Development and validation of a novel nomogram to predict aneurysm rupture in patients with multiple intracranial aneurysms: a multicenter retrospective study

SUPPLEMENTRY METERIALS

Table S1. Major packages of R software used in this study.

Functions	**R package**
logistic regression analysis	glm
Plot the receiver operating curve (ROC) and measure the area under the ROC (AUC)	pROC
Hosmer and Lemeshow goodness of fit (GOF) test	ResourceSelection
Plot bar diagrams	ggplot2
Plot calibration curves, Brier score and develop nomogram	rms
Decision curve analysis (DCA)	rmda

Table S2. The baseline characteristics and univariable analysis between ruptured and unruptured group of 700 patients and 1671 aneurysms

Characteristic	Ruptured cohort	Unruptured cohort	P value	OR	95%CI
Patients					
No.	158(22.6)	542(77.4)			
Female sex	119 (75.3)	356(65.4)	**0.023**	1.594	1.066-2.385
Age (years)	58.4(12.3)	57.2(10.1)	0.253	1.011	0.994-1.028
< 50	35(22.2)	109(20.1)	**0.013**	-	-
50-70	95(60.1)	380(70.1)		0.779	0.500-1.212
≥ 70	28(17.7)	53(9.8)		1.645	0.907-2.985
History of SAH	36(22.8)	7(1.3)	**< 0.001**	22.553	9.803-51.884
Number of IAs	2.5(0.9)	2.3(0.7)	**0.017**	1.277	1.038-1.571
2	202(64.6)	401(74.0)	**0.036**	-	-
3-4	51(32.3)	134(24.7)		1.496	1.014-2.207
>4	5(3.2)	7(1.3)		2.808	0.873-9.030
Comorbidities					
Hypertension	97 (61.4)	271(50.0)	**0.012**	1.590	1.107-2.283

Diabetes	10 (6.3)	67(12.4)	**0.033**	0.479	0.240-0.955
Hypercholesterolemia	16 (10.1)	58(78.4)	0.836	0.940	0.524-1.686
Heart diseases	10 (6.3)	55(10.1)	0.146	0.598	0.298-1.203
History of stroke	15 (9.5)	63(11.6)	0.454	0.798	0.441-1.443
Smoking	35 (22.2)	95(17.5)	0.188	1.339	0.866-2.070
Drinking	31 (19.6)	75(13.8)	0.074	1.520	0.957-2.413
Aneurysms					
Size, mm	5.7(3.1)	5.2(4.3)	0.214	1.022	0.987-1.058
< 3	22(13.9)	418(27.6)	Ref	-	-
3-7	99(62.7)	808(53.4)	0.773	0.737	0.093-5.860
7-15	34(21.5)	231(15.3)	0.604	1.715	0.223-13.185
15-25	2(1.3)	42(2.8)	0.492	2.061	0.263-16.175
>25	1(0.6)	14(0.9)	0.748	0.660	0.056-7.925
Neck	3.9(1.85)	4.0(2.66)	0.407		
> 3.9	96(60.8)	966(63.8)	0.443	1.141	.0815-1.596
Aspect ratio	1.5(0.82)	1.2(0.66)	<0.001		
>1.5	64(40.5)	291 (19.2)	0.001	2.859	2.030-4.027
Branching to parent ratio	1.2(0.3)	1.1(0.3)	0.017	1.646	1.088-2.491
>1.2	50(31.6)	273(18.0)	<0.001	2.103	1.467-3.014

Neck to parent ratio	1.3(0.61)	1.2(0.70)	0.090		
>1.2	55(34.8)	463(30.6)	0.276	1.211	0.858-1.710
Size ratio	1.8(0.88)	1.4(1.07)	<0.001	1.299	1.156-1.460
>1.7	63(39.9)	299(19.8)	<0.001	2.653	1.911-3.793
Locations of aneurysms					
Internal carotid artery	84 (53.2)	897(59.3)	Ref	-	-
Posterior communicating artery	18(11.4)	207(13.7)	0.784	0.929	0.546-1.579
Anterior cerebral artery and branches	13(8.2)	130(8.6)	0.027	1.068	0.579-1.970
Middle cerebral artery	10(6.3)	128(8.5)	0.796	0.834	0.422-1.649
Posterior circulation	33(12.7)	151(10.8)	<0.001	2.334	1.506-3.616
Location of Posterior circulation	33(20.9)	151(10.0)	<0.001	2.381	1.566-3.620
Geometry					
Regular	70(44.3)	1001(66.2)	Ref	-	-
Irregular	88(55.7)	513(33.8)	<0.001	2.458	1.764-3.424
Parent artery configuration					
Sidewall aneurysm	93(58.9)	1168(77.2)	Ref	-	-
Bifurcation location	65(41.1)	345(22.8)	<0.001	2.366	1.686-3.321
Inflow angle, mean (SD)	102(29)	108(29)	0.008	1.008	1.002-1.013

Outflow angle, mean (SD)	103(29)	101(31)	0.362	1.002	0.997-1.008
Branching angle, mean (SD)	130(35)	137(34)	0.017	0.995	0.990-0.999

Table S3. Baseline characteristics of derivation cohort and validation cohort

Characteristic	Derivation Cohort (n=1171)	Validation Cohort (n=500)	P-value
Aneurysm ruptured	104(8.9)	54 (10.8)	0.220
Female sex	813(69.4)	334(66.8)	0.289
Age (years)	57.9(10.7)	58.0(11.2)	0.785
< 50	237(20.2)	92 (18.4)	0.477
50-70	791(67.5)	338(36.7)	
≥ 70	143(12.2)	70(14.0)	
History of SAH	79(6.7)	34(6.8)	0.968
Number of aneurysms	2.6(1.1)	2.6(1.0)	0.394
2	701(59.9)	308(61.6)	0.796
3-4	417(35.6)	171(34.2)	
>4	53(4.5)	21(4.2)	
Comorbidities			
Hypertension	624 (53.3)	269(53.8)	0.848
Diabetes	136 (11.6)	44(8.8)	0.089
Hypercholesterolemia	121(10.3)	57(11.4)	0.517
Heart diseases	118(10.1)	42(8.4)	0.286
History of stroke	131 (11.2)	60(12.0)	0.632
Smoking	219 (18.7)	99(19.8)	0.601
Drinking	159 (13.6)	84(16.8)	0.087
Size	5.2(4.0)	5.4(4.7)	0.191
< 3	305(26.0)	135(27.0)	0.225
3-7	638(54.5)	269(53.8)	
>7	228(19.5)	96(19.2)	
Neck	4.0(2.6)	4.1(2.6)	0.660
> 3.9	751(64.1)	311(62.2)	0.452
Aspect ratio	1.21(0.70)	1.23(0.67)	0.580
>1.5	237(20.2)	118 (23.6)	0.124

Branching to parent ratio	1.2(0.3)	1.1(0.3)	0.297
>1.2	220(18.8)	103(20.6)	0.390
Neck to parent ratio	1.18 (0.70)	1.20(0.73)	0.537
>1.2	366(31.3)	152(30.4)	0.729
Size ratio	1.37(1.02)	1.43(1.15)	0.281
>1.7	246(21.0)	116(23.2)	0.319
Location of PC	132(11.3)	52(10.4)	0.602
Irregular shape	410(35.0)	190(38.0)	0.244
Bifurcation location	277(23.7)	133(26.6)	0.200
Inflow angle, mean (SD)	97(35)	100(31)	0.064
Outflow angle, mean (SD)	102(31)	101(30)	0.660
Branching angle, mean (SD)	136(34)	136(35)	0.992

SAH, subarachnoid hemorrhage; PC, posterior circulation

Table S4. Baseline characteristics of derivation cohort and validation cohort in subarachnoid hemorrhage patient with multiple aneurysms.

Characteristic	Derivation Cohort (n=271)	Validation Cohort (n=129)	P-value
Aneurysm ruptured	113(41.7)	45 (34.9)	0.193
Size			
< 3	73(26.9)	43(33.3)	0.407
3-7	161(59.4)	71(55.0)	
>7	37(13.7)	15(11.6)	
Neck > 3.9	73(26.9)	35(27.1)	0.967
Aspect ratio >1.5	80(29.5)	29(22.5)	0.139
Branching to parent ratio >1.2	79(29.2)	28(21.7)	0.116
Neck to parent ratio >1.2	76 (28.0)	36(27.9)	0.977
Size ratio >1.7	68(25.1)	30(23.3)	0.690
Location of Posterior circulation	36(13.3)	22(17.1)	0.317
Irregular shape	112(41.3)	54(41.9)	0.920
Bifurcation location	100(36.9)	22(32.6)	0.396
Inflow angle, mean (SD)	97(35)	99(31)	0.064
Outflow angle, mean (SD)	102(31)	101(30)	0.655
Branching angle, mean(SD)	136(34)	136(35)	0.992

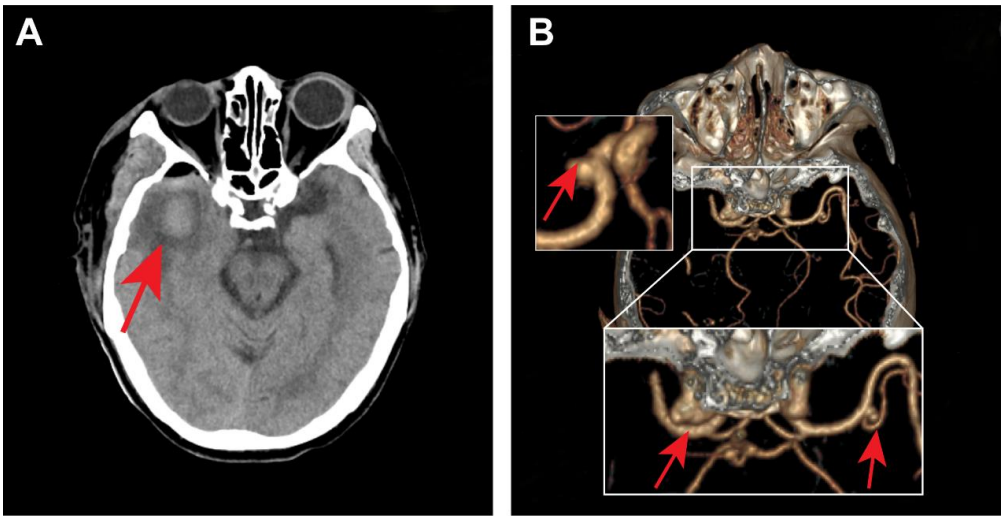

Figure S1: Definitive hemorrhage pattern to confirm the ruptured aneurysm.

A 58-year-old men who presented with SAH (A, non-contrast CT scan) was found to have right internal carotid aneurysm and left MCA aneurysms (red arrows, right image, CTA). A focal hematoma in the anterior circulation (black arrow, left image) delineated the right internal carotid aneurysm as the source of bleeding,

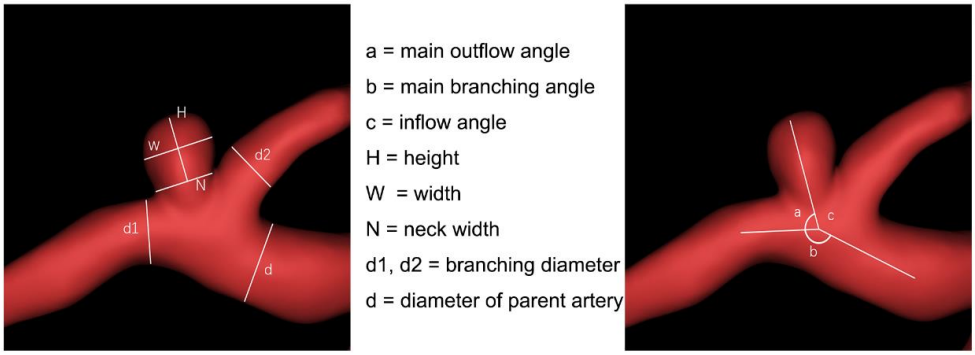

Figure S2: Measurements of the aneurysm: dimensions (left) and related angles (right).

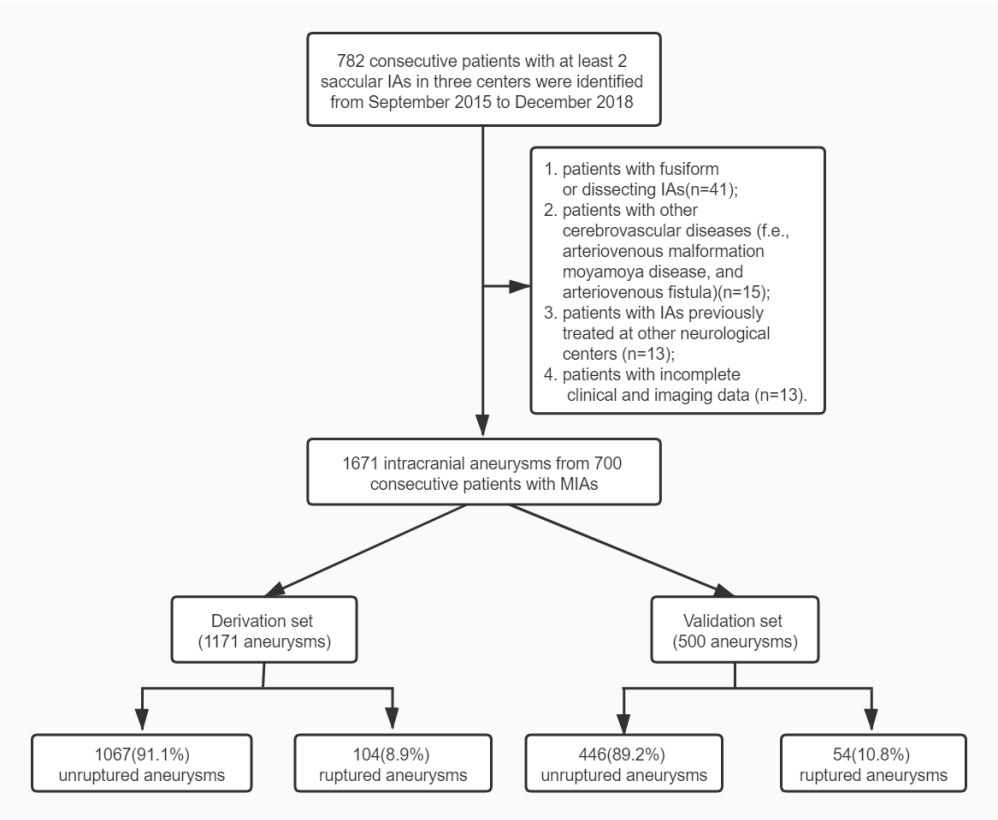

Figure S3: Flowchart of our study.
IA, intracranial aneurysm; MIAs, multiple intracranial aneurysms.

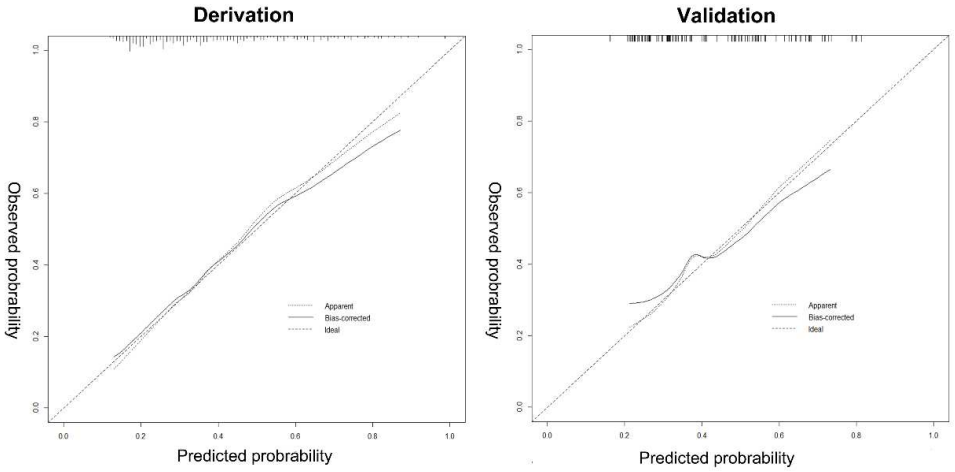

Figure S4: Calibration curves of the model of MIA patients with SAH in the derivation (A) and validation (B) set.

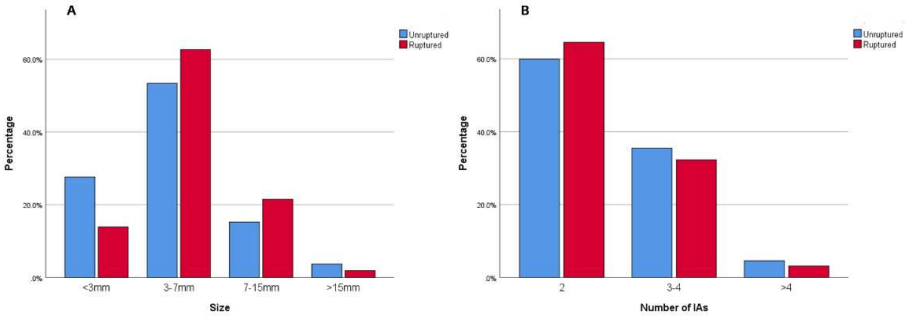

Figure S5: Distribution of aneurysm size(A) and number of combined aneurysms (B) in the ruptured and unruptured aneurysms.

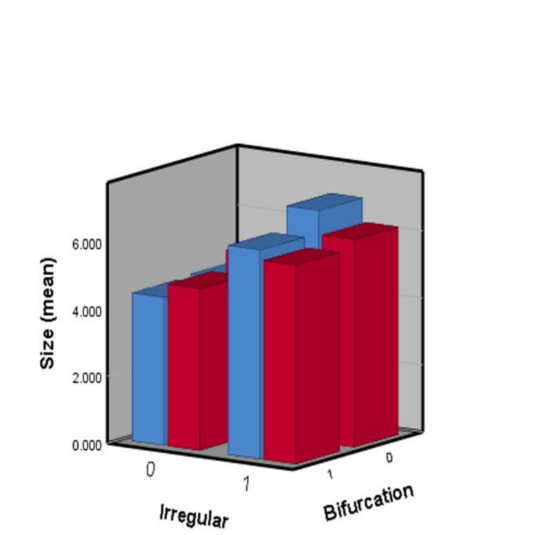

Figure S6: Relationship between mean aneurysm size and irregularities and bifurcation location.