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Selective Carotid Shunting Based on Intraoperative Transcranial Doppler Imaging during Carotid Endarterectomy: A Retrospective Single-Center Review

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Background: Carotid endarterectomy (CEA) with selective shunting is the surgical method currently used to treat patients with carotid artery disease. We evaluated the incidence of major postoperative complications in patients who underwent CEA with selective shunting under transcranial Doppler (TCD) at our institution. ***Methods:*** The records of 45 patients who underwent CEA with TCD-based selective shunting under general anesthesia from November 2009 to June 2015 were reviewed. The risk factors for postoperative complications were analyzed using univariate and multivariate analysis. ***Results:*** Preoperative atrial fibrillation was observed in three patients. Plaque ulceration was detected in 10 patients (22.2%) by preoperative computed tomography imaging. High-level stenosis was observed in 16 patients (35.5%), and 18 patients had contralateral stenosis. Twenty patients (44.4%) required shunt placement due to reduced TCD flow or a poor temporal window. The 30-day mortality rate was 2.2%. No cases of major stroke were observed in the 30 days after surgery, but four cases of minor stroke were noted. Univariate analysis showed that preoperative atrial fibrillation (odds ratio [OR], 40; p=0.018) and ex-smoker status (OR, 17.5; p=0.021) were statistically significant risk factors for a minor stroke in the 30-day postoperative period. Analogously, multivariate analysis also found that atrial fibrillation ($p<0.001$) and ex-smoker status (p=0.002) were significant risk factors for a minor stroke in the 30-day postoperative period. No variables were identified as risk factors for 30-day major stroke or death. No wound complications were found, although one (2.2%) of the patients suffered from a hypoglossal nerve injury. ***Conclusion:*** TCD-based CEA is a safe and reliable method to treat patients with carotid artery disease. Preoperative atrial fibrillation and ex-smoker status were found to increase the postoperative risk of a small embolism leading to a minor neurologic deficit.

Key words: 1. Carotid endarterectomy
2. Transcranial Doppler ultrasonography
3. Selective shunt

INTRODUCTION

Carotid endarterectomy (CEA) is a surgical procedure performed in patients with carotid artery disease. This procedure can prevent stroke, which is the second most common cause of death worldwide. Indeed, CEA is now the most widely used surgical procedure performed on the peripheral vessels in the United States. The indications for CEA have been well summarized by Rothwell et al. [1], and in 2004, the Food and Drug Administration approved a stenting procedure for

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severe carotid artery stenosis in symptomatic high-risk patients. However, debates continue regarding patient eligibility, surgical technique, and the recommended method of anesthesia, as discussed in the 2008 General Anesthesia versus Local Anesthesia for Carotid Surgery (GALA) trial [2].

Although CEA is performed to prevent stroke, it can have adverse outcomes, including stroke, myocardial infarction, or even death. The most controversial issue associated with CEA in terms of shunting to provide cerebral protection. Routine shunting, non-shunting, and selective shunting have all been discussed for decades, but the best method for cerebral protection during CEA has not yet been established. The methods of cerebral monitoring that are used for selective shunting have also been the subject of intense discussion. Transcranial Doppler (TCD), cerebral oximetry (CO), electroencephalography (EEG), somatosensory evoke potential (SSEP), and stump pressure (SP) have all been used for cerebral monitoring, but TCD and CO are currently the most widely used techniques. Since 2009, our team has performed CEA with selective shunting using TCD. The aim of the present study was to analyze our results in terms of the postoperative 30-day stroke rate, the 30-day mortality rate, and the incidence of other side effects. Furthermore, we aimed to identify the factors related to the risk of 30-day stroke and mortality after CEA.

METHODS

A total of 50 patients who underwent CEA between November 2009 and March 2015 were enrolled in this retrospective review study. Clinical information was obtained from the subjects' medical records at the Daegu Catholic Medical Center, Daegu City, Korea. Of these 50 patients, fiver were excluded: three underwent concomitant cardiac surgery (coronary artery bypass surgery in two patients and mitral valve replacement using the maze procedure in one) and two were administered regional anesthesia. Therefore, a total of 45 patients were ultimately enrolled in the study. TCD was employed for intraoperative neurological monitoring, and shunting was selectively used in cases with a poor temporal window or a mean flow velocity in the middle cerebral artery that had decreased to 30% of the baseline value, as measured with TCD. All procedures were performed by a single cardiovascular surgeon. The potential variables that could influence the clinical outcomes of 30-day stroke and mortality were sex, age, hypertension, diabetes mellitus (DM), the presence of symptoms, hyperlipidemia, coronary artery disease, current or previous smoking status, current or previous alcohol consumption, ulcerative lesions on the carotid artery, contralateral lesions, high-level lesions (stenosis above the second cervical vertebra), atrial fibrillation, duration of the procedure, use of a shunt, and the side on which the procedure was performed.

For TCD monitoring, the Doppler-box was used (DWL, Sipplingen, Germany) and monitored by a neurologist and a sonographer for the duration of the procedure. Patients were administered daily antiplatelet agents until the day of the procedure, which were restarted on the first day after the surgery. Brain diffusion magnetic resonance imaging (MRI) was performed on all patients postoperatively.

1) Surgical procedure

Under general anesthesia in the supine position, the patient's head was hyperextended and rotated to the contralateral side. A 6-cm skin incision was made along the medial border of the sternocleidomastoid muscle. The platysma and underlying soft tissue were dissected using electrocauterization. The facial venous plexus was ligated and separated to increase exposure and the carotid sheath was identified and opened. The superior thyroid artery was then identified and controlled with a vessel loop. The external carotid artery (ECA), internal carotid artery (ICA), and common carotid artery (CCA) were mobilized and controlled using vessel loops. Sequential clamping was applied using a standard method, and middle cerebral arterial flow was preserved via collateral flow from the circle of Willis as confirmed by TCD. On the basis of the TCD findings, a shunt (Pruitt-Inahara; LeMaitre Vascular Inc., Burlington, MA, USA) was used in cases with a 70% or greater reduction in middle cerebral artery (MCA) flow or in cases where only a poor temporal view was available. A linear arteriotomy was performed extending from the CCA to the ICA. If a shunt was needed, a distal shunt was inserted into the ICA followed by a proximal shunt in the CCA. The balloon was then inflated by re-

Table 1. Demographics and risk factors in the 45 patients included in this study

Demographics and risk factors	No. of patients (%)
Sex	
Male	35 (77.8)
Female	10 (22.2)
Mean age (yr)	70 (range, 48–86)
Preoperative neurologic symptoms	42 (93.3)
Hypertension	29 (64.4)
Diabetes mellitus	15 (33.3)
Hyperlipidemia	20 (44.4)
Coronary artery disease	20 (44.4)
Current smoker	7 (15.6)
Ex-smoker	9 (20.0)
Current alcohol user	8 (17.8)
Ex-alcohol user	3 (6.6)
Ulceration on carotid artery	10 (22.2)
Contralateral lesion	18 (40.0)
High-level stenosis	16 (35.6)
Preoperative atrial fibrillation	3 (6.6)

moving the clamps at the ICA and CCA. The subintimal plane was raised and passed with a dissector, and a clean cut made at the proximal lesion with a scalpel in order to gently peel away the plaque at the upper lesion, after which the remainder of the denuded lesion was smoothed down. Once the shunt was applied, the balloon was deflated, and distal and proximal shunts removed by reapplying the clamp. A bovine pericardial patch (Vascu-Guard; Synovis, St. Paul, MN, USA) was used for arteriotomy closure. Before securing the suture, sequential declamping, with the ICA declamped 10 seconds after declamping the ECA and CCA, was performed in order to flush out atheromatous debris. Each layer of the wound was closed, and a drain was placed.

2) Statistical methods

The aim of this study was to identify risk factors that could contribute to poor postoperative results. Variables were analyzed using IBM SPSS ver. 21.0 (IBM Co., Armonk, NY, USA). Univariate analysis was performed using Pearson's chi-square test or Fisher's exact test, and multivariate analysis was performed using multivariate logistic regression to identify risk factors associated with 30-day stroke and mortality. All p-values <0.05 were considered to indicate statistical significance.

Table 2. Postoperative complications within 30 days after surgery

Complications	No. of patients (%)
Death	1 (2.2)
Neurologic complication	
Major stroke	0
Minor stroke	4 (8.9)
Hypoglossal injury	1 (2.2)
Non-neurologic complications	2 (4.4)
Myocardial infarction	0
Wound-related complications	0

RESULTS

The mean age of the patients in this study was 70 years (range, 48–86 years), and 30 patients were men. The operative duration ranged from 94 minutes to 327 minutes, with a mean duration of 166.89 minutes. Plaque ulceration was detected in 10 patients (22.2%) by preoperative computed tomography imaging. High-level stenosis, defined as stenosis above the second cervical spinal vertebra, was observed in 16 patients (35.5%), while contralateral stenosis was observed in 18 patients. Twenty patients (44.4%) required shunt placement due to reduced TCD flow or a poor temporal window. The patient characteristics are presented in Table 1.

One death occurred within 30 days of surgery, in a 66 year-old female patient with DM who had undergone coronary artery bypass surgery one year prior to CEA. The patient died from fulminant acute respiratory distress syndrome on the sixth postoperative day. The 30-day major stroke rate was 0%, although four patients (8.9%) were diagnosed with minor stroke with either no symptoms and only radiologic confirmation or mild neurological symptoms. All patients recovered soon after onset, within the 30-day postoperative period. Patients with no symptoms and only radiologic findings showed small embolic infarctions that were confirmed by brain MRI. None of the patients with minor strokes experienced permanent sequelae. Twenty patients (44.4%) underwent shunting, of whom 14 (31.1%) had poor temporal view. Hypoglossal nerve injury was found in one patient (2.2%) who exhibited tongue deviation after surgery. The postoperative complications are presented in Table 2.

No specific variables were identified as risk factors for 30-day major stroke or mortality. However, univariate analysis found ex-smoker status (odds ratio, [OR], 17.5; p=0.021) and preoperative atrial fibrillation (OR, 40; p=0.018) to be risk factors for the incidence of a minor stroke within 30 days after the procedure. Of the four patients who experienced minor strokes, two were ex-smokers, one had atrial fibrillation, and one fulfilled both criteria. Multivariate logistic regression confirmed these results, finding that atrial fibrillation ($p<0.001$) and ex-smoker status (p=0.002) were independent risk factors for the incidence of a minor stroke within 30 days of the operation.

A bovine pericardial patch was used for arterial closure and a Jackson-Pratt drain was used for all patients. No wound-related complications, such as wound dehiscence, postoperative bleeding, or hematoma, were encountered. All surgical procedures were successfully conducted without restenosis.

DISCUSSION

Many considerations must be kept in mind when performing CEA, including the anesthesia method, the use of a shunt, and the method of cerebral monitoring. Before publication of the GALA trial, the recommended method of anesthesia was a particularly controversial topic. However, as it is now clear that no one method is superior to another, surgeons may use the method of their choice for anesthesia during CEA. The most reliable method for determining whether shunting is necessary after cross-clamping is neurological examination under local or regional anesthesia in conscious patients [3,4]. When CEA was first performed in our center, we chose to apply local anesthesia based on its reliability for neurological monitoring. However, after completing several operations, this strategy was reconsidered, due to the prolonged induction time associated with local anesthesia, experiences with the failure of local anesthesia, and poor patient cooperation during surgery. The GALA study found that approximately 3.9% of patients under local anesthesia must be switched over to general anesthesia during CEA [2]. In addition, the neurological examination of conscious patients is not always reliable as the onset of a deficit secondary to cerebral hypoperfusion may be delayed [4].

The effect of CEA on reducing the risk of stroke has been well established, however, it can paradoxically precipitate stroke in 1%–24% of cases, depending on the center and surgical indications [5]. Stroke caused by CEA results from hemodynamic factors and thromboembolism. Ackerstaff et al. [5] found that transient embolism occurred during dissection in 25% of all endarterectomies. Steed et al. [6] found that intraoperative neurological deficits were most often associated with carotid artery dissection or clamp release (83%) and only rarely with cross-clamping (17%). Shunting is also a cause of embolism, and the risk of carotid artery dissection or embolism during shunting has been reported to be between 1% and 3% [7].

While strategies for reducing the risk of stroke have been investigated, a consensus regarding shunting and cerebral monitoring during CEA has not yet been reached. Concerns have been expressed regarding unwarranted routine shunting, including its unnecessary use in approximately 85% of patients [8]. Bennett et al. [9] reported that intraoperative shunting during CEA had no clinical benefit, even in patients who may be at high risk for intraoperative cerebral hypoperfusion due to severe stenosis or occlusion of the contralateral carotid artery.

Recently, a trend has emerged in which selective shunting is supported by several kinds of cerebral monitoring. The advantages and disadvantages of various cerebral monitoring methods have been described by several researchers.

EEG is a valuable tool for the detection of ischemia in the cortex, although it is limited in that it is difficult to identify ischemia in the subcortical region using EEG. In addition, it shows a high false positive rate and low sensitivity in patients who have experienced a recent stroke or exhibit active neurological deficits [7,10,11]. Under general anesthesia, a lag may exist between cerebral ischemia and the emergence of recognizable EEG findings, due to variation in how neuronal damage and resultant patterns of cerebral blood flow are reflected in EEG [10]. SSEP is neither sensitive nor specific, but it can be helpful in cases of with a history of stroke in which EEG is of limited utility [7,11]. Bispectral index monitoring correlates poorly with the clinical signs of cerebral ischemia. SP is specific and has a low false positive rate, but has low sensitivity and a high false negative rate. Near-infrared spectroscopy (NIRS) was, until recently, widely used, with benefits including ease of use, simple interpretation of results, low cost, the non-invasiveness of the technique, portability, and high negative predictive value; however, it has a low specificity and positive predictive value [7]. In addition, NIRS is not suitable for the detection of variations in middle cerebral arterial flow, as the sensor must be placed over the frontal lobe and thus may be affected by blood flow in the extracranial tissue, as well as by ambient light. General anesthesia also affects regional cerebral oxygenation [11]. Whiten and Gunning [7] suggested using jugular venous bulb oxygen saturation, which has a low specificity and positive predictive value, as well as early stage xenon-133, which is expensive and not specific.

TCD is a technique widely used by vascular surgeons, and was first described by Aaslid in 1982 [12]. Although the need for a skilled sonographer and poor temporal views in certain patients do present challenges, it continues to be the most widely used technique for monitoring cerebral perfusion. Several studies have analyzed the efficacy of TCD as a tool for cerebral monitoring in selective shunting. While Spencer et al. [13] found that TCD was superior to SP as an indicator for the use of shunting, recent studies have suggested it may not be superior to other monitoring techniques [3,4,7,12]. TCD showed minimal benefits in that only severe ischemia could be detected at clamping, and the use of TCD was not found to improve the decision-making process for shunt use during CEA. Ali et al. [4] reported that TCD was less accurate than CO in predicting the need for carotid shunting during CEA. However, TCD has been found to be the optimal monitoring option for the detection of emboli. TCD can detect solid emboli, as first reported by Spencer et al. [13] in 1990. No other monitoring technique can identify microemboli during CEA in real time. In this context, acoustic feedback provides good results in reducing microemboli through delicate handling of the carotid artery during dissection, shunting, and clamp release. Reducing microemboli during carotid surgery is important for preventing postoperative neurological complications. The relationship between microemboli and perioperative cerebral complications was studied by Ackerstaff et al. [5]. During CEA, the presence of a microembolism (>10 microemboli) during dissection showed a statistically significant relationship with perioperative cerebral complications and new ischemic lesions on MRI scans of the brain. Moreover, the presence of a microembolism during shunting is known to be related to intraoperative complications [5].

In a recent study, we used a shunt when MCA flow decreased to a level lower than 30% of the baseline value. No definitive cut-off value exists for deciding on shunting under TCD monitoring, although several articles have proposed cut-off values for MCA flow. Moriz et al. [3] compared the accuracy of TCD, NIRS, SP, and SSEP in the detection of cerebral ischemia after clamping, finding that the use of a 50% reduction in MCA velocity as a cut-off provided 100% sensitivity and 86% specificity in detecting cerebral ischemia. Ali et al. [4] further showed that a greater than 50% reduction in MCA flow provided 75% sensitivity, 75.5% specificity, a 37.5% positive predictive value, and a 93.9% negative predictive value for the detection of cerebral ischemia. Cao et al. [12] found that a the use of a 70% or greater reduction in MCA flow as a cut-off provided 83% sensitivity, 96% specificity, a 71% positive predictive value, and a 98% negative predictive value. As stated earlier, the cut-off values for MCA flow reduction vary by both center and surgeon. A 70% reduction in MCA flow was the criterion adopted in this study, with a level of accuracy that corresponds to the standards reported in the literature.

Rothwell et al. [1] analyzed pooled data from the North American Symptomatic Carotid Endarterectomy Trial (NASCET), the European Carotid Surgery Trial, and the Veteran's Administration Trial. In that study, the 30-day mortality rate and combined 30-day stroke and mortality rate for 3,248 patients who had undergone CEA were found to be 1.1% and 14.2%, respectively. Vaniyapong et al. [14] analyzed the data of 17,703 patients from the Cochrane Collaboration meta-analysis of the use of regional versus general anesthesia for CEA and reported the 30-day stroke rate to be 4.5% and the 30-day mortality rate to be 1.1%. In addition, the postoperative myocardial infarction rate was found to be 2.2%. In the GALA trial, the 30-day stroke rate was reported to be 4.8% under general anesthesia and 4.5% under local anesthesia [2]. Aburahma et al. [8] reviewed 2,254 CEA patients who underwent TCD monitoring on the basis of a PubMed/MEDLINE and Cochrane Database literature search and found that the mean reported perioperative stroke rate for selective shunting using TCD was 4.8%. A subsequent study used the 2012 CEA-targeted American College of Surgeons National Surgical Quality Improvement Program database and found that the overall incidence of combined 30-day stroke or mortality in 3,845 patients was 3.0%, while the overall 30-day incidence for non-stroke-related major morbidities was 5.3% [15]. Reported combined 30-day stroke and mortality rates of 5.2% and 1.8% in 291 and 3,092 CEA patients, respectively [15]. In our present study, the 30-day mortality rate was 2.2%, which corresponds to the results of previously published studies. The present study demonstrated excellent results regarding the incidence of stroke, as no patients showed any major neurological complications and only four minor strokes were reported as sequelae of the procedure. The high rate of poor temporal view (31%) leading to shunting could have led to embolic infarction resulting in a minor stroke.

Both univariate and multivariate analysis showed that atrial fibrillation ($p<0.001$) and ex-smoker status ($p=0.002$) were variables that significantly affected the 30-day incidence of minor strokes. Several recent studies have reported findings in accordance with these conclusions. Jack et al. [16] found that the variables influencing 30-day stroke and mortality incidence included a history of transient ischemic attack or stroke, atrial fibrillation, contralateral carotid occlusion, congestive heart failure, and DM. Hannan et al. [17] analyzed 3,644 CEA patients and found an in-hospital postoperative stroke or mortality rate of 1.84%. Univariate analysis identified hypertension, cardiac valve disease, DM, preoperative atrial fibrillation, symptomatic carotid disease, contralateral carotid occlusion, and degree of ICA stenosis as significant predictors of stroke or mortality [17]. A 2010 study by Harthun and Stukenborg [18] analyzed 20,022 CEA patients and reported remarkably low stroke (0.94%) and mortality (0.29%) rates. Atrial fibrillation was found to be a significant and strong predictor of perioperative stroke and mortality rates (OR, 2.45; $p<0.0001$).

Cranial nerve injuries have been reported in approximately 7% of patients, with less than 1% of patients experiencing permanent injuries [1]. Ballotta et al. [19] reported cranial nerve deficits in 25 of 200 patients who underwent CEA. The NASCET found the incidence of injuries to the facial, vagus, and hypoglossal nerves was 2.2%, 3.5%, and 3.7%, respectively [20]. Our results regarding nerve injuries were consistent with those data, with a postoperative hypoglossal nerve injury reported in one patient (2.2%). In order to reduce the incidence of hypoglossal nerve injuries, extreme caution during digastric muscle dissection is necessary. A relatively high incidence of nerve injuries was observed in the GALA trial [2]. Cranial nerve injury occurred in 10.5% and 12% of patients under general and local anesthesia, respectively. Surprisingly, in the present study, no postoperative wound complications were observed. We routinely performed conventional endarterectomy and repaired the wounds with a bovine patch, while a Jackson-Pratt drain was placed to prevent wound hematoma. In the GALA trial [2], the postoperative wound complications occured in 8.3% of the patients who underwent general anesthesia and 8.5% of the patients who underwent local anesthesia. The surgical technique used in the present study may be recommended in terms of postoperative wound complication.

Due to the poor temporal window, we considered including all patients with shunting in this study. However, a poor temporal window was unavoidable under TCD-based CEA in 10%–20% of the patients [5,10,11]. All CEA patients who met the inclusion criteria and underwent TCD were ultimately enrolled in this study. The results of the present study correspond to the expected outcomes based on the results of previous studies. Unfortunately, the retrospective nature of this study and the small sample size are unavoidable limitations. We have recently begun to implement an additional monitoring system (CO) during CEA, and more reliable studies assessing this technique should be conducted in the near future.

CONFLICT OF INTEREST

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

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REFERENCES

1. Rothwell PM, Eliasziw M, Gutnikov SA, et al. *Analysis of pooled data from the randomised controlled trials of endarterectomy for symptomatic carotid stenosis*. Lancet 2003;361: 107-16.
2. GALA Trial Collaborative Group, Lewis SC, Warlow CP, et al. *General anaesthesia versus local anaesthesia for carotid surgery (GALA): a multicentre, randomised controlled trial.* Lancet 2008;372:2132-42.
3. Moritz S, Kasprzak P, Arlt M, Taeger K, Metz C. *Accuracy of cerebral monitoring in detecting cerebral ischemia during carotid endarterectomy: a comparison of transcranial Doppler sonography, near-infrared spectroscopy, stump pressure, and somatosensory evoked potentials*. Anesthesiology 2007;107: 563-9.
4. Ali AM, Green D, Zayed H, Halawa M, El-Sakka K, Rashid HI. *Cerebral monitoring in patients undergoing carotid endarterectomy using a triple assessment technique*. Interact Cardiovasc Thorac Surg 2011;12:454-7.
5. Ackerstaff RG, Jansen C, Moll FL, Vermeulen FE, Hamerlijnck RP, Mauser HW. *The significance of microemboli detection by means of transcranial Doppler ultrasonography monitoring in carotid endarterectomy*. J Vasc Surg 1995;21: 963-9.
6. Steed DL, Peitzman AB, Grundy BL, Webster MW. *Causes of stroke in carotid endarterectomy*. Surgery 1982;92:634-41.
7. Whiten C, Gunning P. *Carotid endarterectomy: intraoperative monitoring of cerebral perfusion*. Curr Anaesth Crit Care 2009;20:42-5.
8. Aburahma AF, Mousa AY, Stone PA. *Shunting during carotid endarterectomy*. J Vasc Surg 2011;54:1502-10.
9. Bennett KM, Scarborough JE, Cox MW, Shortell CK. *The impact of intraoperative shunting on early neurologic outcomes after carotid endarterectomy*. J Vasc Surg 2015;61:96-102.
10. Ackerstaff RG, van de Vlasakker CJ. *Monitoring of brain function during carotid endarterectomy: an analysis of contemporary methods*. J Cardiothorac Vasc Anesth 1998;12: 341-7.
11. Howell SJ. *Carotid endarterectomy*. Br J Anaesth 2007;99: 119-31.
12. Cao P, Giordano G, Zannetti S, et al. *Transcranial Doppler monitoring during carotid endarterectomy: is it appropriate for selecting patients in need of a shunt?* J Vasc Surg 1997; 26:973-9.
13. Spencer MP, Thomas GI, Moehring MA. *Relation between middle cerebral artery blood flow velocity and stump pressure during carotid endarterectomy*. Stroke 1992;23:1439-45.
14. Vaniyapong T, Chongruksut W, Rerkasem K. *Local versus general anaesthesia for carotid endarterectomy*. Cochrane Database Syst Rev 2013;12:CD000126.
15. Bennett KM, Scarborough JE, Shortell CK. *Predictors of 30-day postoperative stroke or death after carotid endarterectomy using the 2012 carotid endarterectomy-targeted American College of Surgeons National Surgical Quality Improvement Program database*. J Vasc Surg 2015;61:103-11.
16. Jack CI, Lee T, Moyle P, Hughes M, Vinjamuri S. *The importance of posture in the early stages of stroke: its influence on cerebral perfusion*. Age Ageing 2001;30:428.
17. Hannan EL, Popp AJ, Feustel P, et al. *Association of surgical specialty and processes of care with patient outcomes for carotid endarterectomy*. Stroke 2001;32:2890-7.
18. Harthun NL, Stukenborg GJ. *Atrial fibrillation is associated with increased risk of perioperative stroke and death from carotid endarterectomy*. J Vasc Surg 2010;51:330-6.
19. Ballotta E, Da Giau G, Renon L, et al. *Cranial and cervical nerve injuries after carotid endarterectomy: a prospective study*. Surgery 1999;125:85-91.
20. Ferguson GG, Eliasziw M, Barr HW, et al. *The North American Symptomatic Carotid Endarterectomy Trial: surgical results in 1415 patients*. Stroke 1999;30:1751-8.