The Basilar Artery on Computed Tomography Angiography Prognostic Score for Basilar Artery Occlusion

Fana Alemseged, MD; Darshan G. Shah, MBBS; Marina Diomedi, MD; Fabrizio Sallustio, MD; Andrew Bivard, PhD; Gagan Sharma, MCA; Peter J. Mitchell, MD; Richard J. Dowling, MBBS; Steven Bush, MBBS; Bernard Yan, MBBS; Carlo Caltagirone, MD; Roberto Floris, MD; Mark W. Parsons, MBBS, PhD; Christopher R. Levi, MBBS; Stephen M. Davis, MD; Bruce C.V. Campbell, MBBS, PhD

Background and Purpose—Basilar artery occlusion is associated with high risk of disability and mortality. This study aimed to assess the prognostic value of a new radiological score: the Basilar Artery on Computed Tomography Angiography (BATMAN) score.

Methods—A retrospective analysis of consecutive stroke patients with basilar artery occlusion diagnosed on computed tomographic angiography was performed. BATMAN score is a 10-point computed tomographic angiography–based grading system which incorporates thrombus burden and the presence of collaterals. Reliability was assessed with intraclass coefficient correlation. Good outcome was defined as modified Rankin Scale score of ≤3 at 3 months and successful reperfusion as thrombolysis in cerebral infarction 2b-3. BATMAN score was externally validated and compared with the Posterior Circulation Collateral score.

Results—The derivation cohort included 83 patients with 41 in the validation cohort. In receiver operating characteristic (ROC) analysis, BATMAN score had an area under receiver operating characteristic curve of 0.81 (95% confidence interval [CI], 0.7–0.9) in derivation cohort and an area under receiver operating characteristic curve of 0.74 (95% CI, 0.6–0.9) in validation cohort. In logistic regression adjusted for age and clinical severity, BATMAN score of <7 was associated with poor outcome in derivation cohort (odds ratio, 5.5; 95% CI, 1.4–21; *P*=0.01), in validation cohort (odds ratio, 6.9; 95% CI, 1.4–33; *P*=0.01), and in endovascular patients, after adjustment for recanalization and time to treatment (odds ratio, 4.8; 95% CI, 1.2–18; *P*=0.01). BATMAN score of <7 was not associated with recanalization. Interrater agreement was substantial (intraclass coefficient correlation, 0.85; 95% CI, 0.8–0.9). BATMAN score had greater accuracy compared with Posterior Circulation Collateral score (*P*=0.04).

Conclusions—The addition of collateral quality to clot burden in BATMAN score seems to improve prognostic accuracy in basilar artery occlusion patients. **(*Stroke*. 2017;48:631-637. DOI: 10.1161/STROKEAHA.116.015492.)**

Key Words: angiography ■ basilar artery ■ prognosis ■ reperfusion ■ stroke

Basilar artery occlusion (BAO) comprises ≈1% of all strokes and is one of the most devastating neurological conditions associated with high risk of disability and mortality if recanalization does not occur.[1–3]

Despite recent breakthroughs in the treatment of large vessel occlusion ischemic stroke, BAO patients were excluded from recent randomized controlled trials,[4–8] and the evidence for treatment is derived largely from small retrospective studies.[9,10] The Australian Urokinase Stroke Trial is the only completed randomized trial, in which 16 patients were randomized, and a good outcome was observed in 4 of 8 patients who received intra-arterial urokinase compared with 1 of 8 patients in the control group,[11] with a significant association between successful recanalization and favorable outcome in pooled observational data.[12] However, the largest prospective observational study in BAO patients showed similar outcomes

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From the Department of Medicine and Neurology, Royal Melbourne Hospital, University of Melbourne, Parkville, Australia (F.A., D.G.S., B.Y., S.M.D., B.C.V.C.); Department of Neurology (F.A., M.D., F.S., C.C.) and Department of Diagnostic Imaging and Interventional Radiology (R.F.), University Hospital Tor Vergata, Rome, Italy; I.R.C.C.S., Santa Lucia Foundation, Rome, Italy (M.D., C.C.); Department of Neurology, John Hunter Hospital, University of Newcastle, Australia (A.B., M.W.P., C.R.L.); and Department of Radiology, Royal Melbourne Hospital, University of Melbourne, Parkville, Australia (G.S., P.J.M., R.J.D., S.B.).

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Correspondence to Bruce C.V. Campbell, MBBS, PhD, Department of Neurology, Royal Melbourne Hospital, Grattan St, Parkville VIC 3050, Australia. E-mail bruce.campbell@mh.org.au

in patients treated with intravenous thrombolysis and intra-arterial treatment,[13] and the American Heart Association/American Stroke Association guidelines state that there is uncertainty about the benefit of thrombectomy in BAO which may be reasonable in carefully selected patients with posterior circulation strokes, when initiated within the first 6 hours of stroke onset (Class IIb; Level of Evidence C).[14]

Given this uncertainty, the identification of factors predictive of outcome and treatment response may be clinically useful pending results from randomized trials (eg, BASICS [Basilar Artery International Cooperation Study; http://www.clinicaltrials.gov: NCT01717755] and BEST [Acute Basilar Artery Occlusion: Endovascular Interventions vs Standard Medical Treatment; http://www.clinicaltrials.gov: NCT02441556]). Several studies have identified age, National Institutes of Health Stroke Scale (NIHSS), time to treatment (OTT), and collateral status as possible predictors of outcome in BAO.[10,15,16] The posterior circulation Acute Stroke Prognosis Early CT score uses computed tomographic angiography (CTA) source images to predict outcome in BAO patients.[17] However, it has not been widely adopted in treatment decision making.

CTA is a standard approach to diagnose BAO and can noninvasively assess collateral status which plays a key role in the outcome of these patients. The posterior communicating arteries (PComs) are the main collateral pathway involved in BAO.[18,19] Recently, the Posterior Circulation Collateral score (PC-CS) was proposed: a 10-point grading score assessing collaterals on CTA as the presence of posterior inferior cerebellar arteries, anterior inferior cerebellar arteries (AICAs), superior cerebellar arteries (SCAs), and PComs. There was a significant association between good collateral status (especially the presence of PComs) and a favorable outcome.[20] An alternative approach is the Posterior Circulation Computed Tomography Angiography (pc-CTA) score which allocates 1 point for each occluded segment[1] of the vertebrobasilar system. Increased clot burden was associated with worse functional outcome.[21]

When the trunk of the basilar artery is occluded, a drop in perfusion pressure at the confluence of the posterior cerebral arteries (PCAs) leads to reverse filling through PComs if they are present. This reversed flow may supply flow distal to the clot and generate residual flow in the ischemic region, by maintaining the patency of the perforating arteries and the SCA branches. A second collateral pathway can flow via the posterior inferior cerebellar arteries which can be supplied by the anterior spinal artery; thus, if vertebral arteries remain patent at the origin, they may generate flow through the posterior inferior cerebellar artery into the AICAs, the SCAs, and the perforating arteries.[2] Fetal PComs (with absent P1 segments) may be protective in BAO because of the smaller territory at ischemic risk and the preservation of penetrating arteries to the midbrain and thalamus that arise from the anterior circulation-supplied fetal PCom.[2,18]

Given this pathophysiology, we tested the prognostic accuracy of a new radiological score in BAO which takes into account both the extent of the occlusion (which may correlate with the number of obstructed perforating arteries and consequently with the extent of ischemia) and the presence of PComs (that may prolong ischemic tolerance).

Methods

Patients

Using prospectively collected clinical and radiological databases, we retrospectively identified consecutive stroke patients who presented within 24 hours of symptomatic BAO demonstrated on CTA. The derivation cohort (DC) for the score included patients treated at Royal Melbourne Hospital (Melbourne, Victoria, Australia) between June 2005 and May 2016. The score was then validated in consecutive patients treated at the John Hunter Hospital, University of Newcastle, New South Wales, Australia and at the University Hospital of Tor Vergata, Rome, Italy.

All eligible patients received intravenous thrombolysis followed by endovascular treatment (EVT; intra-arterial therapy with urokinase or mechanical thrombectomy), consistent with current guidelines. Otherwise, patients proceeded directly to EVT with a treatment window ≤24 hours. Exclusion criteria for EVT were modified Rankin scale score of >3.

Clinical baseline variables, including age, sex, risk factors, treatment regimens, stroke type according to The Trial of Org 10172 in Acute Stroke Treatment classification, recanalization and procedural details, NIHSS, Glasgow coma scale, glycemia, and blood pressure, at admission were recorded. Time of onset of symptoms was recorded as described by the patient or witness; if unknown, it was considered to be the last time the patient was seen well. In patients presenting with mild symptoms followed by sudden onset of decrease in conscious state, the time of deterioration in clinical state was taken as estimated time of occlusion.

OTT was defined as the time from onset to arterial puncture and categorized into OTT of 0 to 6, 6 to 12, and >12 hours. We then compared our score with previous radiological scores described in the setting of BAO.[20,21] The Melbourne Health Human Research Ethics Committee approved this study.

Imaging Protocol

Noncontrast CT and CTA were performed using a multidetector CT scanner (16-slice Somatom or 128-slice Definition FLASH; Siemens Healthcare, Forchheim, Germany) at Royal Melbourne Hospital, Melbourne, Australia; GE LightSpeed VCT 64-slice multidetector CT scanner (GE Healthcare, Waukesha) at the University Hospital of Tor Vergata, Rome, Italy; and 64-slice Brilliance (Philips, Cleveland) or 320-slice Aquilion One (Toshiba Medical Systems, Otawara, Japan) scanners at the John Hunter Hospital, University of Newcastle, New South Wales, Australia.

CTA acquisition included the region from the aortic arch to the cerebral vertex. These neuroimaging data were reviewed using the institutional Picture and Archiving System.

Imaging Analysis: Grading System

We developed the Basilar Artery on Computed Tomography Angiography (BATMAN) score as a semiquantitative CTA-based grading system to quantify both the extent of the BAO and the presence of collateral circulation from PComs.

We divided the vertebrobasilar system into 6 segments, including vertebral arteries (considered as 1 segment), each PCA (considered separately), and the 3 segments of basilar artery.[1] In binary logistic regression, including all the above segments plus PComs, absence of PComs (bilateral or unilateral) was the strongest predictor of poor clinical outcome with an odds ratio (OR) of 6.8 (95% confidence interval [CI], 2–21; P=0.001; Table 1). Therefore, we decided to allocate 2 points for each PCom and 1 point for a hypoplastic PCom (defined as smaller than 1 mm)[22] if in continuity with the top of the basilar artery via a P1 PCA segment, or 3 points for each fetal PCom (to incorporate the point otherwise attributed to a patent P1 segment).

Table 1. Logistic Regression Preliminary to Basilar Artery on Computed Tomography Angiography Score

	OR (95% CI)	*P* Value
Vertebral artery	1.1 (0.5–2.2)	0.8
Proximal basilar artery	1.6 (0.4–7.3)	0.6
Middle basilar artery	2.8 (0.9–8.8)	0.07
Distal basilar artery	1.2 (0.3–5.6)	0.8
Posterior cerebral arteries	2.0 (0.6–8.2)	0.2
Absence of PComs (unilateral or bilateral)	6.8 (2–21)	0.001

CI indicates confidence interval; OR, odds ratio; and PCom posterior communicating artery.

We allocated 1 point for each of the other segments giving a maximum score of 10 (Figures 1 and 2):

1. 1 point if either intracranial vertebral artery was patent;
2. 1 point for each patent segment of the basilar artery, the proximal segment, extending from the vertebrobasilar junction to the origin of AICAs, the middle segment from the origins of AICAs to the origin of SCAs, and the rostral segment from the origin of SCAs to its rostral end; and
3. 1 point for each patent P1 segment of PCA.

Two investigators experienced in stroke imaging (F.A. and D.G.S.) independently reviewed the CTA images, blinded to clinical outcome. In case of disagreement, the final score was reached by consensus.

Outcome Measures

The primary objective of our study was to evaluate the prognostic value BATMAN score by testing its association with functional outcome. We also investigated the association of BATMAN score with outcome stratified by angiographic reperfusion status.

Functional outcome was assessed at 3 months according to the modified Rankin scale with a favorable outcome defined as modified Rankin scale score of 0 to 3, in accordance with the BASICS definition.[13] Additional data on NIHSS were available for the validation cohort (VC) allowing assessment of early neurological deterioration, defined as an increase of NIHSS score of ≥4 in the first 72 hours after the stroke.[23] Successful reperfusion was assessed by thrombolysis in cerebral infarction scale and defined as thrombolysis in cerebral infarction 2b-3.[16]

Statistical Analysis

Statistical analyses were performed using IBM SPSS version 23 software (IBM SPSS Statistics, Armonk, NY). Analysis of univariate data was performed using the Mann–Whitney *U* test for continuous data and Fisher exact test for categorical variables. Intraclass correlation coefficient was used to assess interrater agreement. Receiver operating characteristic (ROC) analysis was used to assess prognostic performance and the optimal score threshold to differentiate between good and poor outcome determined using Youden index (J=sensitivity+specificity−1). Area under ROC curve (AROC) was compared using the method of Hanley and McNeill.[24] Multivariate binary logistic regression was performed with covariates included if $P<0.1$ in univariate analysis. Bayesian information criterion (BIC) was used as a scalar measure to compare the overall goodness of fit for regression models incorporating different prognostic scores. Lower BIC indicates a more informative model with differences >10 regarded as a very strong evidence of model superiority.[25]

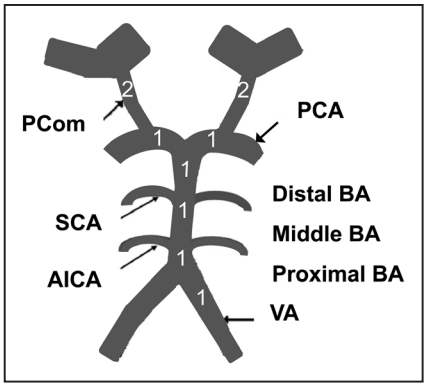

Figure 1. Basilar Artery on Computed Tomography Angiography score arterial segments. AICA indicates anterior inferior cerebellar artery; BA, basilar artery; PCA, posterior cerebral artery; PCom, posterior communicating artery; SCA, superior cerebellar artery; and VA, vertebral artery.

Results

Overall, 124 patients from 3 participating centers were included during the period of study after 10 were excluded because of missing follow-up. There were 83 patients in the DC and 41 patients in the VC. The 2 cohorts did not differ in their baseline characteristics (Table 2). Overall, 34 of 83 (41%) patients in the DC and 20 of 41 (49%) in the VC achieved a good outcome at 3 months. Among 73 patients undergoing EVT, 41 (56%) were treated within 6 hours from onset (or coma); overall good outcome was achieved in 31 (42.5%) patients and in 21 (51%) patients treated within 6 hours.

Derivation and Validation of the BATMAN Score

In univariate analysis of the DC, older age, higher NIHSS, the presence of coma, and diabetes mellitus were associated with poor outcome. The involvement of PCAs (P=0.007) and the absence of PComs (unilateral or bilateral) were strongly associated with poor outcome (P=0.001). In the VC, higher NIHSS was associated with poor outcome. Favorable outcome did not differ between intravenous thrombolysis and EVT patients in either cohort (P>0.1). Patients with a lower BATMAN score were more likely to have a poor outcome in both cohorts (Table 3). The distribution of BATMAN score and the distribution of modified Rankin scale according to the BATMAN score groups are shown in Table I in the online-only Data Supplement and in Figure 3.

In ROC analysis of the DC, AROC was 0.81 (95% CI, 0.7–0.9). The optimal threshold to differentiate patients likely to have a poor outcome was a BATMAN score of <7 (sensitivity=84%, specificity=76%). Patients with an unfavorable BATMAN score were more likely to present in coma (79% versus 21%, P=0.009). Baseline characteristics according to the BATMAN score groups in the DC are summarized in Table II in the online-only Data Supplement. In multivariate analysis, after adjustment for age and NIHSS, unfavorable BATMAN score was independently associated with poor outcome (OR, 5.5; 95% CI, 1.4–21; P=0.01).

The BATMAN score maintained acceptable performance in the VC with AROC 0.74 (95% CI, 0.6–0.9). In multivariate analysis, BATMAN score of <7 remained independently associated with poor outcome after adjustment for age and NIHSS (OR, 6.9, 95% CI, 1.4–33; P=0.01). Moreover, it was associated with early neurological deterioration (OR, 9.0; 95% CI, 0.9–86; P=0.05).

Table 2. Baseline Characteristics in Derivation Cohort and Validation Cohort

	Derivation Cohort (n=83)	Validation Cohort (n=41)	*P* Value
Age (y), mean	66±15	62±16	0.2
NIHSS, median (IQR)	16 (6–28)	17 (7–29)	0.7
Coma, n (%)	29 (35)	12 (29)	0.5
Male sex, n (%)	58 (70)	27 (66)	0.7
Risk factors, n (%)			
Hypertension	39 (47)	22 (54)	0.6
Hypercholesterolemia	24 (29)	9 (22)	0.5
Diabetes mellitus	21 (25)	11 (27)	0.9
Atrial fibrillation	25 (30)	8 (19.5)	0.3
Smoking	17 (20.5)	13 (32)	0.2
Coronary artery disease	22 (26.5)	5 (12)	0.1
Previous TIA/stroke	7 (8.5)	5 (12)	0.5
Stroke cause, n (%)*			
Cardioembolic	22 (26.5)	11 (27)	0.9
Atherosclerotic	19 (23)	16 (39)	0.1
Other	14 (17)	2 (5)	0.1
Undetermined	28 (34)	12 (29)	0.7
Intravenous thrombolysis, n (%)	26 (31)	32 (78)	<0.001
Endovascular treatment, n (%)	56 (67.5)	17 (41.5)	0.007
Heparin infusion, n (%)	9 (11%)	0	0.03
Location of the occlusion, n (%)			
Proximal basilar artery	27 (32.5)	14 (34)	0.9
Middle basilar artery	44 (53)	14 (34)	0.06
Distal basilar artery	56 (67.5)	25 (61)	0.5
Posterior cerebral arteries	45 (54)	17 (41.5)	0.2
Vertebral arteries	34 (41)	9 (22)	0.2
Absence of PComs	38 (46)	22 (54)	0.4
BATMAN score, median (IQR)	6 (4–7)	6 (5–7)	0.1
pc-CTA score, median (IQR)	3 (2–4)	2 (1–3)	0.01
PC-CS score, median (IQR)	5 (4–7)	5 (4–6)	0.1

Note: 3 patients did not receive treatment because of extensive early ischemic changes on admission noncontrast computed tomography. BATMAN indicates Basilar Artery on Tomography Angiography; IQR, interquartile range; NIHSS, National Institutes of Health Stroke Scale; PC-CS, Posterior Circulation Collateral score; pc-CTA, posterior circulation computed tomographic angiography; PCom, posterior communicating artery; and TIA, transient ischemic attack.

*Trial of Org 10172 in Acute Stroke Treatment classification.

Comparison of BATMAN Score With Other Predictive Models in the Pooled Cohort of Patients

In univariate analysis of the pooled cohort of endovascular patients (n=73), successful recanalization, OTT, and BATMAN score were associated with poor outcome (Table III in the online-only Data Supplement). BATMAN score was independently associated with functional outcome after adjustment for recanalization and OTT (OR, 4.8; 95% CI, 1.2–18; *P*=0.01). An unfavorable BATMAN score was also associated with higher risk of mortality (OR, 7.4; 95% CI, 1.2–44; *P*=0.03, after adjustment for age and NIHSS).

Recanalization success was similar in the favorable (26/33, 79%) and unfavorable (31/40, 77.5%) BATMAN score groups (*P*=0.9). Procedural times did not differ between favorable (median 93 minutes [IQR, 59–153]) and unfavorable (105 minutes (IQR 70–283]) BATMAN score groups (*P*=0.3). Poor outcome occurred in 90% of patients with unfavorable BATMAN score versus 85% of patients with favorable BATMAN score (*P*=0.9) if recanalization was not achieved, whereas it occurred in 76% of patients with unfavorable BATMAN score versus 24% of patients with favorable BATMAN score (*P*=0.001) with successful recanalization. Poor outcome was similar between patients treated 0 to 6 hours (7/20, 35%) and >6 hours (5/13, 38.5%) in the favorable BATMAN score group (*P*=0.9) and in 62% (13/21) of patients treated 0 to 6 hours versus 89.5% (17/19) of patients treated >6 hours in the unfavorable BATMAN score group (*P*=0.07).

We then compared BATMAN score with previously described prognostic scores for CTA in BAO[20,21] (Table IV in the online-only Data Supplement). Given the small sample size of VC, these were assessed in all 124 patients. In ROC analysis, BATMAN score (AROC, 0.8; 95% CI, 0.7–0.9) showed significantly higher accuracy in comparison with PC-CS (AROC, 0.63; 95% CI, 0.5–0.7; *P*=0.04) and the absence of PComs (AROC, 0.65; 95% CI, 0.5–0.7; *P*=0.05), but not with pc-CTA (AROC, 0.69; 95% CI, 0.6–0.8; *P*=0.1). Although an unfavorable PC-CS group (OR, 1.8; 95% CI, 1.0–3.2; *P*=0.04, after adjustment for age) and a lower pc-CTA (OR, 1.6; 95% CI, 1.1–2.1; *P*=0.008, after adjustment for age) were associated with poor outcome, these associations were not robust to adjustment for NIHSS for either score. Moreover, BATMAN score performed better than the model including other scores in logistic regression adjusted for age (BATMAN score BIC=132 versus PC-CS BIC=154, PComs BIC=159, and pc-CTA BIC=158). Interrater agreement between the 2 investigators was moderate for PC-CS (intraclass coefficient correlation, 0.67; 95% CI, 0.47–0.78) and substantial for BATMAN score (intraclass coefficient correlation, 0.85; 95% CI, 0.76–0.90) and pc-CTA (intraclass coefficient correlation, 0.87; 95% CI, 0.81–0.92).

Discussion

BATMAN score is a systematic scoring system for CTA that seems to have substantial interrater reliability and maintained prognostic accuracy in an external VC. Patients with unfavorable BATMAN score are less likely to have a good outcome, even when successful recanalization is achieved. The prognostic value of BATMAN score applied to patients treated within and beyond 6 hours. Patients with favorable BATMAN score may achieve good outcomes after recanalization, even in delayed time windows. This emphasizes the importance of collateral assessment in the posterior circulation, analogous to the more established role of collateral assessment in the anterior circulation.[6]

Although the PC-CS proposed by the BASICS group showed a significant association between the number of

Table 3. Comparison Between Patients With Good and Poor Outcomes

	Derivation Cohort (n=83)			Validation Cohort (n=41)		
	Good Outcome (n=34)	Poor Outcome (n=49)	*P* Value	Good Outcome (n=20)	Poor Outcome (n=21)	*P* Value
Age (y), mean	61±17	69±12	0.01	59±17	65±14	0.3
NIHSS, median (IQR)	8 (3–15)	22 (8–28)	0.004	10 (4–19)	20 (11–33)	0.02
Coma, n (%)	5 (15)	24 (49)	0.002	3 (15)	9 (43)	0.08
Male sex, n (%)	21 (62)	37 (75.5)	0.2	11 (55)	16 (76)	0.2
Risk factors, n (%)						
Hypertension	14 (41)	25 (51)	0.9	11 (55)	11 (52)	0.9
Hypercholesterolemia	8 (23.5)	16 (33)	0.6	5 (25)	4 (19)	0.5
Diabetes mellitus	3 (9)	18 (37)	0.005	4 (20)	7 (33)	0.5
Atrial fibrillation	10 (29)	15 (31)	0.9	3 (15)	5 (24)	0.7
Smoking	9 (26.5)	8 (16)	0.3	6 (30)	7 (33)	0.9
Coronary artery disease	8 (23.5)	14 (29)	0.8	2 (10)	3 (14)	0.9
Previous TIA/stroke	2 (6)	5 (10)	0.7	2 (10)	3 (14)	0.9
Stroke cause, n (%)*						
Cardioembolic	9 (26.5)	13 (26.5)	0.9	5 (25)	6 (29)	0.9
Atherosclerotic	6 (18)	13 (26.5)	0.4	5 (25)	11 (52)	0.07
Other	3 (9)	15(31)	0.03	2 (10)	0	0.2
Undetermined	11 (32)	13 (26.5)	0.6	7 (35)	5 (24)	0.5
Intravenous thrombolysis, n (%)	11 (32)	15 (31)	0.9	16 (80)	16 (76)	0.9
Endovascular treatment, n (%)	25 (73.5)	31 (63)	0.3	7 (35)	10 (48)	0.5
Heparin infusion, n (%)	6 (18)	3 (6)	0.1			
Location of the occlusion, n (%)						
Proximal basilar artery	9 (26.5)	18 (37)	0.3	8 (40)	6 (29)	0.5
Middle basilar artery	14 (41)	30 (61)	0.08	4 (20)	9 (43)	0.2
Distal basilar artery	23 (68)	33 (67)	0.9	11 (55)	14 (67)	0.5
Posterior cerebral arteries	12 (35)	33 (67)	0.007	6 (30)	11 (52)	0.2
Vertebral arteries	12 (35)	22 (45)	0.5	3 (15)	6 (29)	0.4
Absence of PComs	8 (23.5)	30 (61)	0.001	10 (50)	12 (57)	0.7
BATMAN score, median (IQR)	7 (6–8)	5 (3–6)	<0.001	7 (6–8)	6 (5–6)	0.004
pc-CTA score, median (IQR)	2 (2–3)	3 (2–4)	0.02	1 (1–2)	3 (1–3)	0.01
PC-CS score, median (IQR)	6 (4–8)	4 (3–6)	0.03	5 (4–7)	5 (4–6)	0.3

BATMAN indicates Basilar artery on Tomography Angiography; IQR, interquartile range; NIHSS, National Institutes of Health Stroke Scale; PC-CS, Posterior Circulation Collateral score; pc-CTA, posterior circulation computed tomographic angiography; PCom, posterior communicating artery; and TIA, transient ischemic attack.

*Trial of Org 10172 in Acute Stroke Treatment classification.

ineffective collaterals and poor outcome in a large cohort of BAO patients, a moderate interrater agreement was observed between the investigators, and an external validation of this model was not previously performed. We validated the PC-CS model in an independent cohort and found similar prognostic accuracy. In our analysis, PC-CS remained predictive of outcome after adjustment for age, but not for stroke severity. These results are consistent with the BASICS findings. We found the BATMAN score to be more prognostically accurate than PC-CS in both ROC and logistic regression analyses. Furthermore, interrater agreement was higher for BATMAN score.

The BASICS authors confirmed a statistically significant reduction in risk of poor outcome in the presence of at least 1 PCom and for larger caliber PComs in their multivariate analysis (risk ratio, 0.79; 95% CI, 0.66–0.95; and 0.76; 95% CI, 0.61–0.96, respectively).[20] Similarly, Goyal et al[19] showed that patients with bilateral PComs on CTA have more favorable outcome than patients with unilateral/absent PCom (*P*=0.001), and Hong et al[18] showed that fetal PComs

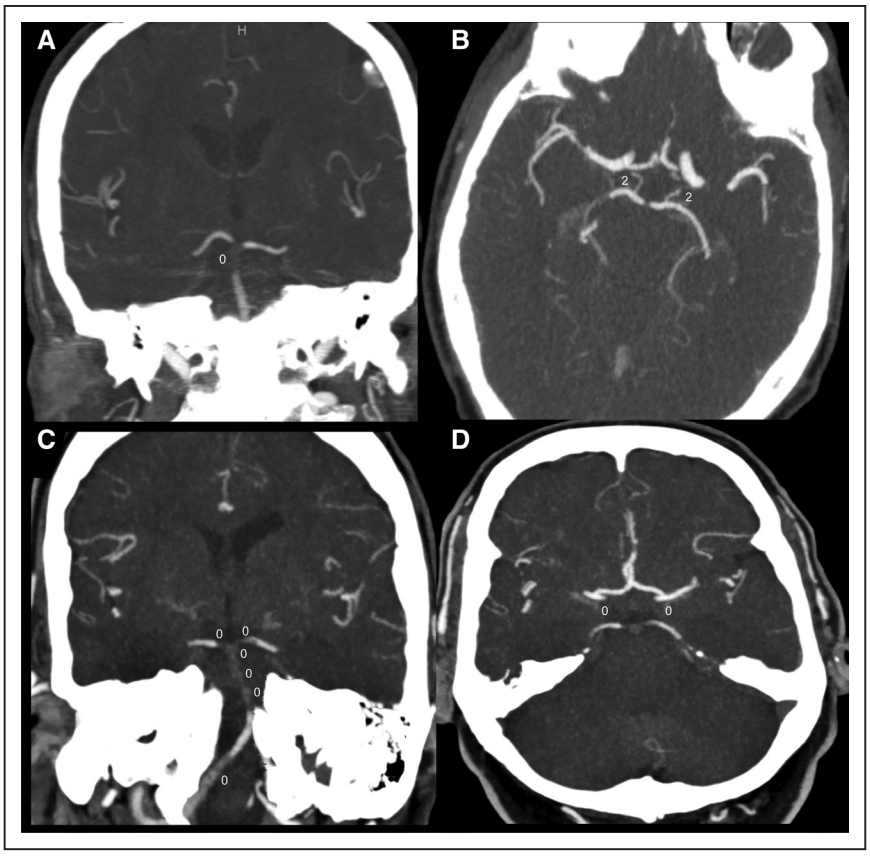

Figure 2. A and **B**, A patient with BATMAN score=9 (distal basilar occlusion only and bilateral PComs). **C** and **D**, A patient with BATMAN score=0 (extensive occlusion of basilar artery and absence of PComs). BATMAN indicates Basilar Artery on Computed Tomography Angiography; and PComs, posterior communicating arteries.

were predictors of good prognosis in BAO (OR, 5.1; 95% CI, 1.4–18.8). PComs, therefore, seem to be the main collaterals pathways involved in the pathophysiology of BAO, although 1 recent series was unable to find an association between collaterals and outcome.[26]

In our study, we decided to consider collaterals not in isolation but as a modifying factor which could play a role in limiting or worsening the ischemic damage secondary to the extent of BAO. BATMAN score is the first radiological score that takes into account the extent of BAO (in terms of functional localization rather than thrombus length) and thus the likely number of obstructed perforating arteries and other collaterals (posterior inferior cerebellar arteries, AICAs, and SCAs), adjusted for the protective effect of PCom collaterals. Indeed, although the presence of PComs was confirmed as a good predictor of outcome in our population, BATMAN score performed better than a stand-alone PCom assessment and better than the other scores mentioned above.

BATMAN score was confirmed as a strong predictor of functional outcome and mortality even in endovascular patients. This was not because of a difference in recanalization success between BATMAN categories. Patients with favorable BATMAN score seem likely to benefit from successful recanalization and achieve good functional outcome (76% in our series), whereas severe disability or death occurred in 76% of those with poor collaterals and extended thrombus burden, despite successful recanalization. BATMAN score may, therefore, be a useful tool to identify patients unlikely to benefit from reperfusion therapies. Nevertheless, treatment protocols in our patients included intra-arterial therapy with urokinase and mechanical thrombectomy with different generation devices. Further studies in larger series of patients treated with

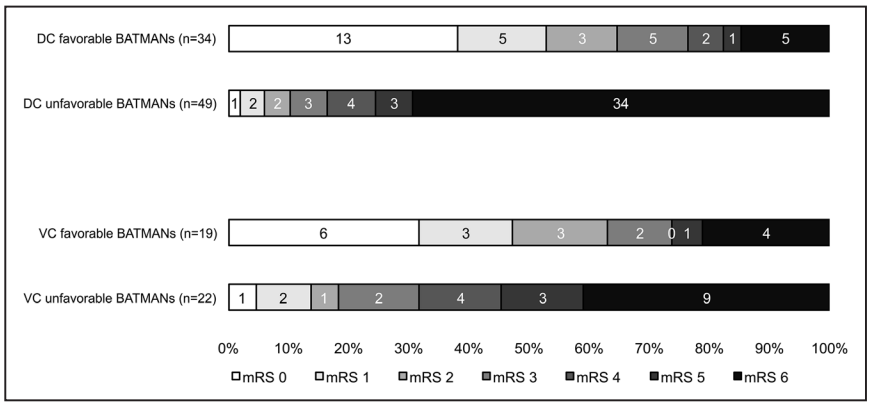

Figure 3. Distribution of modified Rankin scale (mRS) at 3 months according to Basilar Artery on Computed Tomography Angiography (BATMAN) score groups in the derivation cohort (DC) and validation cohort (VC).

mechanical thrombectomy using recent devices are needed to confirm these findings and to better define the time window to treat patients with a favorable score.

In our population, the rate of good functional outcome was consistent with other previous studies[10,16] but higher than the 32% reported in the BASICS registry. Similarly, 42.5% of endovascular patients achieved a good outcome, in accordance with recent observational data.[16,26]

The main limitation of our study is its retrospective nature and the relatively small number of patients. Treatment protocols selection for EVT differed between our DC and VC, and several scanners were used for the acquisition of CTA images. However, these differences increase the generalizability of our results. Contrast-enhanced magnetic resonance angiography may also allow assessment of BATMAN score.

Conclusions

This study has developed and validated a new radiological score using CTA in BAO patients evaluating both the extent of the occlusion and the presence of collaterals. BATMAN score may be a useful prognostic marker of outcome in BAO and is easy to assess in the acute setting. Further studies in larger and prospective series are warranted to validate BATMAN score and to further clarify patients who are more likely to benefit from reperfusion therapies.

Disclosures

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The Basilar Artery on Computed Tomography Angiography Prognostic Score for Basilar Artery Occlusion

Fana Alemseged, Darshan G. Shah, Marina Diomedi, Fabrizio Sallustio, Andrew Bivard, Gagan Sharma, Peter J. Mitchell, Richard J. Dowling, Steven Bush, Bernard Yan, Carlo Caltagirone, Roberto Floris, Mark W. Parsons, Christopher R. Levi, Stephen M. Davis and Bruce C.V. Campbell

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SUPPLEMENTAL TABLES

Table I. Distribution of BATMAN score.

BATMAN score (0-10)	Derivation cohort (n=83)	Validation cohort (n=41)	Overall (n=124)
9	5 (6%)	2 (5%)	7 (6%)
8	9 (11%)	6 (15%)	15 (12%)
7	20 (24%)	11 (27%)	31 (25%)
6	12 (14.5%)	10 (24%)	22 (18%)
5	10 (12%)	9 (22%)	19 (15%)
4	11 (13%)	2 (5%)	13 (10.5%)
3	9 (11%)	1 (2.5%)	10 (8%)
2	4 (5%)	0	4 (3%)
1	2 (2.5%)	0	2 (2%)
0	1 (1%)	0	1 (1%)

Table II. Baseline characteristics according to BATMANs in the Derivation cohort.

	Derivation cohort (n=83)		
	Favorable BATMANs (n=34)	Unfavorable BATMANs (n=49)	p
Age (years), mean	62±17	69±12	0.03
NIHSS*, median (IQR)	9 (4.5-16.5)	22 (8-28)	0.02
Coma, n (%)	6 (18)	23 (47)	0.009
Male sex, n (%)	22 (65)	36 (73.5)	0.5
Risk factors, n (%)			
Hypertension	12 (35)	27 (55)	0.1
Hypercholesterolemia	9 (26.5)	15 (31)	0.9
Diabetes Mellitus	5 (15)	16 (33)	0.8
Atrial fibrillation	9 (26.5)	16 (33)	0.6
Smoking	7 (21)	10 (20.5)	0.9
Coronary artery disease	7 (21)	15 (31)	0.5

Previous TIA†/Stroke	1 (3)	7 (14)	0.1
Stroke etiology‡, n (%)			
Cardioembolic	7 (21)	15 (31)	0.5
Atherosclerotic	6 (18)	8 (16)	0.9
Other	5 (15)	13 (26.5)	0.2
Undetermined	15 (44)	12 (24.5)	0.1
Mean arterial pressure, mmHg, median (IQR)	91 (87-107)	105 (95-111)	0.1
Glycemia, mmol/l, median (IQR)	6 (5-8)	7 (6-8)	0.4
Time from onset to CTA§, median (IQR)	250 (124-454)	200 (119-360)	0.4
Intravenous thrombolysis, n (%)	10 (29.5)	15 (31)	0.9
Endovascular treatment, n (%)	26 (76.5)	30 (61)	0.1
Heparin infusion, n (%)	5 (15)	4 (8)	0.5
Location of the occlusion, n (%)			
Proximal basilar artery	10 (29.5)	17 (35)	0.6
Middle basilar artery	14 (41)	30 (61)	0.08
Distal basilar artery	19 (56)	37 (75.5)	0.09
Posterior cerebral arteries	8 (23.5)	37 (75.5)	0.001
Vertebral arteries	11 (32)	23 (47)	0.3
Absence of PComs‖	4 (12)	34 (69)	0.001
pcASPECTS#, median (IQR)	10 (9-10)	10 (9-10)	0.08

*NIHSS National Institutes of Health Stroke Scale; †TIA transient ischemic attack; ‡Trial of Org 10172 in Acute Stroke Treatment (TOAST) classification; §CTA Computed Tomography Angiography;‖PCom posterior communicating artery; #pcASPECTS Posterior Circulation Acute Stroke Prognosis Early CT score. NB 3 patients did not receive treatment because of extensive early ischemic changes on admission non contrast CT.

Table III. Univariate analysis in the pooled cohort of endovascular patients.

	Good outcome (n=31)	Poor outcome (n=42)	OR‡ (95% CI§)	p
Time to treatment, n (%)				
0-6 hours	21 (68)	20 (48)	2.2 (1.0-4.7)	0.05
6-12 hours	9 (29)	16 (38)		
>12 hours	1 (3)	6 (14)		

Successful recanalization, TICI* 2b-3, n (%)	29 (93.5)	28 (67)	0.1 (0.0-0.7)	0.01
BATMANs, median (IQR)	7 (6-8)	4 (3-5)	0.6 (0.4-0.8)	0.001

*TICI Thrombolysis in Cerebral Infarction; †BATMANs Basilar artery on Tomography Angiography score; ‡OR, odd ratio for poor outcome; §CI confidence interval

Table IV. BATMANs versus other vascular scores in the pooled cohort.

	Pooled Cohort (n=124)		
	Favorable BATMANs (n=53)	Unfavorable BATMANs (n=71)	p
Good PC-CS* (6-10), n (%)	33 (65)	12 (18)	0.001
Intermediate PC-CS (4-5), n (%)	15 (29)	35 (51)	
Poor PC-CS (0-3), n (%)	3 (6)	21 (31)	
pc-CTA†, median (IQR)	2 (1-2)	3 (2-4)	0.0001

*PC-CS Posterior Circulation Collateral Score; †pc-CTA posterior circulation Computed Tomography Angiography. NB In 5 patients PC-CS was not assessed for artefacts/not evaluable PICAs.