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Cost-Effectiveness of Carotid Endarterectomy versus Carotid Artery Stenting for Treatment of Carotid Artery Stenosis

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Background: Symptomatic or asymptomatic patients with significant carotid artery stenosis (range, 70% to 99%) generally undergo either carotid artery endarterectomy (CEA) or carotid artery stenting (CAS) to prevent stroke. In this study, we evaluated the cost effectiveness of these two treatment modalities. ***Methods:*** A total of 47 patients (mean age, 67.1±9.1 years; male, 87.2%) undergoing either CEA (n=28) or CAS (n=19) for the treatment of significant carotid artery stenosis were enrolled in this study. Hospitalization costs were subdivided into three parts, namely pre-procedure, procedure and resource, and post-procedure costs. ***Results:*** Total hospitalization costs were similar in both groups of CEA and CAS (6,377 thousand won [TW] vs. 6,703 TW, p=0.255); however, the total cost minus the pre-procedure cost was higher in the CAS group than in the CEA group (4,948 TW vs. 5,941 TW, $p<0.0001$). The pre-procedure cost of the CEA group was higher than that of the CAS group (1,429 TW vs. 762 TW, $p<0.0001$). However, the procedure and resource cost was higher in the CAS group because the resource cost was approximately three times higher in the CAS group than in the CEA group. The post-procedure cost was higher in the CEA group because hospital stays were approximately two times longer. ***Conclusion:*** The total hospitalization cost was not different between the CEA and the CAS groups. The pre-procedure cost was high in the CEA group, but the cost from procedure onset to discharge, including the resource cost, was significantly lower in this group.

Key words: 1. Carotid arteries
2. Endarterectomy
3. Stents

INTRODUCTION

Patients with significant carotid artery stenosis (range, 60% to 90%) suffer from rates of disabling or fatal ischemic stroke that are twice that of the general population [1]. Atherosclerosis and inflammatory buildup of atheromatous plaque are the most common causes of carotid artery stenosis. Carotid artery stenosis is diagnosed by color Doppler ultrasound, four-vessel angiography, and computed tomographic (CT) angiography. Since the introduction of carotid endarterectomy (CEA) for the treatment of carotid artery stenosis by Eastcott et al. [2] in 1954, it has been a major procedure for

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the treatment of symptomatic or significant asymptomatic carotid stenosis. A randomized controlled trial of endarterectomy for symptomatic carotid stenosis showed that the procedure significantly reduced the risk of stroke in patients with 70% stenosis or greater [3]. Recently, carotid artery stenting (CAS) has been recommended as an alternative method for the treatment of significant carotid artery stenosis because it is a less invasive approach and avoids major surgery. Studies have shown no differences between the two treatment methods in terms of post-procedure results, risk of subsequent stroke, and occurrence of myocardial infarction and death [4-6]. In addition to treatment efficacy, the cost-effectiveness of the carotid artery stenosis treatment is an important aspect that requires careful consideration. There have been previous reports demonstrating that hospital costs of CAS are higher than those of CEA [7-9]. In this study, we analyzed hospital costs and clinical outcomes of patients undergoing CAS or CEA at Cardiovascular Center in Chonbuk National University Hospital.

METHODS

A total of 47 patients (mean age, 67.1±9.1 years; male, 87.2%) undergoing CAS or CEA for significant carotid artery stenosis between January 2007 and May 2012 at Chonbuk National University Hospital were enrolled in this study. Patient data were retrospectively analyzed, and the study was approved by institutional review board of Chonbuk National University Hospital (IRB 2013-06-021-001). The severity of carotid artery stenosis was expressed as a percentage of luminal narrowing by the method of the North American Symptomatic Carotid Endarterectomy Trial [10]. Significant stenosis was defined as more than 70% luminal narrowing as assessed by a duplex ultrasound examination, carotid angiography, or CT angiography. A significant lesion seen on magnetic resonance imaging (MRI) was re-confirmed with four-vessel angiography or CT angiography. There were 28 patients (59.6%) and 19 patients (40.4%) who underwent CEA and CAS, respectively. Hospital costs were subdivided into three parts: pre-procedure, procedure (CAS or CEA) and resource, and post-procedure costs. The pre-procedure cost included all costs for radiologic studies and clinical laboratory examinations prior to the procedure. The procedure cost was the sum of costs for CEA or CAS, anesthesia during the CEA, and angiography during CAS. The resource cost included the cost of the prostheses (devices and catheters for CAS or vascular patch for CEA) and surgical materials (glue and shunt catheter for CEA). The post-care cost included medication and other general hospital costs (nursing, admission room fee, labor, etc.). The major periprocedural complications included stroke, death, and myocardial infarction within 30 days post-procedure. All costs are expressed in the unit of thousands of Korean won (TW).

1) Carotid endarterectomy

CEA was performed under general anesthesia with endotracheal intubation. A radial artery cannulation was used for monitoring blood pressure, and the operation was performed using a previously described technique [11]. The common, internal, and external carotid arteries were dissected, and the carotid body was injected with a 1.0% lidocaine solution to prevent hemodynamic instability. The activated coagulation time was maintained at greater than 250 seconds with systemic heparin 5,000 IU. During the CEA, an 8-French shunt (Pruitt-Inahara carotid shunt with T-port; LeMaitre Vascular Inc., Burlington, MA, USA) was routinely used in all patients. After the stenotic atheroma and thrombus were removed, the arterial lumen was cleaned with a heparin solution, leaving only the intact adventitial layer. The arteriotomy incision was augmented with a commercial bovine pericardial patch of 5-mm width (Vascu-Guard peripheral vascular patch; Synovis Life Technologies Inc., St. Paul, MN, USA) using three interrupted 6-0 polypropylene sutures for the heel and toe and continuous 6-0 polypropylene sutures for the remaining suture. The suture line was reinforced with the application of surgical glue. On postoperative day 1, 100 mg of oral aspirin and 75 mg of clopidogrel were started.

2) Carotid artery stenting

At least 48 hours before the procedures, 100 mg of aspirin and 75 mg of clopidogrel were prescribed and continued after the procedure. Under fluoroscopy, a 7-French sheath and JR4 catheter were used for approaching the carotid artery through the right femoral artery. After 80 IU/kg of systemic heparin

Table 1. Baseline characteristics

Characteristic	CEA group (n=28)	CAS group (n=19)	p-value
Age (yr)	65.8±10.7	68.9±5.6	0.260
Males	26 (92.9)	15 (78.9)	0.720
Symptomatic	20 (71.4)	6 (31.6)	0.007
Contralateral stenosis (＞70%)	6 (21.4)	4 (21.1)	0.970
Older than 75 years	6 (21.4)	3 (15.8)	0.204
Previous cerebral infarction	12 (42.9)	10 (52.6)	0.161

Values are presented as mean±standard deviation or number (%).
CEA, carotid endarterectomy; CAS, carotid artery stenting.

Table 2. Preoperative comorbidities in patients undergoing CEA and CAS

Comorbidity	CEA group	CAS group	p-value
Coronary artery disease	8 (28.6)	18 (94.7)	＜0.0001
Hypertension	18 (64.3)	14 (73.7)	0.498
Diabetes mellitus	6 (21.4)	7 (36.8)	0.246
Dyslipidemia	16 (57.1)	14 (73.7)	0.247
Chronic kidney disease	1 (3.5)	1 (5.3)	0.999
Atrial fibrillation	1 (3.5)	1 (5.3)	0.999
Hyperthyroidism	0	1 (5.3)	0.413
Hypothyroidism	1 (3.5)	0	0.999

Values are presented as number (%).
CEA, carotid endarterectomy; CAS, carotid artery stenting.

was injected, an aortogram was performed to identify the aortic arch, innominate artery, left common carotid artery, and left subclavian artery. After the diseased carotid artery was selected with a JR4 catheter, a stiffer wire (Terumo 0.889 mm) was inserted, and a shuttle sheath was advanced to the common carotid artery for the carotid arteriogram. The cerebral protection device (Filter-Wire; Boston Scientific Co., Boston, MA, USA or Angioguard; Cordis Co., Miami, FL, USA) was positioned using a 9.03224-mm wire, and pre-dilatation was performed with a 2- to 3-mm balloon. The stent was placed across the lesion and deployed, followed by the removal of the protection device as well as of all sheaths and wires. The femoral access site was closed with a closure device (Perclose ProGlide; Abbott Laboratories, Abbott Park, IL, USA).

3) Statistical methods

The statistical analysis was performed using PASW SPSS ver. 18.0 (SPSS Inc., Chicago, IL, USA). Continuous variables were expressed as mean±standard deviation and analyzed with a Student t-test. Categorical variables were expressed as numbers and percentages, and groups were compared with Fisher's exact test. A p-value less than 0.05 was considered statistically significant.

RESULTS

The mean ages of the patients in the CEA (n=28) and CAS (n=19) groups were 65.8±10.7 years and 68.9±5.6 years, respectively (p=0.260). Symptomatic patients were found more often in the CEA group (71% vs. 31.6%, p=0.007) (Table 1). In the CAS group, there were 18 patients (94.7%) with coronary artery disease. With the exception of coronary artery disease, there were no differences in comorbidities between the two groups (Table 2). In the CEA group, two patients were referred to a surgeon for CEA as CAS was found to be an inappropriate treatment for their condition. Additionally, one patient with bilateral carotid artery disease underwent CEA on the side opposite to a previously unsatisfactory unilateral CAS.

The pre-procedure cost was higher in the CEA group than in the CAS group (CEA vs. CAS, 1,429±504 vs. 762±342; p＜0.0001). The procedure cost was similar in the two groups (CEA vs. CAS, 1,404±153 vs. 1,245±426; p=0.134). However, the procedure and resource costs were higher in the CAS group than in the CEA group (CEA vs. CAS, 2,622±332 vs. 5,122±674; p＜0.0001) because the resource costs of the CAS were much higher than those of CEA (CEA vs. CAS 3,877±415 vs. 1,218±282; p＜0.0001). The post-procedure cost was higher after CEA than CAS (2,026±467 vs. 819±501; p＜0.0001). Consequently, the total hospital costs did not differ between the two groups (CEA vs. CAS, 6,377±910 vs. 6,703±1,008; p=0.255). However, the cost from procedure onset to discharge was lower in the CEA group than in the CAS group (4,948±687 vs. 5,941±935; p＜0.0001) (Table 3).

The hospital stay was longer in the CEA group than in the CAS group (9.4±3.0 days vs. 4.8±3.2 days; p＜0.001) (Table 3). Cerebral infarction due to embolism during or after the

Table 3. Comparison of the hospital costs between the CEA group and CAS group

Variable	CEA (n=28)	CAS (n=19)	p-value
Pre-procedure (TW)	1,429±504	762±342	<0.0001
Total procedure (TW)	2,622±332	5,122±674	<0.0001
Resource (TW)	1,218±282	3,877±415	<0.0001
Procedure (TW)	1,404±153	1,245±426	0.134
Post-procedure (TW)	2,026±467	819±501	<0.0001
Medication (TW)	681±203	254±376	<0.0001
Others (TW)	1,345±327	655±447	<0.0001
Procedure onset to discharge cost (TW)	4,948±687	5,941±935	<0.0001
Total hospital cost (TW)	6,377±910	6,703±1,008	0.255
Hospital stay (day)	9.4±3.0	4.8±3.2	<0.0001

Values are presented as mean±standard deviation.
CEA, carotid endarterectomy; CAS, carotid artery stenting; TW, thousand won.

procedures occurred in one CEA patient and in two CAS patients. Within the CAS group, one patient had an acute embolic infarction in the right medial cerebral artery territory, which occurred after a right-sided procedure and presented with transient left-sided motor weakness. The complication resolved within one month. The other CAS patient underwent a right-sided CAS and suffered a multifocal embolic infarction in the left fronto-parietal lobe and the left caudate and lentiform nuclei, which presented with a right hemiparesis (grade IV). The complication did not completely resolve, and the patient suffered generalized weakness and dizziness for more than two years. In the CEA group, one patient had marked hypoglossal nerve palsy immediately after surgery that completely resolved within one month. All patients survived both the CEA and CAS procedures.

DISCUSSION

This study showed no differences in hospital costs between the CEA and the CAS procedures. However, the cost from procedure onset to discharge was lower in the CAE group due to the higher cost of CAS devices. This finding is similar to the findings of most previous studies, which showed CAS to be 40% to 118% more expensive than CEA in terms of hospital costs [7,8,12]. In our study, the pre-procedure cost of CEA was approximately two times higher than that of CAS, which is the result of the extensive pre-procedural evaluation required. In the CEA group, coronary arteries, peripheral arteries, aorta, lungs, and abdominal organs (liver, gallbladder, etc.) as well as brain and cerebral arteries were sufficiently evaluated before surgery. On the other hand, the CAS group was mostly asymptomatic and diagnosed with carotid artery stenosis combined with coronary artery disease, and the extent of the preoperative evaluation of other organs, including the aorta, was limited. In the CEA group, carotid duplex ultrasound, CT carotid artery angiography, CT aortography, CT coronary angiography, and brain MRI and magnetic resonance angiography were routinely ordered preoperatively by neurologists and surgeons. However, in the CAS group, carotid duplex ultrasound was frequently the only preoperative diagnostic test performed by cardiologists. This difference in the pre-procedure evaluation in the two groups resulted in a significant difference in the pre-procedure cost. In patients with carotid artery stenosis, sufficient pre-procedure evaluations are required because it is necessary to evaluate for coexisting vascular diseases that may be present secondary to hypertension, diabetes, or dyslipidemia. In those undergoing CEA or CAS, hypertension and dyslipidemia were found in 80% to 85% of patients, and a previous diagnosis of coronary disease and diabetes was made in 20% to 30% [6]. As carotid artery stenosis is no longer considered to be a localized disease, the possibility of other vascular diseases coexisting with CAS has to be considered.

Another major source of the cost difference between CAS and CEA is the resource cost. Costly devices, such as sheaths, angiographic catheters, carotid artery stents, balloon devices, and embolism protect filters, are used during CAS, but only a bovine pericardial patch and a shunt catheter are used during CEA. Stents and embolic protection filters used for CAS are expensive and are a main cause of higher costs associated with CAS. Although the CAS was 40% more costly than the CEA, it did not provide better clinical outcomes or a reduction in the length of hospital stay in a previous study [13]. The procedure cost, which consisted of the operation and anesthesia fees in CEA and the angioplasty and stenting fees in CAS, was similar between the two groups (p=0.134). In our study, the hospital stay was two times longer for the CEA group than the CAS group. Not considering medication and nursing fees and room charges in the CEA group, expensive postoperative CT carotid angiography was performed to confirm carotid artery patency, which was not examined in the CAS group. Most CAS patients were admitted to the hospital primarily due to coronary artery disease, and carotid artery stenosis was diagnosed during a pre-procedural cardiac evaluation prior to coronary angiography. Additionally, patients in the CAS group were more frequently asymptomatic compared with those in the CEA group.

Periprocedural cerebral infarction occurred in three patients: two patients in the CAS group and one patient in the CEA group. This CEA patient had evidence of a focal cerebral infarction on brain CT scans and presented with a minor disturbance in tongue movement. In contrast, the above-mentioned two CAS patients suffered from more severe neurologic events. The next major complicating symptoms—dysphagia, tinnitus, and hearing impairment—were observed in one CEA patient who had a traction injury of the right hypoglossal nerve, which disappeared within one month.

There were no other major complications, such as death or myocardial infarction, in the two groups. Such perioperative complications become causative factors of higher hospital costs. The small number of patients in this study showed no statistical differences in clinical outcomes of the two treatment methods. However, some patients were inappropriate candidates for CAS and were referred to a surgeon for CEA. The CEA procedure was still safer than the CAS even though CAS devices have been improved to prevent embolism. Recently, the incidence of periprocedural ipsilateral stoke has been found to be more in the case of CAS than in the case of CEA (4.1% vs. 2.3%) [6], and the two procedures have been considered beneficial for the treatment of coronary artery stenosis and the risk of these procedures have been overcome [14]. In this study, we obtained satisfactory clinical results after CEA and CAS with similar cost-effectiveness.

In conclusion, the total hospitalization costs were not different between the CAS and the CEA groups. The pre-procedure cost was higher in the CEA group due to more extensive pre-procedure evaluations. However, the cost from procedure onset to discharge was lower in the CEA group than in the CAS group because resource costs were much higher in the CAS group. More severe periprocedural embolic strokes occurred in the CAS group, and some patients who were poor candidates for CAS were referred to a surgeon for CEA. We conclude that CEA is a safer procedure than CAS, but with a similar cost-effectiveness to CAS.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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