Decompressive craniectomy for internal carotid artery and middle carotid artery infarctions: a long-term comparative outcome study

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OBJECTIVE Malignant internal carotid artery (ICA) infarction is an entirely different disease entity when compared with middle cerebral artery (MCA) infarction. Because of an increased area of infarction, it is assumed to have a poorer prognosis; however, this has never been adequately investigated. Decompressive craniectomy (DC) for malignant MCA infarction has been shown to improve mortality rates in several randomized controlled trials. Conversely, aggressive surgical decompression for ICA infarction has not been recommended. The authors sought to compare the functional outcomes and survival between patients with ICA infarctions and those with MCA infarctions after DC in the largest series to date to investigate this assumption.

METHODS A multicenter retrospective review of 154 consecutive DCs for large territory cerebral infarctions performed from 2005 to 2020 were analyzed. Patients were divided into ICA and MCA groups depending on the territory of infarction. Variables, including age, sex, medical comorbidities, laterality of the infarction, preoperative neurological status, primary stroke treatment, and the time from stroke onset to DC, were recorded. Univariable and multivariable analyses were performed for the clinical exposures for functional outcomes (modified Rankin Scale [mRS] score) on discharge and at the 1- and 6-month follow-ups, and for mortality, both inpatient and at the 1-year follow-up. A favorable mRS score was defined as 0–2.

RESULTS There were 67 patients (43.5%) and 87 patients (56.5%) in the ICA and MCA groups, respectively. Univariable analysis showed that the ICA group had a comparably favorable mRS (OR 0.15 [95% CI 0.18–1.21], $p = 0.077$). Inpatient mortality (OR 1.79 [95% CI 0.79–4.03], $p = 0.16$) and 1-year mortality (OR 2.07 [95% CI 0.98–4.37], $p = 0.054$) were comparable between the groups. After adjustment, a favorable mRS score at 6 months (OR 0.17 [95% CI 0.018–1.59], $p = 0.12$), inpatient mortality (OR 1.02 [95% CI 0.29–3.57], $p = 0.97$), and 1-year mortality (OR 0.94 [95% CI 0.41–2.69], $p = 0.88$) were similar in both groups. The overall survival, plotted using the Cox proportional hazard regression, did not show a significant difference between the ICA and MCA groups (HR 0.581).

CONCLUSIONS Unlike previous smaller studies, this study found that patients with malignant ICA infarction had a functional outcome and survival that was similar to those with MCA infarction after DC. Therefore, DC can be offered for malignant ICA infarction for life-saving purposes with limited functional recovery.

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KEYWORDS decompressive craniectomy; surgical decompression; stroke; functional outcome; survival

THE treatment of stroke has been revolutionized in recent decades by significant progress in thrombectomy,¹ neuroimaging,² and improved access to medical therapy.³ However, certain held beliefs in stroke management, such as the futility of decompressive crani-

ectomy (DC) for internal carotid artery (ICA) cerebral infarctions, have never been adequately investigated.

ICA infarction is relatively less common than middle cerebral artery (MCA) infarction, accounting for 19.5% and 65% of large-vessel occlusive strokes, respectively.⁴

ABBREVIATIONS ACA = anterior cerebral artery; DC = decompressive craniectomy; CCI = Charlson Comorbidity Index; GCS = Glasgow Coma Scale; ICA = internal carotid artery; ICP = intracranial pressure; MCA = middle cerebral artery; mRS = modified Rankin Scale; NICU = neurosurgical intensive care unit; PCA = posterior cerebral artery.

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The pathophysiology of an ICA infarction is similar to that of an MCA infarction, although the affected territory is larger. Occlusion of the vessel results in the interruption of blood flow in the areas of the brain perfused by it. The resultant cell death causes malignant cerebral edema in the acute to subacute period, which leads to raised intracranial pressure. This in turn results in uncal, transtentorial herniation, and ultimately, tonsillar herniation, leading to death.⁵ In ICA infarction, with a larger volume of brain infarcted (i.e., MCA with anterior cerebral artery [ACA] and/or posterior cerebral artery [PCA] territory), more cerebral edema is produced, and intracranial pressure (ICP) is increased compared with that of MCA infarction.⁶ The current treatment of ICA occlusion is aimed at preventing the establishment of an infarct by recanalization of the vessel and restoration of cerebral perfusion. The use of intravenous thrombolytics have not proven to be greatly beneficial,⁷ and the mainstay of current treatment is endovascular thrombectomy with or without stenting.^{4,7-9}

Malignant cerebral edema can lead to a mortality rate of 80% when treated medically.^{10,11} DC has been established as a treatment for malignant cerebral edema for strokes, but its use has mainly been focused on MCA infarction.^{10,12-19} Various randomized controlled trials have shown a significant improvement in the survival of patients who underwent DC for malignant MCA infarction,²⁰⁻²² from 29% to 78%. However, an improvement in functional outcomes was not demonstrated.²³ Previous studies have also found that significant predictors of mortality and poor functional outcome in such patients included older age, previous history of stroke, diabetes mellitus, preoperative low Glasgow Coma Scale (GCS) score, the presence of anisocoria, a midline shift > 10 mm, and an increased time from the onset of stroke to DC.^{12,24-28}

The aim of this study was to determine if DC is as effective in reducing mortality and morbidity in patients with malignant ICA infarction compared with those with malignant MCA infarction and to review the long-term outcomes in both groups of patients.

Methods

Study Design

This multicenter retrospective study was conducted in Tan Tock Seng Hospital and Singapore General Hospital, two of the largest neurosurgical units in Singapore, a multicultural Asian city. From January 2005 to March 2020, all consecutive patients who were admitted for large territory infarction in the MCA or ICA territory and subsequently underwent therapeutic DC for malignant cerebral edema were recruited. Institutional ethics review board was obtained.

Inclusion and Exclusion Criteria

Patients aged 18 to 95 years who underwent therapeutic DC for either an MCA or ICA territory infarction at our two main hospitals were included. An MCA infarction was defined as cerebral infarction occurring within the MCA territory, while an ICA infarction was defined as cerebral infarction occurring within the ACA or PCA territory in addition to the MCA territory. These patients were select-

ed based on the institutional protocol determined by the neurosurgical and neurology departments. The inclusion criteria included having an acute large territory infarction involving more than 50% of MCA territory on imaging; a premorbid modified Rankin Scale (mRS) score of < 3; and clinical deterioration according to the GCS score, pupillary reaction, or progression of focal neurological deficit. Patients who were comatose with a GCS score < 6, those with fixed and dilated bilateral pupils, those with serious medical comorbidities that precluded surgery, and those with a likely life expectancy < 3 years were excluded. Our study also excluded patients who underwent prophylactic DC and patients with a large territory infarction due to surgical complications or trauma.

Surgical Procedure and Periprocedural Care

On admission, patients meeting the American Heart Association/American Stroke Association stroke guidelines¹⁷ underwent thrombolytic intravenous therapy with recombinant tissue plasminogen activator (rtPA) and/or thrombectomy. Patients were subsequently admitted to a dedicated stroke unit or high-dependency ward. On satisfying the abovementioned inclusion and exclusion criteria, therapeutic DC was offered.

Decompressive hemicraniectomy was performed as follows: a large reverse-question-mark skin incision was performed ipsilateral to the side of the stroke. A large bone flap with a diameter of at least 12 cm was removed, with additional subtemporal decompression performed. The dura mater was opened in a linear, curvilinear, or stellate fashion. An ICP monitor was inserted to allow ICP-guided management postoperatively. Closure was performed with a dural substitute that was either secured in a loose fashion or laid over the original dura. Epidural drains were inserted, and soft tissue was closed in layers.

All patients remained intubated and sedated postoperatively and were managed in a dedicated neurosurgical intensive care unit (NICU). Medical management was then instituted as required to control ICP postoperatively (targeting < 20 mm Hg) with sedation, osmotic diuretics, and barbiturate coma.

Data Collection

Records and imaging files were reviewed for the current analysis, and clinical, radiological, and monitoring data were extracted. The recruited patients were classified into two groups based on the territory of the ischemic infarction: an MCA infarction group (limited to the MCA territory) and an ICA infarction group (extended to involve the MCA and ipsilateral ACA and/or PCA territory). Patient characteristics, including age, sex, past medical history formulated using the Charlson Comorbidity Index (CCI), laterality of the infarction, and the time elapsed from stroke onset to decompressive surgery, were recorded. The clinical status of each patient was assessed both pre- and postoperatively by using the GCS and by observing the presence of pupillary dilation. The primary treatment of the stroke with either thrombolysis or thrombectomy was also documented.

Outcome measures, including the length of stay in the

NICU (days) and the overall hospital stay (from admission to discharge or death, in days), postoperative morbidity and mortality during the follow-up duration, and function, were documented. Dates of death (including both inpatient and outside the hospital) were obtained from the Singapore National Registry of Diseases Office. De-identification of our patient data set was also performed by the Singapore National Registry of Diseases Office. Functional outcome was assessed using the mRS score at discharge and at 1 month and 6 months after the procedure. In our study, a CCI score ≤ 2 , a GCS score > 8 , and an mRS score of 0–2 were defined as favorable. The mean follow-up duration was formulated based on attendance at follow-up visits.

Statistical Analysis

Variable distributions are described using frequency (%) and mean $\pm$ standard deviation or median (IQR) for categorical and continuous variables, respectively. The two patient groups were compared using the chi-square test (or the Fisher's exact test, where appropriate) and the two-sample t-test (or the Mann-Whitney U-test, depending on the normality assumption) for categorical and continuous variables, respectively, for statistical significance.

Multivariable logistic regression models with Firth's penalized likelihood were performed to investigate outcomes, including the 6-month mRS score, inpatient mortality, and 1-year mortality, after adjusting for potential confounders identified by either clinical literature or univariable analysis. A Cox proportional hazard survival curve was plotted, and the hazard ratio was used to assess the difference between the survival curve. Statistical significance was set at $p < 0.05$. Data analyses were performed using IBM SPSS Statistics version 20.0 (IBM Corp.).

Results

Patient Characteristics

A total of 154 therapeutic DCs were performed during the study period; 67 were performed in patients with an ICA infarct, and 87 were performed in patients with an MCA infarct. Both groups were comparable in terms of the mean age (ICA, 56.7 ± 11.3 years; MCA, 58.5 ± 12.6 years), sex (ICA, 65.7% male; MCA, 69.0% male), medical comorbidities (median CCI score 2 for both groups), preoperative neurological status (the median GCS score 9 for both groups), the presence of anisocoria (ICA, 19.4%; MCA, 12.6%), primary stroke treatment such as thrombolysis (ICA, 34.3%; MCA, 35.6%) and thrombectomy (ICA, 4.5%; MCA, 4.6%), and the mean time from onset of the stroke to decompressive surgery (ICA, 42.1 ± 28.7 hours; MCA, 39.6 ± 26.6 hours). Of note, the proportion of left-sided surgeries between the two groups approached significance (ICA, 31.3%; MCA, 46.0%; $p = 0.066$). These characteristics are summarized in Table 1.

Inpatient Postoperative Outcomes

With regard to postoperative outcomes, the median postoperative GCS score (ICA, 9 and MCA, 11; $p = 0.045$) and percentage of patients with postoperative anisocoria (ICA, 14.9% and MCA, 4.6%; $p = 0.045$) were signifi-

TABLE 1. Characteristics of the ICA and MCA patient groups

	ICA Infarct Group (n = 67)	MCA Group (n = 87)	p Value
Age, yrs			0.35
Range	29–77	24–92	
Mean $\pm$ SD	56.7 ± 11.3	58.5 ± 12.6	
Sex, n (%)			0.67
M	44 (65.7)	60 (69.0)	
F	23 (34.3)	27 (31.0)	
Median CCI score (IQR)	2 (1–3)	2 (1–3)	0.81
Laterality, n (%)			0.066
Lt	21 (31.3)	40 (46.0)	
Rt	46 (68.7)	47 (54.0)	
Median preop GCS score (IQR)	9 (8–10.75)	9 (8–11)	0.42
Preop anisocoria, n (%)	13 (19.4)	11 (12.6)	0.25
Thrombolysis, n (%)	23 (34.3)	31 (35.6)	0.87
Thrombectomy, n (%)	3 (4.5)	4 (4.6)	>0.99
Time to decompression, hrs			0.58
Range	8–408	6–264	
Mean $\pm$ SD	42.1 ± 28.7	39.6 ± 26.6	

* Chi-square test (or Fisher exact test, where appropriate) and two sample t-test (or Mann Whitney U-test, depending on normality assumption) for categorical and continuous variables, respectively.

cantly different. The median overall length of stay in the NICU (ICA, 8 days; MCA, 6 days) and the median overall hospital stay (ICA, 40 days; MCA, 30 days), the need for tracheostomy (ICA, 20.9%; MCA, 18.4%), and the rate of complications (ICA, 14.9%; MCA, 6.9%) were comparable. The proportion of inpatient deaths (ICA, 23.9%; MCA, 14.9%) and a favorable mRS score at the time of discharge (ICA, 1.5%; MCA, 1.1%) were also comparable. However, patients with an MCA infarct were more likely to go home or to a rehabilitation facility on discharge (MCA, 63.2; ICA, 43.3%; $p = 0.017$). These outcomes are detailed in Table 2.

Long-Term Outcomes

Both groups of patients underwent follow-up for an adequate duration; the median duration for the ICA group was 24 months and for the MCA group, 36 months. The difference in mortality at the 1-year interval trended toward significance (ICA, 35.5%; MCA, 21%; $p = 0.054$). When considering functional outcomes, favorable mRS scores were similar between the groups at the 1-month (ICA, 1.6% and MCA, 2.4%; $p > 0.99$) and 6-month (ICA, 1.8% and MCA, 10.8%; $p = 0.077$) marks. The long-term outcomes highlighted in Table 3 and Fig. 1 demonstrate the number of patients included in our analysis at each critical timepoint.

Functional Outcome and Mortality

When considering inpatient mortality, having good preoperative (HR 0.36 [95% CI 0.16–0.84], $p = 0.015$) and

TABLE 2. Inpatient outcomes of the ICA and MCA groups

	ICA Infarct Group (n = 67)	MCA Infarct Group (n = 87)	p Value
Median postop GCS score	9 (6–12)	11 (9–12)	0.045
Postop anisocoria	10 (14.9)	4 (4.6)	0.045
Median NICU LOS, days	8 (5–11)	6 (4–10)	0.081
Median overall LOS, days	40 (21–60)	30 (20–49)	0.18
Tracheostomy	14 (20.9)	16 (18.4)	0.70
Complications	10 (14.9)	6 (6.9)	0.11
Inpatient mortality	16 (23.9)	13 (14.9)	0.16
Favorable discharge mRS score	1 (1.5)	1 (1.1)	>0.99
Discharge location			0.017
Home/rehab facility	29 (43.3)	55 (63.2)	
Nursing facility	18 (26.5)	10 (11.4)	
Repatriation	4 (6.0)	8 (9.2)	

LOS = length of stay.

Values represent the number of patients (%) unless stated otherwise. Median values are presented as the median (IQR). Boldface type indicates statistical significance.

postoperative (HR 0.047 [0.016–0.14], $p < 0.0001$) GCS score was protective against inpatient mortality, while having preoperative (HR 8.42 [95% CI 3.29–22.34], $p < 0.0001$) and postoperative (HR 10.8 [95% CI 3.28–35.5], $p < 0.0001$) anisocoria and a previous thrombectomy (HR 12.8 [95% CI 2.35–69.9], $p = 0.003$) were associated with inpatient death. After adjusting for confounders, the postoperative GCS score (HR 0.035 [95% CI 0.008–0.15], $p < 0.0001$), preoperative anisocoria (HR 7.12 [95% CI 1.60–31.7], $p = 0.010$), and having had a thrombectomy (HR 19.1 [95% CI 1.73–210], $p = 0.016$) remained statistically significant. ICA infarction, before and after adjustment, was not associated with inpatient mortality.

Factors associated with a favorable 6-month mRS score included age < 60 years (OR 7.49 [95% CI 0.91–61.7], $p = 0.038$) and a favorable CCI score (OR 7.02 [95% CI 0.85–57.8], $p = 0.043$). Having an ICA rather than an MCA infarction was not associated with an unfavorable 6-month mRS score before (OR 0.15 [95% CI 0.18–1.21], $p = 0.077$) and after (OR 0.17 [95% CI 0.018–1.59], $p = 0.12$) adjustment. Having a left-sided infarct also had no association with the 6-month mRS score both without (OR 0.21 [95% CI 0.025–1.71], $p = 0.16$) and with (OR

0.12 [95% CI 0.013–1.12], $p = 0.063$) adjustment. Figure 2 gives a graphical representation of the mRS score at 6 months when considering both the extent and laterality of the infarction (a favorable mRS score in the right ICA infarction, 1 [2.4%] and right MCA infarction, 7 [16.7%]; a favorable mRS score in the left ICA infarction, 0 [0%] and left MCA infarction, 1 [3.1%]).

Variables associated with mortality at the 1-year follow-up included having a low CCI score (HR 0.42 [95% CI 0.20–0.89], $p = 0.021$), good preoperative (HR 0.31 [95% CI 0.14–0.68], $p = 0.002$) and postoperative (HR 0.051 [95% CI 0.020–0.13], $p < 0.0001$) GCS score, preoperative (HR 5.91 [95% CI 2.30–15.2], $p < 0.0001$) and postoperative (HR 11.6 [95% CI 3.00–45.0], $p < 0.0001$) anisocoria, and a previous thrombectomy (HR 7.50 [95% CI 1.39–40.4], $p = 0.016$). After adjustment, having a favorable postoperative GCS score (HR 0.041 [95% CI 0.012–0.15], $p < 0.0001$) and a previous tracheostomy (HR 0.26 [95% CI 0.071–0.52], $p = 0.0023$) remained significant. Having an ICA infarction was not associated with 1-year mortality before or after multivariable analysis.

Overall Survival

When all-cause mortality is considered, the Cox proportional hazard regression does not demonstrate any statistical difference between the ICA and MCA groups (HR 0.581) after adjusting for age, side of infarction, time from stroke onset to DC, CCI score, preoperative and postoperative GCS score, and anisocoria (Fig. 3).

Discussion

There is a paucity of studies in the literature regarding surgical decompression of large territory ICA infarction. Studies on ICA infarction were generally more conservative when recommending surgery compared with MCA infarction, due to findings of higher mortality and poorer functional outcome in ICA infarction.^{12,15,26–28} Nevertheless, these were smaller retrospective studies that may not have captured an adequate spectrum of this disease population. Our study has demonstrated that the long-term functional and survival outcomes of patients who underwent therapeutic DC for ICA infarction were comparable to those of patients who underwent DC for MCA infarction. To the best of our knowledge, this is the largest study of ICA infarction with regard to outcomes after decompressive surgery.

The patients in our study who underwent ICA decompression were selected carefully based on good prognos-

TABLE 3. Long-term outcomes of the ICA and MCA patient groups

	ICA Infarct (n = 67)	MCA Infarct (n = 87)	OR (95% CI)	p Value	Adjusted OR (95% CI)	Adjusted p Value
Favorable mRS score at 1 mo	1/62 (1.6)*	2 (2.4)*	0.65 (0.058–7.40)	>0.99	0.95 (0.060–14.0)	0.95
Favorable mRS score at 6 mos	1/57 (1.8)*	8 (10.8)*	0.15 (0.18–1.21)	0.077	7.15 (0.74–69.4)	0.090
1-yr mortality	22 (35.5)	17 (21.0)	2.07 (0.98–4.37)	0.054	0.95 (0.32–2.81)	0.92
Median follow-up duration (IQR), mos	24 (18–39.75)	36 (21.5–48)		0.20		

* Presented as the number of patients/total number of patients available at the stated time point.

FIG. 1. Flowchart of the patients at various time points, and the outcome evaluation at the 1-month and 6-month follow-ups after DC.

tic factors in DC for MCA infarction as described in the literature. Younger age, lower CCI score, an acceptable preoperative GCS score, and a low proportion of patients with anisocoria are characteristics that reflect the relatively good premorbid and neurological status of patients selected for surgery. Fewer left-sided surgeries in the ICA group reflects the perception that large territory dominant hemispheric infarcts tend to have a poorer neurological and hence functional prognosis.²⁹

The ICA group had a worse median postoperative GCS score and persistent anisocoria after decompression, which demonstrates more severe swelling and higher ICP exerted by the infarcted ICA territory compared with the MCA territory. Despite this, the length of stay in the NICU and inpatient morbidity and mortality were comparable in both patient groups. In addition, after adjustment, a favorable mRS score on discharge and at the 1- and 6-month follow-up, as well as 1-year mortality, were similar among both groups; this was despite a significantly larger proportion of ICA infarction patients being discharged to nursing homes, rather than to home or a rehabilitation facility. The overall survival, when considering all-cause mortality, was also comparable between the two groups.

Our study challenges the conventional thinking that ICA infarctions inherently herald a worse functional prognosis and survival despite DC. This notion is associated with the condition having a much larger territory of affected brain tissue, leading to increased cerebral edema.⁶ However, damage to the functional anatomy within the ACA territory may not be reflected in the overall functional status of the patient. Higher cortical function in the ACA territory such as planning, motivation, mood, and

emotions^{30,31} may not directly factor into the ability to perform basic self-care and ambulation. DC, in conjunction with modern ICP-lowering methods, is sufficient to compensate for the increased swelling from the additional region involved in an ICA infarction. Therefore, should the surgical aim of the therapeutic DC be solely for life-saving purposes, having an ICA infarction should not be a deterrent for aggressive surgical intervention.

When comparing the ICA group patients in our study with those presented in the literature,^{12,15,26–28} the former had less mortality and better functional status over a longer follow-up interval. Patients with ICA infarctions who underwent DC in our study had an inpatient mortality of 23.5% and a 1-year mortality of 34.9% compared with 37.5% to 70%^{12,15,26,27} in other studies. This is likely related to better patient selection with a younger population, fewer medical comorbidities, and a better preoperative neurological status. In addition, many of these studies reported on patients who underwent surgical decompression of their ICA infarction prior to 2005. Although the surgical technique has not changed, the anesthesia techniques^{32,33} and perioperative care^{34,35} have advanced, and the philosophy of patient selection has shifted, further improving outcomes. There may also be the effect of “self-fulfilling prophecy” seen in other neurosurgical conditions such as intracerebral hematomas, where prognostic pessimism is associated with early withdrawal of care,^{36,37} possibly leading to the “predicted” poor outcomes.³⁸

On the other hand, our study demonstrated that left-sided infarction showed a trend toward significance, after adjustment, when correlated with an unfavorable 6-month mRS score. More than 90% of people have a left-hemi-

FIG. 2. Comparison of 6-month mRS scores between left- and right-sided infarctions. The solid black line denotes the mRS score threshold between favorable (0–2) and unfavorable (3–6) outcomes.

spheric language dominance.³⁹ The mRS has a global nature that allows the indirect assessment of nonphysical attributes that contribute to well-being, such as language.⁴⁰ Hence, we advise that the counseling process for surgery should be different and nuanced when a dominant hemispheric infarction is concerned.

FIG. 3. Adjusted survival curve using the Cox proportional hazard regression demonstrating no difference in survival between the ICA infarct (blue) and MCA infarct (green) patient groups. Adjusted HR = 0.581. Factors included in the multivariable analysis were age, side of infarction, time to decompression, CCI score, pre- and postoperative GCS scores, and presence of anisocoria.

Previous studies have suggested that DC for malignant infarctions “converts mortality into severe morbidity” and as such has been criticized by some to be an exercise in futility,⁴¹ and others even consider severe disability to be a fate worse than death.⁴² However, when surveys were conducted, the results were encouraging; approximately 80% of patients and/or caregivers when interviewed were satisfied with the surgical outcomes and would give consent again for the procedure. In addition, there was no reported difference in the quality of life in patients with dominant versus nondominant infarcts, even when they experienced dysphasia.^{43,44} In our opinion, the definition of a good quality of life is extremely subjective and is influenced by culture, socioeconomic status, and individual life experience. It is the challenge of the neurosurgeon and neurologist to identify, in a timely manner, where the patient and their family set their threshold for a “favorable mRS score” and to deliver care that conforms to the patient’s ideas, concerns, and expectations.

Cultural beliefs in the context of our study have had implications on decision-making with the performance prophylactic versus therapeutic decompressive surgery.^{45–47} Within the Asian population, brain surgery is viewed as a major event that should be avoided as much as possible. There is also a strong culture of family, with responsibility felt toward close relatives, in addition to a belief in the sanctity of life above and beyond having a good quality of life. Hence, there is likely to be a larger proportion of therapeutic than prophylactic surgeries and a likelihood for patients to be more accepting of having a relatively poor functional outcome if life can be preserved. This also indirectly contributes to the longer overall survival of both the ICA and MCA groups of patients in this study.

When considering long-term functional outcome and mortality, factors such as age, medical comorbidities, preoperative neurological status, and laterality of the infarct may be more consequential. Patients and their families need to be counseled especially carefully when these negative prognostic factors are present. With appropriate patient selection and recent advances in neuroanaesthesia^{32,33} and perioperative care,^{34,35} the negative impression that outcomes for surgical decompression of ICA infarctions are worse than MCA infarctions can be quelled. Thus, these patients should not be given any less of a chance than a similar patient with an MCA infarction.

The main limitation of this study is its retrospective nature. In addition, there were other subgroups of patients with large territory cerebral infarctions who were not addressed in our article. These included patients who underwent prophylactic DC, who may have had a different, more favorable clinical course, and patients who received medical treatment alone, without the performance of DC. The effectiveness of DC for ICA infarction can be further assessed through direct comparison with these subgroups. There was also a small proportion of patients (ICA, 14.9%; MCA, 14.9%) who were lost to follow-up, mainly because of repatriation to their home countries.

This study describes the largest published modern series on ICA infarction after DC (n = 154; ICA, 67 and MCA, 87). Other published series have had sample sizes ranging from 5 to 27, with only 2 of the series published after 2005.^{12,15,26–28} In addition, despite its retrospective nature, information was readily and reliably available from electronic medical records, and patient deaths were retrieved from an external government registry that provided the exact date of all inpatient and out-of-hospital deaths. We recommend that a systematic review, or a study with a larger sample size, be performed to further validate our claim.

Conclusions

Unlike previous smaller studies, this study found that patients with malignant ICA infarction have a similar functional outcome and survival to those with MCA infarction after DC. Therefore, DC can be offered for malignant ICA infarction for life-saving purposes with limited functional recovery.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Lee. Acquisition of data: Lim, Vedicherla, Chan, Primalani, Tan. Analysis and interpretation of data: Lim. Drafting the article: Lim, Primalani, Lee. Critically revising the article: Lim, Lee. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Lim. Statistical analysis: Lim, Saffari. Study supervision: Lee.

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