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► To cite this version:

Mahmoud Elhorany, Grégoire Boulouis, Wagih Ben Hassen, Sophie Crozier, Eimad Shotar, et al.. Outcome and recanalization rate of tandem basilar artery occlusion treated by mechanical thrombectomy. *Journal de Neuroradiologie / Journal of Neuroradiology*, 2020, 47, pp.404 - 409. 10.1016/j.neurad.2020.08.004 . hal-03493468

HAL Id: hal-03493468

<https://hal.science/hal-03493468>

Submitted on 17 Oct 2022

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1 **Original Article**

2 **Outcome and Recanalization Rate of Tandem Basilar Artery**
3 **Occlusion Treated by Mechanical Thrombectomy**

4
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31

32 *Word Count of main text:* 3900.

33 *Word count of abstract:* 247.

34 **Total number of tables and figures:** Tables:2, figures:2.

35 *Total number of references:* 23.

36

37 **Short title**

38 *Thrombectomy in Tandem Basilar Artery Occlusion.*

39

40 **Key words**

41 *Basilar artery occlusion, tandem, vertebral artery occlusion, mechanical thrombectomy,*
42 *recanalization, outcome.*

43 **Declarations**

44

45 **Funding**

46 This research received no specific grant from any funding agency in the public, commercial, or
47 not-for-profit sectors.

48 **Conflicts of interest/Competing interests**

49 Pr F. Clarençon reports conflict of interest with Medtronic, Guerbet, Balt Extrusion, Penumbra
50 (payment for readings), Codman Neurovascular and Microvention (core lab).

51 Dr N. Sourour is consultant for Medtronic, Balt Extrusion, Microvention.

52 **Ethical approval**

53 This study received the approval of our institutional review committee. The need for written
54 informed consent from patients has been removed for the retrospective analysis of data
55 routinely acquired by our ethics committee.

56 **Availability of data and material**

57 The data supporting the conclusion of this study are available upon appropriate request from the
58 corresponding author (F.C).

59 **Author contributions**

60 All the co-authors shared equally to prepare and accomplish this manuscript.

61 Frederic Clarençon and Olivier Naggara supervised the work and critically reviewed the
62 manuscript.

63 **Acknowledgements**

64 None

1 **Original Article**

2 **Outcome and Recanalization Rate of Tandem Basilar Artery**
3 **Occlusion Treated by Mechanical Thrombectomy**

4
5 **Abstract**

6 **Background**

7 Tandem basilar artery occlusions (tBAO) are defined as concomitant basilar artery and
8 extracranial dominant vertebral artery occlusions. The prognosis of such tBAO treated by
9 mechanical thrombectomy (MT) has been scantily reported.

10

11 The purpose of our study was to compare the safety and effectiveness of MT for patients with
12 tBAO compared to those with non-tandem basilar artery occlusions (ntBAO).

13

14 **Patients and Methods**

15 Retrospective analysis of a database of patients who underwent MT at two academic centres.

16 All patients treated for BAO were retrieved. Patients with tBAO, defined as a concomitant
17 BAO and extracranial vertebral artery (VA) occlusion or severe stenosis $\geq 70\%$ (V1 or proximal
18 V2 segment) were compared with patients with non-tandem BAO (ntBAO).

19

20 **Results**

21 A total of 15 patients with tBAO and 74 patients with ntBAO were enrolled. Successful
22 reperfusion (modified thrombolysis in cerebral infarction score $\geq 2b$) was obtained in 73.3%

23 versus 90.5% (OR=0.29, 95%CI: 0.07-1.15), good clinical outcome (3-months modified Rankin
24 scale ≤ 2) was reached by 26.7% versus 32.4% (OR=0.76; 95% CI: 0.24-2.63) and mortality at
25 3-months was 46.7% versus 31% (OR=1.94; 95%CI: 0.63-6) of patients with tBAO versus
26 ntBAO, respectively. Two patients (13.3%) with tBAO and three (4%) with ntBAO had
27 symptomatic intracranial haemorrhage (OR=3.64; 95% CI: 0.55-24).

28

29 **Conclusion**

30 Mechanical thrombectomy for patients with tandem basilar artery occlusion tends to be
31 associated with lower rates of successful reperfusion and good clinical outcome, and higher
32 rate of mortality. Larger multicentre studies are warranted to better precise the proper
33 selection and management of such patients.

34

35 **Abbreviations and acronyms:**

36

37 **tBAO**; tandem basilar artery occlusion, **MT**; mechanical thrombectomy, **ntBAO**; non-tandem
38 basilar artery occlusion, **VA**; vertebral artery, **AIS**; acute ischemic stroke, **LVO**; large vessel
39 occlusion, **BA**; basilar artery, **NIHSS**; National Institute of Health Stroke Scale, **mRS**; modified
40 Rankin scale, **mTICI**; modified thrombolysis in cerebral infarction score, **BAO**; basilar artery
41 occlusion, **SICH**; symptomatic intracranial haemorrhage, **DSA**; digital subtraction
42 angiography.

43

44

45

46 **Introduction**

47

48 Basilar artery occlusion (BAO) is estimated to account for 1% of all acute ischemic stroke (AIS)
49 and 5-10% of those with large intracranial vessel occlusions (LVO). BAO represents a severe
50 subtype of AIS with high disability and mortality rate, up to 70%.[1] Since 2015, mechanical
51 thrombectomy (MT) has become standard of care for the management of anterior circulation
52 AIS with LVO.[2, 3] However, lesser evidence on the safety and effectiveness of MT regarding
53 acute vertebrobasilar artery occlusions exists.[4, 5] It is thought that the pathologic
54 mechanisms and outcomes of stroke in the posterior circulation could be different from those
55 in the anterior circulation due to anatomic differences between both systems.[6]

56

57 Tandem occlusions are defined as concomitant extracranial and intracranial occlusions in the
58 same vascular territory.[7, 8] Tandem BAOs (tBAOs) are hence defined as concomitant
59 vertebral artery (VA) and basilar artery (BA) occlusions.[9] The outcome of patients with
60 tBAOs has been scarcely described in the literature, mainly in short mono-centres
61 literature.[9-16]

62

63 We hypothesized that tBAO might harbour procedural difficulties that might carry different
64 angiographic and clinical outcomes from those with non-tandem BAO (ntBAO). Hence, the
65 aim of this work was to evaluate the reperfusion rate and clinical outcome of patients with
66 tBAO treated with MT in comparison to patients who underwent MT for ntBAO.

67

68 **Patients and methods**

69

70 *Study Design*

71 Retrospective multicentre (2 centres) comparative study was conducted according to the
72 STROBE guidelines.[17]

73

74 *Patient population*

75 Prospectively filled databases of MT procedures for AIS due to LVO performed from 2010 to
76 2019 at two academic centres were retrospectively queried. The study was approved by the
77 institutional review board (IRB). The need for patients' informed consent for retrospective
78 analyses of records and imaging data was waived by our IRB.

79

80 *Inclusion criteria*

81 Among patients treated with MT for AIS with LVO, all patients treated for BAO were retrieved.
82 Inclusion criteria were: acute neurologic symptoms attributable to BAO confirmed by vascular
83 imaging, time interval of 24 hours or less from stroke symptoms' onset defined as the time
84 the patient was last seen well, baseline National Institutes of Health Stroke Scale score
85 (NIHSS) of 4 or higher, no intracranial haemorrhage detected at initial brain imaging.

86

87 The study patients were divided into two groups: tandem BAO (tBAO) including patients with
88 a concomitant BAO and extracranial vertebral artery (VA) occlusion or severe stenosis \geq 70%
89 (V1 or proximal V2 segment); and non-tandem BAO (ntBAO) including patients with isolated
90 BAO.

91

92 *Evaluation Criteria*

93 The primary end point was the rate of good clinical outcome defined as modified Rankin scale
94 (mRS) ≤ 2 at 3-months. Secondary evaluation criteria included the rate of successful
95 reperfusion defined as modified thrombolysis in cerebral infarction score (mTICI) $\geq 2b$,
96 3-months' mortality rate and the rate of major procedure-related complications defined as
97 follows: symptomatic intracranial haemorrhage (SICH) according to the trial of thrombolytic
98 therapy with intravenous alteplase in acute ischaemic stroke (ECASS II) study criteria
99 (responsible for a clinical worsening ≥ 4 points on the NIHSS)[18], embolus to distal territory,
100 vascular perforation, symptomatic vessel dissection and groin puncture complication
101 requiring blood transfusion or surgical repair. Minor procedure-related complications,
102 defined as asymptomatic vessel dissection during the procedure not requiring further
103 intervention and minor groin puncture complications not requiring blood transfusion or
104 surgical repair, were also assessed.

105

106 *More detailed methodology in Supplemental material.*

107

108 In patients with tandem occlusion, a retrograde approach was performed for MT that meant
109 addressing firstly the intracranial occlusion followed by recanalization of the extracranial
110 occlusion.[19]

111

112 The BA was most frequently accessed via the ipsilateral affected VA (the so-called "dirty-road"
113 pathway). The proximal lesion was passed by the intermediate distal access catheter over the
114 guidewire or the micro-guidewire and the microcatheter. Balloon angioplasty for the proximal
115 lesion was performed if failure of passing the proximal lesion. Once the intracranial occlusion

116 was recanalized, the guiding catheter was pulled down under aspiration. Cervical stenting of
117 the proximal occlusion was then decided if a reduction of the intracranial flow was observed
118 on the control digital subtraction angiography (DSA). Alternatively, if access through the
119 affected VA was not possible, access via the contralateral VA (so-called “clean-road” pathway)
120 was then performed.

121

122 *Statistical Analysis*

123 Data analysis was performed using (IBM Corp. Released 2017. IBM SPSS Statistics for
124 Windows, Version 25.0. Armonk, NY: IBM Corp.) χ^2 or Fisher’s exact test was used to compare
125 frequencies, when appropriate. Comparison of means was performed using Student-t test or
126 Mann-Whitney test, depending on the data distribution and the tBAO was the reference.
127 Results were considered statistically significant when P value <0.05.
128 For outcome variables, unadjusted odds ratio (ORs) were calculated by using univariate
129 logistic regression models, including the type of BAO as independent variable.

130 **Results**

131

132 We retrieved 106 patients with posterior circulation ischemic stroke who underwent MT in
133 the two hospitals in the period 2010-2019. Basilar artery LVO was present in 89 patients, with
134 tandem BAO being detected in 15 patients (**Fig. 1**).

135

136 The median initial NIHSS at admission was 22 (IQR: 9-40) versus 21 (IQR: 9-37; $p=0.77$), the
137 mean age was 62.4 ± 12.2 versus 64.8 ± 17.8 years ($p=0.62$); and 73.3% versus 58% of patients
138 were male in the tBAO and ntBAO groups, respectively.

139

140 Atrial fibrillation was more prevalent in the ntBAO patients ($p=0.03$). Stroke etiology was
141 different across groups with “large artery atherosclerosis” found to be more prevalent in the
142 tBAO patients and “cardioembolism” more prevalent in the ntBAO ($p< 0.01$).

143

144 The median DWI-pc-ASPECTS of the tBAO patients (5 [IQR: 3-6]) tended to be lower than that
145 of the ntBAO group (6 [IQR: 4-8]; $p=0.08$).

146

147 There was no difference in the rate of IVT administration between the two groups (46.7% vs
148 38.8%; $p=0.57$ in the tBAO and ntBAO patients, respectively). Nine (60%) and 38 (51.4%)
149 patients in the tBAO and the ntBAO groups underwent the procedure under general
150 anaesthesia ($p=0.58$), respectively.

151

152 The median procedural time was significantly longer in the tBAO patients 102 minutes than
153 in the ntBAO patients 48 minutes ($p=0.04$).

154 Eleven out of the 15 patients with tBAO (73.3%) were treated through the affected VA (“dirty-
155 road-pathway”). Balloon angioplasty was performed in 4 patients (26.7%) to treat the
156 affected VA. Occlusion with coils of the affected VA through the contralateral VA was
157 performed in one patient (7%) after having performed the thrombectomy procedure via the
158 non-occluded VA (“clean-road-pathway”), to avoid delayed embolic showers. Furthermore,
159 one patient with tBAO (7%) underwent direct percutaneous puncture of the third segment of
160 the occluded VA due to failure of repeated ante and retrograde navigation through femoral
161 then radial punctures. The patient had final good recanalization of mTICI 3 without
162 complications at the puncture site.

163

164 No stent was implanted at the acute phase in the cervical VA harboring the occlusion. In one
165 patient (6%), a stent deployment was performed to treat the VA residual stenosis six months
166 after the MT, after stabilization of the patient’s condition. Moreover, balloon angioplasty was
167 performed in one patient to manage underlying BA stenosis, while rescue stents were
168 deployed in other three patients.

169

170 *The baseline demographic and procedural parameters are summarized in **Table 1**.*

171 *Angiographic and clinical outcomes are summarized in **Table 2**.*

172

173 Successful reperfusion (mTICI \geq 2b) was obtained in 73.3% tBAO versus 90.5% ntBAO (OR=0.29;
174 95% CI: 0.07-1.15) cases, respectively. Good clinical outcome (mRS \leq 2 at 3-months) was
175 reached by 26.7% tBAO patients versus 32.4% ntBAO patients (OR=0.76; 95% CI: 0.24-2.63).
176 Mortality at 3-months was 46.7% in tBAO group versus 31% ntBAO group (OR=1.94; 95% CI:
177 0.63-6).

178 As major complications, SICH occurred in two patients (13.3%) with tBAO and three patients
179 (4%) with ntBAO (OR=3.64; 95% CI: 0.55-24). In ntBAO, one patient had distal embolization,
180 and another patient had vessel perforation with distal embolization.

181 As minor complications, two patients (13.3%) of the tBAO group had iatrogenic minimal
182 dissection of the extracranial segment of the vertebral artery during the procedure that did
183 not affect the blood flow and did not require further management. One of them occurred in
184 the occluded vertebral artery, during the recanalization attempt and the other occurred in
185 the patent vertebral artery during the treatment through it, as it was impossible to cross the
186 occluded one.

187 **Discussion**

188

189 The safety and effectiveness of MT in patients with tBAO is still poorly known.[9] Despite
190 absence of significant difference between both groups, patients with tBAO treated with MT
191 tend to have less favorable clinical and angiographic outcomes, with higher mortality rate
192 than those with ntBAO.

193

194 The overall reperfusion rate (87.6%), favorable clinical in term of mRS ≤ 2 (31.5%) and
195 mortality (33.7%) observed in our study were comparable to those reported by meta-analysis
196 on MT in BAO (81%), (42%) and (30%); respectively.[4]

197

198 Endovascular management of tandem occlusions in the posterior circulation is scarcely
199 described in the literature.[9-16] There are two comparative studies that had investigated
200 tBAO [12, 13] in comparison with other underlying pathomechanisms of BAO, including 28
201 and 15 patients with tBAOs, respectively. Notably, the series with the larger number of
202 patients [12] included only Asian patients, who are more prone to develop intracranial arterial
203 stenosis.[20] Moreover, Chang et al and Siebert et al [15, 16], compared the outcome of BAO
204 with and without steno-occlusive lesions, including 13 and 12 patients with VA's V1 steno-
205 occlusion, respectively, considered to be tBAO. By contrary, Xing et al.[14] classified the
206 tandem occlusive lesions to basilo-basilar type if a concomitant proximal and distal BAO was
207 present; and vertebro-basilar type in case of concomitant occlusion of BA and VA regardless
208 the affected VA segment.

209

210 In our study, we chose to define tBAO as occlusion of the dominant VA associated with BAO,
211 contrary to previous studies,[12, 13] in which non-dominant VA occlusions were also included
212 in the tBAO group. Indeed, we think that this definition is more meaningful since occlusion of
213 the non-dominant VA along with the BAO has no additional influence on the blood flow within
214 the vertebrobasilar system and exert no more challenges to recanalize the occluded BA.
215 Moreover, we considered that tandem BAO occlusion should involve the extracranial VA (V1
216 or proximal V2) in parallel to the definition applied to the anterior circulation.[7]
217 We think that repeated attempts to engage the proximal VA by the guiding catheter with
218 multiple buckling back into the aorta is more challenging than crossing occluded or stenosed
219 V3 or V4 segments to reach the occluded BA.

220

221 Interestingly, the overall successful reperfusion rate in tBAO patients of our study (73.3%) was
222 comparable with the one reported by Poppe et al [8] and Labeyrie et al [21] studying tandem
223 occlusions of the anterior circulation AIS (72.2% & 79%, respectively). However, the overall
224 favorable clinical outcome in tBAO patients in our study in term of mRS ≤ 2 (26.7%) and
225 mortality (46.7%) were less favorable than those shown by Poppe et al [8]: 63.3% and 9.1%;
226 and Labeyrie et al [21]: 54% and 21%, respectively.

227 Less favorable clinical outcome despite comparable successful reperfusion rate with those
228 having anterior circulation tandem occlusions might be explained by the phenomenon of
229 futile recanalization (defined as mRS 3-6 despite complete recanalization). [16, 22] Meinel et
230 al [23] found that futile recanalization was more frequent in BAO and might be predicted by
231 age, stroke severity, maneuver count and intracranial stenting.

232

233 Baik et al [12] showed comparable reperfusion rates between the different groups, but a
234 worse clinical outcome in patients with tBAO compared to ntBAO from embolic origin. On the
235 contrary, Piechowiak et al [13] did not find any significant difference in terms of clinical
236 outcome and reperfusion rates between the different subgroups.

237

238 However, the clinical outcome in our tandem group (26.7%) is comparable with that of
239 Baik et al (28%) [12] and less favorable than that showed by Piechowiak et al (53%)[13].
240 Moreover, our study showed higher mortality rate in patients with tBAO (46.7%) than those
241 of Baik et al (25%) [12] and Piechowiak et al (20%)[13].

242

243 To the best of our knowledge, there is no consensus regarding the better access to recanalize
244 tBAO, through the occluded or the non-occluded VA. In line with previous series [9-11, 13,
245 14], we crossed the occluded VA in 73.3 % of the cases and did not report any major
246 complications related to navigation through the occluded VA, except for minimal dissections
247 that did not affect the blood flow and did not require further intervention in three patients.

248

249 By the contrary, Baik et al [12] performed 12 of out 28 MT (43%) in patients with tBAO through
250 the contralateral “clean road”. The authors hypothesized that the patent “clean road” seems
251 to be easier and faster; however, the incidence of recurrent stroke from the non-recanalized
252 affected VA may be increased.

253

254

255

256

257 **Limitations**

258 Our study has several limitations. Firstly, the study design was retrospective in fashion, which
259 favors biases. Secondly, the choice of the techniques and devices was left at the discretion of
260 the operator. This heterogeneity may bring additional biases. Moreover, patients with tBAO
261 tended to have lower DWI-pc-ASPECTS than those with ntBAO; which indeed considered
262 having a confounding effect on the clinical outcome bringing additional bias when comparing
263 both groups. Finally, our work included a limited number of patients, which may hamper the
264 statistical power of our study. This could be explained by the fact that tBAOs are rare; they
265 indeed represented only 17% of the whole database of MT for BAO at the two institutions.

266

267

268

269 **Summary and Conclusion**

270 Mechanical thrombectomy for patients with tandem basilar artery occlusion tends to be
271 associated with lower rates of successful reperfusion and good clinical outcomes, and higher
272 rate of mortality. Nevertheless, further investigations with larger multi-centre series are
273 warranted to confirm our results and pose proper selective criteria for the management of
274 such patients.

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400 **Figure legends**

401 **Figure.1** Study flowchart

402 **Figure.2** A 54-year-old female patient who presented with acute drowsiness and mental
403 change.

404 **(A)** Left subclavian artery digital subtraction angiography (DSA) in postero-anterior
405 (PA) projection showing an occlusion of the origin of the dominant left vertebral artery
406 (VA) (short thick black arrow). **(B)** Left subclavian artery DSA in PA projection after two
407 balloon angioplasties with the Gateway balloon (Boston scientific), showing a
408 satisfactory reopening of the left VA (short thick white arrow). **(C)** Left VA PA
409 angiogram obtained after the balloon angioplasty confirms the occlusion of the mid-
410 basilar artery (BA) (long thin white arrow). **(D)** PA angiogram of left VA showing the
411 final reperfusion of the BA with mTICI-2b after 4 thrombo-aspiration maneuvers (long
412 thin black arrow).

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422 **Tables**

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424 **Table.1 Patients' baseline demographics and procedural parameters.**

Parameter	Overall Population (n=89)	tBAO Group; (n=15)	ntBAO Group; (n=74)	<i>P Value</i>
Median initial NIHSS (IQR)	20(9-39)	22(9-40)	21(9-37)	0.77
Age (±SD)	64.4 (17)	62.4 (12.2)	64.8 (17.8)	0.62
Sex males (%)	54(60.7)	11(73.3)	43(58)	0.39
Vascular risk factors				
HTN (%)	48(53.9)	8(53.3)	40(54)	1.00
DM (%)	20(22.5)	2(13.3)	18(24.3)	0.5
AF (%)	28(31.5)	1(6.7)	27(36.5)	0.03*
IHD (%)	18(20.2)	4(26.7)	14(18.9)	0.49
Smoker (%)	24(27)	5(33.3)	19(27.7)	0.54
Dyslipidemia (%)	37(41.6)	6(40)	31(41.9)	1.00
TOAST criteria				
(Large artery atherosclerosis) (%)	34(38.2)	13(86.7)	21(8.4)	< 0.01*
(Cardioembolism) (%)	31(34.8)	1(6.7)	30(40.5)	
dissection/other (%)	5(5.6)	1(6.7)	4(5.4)	
undetermined etiology (%)	19(21.3)	0(0)	19(25.7)	
Median DWI-pc-ASPECTS(IQR)	6(4-8)	5(3-6)	6(4-8)	0.08
Basilar artery occluded segments				
Proximal (%)	28(31.5)	5(33.3)	23(31)	0.1
Mid-basilar (%)	24(27)	7(46.7)	17(23)	
Distal (%)	37(41.6)	3(20)	34(45.9)	
Posterior communicating artery status				
Absent	27(30.3)	4(26.7)	23(31)	0.34
Unilateral presence	16(18)	1(6.7)	15(20.3)	
Bilateral presence	46(51.7)	10(66.7)	36 (48.6)	
IVT (%)	35(39.3)	7(46.7)	28(37.8)	0.57
Patients underwent GA (%)	47(52.8)	9(60)	38(51.4)	0.58

Median delays: min (IQR)				
Symptoms' onset to imaging	179(131-265)	146 (55-228)	186(138-270)	0.1
Symptoms' onset to arterial puncture	278(220-382)	222 (170-331)	293(226-390)	0.09
Procedural time	65(21-112)	102 (54-148)	48(20-103)	0.04*
Symptoms' onset to reperfusion	360(285-450)	338 (270-385)	364(285-464)	0.29

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426 **tBAO**; tandem basilar artery occlusion, **ntBAO**; non-tandem basilar artery occlusion, **SD**;

427 indicates standard deviation, **IQR**; indicates interquartile range; **NIHSS**; National Institutes of

428 Health Stroke Score, **HTN**; hypertension, **DM**; diabetes mellitus, **AF**; atrial fibrillation, **IHD**;

429 ischemic heart disease, **TOAST**; Trial of Org 10172 in Acute Stroke Treatment, **IVT**; intravenous

430 thrombolysis, **GA**; general anaesthesia, **DWI-pc-ASPECTS**; Diffusion weighted imaging-

431 posterior circulation-Alberta stroke program early CT score, * indicates $P < 0.05$.

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439 **Table 2. Angiographic and clinical outcomes.**

Parameter	Overall Population (n=89)	tBAO Group; (n=15)	ntBAO Group; (n=74)	Unadjusted <i>OR</i> (95% <i>CI</i>)
Successful reperfusion (%)	78(87.6)	11(73.3)	67(90.5)	0.29(0.07-1.15)
mRS of 0–2 at 3 months (%)	28(31.5)	4(26.7)	24(32.4)	0.76(0.24-2.63)
Mortality at 3 months (%)	30(33.7)	7(46.7)	23(31)	1.94(0.63-6)
SICH (%)	5(5.6)	2(13.3)	3(4)	3.64(0.55-24)

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441 **tBAO**; non-tandem basilar artery occlusion, **ntBAO**; non-tandem basilar artery occlusion, **OR**;

442 indicates odds ratio, **95%CI**; confidence interval; **mRS**; modified Rankin Scale, **SICH**;

443 symptomatic intracranial haemorrhage, **NA**; not applicable, *When P<0.05.

Mechanical thrombectomy for patients with posterior circulation acute ischemic stroke (n=106)

Inclusion criteria (n=89)

- # Acute Basilar artery occlusion stroke confirmed by vascular imaging.
- # Time interval stroke symptoms' onset to groin puncture ≤ 24 hours.
- # Initial NIHSS score ≥ 4 .
- # No intracranial haemorrhage detected at initial brain imaging.

Group 1 (n=15)

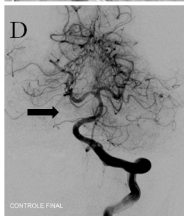
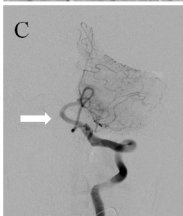
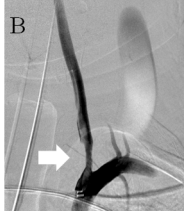
Tandem Basilar artery occlusion

Concurrent Basilar artery and extracranial dominant vertebral artery occlusion

Group 2 (n=74)

non-Tandem Occlusion Basilar artery occlusion

Isolated Basilar artery occlusion



Mechanical thrombectomy for patients with posterior circulation acute ischemic stroke (n=106)

Inclusion criteria (n=89)

- # Acute Basilar artery occlusion stroke confirmed by vascular imaging.
- # Time interval stroke symptoms' onset to groin puncture \leq 24 hours.
- # Initial NIHSS score \geq 4.
- # No intracranial haemorrhage detected at initial brain imaging.

Group 1 (n=15)

Tandem Basilar artery occlusion

Concurrent Basilar artery and extracranial dominant vertebral artery occlusion

- Successful reperfusion=73%
- Good clinical outcome=27%
- Mortality rate=47%
- Symptomatic intracranial haemorrhage=13%

Group 2 (n=74)

non-Tandem Occlusion Basilar artery occlusion

Isolated Basilar artery occlusion

- Successful reperfusion=91%
- Good clinical outcome=32%
- Mortality rate=31%
- Symptomatic intracranial haemorrhage=4%