High Mini-Skin Incision during Carotid Endarterectomy for Carotid Stenosis

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Background: Carotid endarterectomy (CEA) is used to treat carotid stenosis, which is associated with cerebral infarction and may result in neurologic deficits such as stroke, transient ischemic attack (TIA), and local nerve injury. To decrease surgery-related complications and improve patient satisfaction with esthetic outcomes, efforts have been made to minimize incision size instead of using a standard longitudinal incision.

Methods: We performed a retrospective analysis of 151 cases of CEA, of which 110 used conventional incisions and 41 used high mini-skin incisions (HMIs), from March 2015 to December 2021 at a single institution. Short-term (30-day) postoperative results were evaluated for rates of mortality, stroke, TIA, and cranial/cervical nerve injuries. Risk factors for nerve injury were also assessed.

Results: The HMI group showed significantly (p<0.01) shorter operative and clamp times than the conventional group. The HMI group also had significantly shorter incision lengths (5.3±0.9 cm) than the conventional group (11.5±2.8 cm). The rates of stroke, TIA, and death at 30 days were not significantly different between the 2 groups. There was no significant difference in the rate of cranial and cervical nerve injuries, and all injuries were transient. A high lesion level (odds ratio [OR], 9.56; 95% confidence interval [CI], 3.21–28.42; p<0.01) and the clamp time (OR, 1.07; 95% CI, 1.03–1.12; p<0.01) were found to be risk factors for nerve injuries.

Conclusion: Use of the HMI in CEA for carotid stenosis was advantageous for its shorter operative time, shorter internal carotid artery clamp time, reduced neurologic complications, and improved esthetics.

Keywords: Carotid endarterectomy, Mini-skin incision, Cranial and cervical nerve, Carotid stenosis

Introduction

Carotid endarterectomy (CEA) is a treatment option for carotid stenosis; however, the procedure is associated with neurologic complications such as stroke and local neurologic deficits. The conventional incision in CEA is approximately 10–15 cm along the anterior border of the sternocleidomastoid muscle (SCM) [1,2]. Some studies have suggested that larger incisions result in higher rates of cranial and cervical nerve (CCN) injuries involving the hypoglossal, vagus, transverse cervical, great auricular, and facial (mandibular branches) nerves [3].

Minimally invasive surgery techniques have been investigated to minimize trauma, complications, and hospital stays, and to improve esthetic results. The standard incision for CEA is long enough to visualize the anatomy surrounding the carotid vessels, whereas a mini-skin incision has a narrower view of the neck anatomy, making it more difficult to target the carotid stenosis lesion in general. Several studies have explored various surgical techniques (longitudinal versus transverse mini-skin incisions) and different approaches (ante-jugular versus retro-jugular) for CEA to reduce neurologic complications and wound size.

This study aimed to evaluate whether high vertical mini-incision provided operative advantages and positive early postoperative outcomes by focusing on CCN injuries, operative times, and esthetic satisfaction. This study compared the high-level mini-skin incision (HMI) to the con-
ventional incision and analyzed the effects of using the HMI on CCN injury and CEA prognosis. Univariate and multivariate analyses were conducted to identify the possible risk factors for CCN injury.

**Methods**

**Patients**

This retrospective study included 151 consecutive patients from March 2015 to December 2021 at Daegu Catholic University Medical Center in South Korea with follow-up until December 2021. Ten patients who underwent bilateral surgery or had undergone CEA surgery twice were excluded from this study. We performed conventional CEA in both incision groups using cerebral oximetry to monitor cerebral perfusion during surgery. Among the 151 CEA cases, 110 (72.8%) and 41 (27.2%) procedures were performed with conventional incisions (conventional group) and HMIs (HMI group; 5-cm incision), respectively. This study was approved by the Institutional Review Board of Daegu Catholic University Medical Center (IRB no., CR-21-084-L); the requirement for obtaining individual informed consent was waived.

Data were obtained on patient characteristics including age, sex, the severity of the lesion, underlying diseases (i.e., hypertension, diabetes mellitus, and hyperlipidemia), and high level of lesion (i.e., above the second cervical-spine vertebra [C2] or at the angle of the mandible). Stroke was diagnosed using magnetic resonance imaging (MRI), while internal carotid artery (ICA) stenosis was diagnosed with carotid duplex ultrasonography (DUS) or computed tomography angiography (CTA). The degree of stenosis was evaluated by ultrasound with velocity criteria or by CTA, based on the North American Symptomatic Carotid Endarterectomy Trial Criteria [4]. In general, moderate and severe ICA lesions indicated stenosis >50% and 70%, respectively. Based on several studies and guidelines [4], our center set the following indications for CEA: carotid artery stenosis >50% for symptomatic patients and >80% for asymptomatic patients [1]. All CEA procedures in symptomatic patients were performed during the subacute phase (i.e., a week after the cerebral infarction occurred) [5].

**Surgical procedures and techniques**

All the procedures were performed under general anesthesia with endotracheal intubation with the patient positioned in neck extension and head rotation to the opposite side. Conventional incisions were approximately 10–15 cm along the anterior border of the SCM in the range between 1 cm below the mastoid and clavicle joint [1,2]. In the conventional group, incision length was within the study range and determined by operator preference based on the location of the carotid bifurcation. In the HMI group, however, the incisions were started 1.5 cm below the mastoid and measured approximately 5 cm longitudinally; otherwise, they were performed in the same manner (Fig. 1). All incisions in both groups were done without ultrasonographic mapping. Using an ante-jugular approach for carotid dissection, 5,000 IU of heparin was administered intravenously before clamping the carotid arteries. We sequentially clamped the internal, external, and common carotid arteries. The regional oxygen saturation (rSO2) was monitored to assess the cerebral collateral circulation using cerebral oximetry; when the rSO2 dropped below 80% of the baseline value, an intraluminal shunt catheter was inserted for cerebral protection.

**Postoperative management and follow-up**

Blood pressure was maintained below 150 mm Hg of systolic pressure during the postoperative period, and antiplatelet therapy was prescribed on the first postoperative day. After discharge, patients were followed up at 1 month, 3 months, 6 months, and then annually; DUS or CTA was performed annually to evaluate the carotid vessels. Stroke, transient ischemic attack (TIA), death, and local neurological deficits within 30 postoperative days were considered early postoperative outcomes. TIA was defined as a lesion that fully resolved within 24 hours or an incidental asymptomatic finding on MRI. Local neurologic injuries involved several CCNs. Hypoglossal nerve injury was determined by the patient’s inability to stretch the tongue straight, instead tilting it to the operative side and showing tongue deviation or incoordination. Injury to the facial nerve and its mandibular branches was associated with the inability to retract the corner of the mouth on the side of surgery. Injury to the vagus nerve and its branches caused vocal cord palsy, resulting in hoarseness. Numbness of the neck on the operative side could be seen if the transverse cervical nerve was injured. CCN injuries were separated into subgroups (permanent and transient) based on the duration of symptoms over 12 months.

**Statistical analysis**

Continuous variables were analyzed via the t-test and re-
ported as mean±standard deviation, whereas categorical variables were analyzed using the chi-square test and reported as frequency (percentage). The risk factors for CCN injuries were analyzed via logistic regression analysis. Variables with p-values <0.05 in the univariate analysis were included in the multivariate analysis, along with the incision method, to assess whether the HMI technique affected the risk of nerve injury. IBM SPSS ver. 25.0 (IBM Corp., Armonk, NY, USA) was used for statistical analyses.

**Results**

A total of 151 patients were included in this study, with a mean age of 70.4±7.0 years and 72.1±7.4 years in the conventional and HMI groups, respectively. Most patients were men: 89 (80.9%) in the conventional group and 38 (92.7%) in the HMI group. Severe lesions (stenosis >70%) were found in 94 (85.5%) and 39 (95.1%) patients in the conventional and HMI groups, respectively. Furthermore, 25 patients (22.7%) in the conventional group and 9 patients (22.0%) in the HMI group were categorized as high-level (i.e., lesions above C2 and at the angle of the mandible). The patients’ clinical characteristics are shown in Table 1. No significant differences were observed between the 2 groups.

In the conventional and HMI groups, the mean operation time and ICA clamp time were 154.5±42.6 and 50.5±12.7 minutes and 100.9±15.9 and 42.3±9.3 minutes, respectively. Both parameters showed statistically significant differences (p<0.01) (Fig. 2). Only 3 shunts (2.7%) were inserted in the conventional group, while none were needed in the HMI group (p=0.56). The mean incision lengths were 11.5±2.8 cm and 5.3±0.9 cm in the conventional and HMI groups, respectively (p<0.01). The ratio of post- to pre-clamp rSO2 levels, representing the degree of change in cerebral perfusion after ICA clamping, was significantly different between the conventional (5.9%±7.2%) and HMI (2.7%±5.3%) groups (p=0.01). The operative profiles of the

![Fig. 1. Operative wound pictures. (A) Right carotid arteries, exposed with the superior thyroid artery tagged by a vessel loop. (B, C) Operative wound closed with a Jackson-Pratt drain inserted. (D) Wound scar a week after discharge.](http://www.jchestsurg.org)
patients are presented in Table 2.

No postoperative deaths were observed in either group. There were 8 (7.3%) and 3 (7.3%) cases of stroke that occurred within 30 postoperative days in the conventional and HMI groups, respectively (p>0.99). In the conventional group, a stroke was due to ICA occlusion right after the operation, causing a stuporous mentality that was resolved by re-operation. And another stroke was due to hemorrhagic changes in the infarcted area (not ischemic stroke) that caused shock and seizures. Furthermore, the conventional group had 4 cases (3.6%) of TIA, while no TIA was detected in the HMI group (p=0.58).

The number of CCN injuries was 20 (18.2%) and 5 (12.2%) in the conventional and HMI groups, respectively (p=0.38). CCN injuries in the conventional group included 16 (14.5%) hypoglossal, 1 (0.9%) facial mandibular branch, 2 (1.8%) vagus and vagus branch, and 1 (0.9%) transverse cervical nerve injuries. CNN injuries in the HMI group included 4 (9.8%) hypoglossal and 1 (2.4%) facial mandibular branch nerve injuries. All CCN injuries in both groups were transient, with recovery within a year. No significant differences were observed between the 2 groups in the early postoperative outcomes (Table 3).

The univariate and multivariate risk factors for CCN injury were assessed using logistic regression analysis. Both univariate and multivariate analyses for the HMI group showed no statistical significance. Age, the presence of a high-level lesion, and ICA clamp time were considered risk factors for CCN with odds ratios of 0.90 (95% confidence interval [CI], 0.83–0.97; p=0.01), 9.56 (95% CI, 3.21–28.42; p<0.01), and 1.07 (95% CI, 1.03–1.12; p<0.01), respectively (Table 4).

Discussion

Several types of incision and approaches for CEA have been investigated to reduce neurologic complications,

| Variable                              | Conventional (N=110) | High mini-skin incision (N=41) | p-value |
|---------------------------------------|----------------------|--------------------------------|---------|
| Operation time (min)                  | 154.5±42.6           | 100.9±15.9                     | <0.01*  |
| ICA clamp time (min)                  | 50.5±12.7            | 42.3±9.3                       | <0.01*  |
| Shunt used                            | 3 (2.7)              | 0                               | 0.56    |
| Post/Pre (%)                          | 5.9±7.2              | 2.7±5.3                        | 0.01*   |
| Post/End (%)                          | 1.5±11.6             | 5.1±10.2                       | 0.09    |
| Incision length (cm)                  | 11.5±2.8             | 5.3±0.9                        | <0.01*  |

Values are presented as mean±standard deviation or number (%).

Table 3. Early postoperative outcomes (<30 days)

| Variable                              | Conventional (N=110) | High mini-skin incision (N=41) | p-value |
|---------------------------------------|----------------------|--------------------------------|---------|
| 30-Day stroke                         | 8 (7.3)              | 3 (7.3)                        | 1.00    |
| Transient ischemic attack             | 4 (3.6)              | 0                               | 0.58    |
| Cranial and cervical nerve injury     | 20 (18.2)            | 5 (12.2)                       | 0.38    |
| Hypoglossal nerve                     | 16 (14.5)            | 4 (9.8)                        | 0.44    |
| Facial nerve and mandibular branches  | 1 (0.9)              | 1 (2.4)                        | 0.47    |
| Vagus nerve and its branches          | 2 (1.8)              | 0                               | 1.00    |
| Transverse cervical nerve             | 1 (0.9)              | 0                               | 1.00    |
| Great auricular nerve                 | 0                    | 0                               | -       |
| 30-Day death                          | 0                    | 0                               | -       |

Values are presented as number (%).
wound size, and operative time. Although it is understood that a minimal incision is required to reduce the operative wound size, there are no fixed guidelines. To decrease neurologic deficits and improve cosmetic effects, some centers have used minimal longitudinal incisions in a conventional manner, with or without sonographic assistance [2,6]. Furthermore, transverse incisions camouflaged in a skin-crease have also been investigated [3,7-9].

Studies of vertical incisions in CEA have shown that a minimal incision causes fewer local neurologic complications than a conventional incision, but no statistical differences have been observed in the incidence of stroke and death [2,6,10]. This is corroborated by the results of our study. De Donato et al. [2] did show a statistically significant difference (p<0.01) in the occurrence of CCN, with 60/446 (13.4%) in the conventional group and 25/496 (5.1%) in the mini-skin incision group. In that study, CEA was performed with a longitudinal mini-incision along the anterior border of the SCM, and the level of incision was targeted to the carotid bifurcation by DUS. Subsequently, the carotid bifurcation was reached via an antero- or retro-jugular approach. In contrast, our study consistently used a vertical mini-incision along the anterior border of the SCM, beginning 1.5 cm from the mastoid. The carotid was not marked and the carotid bifurcation was reached by an antero-jugular approach only. Notably, there was no statistically significant difference in the incidence of local neurologic complications between our 2 groups (p=0.39).

Conventional incisions have been reported to result in a high incidence of local neurologic complications and unsatisfactory cosmetics [3,11-13]. Transverse incisions have been studied as an alternative at several centers to decrease rates of CCN injuries and stroke and to achieve better cosmetic results. Transverse incisions along Langer’s lines, which are camouflaged in the skin crease, showed much better results with respect to wound healing and esthetics [3,7-9]. To reduce the incidence of CCN injury, some studies tried to decrease the retracting force by using a subplatysmal flap [3,7]. While the benefits of transverse incisions are a satisfactory wound appearance and CCN injury and stroke rates that are no higher than with other techniques [3,14-16], the disadvantages include difficulty managing high carotid bifurcations and the fact that these incisions are limited to vertical retraction. A high-level lesion is a high surgical risk in CEA by a transverse incision because it is challenging to extend the operative wound longitudinally, risking high morbidity and disturbance of the surgical field by bony structures. Therefore, transverse incisions are not routinely implemented for high and extensive lesions. Even with these known limitations, no studies have evaluated the difference between the longitudinal mini-incision and the transverse incision.

### Table 4. Univariate and multivariate analysis for cranial and cervical nerve injuries using logistic regression analysis

| Variable                        | Univariate analysis | Multivariate analysis |
|---------------------------------|---------------------|-----------------------|
|                                 | OR (95% CI)         | p-value               | OR (95% CI)         | p-value               |
| Age                             | 0.92 (0.86–0.98)    | 0.01*                 | 0.90 (0.83–0.97)    | 0.01*                 |
| Body mass index                 | 1.09 (0.92–1.28)    | 0.31                  |                       |                       |
| Sex (female vs. male)           | 0.41 (0.90–1.87)    | 0.25                  |                       |                       |
| Severity (severe vs. moderate)  | 0.66 (0.20–2.20)    | 0.49                  |                       |                       |
| Asymptomatic                    | 1.67 (0.60–4.71)    | 0.33                  |                       |                       |
| Hypertension                    | 2.82 (0.79–10.02)   | 0.11                  |                       |                       |
| Diabetes mellitus               | 0.74 (0.30–1.84)    | 0.52                  |                       |                       |
| Hyperlipidemia                  | 4.07 (1.16–14.36)   | 0.03*                 | 4.54 (0.98–20.94)    | 0.53                  |
| Ulcerative lesion               | 1.43 (0.59–3.47)    | 0.43                  |                       |                       |
| Atrial fibrillation             | 0.48 (0.06–3.96)    | 0.50                  |                       |                       |
| Contralateral lesion            | 0.70 (0.26–1.90)    | 0.49                  |                       |                       |
| High-level of lesion            | 8.45 (3.31–21.56)   | <0.01*                | 9.56 (3.21–28.42)    | <0.01*                |
| Operative method (HMI vs. conventional) | 0.63 (0.22–1.80)   | 0.38                  | 1.42 (0.37–5.42)    | 0.61                  |
| Operation time                  | 1.01 (1.00–1.02)    | 0.02*                 | 1.01 (1.00–1.02)    | 0.47                  |
| ICA clamp time                  | 1.06 (1.02–1.10)    | <0.01*                | 1.07 (1.03–1.12)    | <0.01*                |
| Post/Pre (%)                    | 0.96 (0.90–1.03)    | 0.26                  |                       |                       |
| Post/End (%)                    | 1.00 (0.96–1.04)    | 0.86                  |                       |                       |

OR, odds ratio; CI, confidence interval; HMI, high mini-skin incision; ICA, internal carotid artery; rSO2, regional oxygen saturation; Post/Pre (%), the ratio of post- to pre-clamp rSO2 level representing changes in the degree of cerebral perfusion after ICA clamping; Post/End (%), the ratio of pre-clamp to post-declamp rSO2 level representing changes in the degree of cerebral perfusion after endarterectomy.

*p<0.05 (statistically significant).
Conventional exposure of the carotid artery in CEA is through the anterior and medial layers of the internal jugular vein after dissection of the SCM. Encounters with the facial vein and other branches of the internal jugular vein while exposing the ICA, require the operator to retract the veins laterally, mobilize the ansa cervicalis, and dissect cranial nerve XII (the hypoglossal nerve), especially if the lesion coexists with a high bifurcation. As an alternative, a retro-jugular approach to the carotid bifurcation reduces this risk and has a shorter operative time, but it is associated with the risk of vagal or accessory nerve injury. Several studies have investigated novel approaches and compared the incidence of neurologic complications to that of the conventional anteromedial jugular approach [17,18]. Antoniou et al. [17] conducted a meta-analysis of retro-jugular versus ante-jugular approaches for CEA and showed a higher incidence of laryngeal nerve damage in the retro-jugular approach than in the ante-jugular approach (8.1% and 2.2%, respectively; p=0.004), and no statistically significant difference in the incidence of hypoglossal or accessory nerve damage, persisting nerve damage, stroke, or death. No definitive approach to the ICA has been identified.

Since small incisions expose fewer local nerves, mini-skin incisions are expected to result in fewer neurological deficits. Sinha et al. [3] studied the transverse incision with subplatysmal flaps and showed that a 5.0±0.5 cm incision size had no statistical difference in terms of cranial nerve injuries. Ascher et al. [6] reported a longitudinal mini-incision of 3.6±1.3 cm, and de Donato et al. [2] demonstrated a vertical mini-incision of 4.5±0.5 cm with lower CCN injury rates than that of the conventional incision (5.1% versus 13.4%; p<0.01). In our study, the HMI group had a significantly shorter incision (5.3±0.9 cm) than the conventional group (11.5±2.8 cm). However, no significant difference was observed between the 2 groups in terms of stroke, death, and local neurologic deficits. In addition to fewer neurologic complications with small incisions, several studies have shown more favorable esthetic results based on quantified assessments of subjective factors [2,8,9].

Small incisions present a small operative field, which generally indicates a longer operative time. The only previous study investigating whether a minimal incision affected operation time was by de Donato et al. [2], which found no statistically significant difference in the operative and clamp times between the mini-skin incision and conventional groups (p=0.06). In contrast, our study showed a significantly shorter operative time and clamp time in the HMI group than in the conventional group. The conventional group underwent long incisions beginning 2 fingers below the mandible without strict measures to prevent the mandibular branch of the trigeminal nerve from being injured. When we needed a higher level of visibility for a distal lesion during the operation, the vertical incision was extended to 1 cm below the mastoid. Considering that a high-level lesion was the most difficult surgical challenge, we developed a protocol to routinely begin each mini-skin incision 1.5 cm below the mastoid. Targeting the bifurcation area and the ease of accessing it through the HMI contributed to the observed decrease in operative and clamp time. Furthermore, rapid localization and visualization at the distal area of the ICA and the shorter closure time for a minimal wound are other likely reasons for the shorter operative times in the HMI group. In the conventional group, if the lower level of the incision contributed to limited visualization of a high lesion and the operator was unwilling to extend the incision because of the additional risk for nerve injury, the operative and clamp times could be prolonged.

Cranial nerve injuries after CEA were reported in 5.6% of cases by the Vascular Study Group of New England. The risk factors were assessed by several studies and found to be expedited surgery and re-exploration for postoperative neurologic problems [19,20]. In our study, there was no significant difference in the rate of CCN injury between both groups; however, they had statistically significant differences for ICA clamp time, which was identified as a risk factor for CCN injury. Although our study did not show a statistically significant relationship between clamp time and neurologic deficits, the vertical HMI technique shortened the clamp time and thus might have decreased the risk of CCN injury.

This study had some limitations. First, there might have been bias because the operations were performed by three different surgeons in a single center. Most of the operations in the conventional incision group were performed by 2 expert cardiovascular surgeons, while the operations in the HMI group were performed by a junior surgeon with <100 cases of CEA. Despite the fact that the HMI group was operated on by a beginner, they had comparable results, suggesting that the HMI technique has the potential to become a superior method. Second, this was a retrospective study and was conducted at a single institution. Third, cosmetic evaluations were not conducted in an objective and numerical way because the focus was on clinical outcomes and neurologic complications. However, other studies have already shown that minimal incisions provide significant patient satisfaction [2].

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In conclusion, HMI without ultrasonographic guidance is a recommended incision technique for CEA to target the carotid bifurcation and decrease wound size with positive esthetic results. It has the potential to result in fewer neurologic complications by reducing clamp time, a known risk factor. Future studies with greater numbers of HMI cases are necessary to verify its efficacy and low rate of CCN injuries.

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Conflict of interest

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

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