Journal of Clinical Neuroscience 32 (2016) 109–114

Contents lists available at ScienceDirect

Journal of Clinical Neuroscience

journal homepage: www.elsevier.com/locate/jocn

Clinical Study

Increased risk for complications following diagnostic cerebral angiography in older patients: Trends from the Nationwide Inpatient Sample (1999–2009)

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ARTICLE INFO

Article history:
Received 17 April 2016
Accepted 20 April 2016

Keywords:
Cerebral angiography
Cerebrovascular imaging
Complications
CT angiography
National Inpatient Sample
Population outcomes

ABSTRACT

The full utility of diagnostic cerebral angiography, an invasive cerebrovascular imaging technique, is currently debated. Our goal was to determine trends in diagnostic cerebral angiography utilization and associated complications from 1999 through 2009. The National Inpatient Sample (NIS) was used to identify patients who received primary cerebral angiography from 1999–2009 in the United States. We observed trends in discharge volume, total mean charge, and post-procedural complications for this population. Data was based on sample projections and analyzed using univariate and multivariate regression. There were a total of 424,105 discharges indicating primary cerebral angiography nationwide from 1999–2009. The majority of these cases (65%) were in patients older than 55 years. Embolic stroke was the most frequent complication, particularly in the oldest age bracket, occurring in 16,304 patients. The risk for complications increased with age ($p < 0.0001$) and with other underlying health conditions. Pulmonary, deep vein thrombosis, and renal associated comorbidities resulted in the greatest risk for developing post-procedural complications. Throughout the study period case volume for cerebral angiography remained constant while total charge per patient increased from $17,365 in 1999 to $45,339 in 2009 ($p < 0.001$). While the overall complication rate for this invasive procedure is relatively low, the potential risk for embolic stroke in older patients is significant. It is worth considering less invasive diagnostic techniques for an older and at risk patient population.

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1. Introduction

Primary cerebral angiography is an invasive technique used in the evaluation and treatment of many cerebrovascular disorders [1]. It involves introduction of a catheter through the femoral artery followed by a transarterial contrast injection in the relevant artery and X-ray imaging. Since the adoption of digital subtraction imaging over 20 years ago, improvements in contrast dyes, catheters and guidewires have been the most significant procedural changes [2–4]. Throughout this period, technological advancements have brought CT angiography and other noninvasive imaging techniques into clinical practice. The appropriate circumstances and risks for both CT and primary cerebral angiography have been debated [1,5]. Additionally, recent improvements in 128 slice CT angiography have bolstered our non-invasive imaging armamentarium [6]. Although CT angiography offers a non-invasive alternative, cerebral angiography remains the gold standard for endovascular imaging and preoperative care because of its resolution capabilities [7].

A comprehensive understanding of the associated risks with primary cerebral angiography would help delineate its current utility. To date, a low but still definitive risk of complication following a cerebral angiography procedure has been documented [4,8–12]. Groin hematoma and local bruising are the most common complications. Neurological complications are less common and mostly transient when they do occur [4]. The low risk and high resolution of cerebral angiography has validated its use for preoperative care. However, most supporting studies were conducted at a single institution, resulting in a paucity of population data [10]. Additionally, little is known about the population of patients using these

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http://dx.doi.org/10.1016/j.jocn.2016.04.007
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procedures. Age and cardiovascular disorders have been shown to increase the risk of complications [4,8,12]. The interplay between other comorbidities and cerebral angiography is poorly defined on a national level. Our study used a nationwide database to determine trends in cerebral angiography usage, associated complications, and patient discharge costs between 1999 and 2009.

2. Methods

2.1. Standard protocol approvals

This study did not include human subjects or identifiers and is in compliance with Stanford School of Medicine policies.

2.2. Database

Data from 1999 through 2009 was obtained from the Nationwide Inpatient Sample (NIS) hospital discharge database [13]. The NIS is part of a family of databases maintained by the Healthcare Cost and Utilization Project (HCUP) sponsored by the Agency for Healthcare Research and Quality. The NIS is a 20% stratified sample of non-federal hospitals from 46 participating states [14]. It represents the largest all-payer inpatient care database in the United States and includes demographic data, procedural codes, diagnosis, and mortality rates.

2.3. Data extraction and outcomes

Patients who underwent primary cerebral angiography identified by the International Classification of Disease 9th Revision codes (ICD-9 CM: 88.41) between 1999 and 2009 were queried. We split our study period between 1999–2004 and 2004–2009 in order to categorically compare changes over time. Outcomes included discharges, length of stay, and mean total charge per discharge among patients undergoing primary cerebral angiography. Annual discharge patterns and hospital-level weights were used to produce national estimates for primary and secondary outcomes.

Both individual and hospital level characteristics were characterized in relation to risk of complications. In addition to in-hospital mortality, adverse events and complications were categorized as embolic stroke (ICD-9 CM: 434.11), hematoma (ICD-9 CM: 998.12), contrast-induced nephropathy (ICD-9 CM: 584.9), renal dye allergies (ICD-9 CM: V1508), neurological complications (ICD-9 CM: 997.00, 997.01, 997.02, 997.03, 997.04, 997.05, 997.06, 997.07, 997.08, 997.09), pulmonary complications (ICD-9 CM: 518.5, 518.81, 518.84, 997.3), cardiac complications (ICD-9 CM: 997.1, 41.0), and deep venous thrombosis (DVT) (ICD-9 CM: 415.11, 453.40, 453.8, 453.9). To characterize the association between procedural complications and medical comorbidities, we utilized comorbidity categories from the Elixhauser Index [15].

2.4. Statistical analysis

Statistics were calculated using Student's t-test, Wilcoxon–Mann–Whitney, chi-squared, and Kruskal–Wallis tests as appropriate and considered significant at the $p = 0.05$ level. Statistical analyses were performed using the survey estimation procedures (SURVEYFREQ, SURVEYMEANS, SURVEYLOGISTIC) of SAS version 9.4 (SAS Institute, Cary, NC, USA).

3. Results

3.1. Patient population

From 1999 through 2009 an estimated 424,105 patients nationwide underwent primary cerebral angiography. The majority of patients (65%) were older than 55 years and the mean age was 60.3 years (Table 1). Less than 5% of procedures were in patients under 30 years of age. 52% of all patients were female and the mean length of stay was 5.0 (4.9–5.1) days (Table 1). Most patients were admitted to public hospitals (77%) and teaching centers (62%). Of all the cerebral angiography patients, 45% were on Medicare and only 6% were uninsured. The majority of cases were designated as non-emergency admission (62%). Although the annual rate of utilization did not significantly increase ($p = 0.66$), the mean total charge per discharge rose from $17,365 in 1999 to $45,339 in 2009 ($p < 0.001$) (Fig. 1). The most common primary diagnosis for patients undergoing primary cerebral angiography was unspecified cerebral artery occlusion with cerebral infarction (21.4%) (Table 2). Other common primary diagnoses included subarachnoid hemorrhage (13.10%) and unspecified cerebral ischemia (11.60%).

3.2. Complications

Out of the 424,105 procedures, 6,721 (1.6%) patients died while in the hospital (Table 3). Contrast-induced nephropathy and hematoma were observed in 2% and 1% of patients respectively. Neurological complications were observed in only 631 patients (less than 1% of all procedures). Embolic stroke was the most common complication effecting 16,304 patients (3.8%).

Patients with pulmonary complications had a significantly longer length of stay, 11.5 (10.5–12.6, $p < 0.001$) days, relative to patients without complications. Additionally, the mean total charge for these patients was $97,171 ($82,295–$104,047). Embolic stroke, the most common complication, averaged a length of stay of 6.7 (6.4–7.0) days and a mean total charge of $40,963 ($37,517–$44,407) (Table 3). DVT complication patients had a longer mean length of stay of 10.0 (9.1–11.0 days, $p < 0.001$) and a mean total charge of $56,971 ($47,182–$66,760). Of all 424,105 patients receiving primary cerebral angiography the mean length of stay was 5.0 days (4.9–5.1) and the mean total charge was $30,195 ($28,466–$31,923) (Table 3).

The majority of cases with complications, 21,293 of 29,642 total cases, were in patients older than 55 (Fig. 2a). Patients who were older than 55 had a 3.14 fold (2.07–4.77, $p < 0.0001$) increase in odds for complications compared to patients less than 17 years of age (Fig. 2a). Additionally, patients who were not on Medicare had significantly lower odds of complication ($p < 0.0001$). A large proportion of these complications were embolic stroke (Fig. 2b). For patients over 55 embolic stoke constituted over half all reported complications (16,028 out of 29,642 cases indicating complication).

3.3. Comorbidities

The most prevalent comorbidities were hypertension (58%), diabetes (21%), fluid and electrolyte disorders (12%), and paralysis (10%) (Table 4). Patients had the highest odds of experiencing any complication if they had comorbid congestive heart failure (odds ratio [OR] 2.83 (2.62–3.07, $p < 0.001$)), pulmonary circulatory disease (OR 3.25 (2.71–2.89, $p < 0.0001$)) or renal failure (OR 3.7 (3.4–4.1, $p < 0.001$)). Of patients with renal failure, 24.8% (23.3–26.4) experienced complications following primary cerebral angiography. Similarly, 23.7% (20.3–27.0) of patients with associated pulmonary disease experienced complications.

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