Decompressive hemicraniectomy: predictors of functional outcome in patients with ischemic stroke

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OBJECTIVE Patients presenting with large-territory ischemic strokes may develop intractable cerebral edema that puts them at risk of death unless intervention is performed. The purpose of this study was to identify predictors of outcome for decompressive hemicraniectomy (DH) in ischemic stroke.

METHODS The authors conducted a retrospective electronic medical record review of 1624 patients from 2006 to 2014. Subjects were screened for DH secondary to ischemic stroke involving the middle cerebral artery, internal carotid artery, or both. Ninety-five individuals were identified. Univariate and multivariate analyses were performed for an array of clinical variables in relationship to functional outcome according to the modified Rankin Scale (mRS). Clinical outcome was assessed at 90 days and at the latest follow-up (mean duration 16.5 months).

RESULTS The mean mRS score at 90 days and at the latest follow-up post-DH was 4. Good functional outcome was observed in 40% of patients at 90 days and in 48% of patient at the latest follow-up. The mortality rate at 90 days was 18% and at the last follow-up 20%. Univariate analysis identified a greater likelihood of poor functional outcome (mRS scores of 4–6) in patients with a history of stroke (OR 6.54 [95% CI 1.39–30.66]; $p = 0.017$), peak midline shift (MLS) > 10 mm (OR 3.35 [95% CI 1.33–8.47]; $p = 0.011$), or a history of myocardial infarction (OR 8.95 [95% CI 1.10–72.76]; $p = 0.04$). Multivariate analysis demonstrated elevated odds of poor functional outcome associated with a history of stroke (OR 9.14 [95% CI 1.78–47.05]; $p = 0.008$), MLS > 10 mm (OR 5.15 [95% CI 1.58–16.79]; $p = 0.007$), a history of diabetes (OR 5.63 [95% CI 1.52–20.88]; $p = 0.01$), delayed time from onset of stroke to DH (OR 1.32 [95% CI 1.02–1.72]; $p = 0.037$), and evidence of pupillary dilation prior to DH (OR 4.19 [95% CI 1.06–16.51]; $p = 0.04$). Patients with infarction involving the dominant hemisphere had higher odds of unfavorable functional outcome at 90 days (OR 4.73 [95% CI 1.36–16.44]; $p = 0.014$), but at the latest follow-up, cerebral dominance was not significantly related to outcome (OR 1.63 [95% CI 0.61–4.34]; $p = 0.328$).

CONCLUSIONS History of stroke, diabetes, myocardial infarction, peak MLS > 10 mm, increasing duration from onset of stroke to DH, and presence of pupillary dilation prior to intervention are associated with a worse functional outcome.

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KEY WORDS decompressive hemicraniectomy; ischemic stroke; vascular disorders

PATIENTS presenting with large ischemic strokes may develop uncontrollable, progressive brain edema that puts them at risk for compression of brain parenchyma and cerebral herniation.²³ There are a limited number of therapeutic options, but research has shown that operative procedures, such as decompressive hemicraniectomy (DH), decrease patient mortality.³² Malignant in-

farction treated only by conservative approaches results in a mortality rate of 80% within the 1st week of the stroke.¹⁵ Edema that does not respond to medical treatment necessitates DH as a life-saving procedure. Studies have demonstrated that DH surgery can result in a reduction of mortality rate to 30% and, if decompression is performed within 24 hours of stroke onset, to 10%.^{7,12,18,24,32} While DH im-

ABBREVIATIONS BMI = body mass index; DH = decompressive hemicraniectomy; DVT = deep vein thrombosis; ICA = internal carotid artery; IVC = inferior vena cava; MCA = middle cerebral artery; MI = myocardial infarction; MLS = midline shift; mRS = modified Rankin Scale; NIHSS = National Institutes of Health Stroke Scale; tPA = tissue plasminogen activator.

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proves patient survival, its effects on patients' functional outcome is still uncertain and the patient's family is presented with the difficult decision of choosing between intervention with DH and medical management.³ However, the long-term prognosis appears to be favorable if patients survive the acute phase of the stroke.¹⁹ In addition, while the functional outcome of patients is not worsened by DH, neurological deficit is likely as a result of initial large-territory ischemia.¹⁵ The eligibility of patients with ischemic stroke to undergo DH might be further informed by functional outcome, mortality, and quality of life data. This information would be highly advantageous for patients and families to allow them to make informed decisions about patient care options. Patient selection for DH relies on neurological examination, baseline patient characteristics, stroke presentation, imaging evaluation, and time from onset of symptoms to surgery.²² The correlation of specific clinical variables preceding DH to patient outcome helps inform clinicians and families about the patient's potential prognosis.¹⁰ The current study inspects an array of clinical variables for potential predictors of functional outcome in patients who underwent DH for ischemic stroke.

Methods

Patient Selection and Data Collection

A total of 1624 patients who underwent any type of craniectomy from 2006 to 2014 were retrospectively screened via electronic medical record. The specific inclusion criterion was DH secondary to ischemic stroke involving the middle cerebral artery (MCA), internal carotid artery (ICA), or both. Individuals were excluded if they had undergone DH for any reason other than for ischemic stroke, or if the MCA or ICA was not implicated. Ninety-five patients were identified. Demographic, radiographic, and treatment characteristics were recorded.

Initial Treatment

All patients with suspected acute ischemic stroke undergo immediate noncontrast CT scanning, CT angiography, and CT perfusion. Conservative treatment is administered in the ICU for blood pressure management, hyperthermia, and hyperglycemia control. Patients with malignant cerebral infarctions are treated with osmotherapy with the use of intravenous mannitol or hypertonic saline, sedation, intubation with hyperventilation, diuretics, and steroids before DH. DH was performed either in response to deterioration in neurological status or as a preventive procedure in patients with space-occupying large hemispheric infarction with significant midline shift (MLS) documented on CT scans. Worsening clinical status was defined as pupillary dilation and signs of cerebral herniation or severe brain edema with mass effect despite medical treatment or hemorrhagic infarction. The timing of the DH procedure depended on the treating neurosurgeon and on other patient characteristics.

Outcome

The primary outcome was functional status assessed by modified Rankin Scale (mRS) score at 90 days and at the latest follow-up. The mRS ranges from 0 (no symptoms)

to 6 (death), with intermediate values (1–5) representing increasing functional and cognitive disability. Poor functional outcome was defined as an mRS score of 4 (moderately severe disability), 5 (severe disability), or 6 (death). In comparison, scores of 0 (no symptoms), 1 (no substantial disability despite the presence of symptoms), 2 (slight disability, but not requiring assistance), and 3 (moderate disability necessitating some help) were considered as favorable outcomes. This categorization was based on physicians' attitudes regarding disability, with most physicians considering an mRS score of 3 as the cutoff between favorable and unfavorable outcome.²¹

Statistical Analysis

Data are presented as mean $\pm$ SD for continuous variables and as frequency for categorical variables. Analysis was carried out using unpaired t-test, chi-square test, and Fisher's exact tests. Univariate analysis was used to test covariates predictive of the following dependent variable: survival and poor functional outcome (mRS scores of 4–6). Interaction and confounding were assessed through stratification and relevant expansion covariates. Factors predictive in univariate analysis ($p < 0.20$) were entered into a multivariate logistic regression analysis. A p value of ≤ 0.05 was considered statistically significant. Statistical analysis was carried out with Stata 10.0.

Results

Patient Characteristics and Outcomes

The patient characteristics prior to DH are summarized in Table 1. There were 95 patients who presented with ischemic stroke involving the MCA (72%), ICA (7%), or both MCA and ICA (21%) and underwent DH. Twenty-nine patients had infarction involving the dominant hemisphere (30.5%) and 66 patients had a lesion in the nondominant hemisphere (69.5%). The mean age was 57 ± 12 years, 60% were male, and the mean body mass index (BMI) was 28.3 ± 7.4 kg/m². Atrial fibrillation was diagnosed in 25% of patients, hypertension in 81%, prior stroke in 20%, diabetes in 33%, and a previous myocardial infarction (MI) in 14%. The mean National Institutes of Health Stroke Scale (NIHSS) score was 16 ± 5 . Nineteen patients had signs of uncal herniation, with a unilaterally fixed and dilated pupil (20%) prior to DH. Tissue plasminogen activator (tPA) was administered in 29% of subjects. In 19% of patients endovascular intervention was performed prior to DH. The mean peak MLS was 9 ± 5 mm. Peak MLS measurements were based on radiological assessments of head CT scans by specialized neuroradiologists. The mean time from stroke onset to DH was 3 ± 3 days.

Outcomes are summarized in Table 2. Tracheostomy was performed in 36% and percutaneous endoscopic gastrostomy in 63% of subjects. Deep vein thrombosis (DVT) occurred in 36% of patients and an inferior vena cava (IVC) filter was placed in 25% of patients. Tracheostomy, percutaneous endoscopic gastrostomy, DVT, and IVC intervention occurred peri-DH. Subjects were hospitalized for a mean total of 22 ± 17 days, reflecting the severity of stroke, comorbidity, and requirement for prolonged intensive care. Most patients were discharged to a rehabilitation center (58%).

The mean mRS score at 90 days post-DH was 4 ± 1 characterized as moderately severe disability and functionally dependent. Seventy-three of 95 patients were further followed up for a mean period of 16.5 months; the remaining 22 patients did not have any available follow-up information after 90 days. At the last follow-up, the mean mRS was 4. Mortality (mRS score of 6) at 90 days post-DH was 18%. There were 2 new deaths after the initial follow-up period (2%). Four patients did not have any clinical follow-up at 90 days and mRS scores could not be obtained. At 90 days, mRS scores of 0 and 1 were not observed, and a score of 2 was observed in only 4 patients (4.4%). An mRS score of 3 (35.2%) represented outcome in the majority of patients in the less severe functional outcome category. Poor functional outcome was observed in 58% of patients, with scores of 4 (31%), 5 (9%), and 6 (18%). At the latest follow-up, poor functional outcome was observed in 52% of patients (Table 2).

Predictors of Poor Functional Outcome

Patient demographics and clinical characteristics were investigated in relationship to mRS scores to identify potential predictors of poor functional outcome (Table 3). In univariate analysis, patients with a history of stroke, history of MI, MLS > 10 mm, or increasing MLS were significantly more likely to have a poor functional outcome (mRS Scores 4–6) at 90 days post-DH. Patients with a history of stroke were predicted to be 6.54 times more likely to develop a poor functional outcome than those without a history of stroke (95% CI 1.39–30.66; $p = 0.017$). History of MI predicted a nearly 9 times greater likelihood of poor functional outcome than no such history (95% CI 1.10–72.76; $p = 0.040$). Patients with an increasing peak MLS (OR 1.1 [95% CI 1.01–1.22]; $p = 0.039$) or peak MLS > 10 mm (OR 3.35 [95% CI 1.33–8.47]; $p = 0.011$) had a greater likelihood of poor functional outcome. Other parameters of note correlated with elevated odds of mRS Scores 4–6 but did not reach statistical significance: age > 65 years (OR 1.41), BMI > 30 kg/m² (OR 1.14), NIHSS score > 17 (OR 1.88), intravenous tPA (OR 1.17), diabetes mellitus (OR 2.23), seizures (OR 1.6), IVC filter (OR 1.21), atrial fibrillation (OR 1.86), and smoking (OR 1.24).

In the multivariate analysis (Table 4), patients with an MLS > 10 mm, adjusting for age, history of stroke, diabetes, pupillary dilation, and hemisphere involved, were 5.15 times more likely to have a poor functional outcome after DH than those with less MLS (95% CI 1.58–16.79; $p = 0.007$). Thus, MLS > 10 mm is a strong predictor of poor functional outcome, irrespective of age, prior stroke, diabetes, pupillary response, or hemisphere involved. Similarly, patients with a history of stroke, adjusting for age, MLS > 10 mm, diabetes, pupillary response, and hemisphere involved, were 9.14 times more likely to have poor outcome than those without a history of stroke (95% CI 1.78–47.05; $p = 0.008$). Patients with diabetes were likely to develop poor outcome when adjusting for age, MLS > 10 mm, history of stroke, pupillary dilation, and hemisphere than patients without diabetes (OR 5.63; 95% CI 1.52–20.88; $p = 0.01$). Increasing days from onset of stroke symptoms to DH was a significant predictor of poor outcome when adjusting for MLS > 10 mm, NIHSS

TABLE 1. Baseline characteristics

Characteristic	Value (%)
No. of patients	95
Age, yrs	
Mean*	57 $\pm$ 12
Range	22–82
Sex, no.	
Male	57 (60)
Female	38 (40)
BMI, kg/m ²	
Mean*	28.3 $\pm$ 7.4
Range	14.5–66.9
Comorbidities, no.	
Hypertension	77 (81)
Hyperlipidemia	39 (41)
Smoking	37 (39)
Diabetes	31 (33)
Atrial fibrillation	24 (25)
Prior stroke(s)	19 (20)
MI	13 (14)
Seizures	12 (13)
Infarct site, no.	
MCA	
Right	43 (46)
Left	21 (22)
Bilateral	4 (4)
ICA	
Right	2 (2)
Left	3 (3)
Bilateral	2 (2)
MCA & ICA	20 (21)
NIHSS total score	
Mean*	16 $\pm$ 5
Range	1–32
Acute intervention, no.	
Intravenous tPA	28 (29)
Endovascular	18 (19)
Peak MLS, mm	
Mean*	9 $\pm$ 5
Range	0–19
Mean days from symptom onset to DH	3 $\pm$ 3
Dom hemisphere/nondom hemisphere	29 (30.5)/66 (69.5)
Pupillary dilation preop	19 (20)

Dom = dominant; nondom = nondominant.

* Mean values are presented $\pm$ SD.

score > 17, history of stroke, and MI (OR 1.32; 95% CI 1.02–1.72; $p = 0.037$). Furthermore, pupillary dilation was significantly associated with higher odds of poor outcome when controlling for age, MLS, history of stroke, diabetes, and cerebral hemisphere (OR 4.19; 95% CI 1.06–16.51; $p = 0.04$). Patients with cerebral infarction involving the dominant hemisphere had higher odds of unfavorable

TABLE 2. Outcomes of ischemic stroke patients after decompressive hemicraniectomy*

Outcome	Value (%)
Hospital duration, days	
Mean	22 ± 17
Range	3–101
Tracheostomy, no.	35 (36)
Gastrostomy, no.	60 (63)
DVT, no.	34 (36)
IVC filter, no.	24 (25)
Discharge location, no.	
Rehabilitation center	55 (58)
Nursing home	11 (12)
Rehabilitation/nursing	4 (4)
Long-term acute care	8 (8)
Hospice	2 (2)
Not known	15 (16)
mRS score at 90 days post-DH/mRS score at last FU†	
0	0 (0)/0 (0)
1	0 (0)/0 (0)
2	4 (4.4)/18 (24.7)
3	32 (35.2)/17 (23.3)
4	29 (31)/17 (23.3)
5	9 (9)/2 (2.7)
6 (death)	17 (18)/19 (26)
Mean	4 ± 1
Median	4

FU = follow-up.

* Values are presented as the number (%) of patients unless otherwise specified.

† mRS scores unknown at 90 days (n = 4)/mRS scores unknown at later follow-up (n = 22).

functional outcome at 90 days than their counterparts (OR 4.73; 95% CI 1.36–16.44; $p = 0.014$), but when this association was tested at the latest follow-up period (mean 16.5 months), cerebral dominance was not significantly related to outcome (OR 1.63, 95% CI 0.61–4.34; $p = 0.328$).

Discussion

The present analysis describes the clinical variables and functional outcomes in patients who underwent DH subsequent to severe cerebral edema that resulted from ischemic stroke.

Decompressive hemicraniectomy can be a life-saving procedure.^{8,11,14,30,31} Its beneficial effects may vary among patients. In this study, we set out to identify risk factors that can be associated with increased mortality rate and poor outcome after surgery and aid the patient selection for DH. The main factors that were significant predictors of poor outcome were a history of stroke, a history of diabetes, a prior history of MLS, a peak MLS > 10 mm, and increasing duration from onset of stroke to DH.

The mortality rates were 18% and 20% at 90 days and at

TABLE 3. Univariate analysis of predictors of poor functional outcome (i.e., mRS Scores 4–6)

Clinical Variable	OR	p Value	95% CI
Increasing age	1.03	0.106	0.99–1.07
Age >65 yrs	1.41	0.507	0.51–3.94
Sex	0.59	0.228	0.25–1.39
BMI	1.01	0.802	0.95–1.07
BMI >30 kg/m ²	1.14	0.800	0.42–3.09
Increasing MLS	1.11	0.039	1.01–1.22
MLS >10 mm	3.35	0.011	1.33–8.47
NIHSS score	1.06	0.216	0.97–1.15
NIHSS score >17	1.88	0.165	0.77–4.59
Increasing days from onset to DH	1.20	0.073	0.98–1.46
tPA intervention	1.17	0.735	0.47–2.96
Endovascular intervention	0.9	0.853	0.30–2.74
Hyperlipidemia	0.99	0.989	0.44–2.25
History of			
Stroke	6.54	0.017	1.39–30.66
Diabetes	2.23	0.101	0.85–5.80
MI	8.95	0.040	1.10–72.76
Seizures	1.6	0.450	0.47–5.42
IVC filter	1.21	0.693	0.46–3.17
Atrial fibrillation	1.86	0.204	0.71–4.87
Tobacco	1.24	0.628	0.51–3.01
Dom hemisphere	2.76	0.043	1.03–7.40
Evidence of pupillary dilation	1.54	0.426	0.52–4.53

the latest follow-up, respectively. A good clinical outcome (mRS score of ≤ 3) was observed in about 40% of patients at 90 days and 48% after more than a year of follow-up. These results are comparable to the results reported by the major clinical trials. The DECIMAL trial reported mRS scores of ≤ 3 at 6-month and 1-year follow-up of 25% and 50%, respectively, after DH (compared with 5.6% and 22.2% in the medical treatment group).³¹ The DESTINY trial reported that 88% of patients who underwent hemicraniectomy survived after 30 days (compared with 47% of patients randomized to conservative therapy), and 47% of patients in the surgical arm had an mRS score of 0–3 at 12 months (compared with 27% of patients in the conservative treatment arm).¹⁴ The HeADDFIRST trial reported that the mortality rates at 21 and 180 days were 21% and 36% in patients who received surgical treatment.⁸ Vahedi et al. conducted a pooled analysis of the major trials and reported that 43% of patients in the decompressive surgery group had an mRS score of ≤ 3 (compared with 21% who received medical management), and the mortality rate was 22% (compared with 71%).³⁰

The ages of patients who underwent DH ranged from 22 to 82 in the present study. The main studies that have evaluated the role of DH excluded patients older than 60 years, and early reports concluded that people older than 60 years do not benefit from DH.^{3,11,14,31} However, since the time those studies were published, there has been an increasing amount of evidence that this procedure is ben-

TABLE 4. Multivariate analysis of poor functional outcome (i.e., mRS Scores 4–6)

Clinical Variable	Univariate Analysis		Multivariate Analysis		
	OR (95% CI)	p Value	Adjusted for	OR (95% CI)	p Value
MLS >10 mm	3.35 (1.33–8.47)	0.011	Hx of stroke, DM, age, pupillary dilation, hemisphere involved	5.15 (1.58–16.79)	0.007
Hx of stroke	6.54 (1.39–30.66)	0.017	MLS >10 mm, DM, age, pupillary dilation, hemisphere involved	9.14 (1.78–47.05)	0.008
Hx of DM	2.23 (0.85–5.80)	0.101	MLS >10 mm, Hx of stroke, age, pupillary dilation, hemisphere involved	5.63 (1.52–20.88)	0.01
Hx of MI	8.95 (1.10–72.76)	0.040	MLS >10 mm, Hx of stroke, DM	4.70 (0.54–40.83)	0.160
Increasing days btwn stroke & DH	1.20 (0.98–1.46)	0.073	MLS >10 mm, NIHSS >17, Hx of stroke, MI	1.32 (1.02–1.72)	0.037
Pupillary dilation	1.54 (0.52–4.53)	0.426	MLS >10 mm, Hx of stroke, DM, hemisphere involved	4.19 (1.06–16.51)	0.04
Dom hemisphere	2.76 (1.03–7.40)	0.043	MLS >10 mm, Hx of stroke, pupillary dilation, DM	4.73 (1.36–16.44)	0.014

DM = diabetes mellitus; Hx = history.

eficial in patients older than 60 years of age and that in fact it can be a life-saving procedure in these patients.^{15,35,36} Some studies have suggested that DH improves survival but results in poor clinical outcome. In our study, in both univariate and multivariate analyses, age was not a significant predictor of clinical outcome and patients older than 65 years did not have higher odds of experiencing a poor outcome. Age may not have been predictive due to selection bias. Most of the surgically treated patients were younger than 65 years (mean 56.6 years, but 75% were younger than 65 years and 90% were younger than 73). However, recently the DESTINY II trial reported that hemicraniectomy significantly improves survival without being associated with severe disability in patients 61 years of age and older (38%) compared with 18% in the control group with a lower mortality rate in the surgery group (33% vs 70%).¹⁵ Furthermore, Zhao et al. have reported that the benefit of the procedure can be extended to patients 80 years of age.³⁶ Therefore, DH should be considered in older patients and patient selection should not be limited to age.

Other important individual characteristics to consider in the selection for DH procedure include patient comorbidities. Not many studies looked at specific comorbidities and evaluated their effect on outcome after surgery. History of diabetes, a previous stroke, and history of MLS were significant predictors of poor functional outcome. Patients with these comorbidities may have some level of functional decline prior to stroke and are more likely to have postoperative complications; therefore, functional outcomes will be worsened after DH. It is important to note that since the incidence of these comorbidities increases with age, older patients may seem to be at a higher risk of poor functional outcome and age may seem to be a stronger predictor of poor clinical outcome. However, that association may be partly due to the accompanying medical problems that are more likely to be present in older patients.²⁶ Therefore, it is important to assess each case separately and make individualized decisions for each patient and take into account not only age, but other comorbidities that significantly affect outcome.

Time from onset of stroke to decompression is a crucial factor in the management of malignant cerebral infarction. Decompressive hemicraniectomy has been shown

to be most effective when performed early, within 48 hours.^{4,13,20,24,25} In the current study, there was a wide variation in the time to DH with a mean of 3 days after symptom onset. Surgery was done in 60% of patients within the first 48 hours and 73% of patients within the first 72 hours. Patients who had more prolonged interventions had significantly higher odds of poor outcome at 90 days. The HAMLET trial reported that surgical decompression reduced case fatality and poor outcome in patients with space-occupying infarctions who were treated within 48 hours of stroke onset, but found no significant benefit after 96 hours.¹¹ Early surgical decompression is most effective in lowering elevated intracranial pressure and preventing transtentorial herniation. Furthermore, pupillary dilation can develop within the first 3 to 5 days and may indicate the presence of significant brainstem shift and clinical deterioration.³³ Patients with pupillary abnormalities were significantly more likely to have poor outcomes. Waiting for evidence of pupillary dilation can impede early intervention and worsens prognosis. Early intervention should be performed prior to the occurrence of this clinical sign when possible.

The MLS was serially monitored by neuroradiology for patients with cerebral edema. The peak value was collected, with a mean shift of 9 mm prior to intervention with DH. The mean MLS for patients who had a favorable outcome was 7.4 mm, whereas the mean MLS for patients with poor outcome was 10 mm. A higher peak MLS prior to surgery and MLS $\geq$ 10 mm significantly worsened outcome after DH. This is related to an increased mass effect and risk of brain herniation with compression of vital structures and hemodynamically, higher impairment of autoregulation.^{1,17}

Decompressive hemicraniectomies for MCA- and ICA-territory infarcts were included in this study. Acute ICA-territory infarctions usually have a poorer prognosis than MCA-territory infarction, and cerebral edema is more severe.³⁴ All patients with ICA infarctions had a poor outcome at 90 days, but none died. The role of DH in the management of ICA infarcts is less well established. Several studies failed to find a significant improvement in outcome after DH in patients with such infarctions.^{17,32,34} Our results show that functional outcome is unlikely to improve in these patients even after DH, but the survival

of these patients should be highlighted, suggesting decompression's positive effect on mortality in patients with malignant ICA infarction.

At 90 days following presentation, 75.9% of patients with a dominant-hemisphere infarction had poor outcome compared to 53.2% of patients with nondominant-hemisphere involvement. This difference was significant. However, further along in the follow-up period (mean 16.5 months), 60% of patients with a dominant-hemisphere infarction had an unfavorable outcome compared to 48% of patients with nondominant-hemisphere involvement, a nonsignificant difference. The debate regarding DH in patients with involvement of the dominant hemisphere stems from the hypothesis that aphasia with loss of communication leads to poor outcome.^{24,27} A significant improvement in aphasia and a better overall outcome, however, have been observed with longer follow-ups.^{5,16} Involvement of the dominant cerebral hemisphere should not preclude surgical decompression because long-term differences in clinical outcome after DH are not significantly different from those seen in patients with nondominant-hemisphere infarctions.^{9,27,29}

Intravenous tPA administration was not a significant predictor of poor outcome after DH. Several other studies have failed to find a significant effect of tPA administration on poor outcome and mortality after surgery as well.^{2,6,28} In the present study 29% of patients received intravenous tPA prior to DH. Although the theoretical risk of increased bleeding during and after the procedure exists, cases involving tPA intervention or endovascular therapy should not exclude the need for DH.

Depending on the severity of the stroke, patients required tracheostomy for ventilatory assistance and percutaneous endoscopic gastrostomy tube placement to provide a route for adequate nutrition. The incidence of DVT (36%) and the need for placement of an IVC filter (25%) were not uncommon during the inpatient recovery period. After total hospitalization for nearly a month, patients were typically discharged to a rehabilitation center. At 90 days post-DH, most patients had disability requiring assistance (mRS scores of 3–5), a minority of patients (4%) were considered functionally independent (mRS score of 2), and 18% of patients were dead (mRS score of 6). An mRS score of 0 (no symptoms) or 1 (no disability despite symptoms) was not observed.

The main limitations of this study include its retrospective single-center nature, which may limit the generalizability of the study, the fact that it did not control for patients without DH receiving intensive medical care, and the subjective nature of the mRS scoring system that was used as a measure of outcome.

Conclusions

Clinical markers such as history of stroke, diabetes, and MI; peak MLS (> 10 mm); time from onset of symptoms to surgery; and evidence of pupillary dilation may provide important prognostic information for predicting poor functional outcome (mRS score of 4–6) in candidates for DH as a result of large ischemic stroke. Based on the description of baseline patient characteristics, individual patients are likely to present with multiple factors that make

it difficult to accurately estimate functional outcome. This stratified array of clinical information is intended to help guide clinicians in estimating functional outcome. Clinical decision making of whether to perform DH takes into account a variety of factors that cannot always be rigidly defined and are not always abundantly clear. As such, additional considerations must be weighed and are combined with objective clinical predictive information to guide decision making.

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Disclosures

Dr. Jabbour reports being a consultant for Covidien.

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Conception and design: Jabbour. Acquisition of data: Daou, Kent, Montano. Analysis and interpretation of data: Daou, Kent, Montano, Chalouhi, Starke. Drafting the article: Jabbour, Daou, Kent, Montano. Critically revising the article: Jabbour, Chalouhi, Tjoumakaris, Rosenwasser. Reviewed submitted version of manuscript: Jabbour, Tjoumakaris. Statistical analysis: Starke. Study supervision: Jabbour, Tjoumakaris, Rosenwasser.

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