 US Medicare beneficiaries 65 years and older were extracted. Data from 105 patients with PCS were compared to data from 5230 patients with ACS. The mean Medicare payments over six months were greater for PCS patients at $37,792, compared to $27,349 for ACS patients. Higher payments for PCS were seen for initial hospital admission ($13,822 vs. $8,511), physician hospital payments ($2,528 vs. $1,891), inpatient rehabilitation ($6,025 vs. $4,777) and hospital readmissions ($10,013 vs. $7,018). Only nursing home costs for ACS patients were higher ($733 vs. $242). PCS patients showed a trend toward better survival (p=.059), but the survival difference disappeared once the effects of population age, race, comorbidities and use of tPA during the Index admission (p=.726) were controlled.

Conclusion: PCS patients have greater costs than ACS patients during early recovery from an ischemic stroke. These differences are not due to comorbid conditions or patient

characteristics, indicating that risk/treatment needs may differ in PCS patients versus ACS patients. The care process post-discharge for PCS patients should be examined to identify opportunities to avert hospital readmissions and improve long term outcomes.

INTRODUCTION

Stroke is a growing threat to an aging population and has a significant effect on individuals, their families, and society. In 2010, stroke was the fourth leading cause of death and the leading cause of long term disability in the United States (Mozaffarian, et al., 2015). An estimated one half of older stroke survivors are left to cope with a moderate or severe disability costing the nation $36.5 billion each year (CDC, 2014).

Current trends in health care have focused on evidence based practice to improve patient outcomes, hospital quality, and lower treatment costs (Greenhalgh, Howick, & Maskrey, 2014). Recent studies have assessed the relationship between cost of stroke (Heidenreich, et al., 2011) and stroke outcomes (Lakshminarayan, et al., 2014) by examining stroke outcomes classified by ICD-9 codes for ischemic or hemorrhagic stroke type.

Studies have used hospital discharge data or Medicare billing data to examine cost savings due to tPA (Prabhakaran, McNulty, O'Neill, & Ouyang, 2012) (Brinjikji, Rabinstein, & Cloft, 2012) (Simpson, et al., 2014), the marginal costs of stroke (Luengo-Fernandez, Silver, Gutnikov, Gray, & Rothwell, 2013), cost differences associated with the use of intravenous (IV) t-PA and intra-arterial tPA (Mauldin, Simpson, Palesch, Spilker, Hill, & Investigators, 2008), and cost differences due to the presence of aphasia (Ellis, Simpson, Bonilha, Mauldin, & Simpson, 2012) or dysphagia (Bonilha, Simpson, Ellis, Mauldin, Martin-Harris, & Simpson, 2014). Brinjikji and colleagues used 2001-2008 the Healthcare Cost and Utilization Project (HCUP) National Inpatient Sample data to identify median charges for anterior ischemic stroke patients treated with IV-t-PA, as well as patient and hospital characteristics associated with variations in charges (Brinjikji, Rabinstein, & Cloft, 2012). Other authors have reported that cost increases with stroke severity (Mittmann, et al., 2012), cost savings may be expected with interventions,\ such as tPA, intra-arterial tPA and embolectomy that improve perfusion within three hours of the stroke (Turk, et al., 2014),\, and cost rises with increased impairments\ such as aphasia or dysphagia (Ellis, Simpson, Bonilha, Mauldin, & Simpson, 2012) (Bonilha, Simpson, Ellis, Mauldin, Martin-Harris, & Simpson, 2014).

However, all reported costs are for strokes defined and coded as either ischemic, hemorrhagic, or both. When stroke is defined in this manner, there is limited ability to understand how the area of the brain damage and resultant functional loss is associated with cost of care. Anecdotal evidence from therapists and clinicians indicates that resource requirements for stroke rehabilitation are more closely related to the area of the brain involved in a stroke, i.e., specific arterial distribution, than to stroke type. The use of ischemic or hemorrhagic diagnosis codes to define stroke may tend to obscure resource use and cost differences for stroke care associated with stroke location. It is possible to differentiate strokes by ICD-9 codes that are assigned to the anterior and posterior cerebral circulation strokes.

This study examined rehabilitation resource use and cost of care for patients with acute ischemic strokes. We used the ICD-9 codes relevant to strokes affecting the anterior and posterior cerebral circulation and identified the costs and outcomes for patients based on this definition for a 5% sample of Medicare billing records from the first half of 2012 (Table 1); we sought to measure: 1) cost of the initial hospital admission and the associated physician payments; 2) cost of inpatient rehabilitation; 3) cost distribution for other types of resources (office visits, skilled nursing care, home health, hospice care, and durable medical equipment (DME); and 4) total cost of care (measured both as charges incurred and as Medicare payments) over 6 months post stroke.

METHODS

Study Population

Medicare is the primary insurance payer of all strokes in the United States, and Medicare's payment policy is standardized across the US. Thus, Medicare billing data are an excellent source to assess the difference in costs associated with anterior versus posterior brain circulation strokes. We used a 5% sample of all Medicare billing data for 2012 for this study. We measured cost from the perspective of Medicare, using payments as recorded in the data. However, because Medicare payments are limited, we also reported total charges for services. While few patients pay what providers charge, a summary of charges is a reasonable indicator of the amount of resources used for providing the care. Both cost and charges are reported in 2012 currency because our time horizon for the study was six months after the date of the stroke admission. All patients having a stroke with any ICD-9 diagnosis code of 433 with 4^{th} and 5^{th} digits of 01, 21, 31, 91 were classified as having a posterior stroke Index admission. Patient with no posterior stroke codes and with a primary diagnosis code of 434 and 4^{th} and 5^{th} digits of 01, 11, or 91 were selected as the comparison group. Cost and charge data were extracted from Medicare bills for hospitalizations for stroke during the first half of 2012. This assured that all stroke cases had a minimum of six months of follow up possible. Only the first admission was used as an Index admission for patients who had more than one stroke admission over the 183 day time horizon of the study. Any subsequent admission for any condition, including re-stroke, was counted as a readmission.

Determination of Cost

All billing data for each patient with an Index admission were extracted and aggregated into resource type groups at the individual patient level. We measured cost separately for the following variables: 1) the Index hospital admission, 2) physician bills for care provided during the Index admission; 3) Inpatient rehabilitation; 4) outpatient rehabilitation; 5) Medical office visits; 6) other outpatient care cost; 7) skilled nursing home cost; 8) hospice care cost; and 9) durable medical equipment costs. Provision of tPA during the index admission was identified by ICD-9 procedure code 99.10 or use of DRG 559. Mechanical embolectomy was identified by ICD-9 procedure codes 38.01, 38.11, or 39.74. Total cost and charges were aggregated at the patient level over 183 days or until death, whichever was shorter. Analyse used chi square and the Wilcoxon non-parametric test for univariate analyses and multivariable log-transformed and survival models to control for population differences. All statistical analyses were performed using SAS version 9.3 with significance level set at $\alpha<0.05$.

RESULTS

A total of 5,335 US Medicare beneficiaries age 65 years or older were extracted from a Medicare 5% anonymous data set from the first half of 2012. All patients had an initial hospitalization ICD-9 code related to either a posterior cerebral circulation or anterior cerebral circulation stroke event. 5,230 patients were found to have a clear ICD-9 code associated with an anterior cerebral circulation stroke, and 105 patients had a clear ICD-9 code associated with a posterior cerebral circulation stroke. The study population descriptive statistics are provided in Table 1.

Mean results comparing the posterior to the anterior circulation stroke are provided in Table 2. There are substantial population differences observed by stroke circulation type. PSC patients have a heavier concentration in the age group 70 to 75 and lower representation in the younger and oldest age categories (p=.0001). Females are more likely to have an ACS than male patients (p=.0011). There were no observed differences in racial distribution between ACS and PCS; however, more than 80% of the population were white p=.0032). In-hospital mortality was similar at 8.6% for PCS and 5.4% for ACS (p=.1586), and discharge destination varied only for discharge to a skilled nursing facility (p=.0151), which was most prevalent for ACS patients (Table 2). It is important to note that about 20 percent of patients were discharged to an inpatient rehabilitation facility, and 8.2% where discharged to hospice (Table 1). We observed a relatively low rate of acute care stroke treatment interventions, which did not differ significantly by stroke type. Use of tPA and endovascular clot retrieval were coded, with 5.5% of PCS patients receiving tPA and 0.59% embolectomy for PCS patients, compared to 4.8% and 1.9% respectively for ACS patients (tPA p=0.7341) (endovascular p=0.0896). Patient survival over the six month study window differed by stroke location. Patients with an ACS appeared more likely to die during the follow-up period (p=0.0578) as seen in the survival curve in Figure1. However, this trend disappeared once we controlled for population differences in tPA use, age, and Charlson comorbidity (p=0.1906).

Resources used for care for PCS compared to ACS patients differed greatly. The mean Medicare charges for the initial acute care hospital admission (Index admission) for PCS was $52,264, which was $13,499 higher than the mean charges for ACS patients, with payments by Medicare differing proportionally ($13,822 vs. $8,511) (p=0.0011). It is important to note that only about 22% of charges were reimbursed by Medicare. Detailed information on cost and charges observed are provided in the Appendix. We calculated physician Part B Medicare payments associated with the Index admission and found that mean payments for PCS patients were $2,528, which was $637 higher than those observed for ACS patients (p=0.0594). The inpatient rehabilitation payments for PCS patients were $6,025, or $1,248 higher than payments for ACS patients (p=0.1674); however, these did not reach statistical significance. There were differential payment patterns observed for other types of care, but because of the large variability observed in the cost and charge data for the sub-categories, many of these differences did not reach statistical significance. Outpatient rehabilitation payments for a posterior cerebral circulation stroke were significantly greater with a difference of $145 (p=0.0383), while there was only a $4 difference in MD office visits (p=0.9468). There were small differences of $228 in home health care payments (p=0.7663) and for DME ($97 difference, p=0.6162); both were greater for PCS patients. Interestingly, nursing home payments for ACS were greater at $733, compared to $245 for PCS patient (p=0.1715), making this the only category that is higher for ACS. Notably, average hospital readmission payments for PCS patients were $10,014, a $2,995 increase over the ACS group (p=0.05). No PCS patients in the cohort received hospice care, and mean hospice payments for ACS patients were only $28 (p=.5155) Figures 2A and 2B show the distribution of mean payments and charges by resource category for PCS versus ACS patients.

Given the differences observed in age and the presence of comorbid conditions for the PCS and ACS, it is important to examine if the differences in payments and charges are due to these non-stroke characteristics, or if they may be ascribed to the location of stroke. We used multivariable regression modeling to assess the effects of differences in patient characteristics at baseline on observed charges and payments. The payment and charges were log-transformed to account for the non-normal distribution of these values. The multivariable analyses indicated that while mean payments and charges, as expected, varied by both patient baseline characteristics and by the type of treatment received, mean payments and charges over the six month study horizon were higher for PCS patients versus ACS patients. Using multivariable modeling to control for all known factors that may affect cost of care, we estimated that, on average, the 6 month healthcare payment for a PCS patient was $30,508 compared to a similar ACS patient of $23,801, after controlling for age, gender, race, discharge disposition, tPA use, and mechanical thrombectomy. This resulted in a statistically significant overall healthcare payment difference of $6,707 over the first six months after stroke (p=0.0002). The results of the multivariable models are provided in Table 3.

DISCUSSION

The current study has several limitations. First, we analyzed only payments made by Medicare as our indicator of cost. Many patients have supplementary insurance and that cost is not counted here. We provided information on charges, but charges are not standardized across hospitals or states and, therefore, may not be the best representation for approximating resources used for a national patient cohort. Second, this analysis examines only the initial hospitalization and up to six months of cost of care, which is a short time horizon. This short study “window” may expect to capture a high proportion of acute rehabilitation cost, but it will not capture much of the high cost of nursing home placement that accrue to the most severely ill stroke patients, and it does not examine the costs over subsequent years that are highly correlated with disability following stroke. Finally, we cannot generalize our cost estimates to younger patients or to patients with other insurance coverage than Medicare. However, we expect that the increase in costs associated with PCS severity will be mirrored for other populations.

We found that both payments and charges were higher for patients with PCS than those observed for ACS patients. This was the case for both the Index hospital admission and for the six-month follow up period. It is important to note that what we have reported here does not capture the very large indirect cost burden that strokes place on both patients and families. Current ICD-9 codes are not designed to track stroke by artery. However, this study has successfully identified and used ICD-9 codes related to posterior and anterior stroke to estimate the differential impact of stroke location on the cost of initial hospitalization and post-acute care up to six months after stroke.

As hypothesized, posterior cerebral circulation strokes have greater overall mean payments made by Medicare of $30,876, as compared to anterior cerebral circulation strokes ($24,495), which represents a Medicare payment difference of $6,381, or 21% higher than payments for ACS, after controlling for comorbidities and patient characteristics. There are several implications. PCS patients use 127.4% more on outpatient treatment and 43.4% more on home health than ACS patients. The data show that PCS patients have a higher hospital readmission cost; however, there is only a $16 difference in charges for outpatient doctor office visits. This indicates that there may be a different set of risk/treatment needs in PCS patients versus ACS patients. Following their discharge, we need to better understand the patterns of care for PCS patients that lead to such differences in readmission risk, yet reflect no difference in use of medical office visits. There may be opportunities for enriching primary care in ways that could prevent hospital readmissions.

CONCLUSION

The US health care environment has gone through significant changes, placing a greater emphasis on quality and cost. Hospital quality and outcome measures are now strongly related to length of stay efficiency and reimbursement for care (Tsai, Orav, & Jha, 2015), (Esposito, Selker, & Salem, 2015) (Leonhardt & Benesch, 2015). Quality measures including discharge destination, length of stay, and hospital readmission affect cost to patients, payers, and society. This study found that patients admitted with a PCS are less likely to be discharged to a nursing home, and much more likely to incur a high cost for acute care hospital readmissions within six months after the stroke. This suggests that we need a better understanding of the specific risk factors associated with readmission that are present for PCS patients, and we need to explore if some of these factors could be mitigated by use of skilled nursing or other services during the follow-up period. This may be an important question for future research because Medicare payment for skilled nursing care is linked stringently to acute care hospital admission, a factor that could be increasing in cost for some types of patients, including those with PCS who are discharged to other settings. One important issue raised by our findings is that patients with PCS stroke are more resource intensive, their charges are higher, and their Medicare payments are also higher. However, given the very low payment-to-charge ratio observed for nearly all categories of resource used for stroke care, PCS patients are more likely to place a heavier demand for resources on providers than ACS patients. Furthermore, given the low payment rates by Medicare across service categories, PCS patients are also more likely to face substantially higher copayments for care, which places a heavy economic burden on patients and their family when they are also burdened with the human costs due to stroke disabilities and impairments.

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TABLES

Table 1: Characteristics of the Study Population

Variable	Label	Frequency	Percent
Type of Stroke	Anterior	5230	98.0%
	Posterior	105	2.0%
Gender	Female	2315	56.6%
	Male	3020	43.4%
Race	White	4265	79.9%
	Black	743	13.9%
	Other	327	6.1%
Age	65 to 70	560	10.5%
	70 to 75	744	14.0%
	75 to 80	708	13.3%
	80 to 85	845	15.8%
	85 to 90	950	17.8%
	Over 90	1528	28.6%
Discharge from Acute Hospital	To Home	2108	39.5%
	To IRF	1110	20.8%
	To SNF	1417	26.6%
	To hospice	281	5.3%
	To Other	419	7.8%
Mortality	Died	292	5.5%
	Alive	5043	94.3%
Treatment	tPA	294	5.51%
	MecEmb	33	.62%

Table 2: Characteristics of Population with Posterior Circulation Versus Anterior Circulation Strokes

Variable	Category	Posterior Circulation Stroke Percent orMean (SD) (n=105)	Anterior Circulation Stroke Percent or Mean (SD) (n=5230)	Statistic
Age	65 to 70	10.5%	10.50%	.0001
	70 to 75	26.7%	13.69%	
	75 to 80	19.1%	13.15%	
	80 to 85	18.1%	15.79%	
	85 to 90	11.4%	17.93%	
	Over 90	14.3%	28.93%	
Gender	Female	41.0%	55.8%	.0011
	Male	59.1%	42.2%	
Race	White	79.0%	80.0%	.0032
	Black	11.4%	14.0%	
	Other	9.6%	6.0%	
Discharge from Acute Hospital	To Home	42.9%	39.5%	.4789
	To IRF	23.8%	20.8%	.4438
	To SNF	16.2%	26.8%	.0151
	To Hospice	2.9%	5.3%	.2642
	To Other	14.2%	7.6%	
Mortality	Died	8.57%	5.41%	.1586
	Alive	94.6%	91.4%	
Treatment Intervention	tPA	4.76%	5.53%	.7341
	MecEmb	1.90%	.59%	.0896
Total Payments	Mean (SD)	$37,546 ($38,210)	$26,616 ($27,620)	.0003

Total Charges	Mean (SD	$135,590 ($150,947)	$98,677 ($125,950)	.0003

Table 3: Multivariable Models for Estimating Payments and Charges while Controlling for Population differences that may Affect Resources Used After Stroke.

Variables	Total Payment Beta*Value	Statistic	Total Charges Beta* Value	Statistic
Posterior Circulation Stroke	reference		reference	
Anterior Circulation Stroke	-0.2569	<.0001	-0.2086	.0042
Age Category	-0.0246	<.0001	-0.0542	<.0001
White Race	reference		reference	
American Indian	0.4022	.0018	0.2374	.1031
Black	0.1116	<.0001	0.0753	.0122
Hispanic Race	0.1486	.0018	0.2046	.0020
Other Race	0.1940	.0001	0.3421	<.0001
Charlson Score	0.1275	<.0001	0.1388	<.0001
Discharged to Inpatient Rehabilitation	reference		reference	
Discharged to Home	-0.7779	<.0001	-0.5802	<.0001
Discharged to Skilled Nursing	-0.4160	<.0001	-0.2915	<.0001
Discharged to Hospice	-0.6650	<.0001	-0.5680	<.0001
Died During Index Admission	-0.5351	<.0001	-0.3789	<.0001
Received tPA	0.2806	<.0001	0.3751	<.0001
Received Mechanical Embolectomy	0.6402	<.0001	0.6485	<.0001
Re-Transformed				

Payment and Charge Estimates:				
Total for Posterior Circulation Stroke	$30,876	.0002	$108,829	.0031
Total for Anterior Circulation Stroke	$24,495		$88,336	

*Beta values represent log-transformed values for cost and charges estimated using a gamma distribute log-link function to account for the skewed distribution of cost and charge data, the retransformed estimates which are controlled for differences in covariates are shown separately in the table.

Figure1: Survival Difference for Patients with PCS compared to ACS Patients Over the Six Months After Stroke

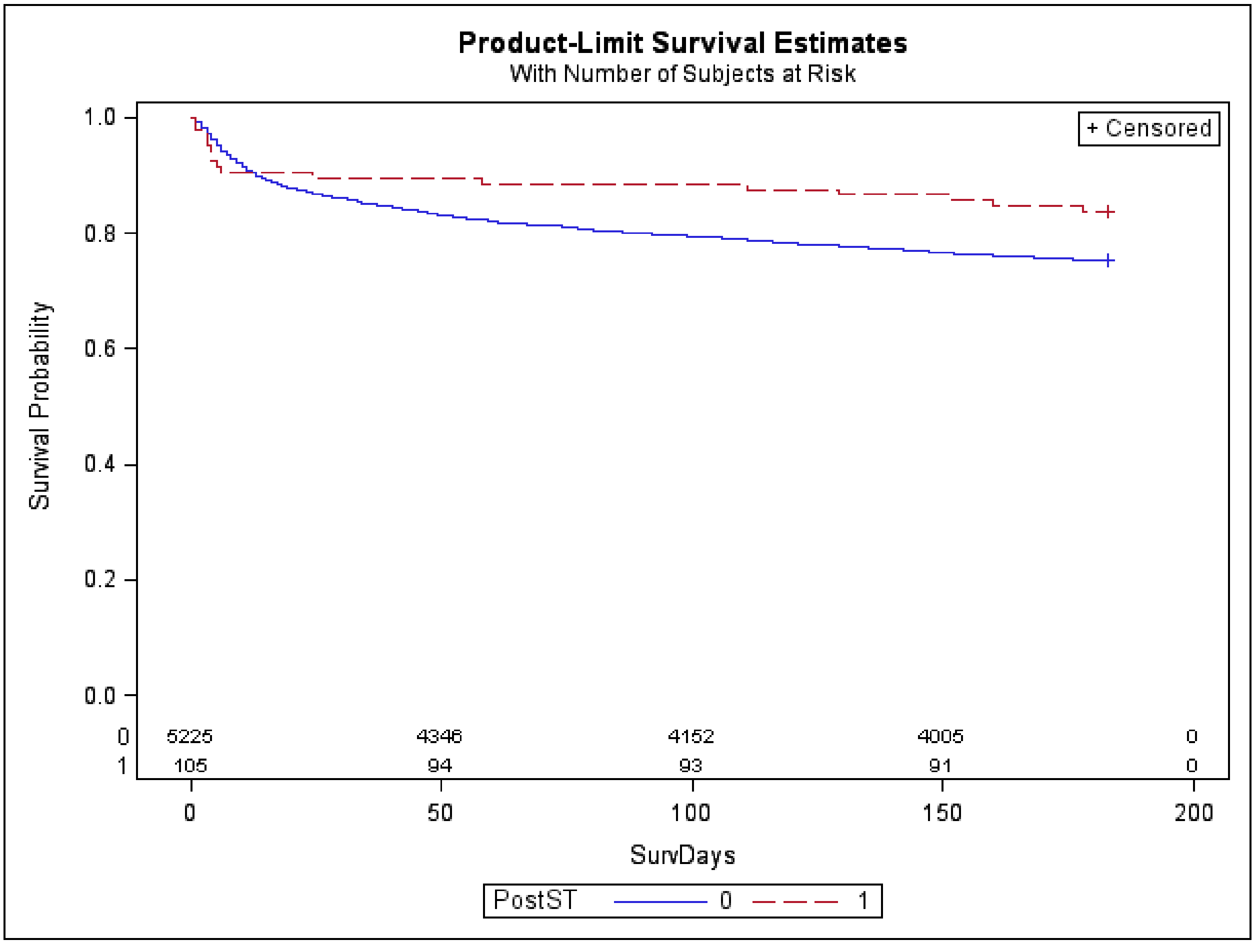
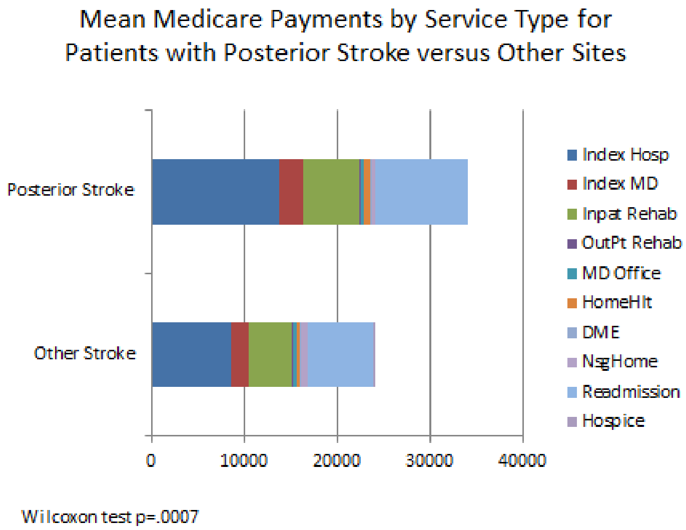
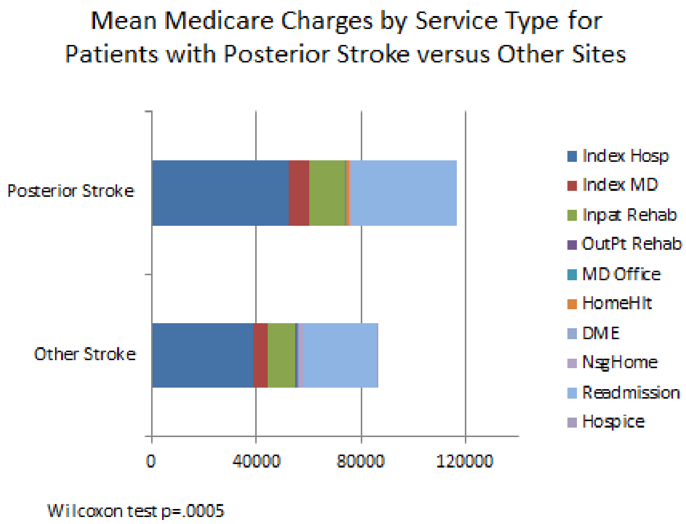


Figure 2: Distribution of Medicare Payments and Charges by Stroke Type





APPENDIX A

The follow-up time is measured as 183 days from the date of admission for the Index stroke. Not all patients receive all types of care, and patients who die during the Index admission will have no expenses for the follow up time. Summary of payments and charges for medical care for the 6 Months follow-up time, or until death (if death within 6 months) after the index hospital admission are provided in the table below. Not all patients had bills in all categories, thus these data show summary charge and payments only for patients who had at least one bill after the index hospital discharges for the type of service in the category.

Table 1: Summary of Charges and Payments by Type of Resource Used over Six Months for the Population

Type of Service	Total Patients	Total Charges (SD)	Total Payments (SD)	Payments as Percent of Charges	LOS or Number of Visits as Relevant (SD)
Index hospital admission for stroke	5335	$39,031 ($47,175)	$8,616 ($8,684)	22%	4.8 days (4.4)
Physician charges Index Hospital Time	5173	$5,659 ($6,243)	$1,963 ($1,803)	35%	NA
Inpatient rehabilitation hospital	1275	$45,782 ($36,778)	$20,092 ($10,614)	55%	15.1 Days (7.5)
Inpatient acute hospital readmissions	3255	$46,701 ($76,019)	$11,599 ($15,422)	25%	6.8 days (7.9)
Medical Office Visits	3335	$1,091 ($1,183)	$631 ($631)	63%	3.9 visits (3.7)
PT and OT Part B Payments	282	$1,750 ($2,234)	$899 ($1,223)	51%	NA
Other Part B Payments	5191	$7,812 ($9,452)	$2,634 ($2,894)	34%	NA
Outpatient Intense Rehab.	4	$1,286 ($1,219)	$453 ($408)	35%	NA
Other Outpatient Payments	2918	$11,295 ($29,341)	$1,556 ($3,000)	14%	NA
Home Health Payments	627	$4,082 ($4,585)	$3,860 ($3,023)	95%	NA
Skilled Nursing facility	408	$17,076 ($18,441)	$9,458 ($9,135)	55%	NA
Hospice	21	$13,024 ($10,924)	$7,015 ($4,883)	54%	NA
Durable Medical Equipment	1321	$1,319 ($5,542)	$381 ($760)	29%	NA

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APPENDIX B

Table 2 Overview of Selected Stroke Syndromes (Moheet & Katzan, 2013)

Brian Circulation	Vascular Territory	Area Affected	Signs and Symptoms
Anterior cerebral circulation	Anterior cerebral artery	Frontal pole and mesial frontal lobe	• Contralateral: leg > face and arm weakness • Frontal signs such as abulia
Anterior cerebral circulation	Middle cerebral artery	Posterior frontal, temporal, parietal lobes	• Contralateral: face and arm > leg weakness, sensory loss to all modalities, visual field cut, visual-spatial neglect • Ipsilateral: gaze preference • Dominant hemisphere affected: aphasia, alexia, agraphia, acalculia
Posterior cerebral circulation	Posterior cerebral artery	Occipital lobe	• Contralateral: homonymous hemianopia • With thalamic involvement: Sensory loss to all modalities or pain
Posterior cerebral circulation	Anterior inferior cerebellar artery	Lateral pontine syndrome	• Contralateral: hemiparesis and hemisensory loss of pain and temperature • Ipsilateral: ataxia
Posterior cerebral circulation	Posterior inferior cerbellar artery	Lateral medulla (Wallenberg syndrome)	• Contralateral: hemibody pain and temperature loss • Ipsilateral: facial pain, hemifacial pain and temperature loss, ataxia, nystagmus, nausea/vomiting, vertigo, Horner's syndrome, dysphagia • Hiccups
Posterior cerebral circulation	Basilar artery	Pons (locked-in syndrome)	• Bilateral: progressive quadriplegia, facial weakness • Lateral gaze weakness with sparing of vertical gaze
Posterior cerebral circulation	Vertebral artery	Medial medulla	• Contralateral: hemibody weakness, loss of vibration and proprioception • Ipsilateral: tongue weakness and/or atrophy

Posterior cerebral circulation	Vertebral artery	Lateral medulla	• Wallenberg syndrome

Table 3 Medicare Revenue codes
RESDAK download 03072015 REV_CNTR_TB Revenue Center

0001	Total charge
0022 SNF claim	paid under PPS submitted as TOB 21X, effective for cost reporting periods beginning on or after 7/1/98 (dates of service after 6/30/98). NOTE: This code may appear multiple times on a claim to identify different HIPPS Rate Code/assessment periods.
0023 Home Health services	Paid under PPS submitted as TOB 32X and 33X, effective 10/00. This code may appear multiple times on a claim to identify different HIPPS/Home Health Resource Groups (HRG).
0024 Inpatient Rehabilitation	Facility services paid under PPS submitted as TOB 11X, effective for cost reporting periods beginning on or after 1/1/2002 (dates of service after 12/31/01). This code may appear only once on a claim.
PT	0420 = Physical therapy-general classification
	0421 = Physical therapy-visit charge
	0422 = Physical therapy-hourly charge
	0423 = Physical therapy-group rate
	0424 = Physical therapy-evaluation or re-evaluation
	0429 = Physical therapy-other
OT	0430 = Occupational therapy-general classification
	0431 = Occupational therapy-visit charge
	0432 = Occupational therapy-hourly charge
	0433 = Occupational therapy-group rate
	0434 = Occupational therapy-evaluation or re-evaluation
	0439 = Occupational therapy-other (may include restorative therapy)
SLP	0440 = Speech language pathology-general classification
	0441 = Speech language pathology-visit charge
	0442 = Speech language pathology-hourly charge
	0443 = Speech language pathology-group rate
	0444 = Speech language pathology-evaluation or re-evaluation
	0449 = Speech language pathology-other

Table 4. Anterior blood supply to the brain and Associated Deficits (Stein, Harvey, Winstein, Zorowitz, & Wittenberg, 2014)

Anterior Cerebral Blood Supply			
Main Artery	**Cerebral Artery**	**Brain Area**	**Associated Deficits**
Internal Carotid	ACA	-Cortical areas of the frontal lobe -Anterior corpus callosum	-Complex physical and cognitive deficits -Contralateral hemiplegia -Minor sensory loss -Left side limb apraxia -Ipsilateral eye deviation -Contralateral hemiplegia -Hemianopsia or contralateral hemianopsia -Left hemineglect Syndrome -Decreased grasp reflex -Paratonia -Palmomental -Aphasia
	MCA	-Large area of cerebral hemisphere -Basal ganglia -Internal capsule -Visual radiations from the thalamus -Frontal and temporal lobe operculum -Lateral convexity of the frontal and temporal lobe	-Edema and intracranial pressure -Significant neurological deficits -Hemianesthesia and an eye deviation towards the lesion -Contralateral hemisensory loss -Homonymous hemianopsia in contralateral visual field -Language deficits in the Broca's and Wernicke's area -Global aphasia -Severe visual and perceptual deficits -Dressing apraxia -Constructional apraxia -Hemineglect syndrome -Anosognosia -Mild sensory deficits -Limb apraxia -Aprosodia

			-Sensory aprosodia
	Anterior Communicating Artery	-Medial aspects of the frontal and parietal lobes -Basal ganglia -Anterior fornix -Anterior corpus callosum	- Contralateral hemiparesis or hemiplegia, involving primarily the lower limbs and pelvic floor musculature -Contralateral Sensory deficits involving primarily the leg and perineum -Apraxia - Disconnection syndrome -Anosmia -Urinary incontinence - Contralateral grasp reflex and or sucking reflex

Table 5. Posterior blood supply to the brain and Associated Deficits (Stein, Harvey, Winstein, Zorowitz, & Wittenberg, 2014)

Posterior Cerebral Blood Supply			
Main Artery	**Cerebral Artery**	**Brian Area**	**Associated Deficits**
Vertebral	Basilar	-Upper spinal cord -Cerebellum -Brainstem	-Impaired coordination -Impaired equilibrium, locomotion and prehension -Dysmetria -Facial and limb motor deficits -Cranial nerve oculomotor deficits -Upgaze paralysis -Ataxic hemiparesis -Mild to severe Vertigo -Mild to severe Nyasia -Asterixis -Comma
		-Midbrain	-Weber Syndrome, -Benedikt Syndrome -Parinaud Syndrome -Koerber-Salus-Elschnig Syndrome
		-Pons	-Millard-Glubler Syndrome -Foville Syndrome -Raymond Syndrome -Pontocerebellar Angle Syndrome -Brissaud Syndrome -One-and-a-Half Syndrome -Locked-In Syndrome

		-Medulla Oblongata	-Paramedian Bulbar Syndrome -Lateral Bulbar Syndrome -Avellis Syndrome -Schmit Syndrome -Jackson Syndrome -Tapia Syndrome -Bonnier Syndrome -Babinski-Nageotte bulbar Syndrome
		-Cerebellum	-Rostral Syndrome -Medial Syndrome -Caudal Syndrome -Caudal and medial Syndrome -Rostrocaudal Syndrome
	PCA	-Anterior temporal lobe -Posterior temporal lobe -Lateral occipital lobe -Medial occipital lobe -Posterior corpus callosum -Thalamus -Hippocampus	-Contralateral sensory Syndrome -Hypoesthesia -Dysesthesia -Contralateral homonymous hemianopsia -Amnestic disorder -Alexia without agraphia -Left neglect Syndrome -Blindness and visual anosagnosia -Severe cognitive deficits
	Posterior Commutating Artery	-Thalamus -Hypothalamus -Optic chiasm -Mamillary bodies	-Oculomotor nerve palsy -Acute vision loss -Confusion -New onset posterior cranium headache -Paresthesias -Limb weakness -Dizziness -Nausea -Memory loss -Language dysfunction

Table 6: Stroke syndromes arranged by vascular territory (Balami, Chen, & Buchan, 2013)

Artery	Syndrome
Middle cerebral artery	-Middle cerebral artery: complete -Middle cerebral artery: superior division -Middle cerebral artery: inferior division -Gerstmann syndrome -Ataxic hemiparesis
Posterior cerebral artery	-Posterior cerebral artery: unilateral occipital -Balint syndrome -Cortical blindness (Anton syndrome) -Weber syndrome -Alexia without agraphia -Thalamic pain syndrome (Dejerine–Roussy syndrome)
Anterior inferior cerebellar artery	-Lateral pontine syndrome (Marie–Foix syndrome)
Posterior inferior cerebellar artery	-Lateral medullary syndrome (Wallenberg syndrome)
Basilar artery	-Locked-in syndrome -Lateral pontine syndrome (Marie–Foix syndrome) -Ventral pontine syndrome (Raymond syndrome) -Ventral pontine syndrome (Millard–Gubler syndrome) -Inferior medial pontine syndrome (Foville syndrome) -Ataxic hemiparesis -Cortical blindness (Anton syndrome) -Medial medullary syndrome (Dejerine syndrome
Vertebral artery	-Medial medullary syndrome (Dejerine syndrome) -Lateral medullary syndrome (Wallenberg syndrome)
Anterior spinal artery	-ASAS
Posterior spinal artery	-PSAS

Table 7 CPT Codes for Rehabilitation:

ALL PHYSICAL THERAPY CPT Codes	'29240', '29530', '29540', '90901', '95831', '95832', '95833', '95834', '95851', '95852', '97001', '97002', ‘97005’, ‘97006’, '97010', '97012', '97014', '97016', '97018', ‘97020’, '97022', '97024', '97026', '97028', '97032', '97033', '97034', '97035', '97036', '97039', '97110', '97112', '97113', '97116', '97124', '97139', '97140', '97150', '97250', ‘97504’, ‘97520’, '97530', '97532', '97533', '97535', ‘97537’, '97542', ‘97545’, ‘97546’, '97597', '97598', ‘97703’, '97750', '97755', '97760', '97761', '97762', '97799', '97810', '97811', '97813', '97814', ‘98925’, ‘98926’, ‘98927’, ‘98928’, ‘98929’, '98960', ‘99509’, 'G0151', 'G0157', 'G0159', 'G0281', 'G0282', 'G0283', 'S8950', 'S9131'
Codes for PT specifically relevant to stroke patient rehab	'29240', '29530', '29540', '90901', '95831', '95832', '95833', '95834', '95851', '95852', '97001', '97002', ‘97005’, ‘97006’, '97010', '97012', '97014', '97016', '97018', ‘97020’, '97022', '97024', '97026', '97028', '97032', '97033', '97034', '97035', '97036', '97039', '97110', '97112', '97113', '97116', '97124', '97139', '97140', '97150', ‘97504’, ‘97520’, '97530', '97532', '97533', '97535', ‘97537’, '97542', ‘97545’, ‘97546’, ‘97703’, '97750', '97755', '97760', '97761', '97762', '97799', ‘98925’, ‘98926’, ‘98927’, '98960', ‘99509’, 'G0151', 'G0157', 'G0159', 'G0283', 'S9131'

Table 8: CPT PLUS 2012 Codes

97535, 99509	Activities of daily living
97113	Aquatic therapy with exercises
97005;	Athletic training – Evaluation
97006	Re-evaluation
97703	Checkout, orthotic/prosthetic
97532	Cognitive skills development
97537	Community/work reintegration
97001 97002	Evaluation
97530	Kinetic therapy; Therapeutic activities
97140	Manual, traction therapy
97034;	Modalities – Contrast baths
97024	Diathermy treatment
97014	Electric stimulation – Unattended
97032	Attended, manual
97010	Hot or cold pack
97036	Hydrotherapy
97026	Infrared light treatment
97033	Iontophoresis
97020	Microwave therapy
97018	Paraffin bath
97012	Traction
97035	Ultrasound
97028	Ultraviolet light
97039	Unlisted services and procedures
97016	Vasopneumatic device
97022	Whirlpool therapy
97504	Orthotics training
98925, 98926, 98927, 98928, 98929	Osteopathic manipulation
97116	Gait training
97150	Group therapeutic
97124	Massage therapy
97112	Neuromuscular reeducation –
97750	Physical performance test
97110	Therapeutic exercises
97545, 97546	Work hardening
97520	Prosthetic training
97533	Sensory integration
97139, 97799	Unlisted services and procedures
97542	Wheelchair management/propulsion
29240	Strapping of the shoulder -
29530	Strapping of the knee -
29540	Strapping of the ankle -
90901	Biofeedback training -

95831	Manual muscle testing with report (separate procedures); extremity (excluding hand) or trunk
95832	Muscle testing, manual (separate procedure) with report; hand, with or without comparison with normal side
95833	Muscle testing, manual (separate procedure) with report; total evaluation of body, excluding hands
95834	Muscle testing, manual (separate procedure) with report; total evaluation of body, including hands
95851	Range of motion measurements and report (separate procedure); each extremity (excluding hand) or each trunk section (spine)
95852	Range of motion measurements and report (separate procedure); hand, with or without comparison with normal side
97250	Myofascial release (no longer a CPT code, but billable under the California workers compensation system in lieu of 97140)
97597, 97598	Débridement (eg, high pressure waterjet with/without suction, sharp selective débridement with scissors, scalpel and forceps), open wound, (eg, fibrin, devitalized epidermis and/or dermis, exudate, debris, biofilm), including topical application(s), wound assessment, use of a whirlpool, when performed and instruction(s) for ongoing care, per session, total wound(s) surface area; first 20 sq cm or less
97755	Assistive technology assessment (eg, to restore, augment or compensate for existing function, optimize functional tasks and/or maximize environmental accessibility), direct one-on-one contact, with written report, each 15 minutes
97760	Orthotic(s) management and training (including assessment and fitting when not otherwise reported), upper extremity(s), lower extremity(s) and/or trunk, each 15 minutes
97761	Prosthetic training, upper and/or lower extremity(s), each 15 minutes
97762	Checkout for orthotic/prosthetic use, established patient, each 15 minutes
97810	Acupuncture, 1 or more needles; without electrical stimulation, initial 15 minutes of personal one-on-one contact with the patient
97811	Acupuncture, 1 or more needles; without electrical stimulation, each additional 15 minutes of personal one-on-one contact with the patient, with re-insertion of needle(s) (List separately in addition to code for primary procedure)
97813	Acupuncture, 1 or more needles; with electrical stimulation, initial 15 minutes of personal one-on- one contact with the patient
98960	Education and training for patient self-management by a qualified, nonphysician health care professional using a standardized curriculum, face-to-face with the patient (could include caregiver /family) each 30 minutes; individual patient

G0151	Services performed by a qualified physical therapist in the home health or hospice setting, each 15 minutes
G0157	Services performed by a qualified physical therapist assistant in the home health or hospice setting, each 15 minutes
G0159	Services performed by a qualified physical therapist, in the home health setting, in the establishment or delivery of a safe and effective physical therapy maintenance program, each 15 minutes
S9131	Physical therapy; in the home, per diem
S8950	Complex lymphedema therapy, each 15 minutes
G0283	Electrical Stimulation to one or more areas for indications other than wound care, as part of a therapy plan
G0281, G0282	Electrical Stimulation for the treatment of wounds
97814	Acupuncture, 1 or more needles; with electrical stimulation, each additional 15 minutes of personal one-on-one contact with the patient, with re-insertion of needle(s) (List separately in addition to code for primary procedure)