

# National trends in carotid endarterectomy and stenting in Korea from 2004 to 2013

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**Abstract.** Stroke imposes a substantial clinical and socioeconomic burden. Carotid endarterectomy (CEA) or carotid artery stenting (CAS) are proven procedures in stroke prevention for the lesions of extracranial carotid disease. Although several studies have addressed national trends regarding carotid revascularization in Western countries, limited data is available with respect to the Korean population. The aim of the present study was to identify the national trend in carotid revascularization in Korea over the previous decade. A serial, cross-sectional study was conducted with the use of time trends to analyze patients undergoing carotid revascularization using CEA and CAS between 2004 and 2013. Health Insurance Review and Assessment Service data was used. The present study endeavored to analyze trends in the number of CEA and CAS procedures for the treatment of extracranial carotid disease in Medicare beneficiaries. A linear-by-linear association was performed to determine the changes of carotid revascularization for the aforementioned period. A total of 23,142 patients received carotid revascularization between 2004 and 2013. CEA was performed in 4,012 and CAS in 19,130 patients. The rate of total carotid revascularization per 1,000,000 Medicare beneficiaries substantially increased during the study period from 22 procedures in 2004 to 57 in 2013 (risk ratio (RR), 2.59; 95% confidence interval (CI), 1.58-4.24;  $P=0.001$ ). CAS increased from 18 procedures in 2004, to 45 in 2013 (RR, 2.50; 95% CI, 1.45-4.32;  $P=0.001$ ). In addition, the number of CEA procedures performed per 1,000,000 Medicare beneficiaries increased from four procedures in 2004, to 11 in 2013 (RR, 2.75; 95% CI, 0.88-8.64;  $P=0.08$ ). In conclusion, total carotid revascularization increased by 255% during the previous 10 years in Korea. This increase predominantly resulted from the 249% increase of CAS. The number and

population-based rates of carotid revascularization remained low, as compared with Western countries.

## Introduction

Stroke constitutes a substantial clinical and socioeconomic burden. It is the second leading cause of death in Korea and the third most common cause of disability-adjusted life-years worldwide (1). Approximately 87% of all strokes are of ischemic origin (2). Extracranial carotid artery disease accounts for up to 15-20% of all ischemic strokes (3,4) and represents an important target in stroke prevention.

Carotid endarterectomy (CEA) is efficacious in stroke prevention. The North American Symptomatic Carotid Endarterectomy Trial showed the significant benefit of CEA in symptomatic patients compared with antiplatelet therapy over 5 years (5). The rate of ipsilateral stroke, including perioperative events, was 15.7% with CEA, as compared with 22% for medically managed patients. The European Carotid Surgery Trial findings indicated that the use of CEA was beneficial for patients with 70-99% stenosis (6). It has previously been demonstrated that successful CEA for asymptomatic patients aged <75 years reduces the 10-year stroke risk (7).

The use of carotid artery stenting (CAS) as a less invasive alternative to surgical intervention has been increasingly performed. The randomized, multicenter Carotid Revascularization Endarterectomy versus Stent Trial compared CAS with CEA for symptomatic and asymptomatic patients (8). There was no significant difference in primary events including stroke, death or myocardial infarction during the periprocedural period and ipsilateral stroke between the two treatment arms (7.2% with CAS compared with 6.8% with CEA; hazard ratio for stenting, 1.11; 95% confidence interval (CI), 0.81-1.51).

Since the introduction of CAS, its annual rate of use increased 250% between 2001 and 2010 in the United States, and there was a 41% decrease in the annual incidence of CEA (9). In the United Kingdom, 17,560 carotid procedures were performed between 2006 and 2009 (10). CAS accounted for <5% of all carotid revascularizations.

A limited amount of comparable information is available in Asian countries, including Korea. Therefore, the present study evaluated the national trends of treatment modality for carotid artery disease in Korea between 2004 and 2013.

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Table I. EDI codes of the carotid artery procedures.

EDI codes	Procedure
O0226	Carotid endarterectomy, complex
O0227	Carotid endarterectomy, complex
O2066	Carotid endarterectomy with patch closure
M6602	Carotid artery stenting

EDI, Electronic Data Interchange.

## Materials and methods

**Data collection.** Health Insurance Review and Assessment Service (HIRA) data were used to evaluate the trends in carotid revascularization in South Korea. The country has a universal health coverage system, in which National Health Insurance covers ~98% of the Korean population. HIRA claims data are collected when South Korean healthcare service providers seek reimbursements for healthcare services that the National Health Insurance Corporation agrees to cover. Approximately 46 million Korean patients submit health insurance claims each year. HIRA claims data are compiled nationally from healthcare providers, and correspond to the number of claims submitted by patients (11).

The Electronic Data Interchange (EDI) database of HIRA contains the operation and management codes. Carotid revascularization data were collected using EDI codes. Table I summarizes the EDI codes for patients who received CEA and CAS. The codes for commonly performed procedures for carotid artery disease include O0226, O0227 and O2066, which refer to open surgery with CEA, and M6602, which is the code for an endovascular CAS procedure.

Carotid revascularization in the previous 10 years was evaluated using EDI data between 2004 and 2013. The total numbers of CEA and CAS procedures used for the treatment of carotid artery disease were calculated for this period. The present study assessed the trends in the number of carotid revascularization procedures using the aforementioned codes. The present study was approved by the Institutional Review Board of Kyung Hee University Hospital (Seoul, Korea).

**Statistical analysis.** For statistical analysis, a linear-by-linear association was performed to determine the trends in the amount of carotid revascularization procedures performed between 2004 and 2013.  $P < 0.05$  (two sided) was considered to indicate a statistically significant difference. Data were analyzed using SPSS statistical software (version 19.0; IBM SPSS, Armonk, NY, USA).

## Results

**Carotid revascularization.** A total of 23,142 patients received carotid revascularization between 2004 and 2013, which comprised 4,012 CEA procedures and 19,130 CAS procedures. The year-by-year profile is detailed in Table II. The proportion of CEA procedures increased from 18.3% in 2004 to 20.2% in 2013. Concurrently, the proportion of

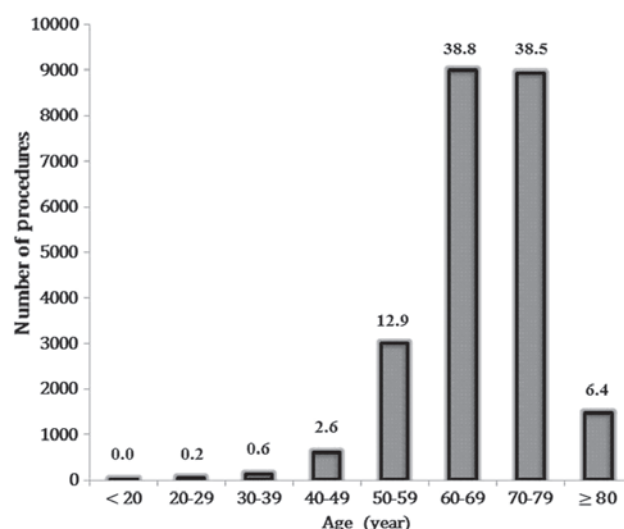


Figure 1. Age distribution of patients treated with carotid revascularization in South Korea between 2004 and 2014. The values above the bars represent the percentage distribution.

CAS procedures decreased from 81.7% in 2004, to 79.8% in 2013. Revascularization was observed to increase with age, and was 12.9% in patients 50-59 years-of-age, 38.8% in those 60-69 years-of-age and 38.5% in patients 70-79 years-of-age (Fig. 1).

**Trends in carotid revascularization.** The total number of carotid revascularizations for the treatment of carotid artery disease increased significantly from 1,080 in 2004, to 2,899 in 2013 (risk ratio (RR), 2.55; 95% CI: 2.38-2.73; Fig. 2A). The frequency of CAS also increased from 882 in 2004 to 2,312 in 2013 (RR 2.49; 95% CI: 2.30-2.69). The number of CEA procedures increased from 198 in 2004, to 587 in 2013 (RR 2.82; 95% CI: 2.39-3.31). The differences in the trends for the two procedures were all statistically significant ( $P < 0.0001$ ).

**Carotid revascularization per 1,000,000 Medicare beneficiaries.** Population-adjusted frequencies of total, CEA and CAS over 10 years are displayed in Fig. 2B. The rate of total carotid revascularization per 1,000,000 Medicare beneficiaries significantly increased from 22 procedures in 2004, to 57 procedures in 2013 (RR 2.59; 95% CI: 1.58-4.24;  $P = 0.001$ ). The number of CAS procedures performed increased in a similar trend, from 18 procedures in 2004 to 45 in 2013 (RR 2.50; 95% CI: 1.45-4.32;  $P = 0.001$ ). The number of CEA procedures performed per 1,000,000 Medicare beneficiaries increased from four procedures in 2004, to 11 in 2013 (RR 2.75; 95% CI: 0.88-8.64;  $P = 0.08$ ).

## Discussion

Several important findings are presented in the current study. Primarily, the overall rate of carotid revascularization was observed to have significantly increased by 255%. Secondly, the proportion of CEA procedures compared with CAS procedures was contrary to the findings reported in Western countries. In the United States, CEA was performed in preference to the CAS procedure in 86.5-96.5% of cases (9).

Table II. Distribution of carotid artery procedures by year for 10 years.

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
CEA	198	202	98	224	642	460	450	567	584	587
(%)	18.3	9.9	5.3	9.6	22.0	22.3	18.6	20.6	21.1	20.2
CAS	882	1,850	1,744	2,116	2,280	1,606	1,971	2,187	2,182	2,312
(%)	81.7	90.1	94.7	90.4	78.0	77.7	81.4	79.4	78.9	79.8
Total	1,080	2,053	1,843	2,340	2,922	2,066	2,421	2,754	2,766	2,899

Endo, endovascular procedures; CEA, carotid endarterectomy; CAS, carotid artery stenting.

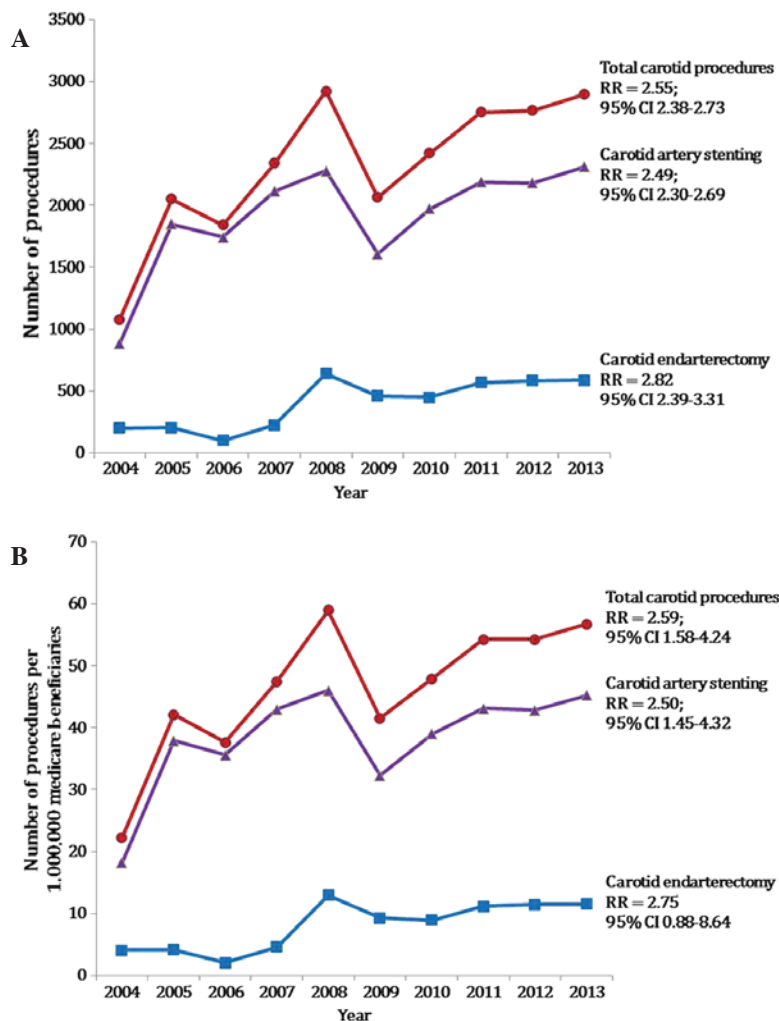


Figure 2. Trends in the total number of carotid procedures (carotid artery stenting and carotid endarterectomy) for carotid artery disease (A) between 2004 and 2013 and (B) per 1,000,000 Medicare Beneficiaries between the same time period. RR, risk ratio; CI, confidence interval.

A study conducted in the United Kingdom reported that the majority (96.2%) of carotid revascularizations involved CEA (10). By contrast, CEA is only performed in 5.3-22.3% of South Koreans. Thirdly, the overall rate of CEA procedures increased by 282% between 2004 and 2013, contrary to the declining trend in Western countries. Finally, the actual number of carotid revascularizations, including CEA and CAS procedures, was relatively low compared with Western countries.

Several factors may explain the increase in the number of carotid revascularization procedures in South Korea. The overall trend in carotid revascularization was similar to the alteration in CAS, as CAS was performed in 77.7-94.7% of cases. Another reason for the increment in the number of carotid revascularization procedures may be a result of the increased frequency of risk factors associated with carotid artery disease. Diabetes and chronic kidney disease, which result in the necessity for hemodialysis, are independent risk

factors for the development of carotid artery disease (12,13). Between 1970 and 2000, the prevalence of diabetes in Korea increased ~3-fold (14). A previous epidemiologic study reported that the incidence of diabetes in those between 70 and 79 years-of-age increased between 2009 and 2011 (15). The number of patients with end-stage renal disease in South Korea has been increasing rapidly, with an annual increase of ~12% between 2000 and 2009, according to registry data (16).

CAS was performed 3.5-17.8 times more frequently when compared with CEA procedures during the study period. In Western countries, CEA is performed more frequently than CAS (10). There are several reasons for the discordance in the use of the two procedures between South Korea and Western countries. The relatively late introduction of CEA to Korea is one such reason. In addition, CAS is less invasive, therefore a decrease in the threshold for CAS in the treatment of carotid artery disease likely represents a major contribution to the increase in the number of CAS procedures (17).

The actual number and population-based rates of carotid revascularization observed during the present study differed from those presented in the US study (9). In the US, the annual rate of all carotid revascularization procedures was demonstrated to be 483-737 per million adults per year (9); whereas the annual incidence of CEA was 418-710 procedures per million adults per year. Although the CAS procedure was less commonly performed, the annual rate was 26-65 procedures per million adults per year. However, in the present study, the annual rate of all carotid revascularizations was 22-59 procedures per million adults per year. Annual incidences of CEA and CAS were 2-13 and 18-46 procedures per million adults per year, respectively. The current study indicated that ~1/20 of revascularization procedures were performed in Korea compared with data from US Medicare beneficiaries.

The changes in the national trend were affected by the publication of randomized trials, including an increase in the utilization of the CAS procedure subsequent to the publication of trials favorable to CAS, and a decrease following the publication of trials indicating the superiority of the CEA procedure (18). Following the publication of CAS-favorable trials, including the Carotid and Vertebral Artery Transluminal Angioplasty Study (19), and Stenting and Angioplasty with Protection in Patients at High Risk for Endarterectomy (20) in 2004, an increase in the use of the CAS procedure was noted for 4 years. Publication of CEA-favorable trials, such as Endarterectomy versus Stenting in Patients with Symptomatic Severe Carotid Stenosis (21) and Stent-Supported Percutaneous Angioplasty of the Carotid Artery versus Endarterectomy (22), influenced the decrease in the utilization of the CAS procedure after 2 years. Since the publication of the CAS-favorable Carotid Revascularization Endarterectomy Versus Stenting Trial (23), the CAS procedure has been increasingly utilized.

Several limitations of the present study should be acknowledged. Foremost, this is a retrospective study based on data from HIRA. In addition, this study analyzed only the annual prevalence of the use of CEA and CAS procedures. The association between the utilization of each of the two procedures and major adverse events including mortality,

stroke and myocardial infarction after carotid revascularization has yet to be explored, and requires further elucidation. Finally, it is important to analyze patients with symptomatic and asymptomatic carotid artery disease; however, HIRA data does not account for this issue.

In conclusion, 23,142 Korean patients underwent carotid revascularization between 2004 and 2013. Total carotid revascularization increased by 255% during this period. This increase is predominantly due to the 249% increase in CAS procedures. In addition, contrary to the decreasing trend in the use of CEA procedures in Western countries, the number of CEA procedures increased in Korea over this time period. The actual number and population-based rates of carotid revascularization were considerably low compared with those of Western countries.

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