



## Article

# Blood Pressure Variability and Outcome in Acute Ischemic and Hemorrhagic Stroke: A Post-Hoc Analysis of the HeadPoST Study

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1 **Blood Pressure Variability and Outcome in Acute Ischemic and Hemorrhagic Stroke: A**  
2 **Post-Hoc Analysis of the HeadPoST Study**

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37

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63 **Itemized list of tables and figures:**

64 Table 1: Baseline characteristics of the 9,156 patients with acute stroke and 4-hourly blood  
65 pressure parameters for 24 hours included in the analysis

66 Table 2: Association of SBP variability with unfavorable shift of the mRS at 90 days

67 Table 3: Multivariate subgroup analysis by AIS etiology, stroke sub-type, head position and  
68 reperfusion therapy

69 Fig. 1: Flowchart of the study procedures

70 Fig. 2: Mean and SD of systolic blood pressure over time

71 Fig. 3: Association between fifths of coefficient of variation (CV) of systolic blood pressure  
72 and unfavorable shift of mRS at 90 days

73 Footnote: Association between fifths of CV of systolic blood pressure at baseline and  
74 unfavorable shift of mRS at 90 days

75 **Keywords:** head position, blood pressure, stroke, intracerebral hemorrhage, acute stroke  
76 outcome

77 **Summary Table**

|   |
|---|
| <p><i>What is known about this topic?</i></p> <ul style="list-style-type: none"><li>• Blood pressure variability (BPV) has been shown to be associated with poor functional outcomes in acute ischemic stroke (AIS) and acute intracerebral hemorrhage (ICH).</li><li>• Traditionally, AIS patients have been nursed in elevated positions (<math>\geq 30^\circ</math>) due to concern over aspiration risk and propensity to reduce raised intracranial pressure.</li><li>• However, disability outcomes do not differ between acute stroke patients nursed in a lying-flat position as compared to a head elevated position.</li><li>• No studies have assessed the relationship between BPV and outcome following adjustment for head position.</li></ul>  |
| <p><i>What this study adds?</i></p> <ul style="list-style-type: none"><li>• This sub-study assessed the predictive potential of BPV on stroke outcomes considering the interaction with head positioning and any associated hemodynamic changes in relation to lying-flat (increased cerebral blood flow and oxygenation) and sitting-up (potential reduction in ICP in large hemispheric AIS).</li><li>• Systolic BPV was associated with unfavorable shift of the mRS at 90 days.</li><li>• AIS etiology, stroke sub-type, head-position or use of reperfusion therapy did not interact with the predictive effects of systolic BPV on stroke outcome.</li><li>• Diastolic BP was associated with unfavorable shift of the mRS at 90 days with a greater magnitude of effect of sitting-up head positioning on DBP variability and outcome.</li></ul> |

78

79

80 **Abstract**

81 The Head Positioning in Acute Stroke Trial (HeadPoST) is a pragmatic, international, cluster  
82 crossover randomized trial of 11,093 patients with acute stroke assigned to a lying-flat (0°) or  
83 sitting-up (head elevated  $\geq 30^\circ$ ) position. This post-hoc analysis aimed to determine the  
84 association between BPV and outcomes for patients from a wide range of international  
85 clinical settings and how the association was modified by randomized head position. BPV  
86 was defined according to standard criteria with the key parameter considered the coefficient  
87 of variation (CV) of systolic BP (SBP) over 24 hours. Outcome was ordinal 90-day modified  
88 Rankin Scale (mRS) score. The association was analyzed by ordinal, logistic regression,  
89 hierarchical, mixed models with fixed intervention (lying-flat vs. sitting-up), and fixed period,  
90 random cluster, and random cluster-period, effects. 9,156 (8,324 AIS and 817 ICH; mean age  
91 68.1 years; 39.2% women) were included in the analysis. CV of SBP had a significant linear  
92 association with unfavorable shift of mRS at 90 days (adjusted odds ratio [OR] 1.06, 95%  
93 confidence interval [CI] 1.02-1.11;  $P=0.01$ ). There was no heterogeneity of the association by  
94 randomized head positioning. In addition, CV of diastolic BP (DBP) (1.08, 1.03-1.12;  
95  $P=0.001$ ) over 24 hours post stroke, was significantly associated with 3-month poor outcome.  
96 The association was more apparent in sitting-up position (1.12, 1.06-1.19) compared with  
97 lying-flat position (1.03, 0.98-1.09) ( $P$  interaction = 0.005). BPV was associated with adverse  
98 stroke outcome, the magnitude of the association was greater with sitting-up head positioning  
99 in terms of DBP variability.

100 ***Clinical Trial Registration:*** [clinicaltrials.gov \(NCT02162017\)](https://clinicaltrials.gov/ct2/show/study/NCT02162017)

101

102 **Introduction**

103 The importance of specialized stroke units is evidenced by randomized trials demonstrating  
104 reductions in death and disability caused by prevention of secondary complications of stroke  
105 [1]. In acute stroke syndromes, elevated blood pressures (BP) have been a particular focus, as  
106 post-stroke hypertension precipitates secondary stroke complications [2]. More recently, BP  
107 variability (BPV), using widely applied measures such as standard deviation (SD) or  
108 coefficient of variation (CV), and measured early after acute ischemic stroke (AIS),  
109 intracerebral hemorrhage (ICH) or transient ischemic attack (TIA), has been shown to be  
110 associated with poor functional outcome [3-5].

111 Traditionally, AIS patients have been nursed in elevated positions ( $\geq 30^\circ$ ) due to concern over  
112 aspiration risk and propensity to reduce raised intracranial pressure (ICP) [6]. However, it is  
113 conceivable that head positioning may impact on BPV, with data from healthy individuals  
114 and AIS patients (in affected hemispheres) showing significant changes in cerebral  
115 hemodynamic parameters during head position changes of varying tilt [7,8].

116 The Head Positioning in Acute Stroke Trial (HeadPoST) was designed to evaluate whether  
117 outcomes for unselected acute stroke patients nursed lying-flat (i.e. fully supine with back  
118 horizontal and face upwards or to the side) were improved compared to those in a sitting-up  
119 position with head elevated to at least 30 degrees [9]. The study showed no significant  
120 difference in modified Rankin Scale (mRS) scores at 90 days between the head position  
121 groups initiated early after presentation and maintained for 24 hours. Accordingly, the  
122 HeadPoST results suggest any changes in cerebral blood flow based on head position initiated  
123 within 24 hours are insufficient to reduce the neurological deficit associated with acute stroke  
124 pathologies [9].

125 However, the potential impact of head positioning and any associated hemodynamic changes  
126 in relation to lying-flat (increased cerebral blood flow and oxygenation) and sitting-up

127 (potential reduction in ICP in large hemispheric AIS) on the predictive potential of BPV on  
128 outcome have yet to be considered. Herein, we report the predictive potential of BPV  
129 parameters on functional outcome in a post-hoc individual patient analysis of the HeadPoST  
130 study.

## 131 **Materials and methods**

### 132 *Patients*

133 HeadPoST was an international, multicenter, cluster-randomized, crossover, open trial with  
134 blinded outcome evaluation, conducted at 114 hospitals in nine countries [9]. The trial was  
135 designed to compare the effects of the lying-flat with the sitting-up position, initiated soon  
136 after stroke and maintained for 24 hours after the onset of acute stroke, full details of which  
137 are outlined elsewhere [9,10].

138 Patients with a clinical diagnosis of acute stroke, including AIS and ICH, were included in  
139 order to facilitate consecutive patient recruitment. Patients were excluded if the clinician-  
140 investigator deemed either head position futile based on compliance or if a TIA was  
141 diagnosed. Other reasons for exclusion were refusal to participate in the intervention and/or  
142 follow-up, or any contraindication to either head position. Patients were assigned a head  
143 position according to the randomization cluster as soon as was feasible after admission to  
144 hospital and they were encouraged to strictly maintain this position for the next 24 hours.  
145 Interruption to the assigned head position was permitted, for three non-consecutive periods of  
146 less than 30 minutes, to permit eating, drinking and toileting, should this not have been  
147 possible in the assigned position.

148 The appropriate ethics committee at each participating center approved the study protocol. A  
149 senior executive officer at each center acted as a ‘guardian’ and provided institutional consent  
150 for this low-risk intervention to be implemented consecutively as part of routine nursing care



151 in each cluster. Written informed consent was then sought from all patients or approved  
152 surrogates for ongoing assessments and data collection.

### 153 *Procedures*

154 Key demographic and clinical characteristics were recorded at the time of enrollment,  
155 including stroke severity measured using the National Institutes of Health stroke scale  
156 (NIHSS) at baseline, 24 hours, and at day 7 (or earlier, on discharge from hospital). A 24-  
157 hour bed-side diary was maintained by the treating clinical nurses to record vital signs, lowest  
158 oxygen saturation and interruptions in head positioning. Follow-up data were collected at 7  
159 days (or at hospital discharge if before 7 days) unless death occurred earlier by independent  
160 outcome assessors blind to group allocation. Data included final diagnosis, repeat NIHSS  
161 score and assessment of functioning using the mRS, a standard disability scale with  
162 categorical scores ranging from 0 to 6 (0 indicates, no symptoms at all; 1, no clinically  
163 significant disability despite symptoms; 2, slight disability; 3, moderate disability requiring  
164 some help; 4, moderately severe disability requiring assistance with daily living; 5, severe  
165 disability, bed-bound, and incontinent; and 6, death).

166 The primary clinical outcome was the ordinal mRS scores at 90 days. BP was measured with  
167 a casual cuff at 4 hourly intervals during the first 24 hours post-stroke and BPV was  
168 calculated from all available BP measurements using BPV measures with demonstrable  
169 independence of mean SBP on an individual patient level. The parameters included were  
170 mean, standard deviation (SD), coefficient of variation (CV) and variation independent of  
171 mean (VIM, a transformation of SD that is defined to be uncorrelated with mean levels) as  
172 well as diastolic BPV over 24 hours (Table I in Supplementary Files). There was an  
173 expectation that limited variation would exist in the standard BP measurement equipment  
174 used across different hospitals and countries. Coefficient of Variation (CV) [ $CV=SD/mean$ ]

175 was derived from these parameters. CV of SBP was categorized into 5 equal groups  
176 (quintiles), using the lowest fifth as the reference group.

### 177 *Statistical analysis*

178 We used ordinal, logistic regression, hierarchical, mixed models with fixed intervention  
179 (lying-flat vs. sitting-up), and fixed period, random cluster, and random cluster-period, effects  
180 to assess the associations. The multivariable model was adjusted for country, prestroke mRS  
181 score, age, sex, baseline NIHSS score, and history of heart disease, stroke or diabetes  
182 mellitus, or hypertension and prior antiplatelet therapy. We also investigated whether the  
183 associations were different between groups by AIS etiology, stroke sub-type and head  
184 position by adding an interaction term to the adjusted statistical models. In study analyses,  
185 two-sided P values are reported and  $P < 0.05$  was considered statistically significant. The SAS  
186 version 9.3 (SAS Institute, Cary, NC) was used for all analyses.

### 187 **Results**

188 The HeadPoST trial included 11,093 patients (39.9% female) whose mean age was 68 years;  
189 patients without a mean systolic BP (46), without 90-day mRS (1,214) and those with a stroke  
190 mimic, TIA or undetermined diagnosis (677) were excluded. 9,156 patients (82.5%) had a  
191 complete set of 4-hourly BP measurements recorded over the first 24 hours, on which  
192 subsequent analyses were undertaken. The study procedures are summarised in a flowchart  
193 (Fig.1). Those excluded at baseline were more likely to be female, have a shorter time  
194 between onset and intervention, less likely to have known hypertension and less likely to be  
195 taking aspirin (Table II in Supplementary Files). Mean age of the participants was 68.1 years,  
196 39.2% were female, 91.1% had AIS, and 8.9% had ICH. The median pretreatment NIHSS  
197 score was 4 (interquartile range, 2 to 9). Time from stroke onset to commencement of head  
198 positioning was 14 hours (interquartile range, 5 to 38). Other baseline characteristics are

199 presented in Table 1. Mean systolic BP was  $156\pm 28$ mmHg and diastolic BP  $87\pm 17$ mmHg,  
200 with mean systolic BP showed a steady fall over the first 24 hours following randomization  
201 (Fig. 2). Baseline characteristics by randomized treatment demonstrated higher incidence of  
202 coronary artery disease and heart failure in the sitting-up group (Table III in Supplementary  
203 Files). The acute values for systolic BPV demonstrated a mean SBP of  $145\pm 18.9$ mmHg, SD  
204 of  $11\pm 7.5$ mmHg and CV of  $8\pm 4.4$ mmHg (Table IV in Supplementary Files). For diastolic  
205 BPV, SD was  $8\pm 4.2$ mmHg and CV  $9\pm 5.3$ mmHg (Table IV in Supplementary Files).

206 Overall, increased systolic BPV parameters were all associated with unfavorable shift of the  
207 mRS at 90 days except VIM (Table 2). Systolic BPV assessed using CV demonstrated a  
208 significant linear association with unfavorable shift of the mRS at 90 days (odds ratio [OR]  
209 effect of 1 SD increment of CV, 1.06 [95% confidence interval] 1.02-1.10;  $P=0.0065$  (Table  
210 2). Mean systolic BP (1.21 [1.16-1.25];  $P<0.0001$ ) and SD of systolic BP (1.10 [1.05-1.15];  
211  $P<0.0001$ ) both demonstrated significant associations with unfavorable shift in mRS at 90  
212 days. There was no heterogeneity of the association by randomized head positioning. The  
213 trend in mean systolic BP and SD of systolic BP demonstrated a progressive downward trend  
214 from 0-12 hours and a plateau from 12-24 hours (Fig. 2). A positive trend was seen for  
215 association of fifths of CV of SBP and unfavorable shift on the mRS at 90 days (Fig. 3). The  
216  $P$ -value of proportional odds assumption for the model of CV and ordinal outcome was  
217 0.0008. The trend demonstrated a consistent risk relationship between differing levels of the  
218 ordinal outcome measure. This was demonstrated by mRS 0-3 vs. 4-6 (1.07 [1.01-1.13];  
219  $P=0.026$ ), mRS 0-4 vs. 5-6 (1.10 [1.03-1.17];  $P=0.004$ ) and mRS 0-5 vs. 6 (1.14 [1.06-1.22];  
220  $P=0.001$ ); showing an increasing association of CV of systolic BP with outcome.

221 With respect to head position, there were no significant changes in systolic BP over 24 hours  
222 by randomized intervention (lying-flat or sitting-up) (Fig. I in the Supplementary Files). Mean  
223 systolic BP was higher in ICH ( $149\pm 19$ ) patients compared to AIS ( $144\pm 19$ ) at successive 4-

224 hourly intervals over the initial 24-hour period ( $P<0.0001$ ) (Fig. II in the Supplementary  
225 Files). The subgroup analysis by AIS etiology, stroke subtype and head position did not  
226 demonstrate any significant associations with adverse outcome from greater systolic BPV  
227 (Table 3).

228 Lastly, increased mean diastolic BP (1.08 [1.03-1.12];  $P=0.001$ ) and mean arterial pressure  
229 (1.06 [1.01-1.10];  $P=0.009$ ) were associated with unfavorable shift of the mRS at 90 days.  
230 (Table V in the Supplementary Files). In addition, CV of diastolic BP (DBP) (1.08, 1.03-1.12;  
231  $P=0.001$ ) over 24 hours post stroke, was significantly associated with 3-month poor outcome  
232 (Table V in Supplementary Files). The association was more apparent in sitting-up position  
233 (1.12, 1.06-1.19) compared with lying-flat position (1.03, 0.98-1.09) ( $P$  interaction = 0.005).  
234 Among patients without AF, mean SBP (1.17 [1.12-1.22];  $P<0.0001$ ), SD (1.05 [1.01-1.09];  
235  $P<0.017$ ), ARV (1.06 [1.01-1.12];  $P<0.015$ ), DBP (1.01 [1.00-1.02];  $P<0.004$ ) and pulse  
236 pressure (1.02 [1.01-1.03];  $P<0.001$ ) were associated with death or disability at 90 days  
237 (Table VI in Supplementary Files).

## 238 **Discussion**

239 Firstly, these post-hoc analyses of the large multicenter HeadPoST trial demonstrated that  
240 increased BPV is associated with poor outcome from stroke as determined by unfavorable  
241 shift in mRS at 90 days. Secondly, there was no interaction of AIS etiology, stroke sub-type,  
242 head-position or use of reperfusion therapy with the predictive effects of BPV on outcome.  
243 Lastly, head position change did not influence systolic BP over the 24-hour period post  
244 stroke.

245 The HeadPoST study design provided an opportunity to test the predictive significance of  
246 BPV across the broad range of patients with acute stroke. The paucity of randomized data  
247 examining head position, and central and peripheral hemodynamics are also apparent.  
248 Furthermore, there are no randomized data to date examining head position and BPV

249 parameters specifically. BPV is an important measure as it provides information on systemic  
250 hemodynamics and can be used for risk assessment. Challenges exist around beat-to-beat  
251 BPV measurements and translation into clinical practice.

252 BPV was assessed from multiple readings taken at various time points after hospital  
253 admission for acute stroke [11]. While heterogeneity exists across the methods of assessment  
254 and BPV metrics used in reporting [11], SD correlates well with mean BP levels and the  
255 number of readings and time period do not generally affect the magnitude of short-term BPV,  
256 though mean BP should always be adjusted for as a consequence of this relationship [11].  
257 Furthermore, this analysis describes the minimum criteria for reporting as determined by a  
258 recent systematic review and meta-analysis (timing, number of BP measurements, duration of  
259 BP monitoring, and a low computational complexity BPV metric) [11]. Importantly, mean  
260 SBP, SD and ARV are crucial confounders as they are often correlated with systolic BPV  
261 [12,13]. ARV was developed as a measure to overcome deficiencies in the commonly used  
262 SD and was largely targeted for use when sampling BP from prolonged ambulatory BP  
263 devices as opposed to casual cuff measurements. Therefore, the focus on measures of BPV  
264 that are not closely correlated with mean SBP, CV and VIM, is key. CV is the most  
265 appropriate index of BPV within this clinical context as it is largely independent of mean SBP  
266 at an individual patient level. This study demonstrated CV to be highly predictive of an  
267 unfavorable outcome as demonstrated by association of worsening fifths of CV with poorer  
268 mRS scores. Interestingly, this study demonstrated DBP variability was also independently  
269 associated with outcome after multivariable adjustment. Though the effect size was small, this  
270 is of interest both pathophysiologically and clinically, particularly as sitting up conferred a  
271 greater magnitude of DBP variability. This appears to be the first time this has been reported,  
272 perhaps largely potentiated by the primary focus of prior work on SBP variability.

273 Nevertheless, this finding warrants further observation in mechanistic studies of central and  
274 peripheral blood pressure changes during alteration in head positioning.

275 Overall, the data from this study do provide support for validation of targeted strategies aimed  
276 at improving BPV independent of head position [14]. Currently there are a lack of data to  
277 support a prognostic benefit, although there have been calls for randomized controlled trials  
278 of interventions to reduce BPV [15]. The basis of such recommendations is in part also due to  
279 the effect of pre-stroke anti-hypertensive therapies on certain BPV parameters, with those on  
280 beta-blocker therapy being reported as having higher SD and VIM but not CV of SBP at 2  
281 weeks [15]. This heterogeneity could explain the borderline VIM result as compared to other  
282 parameters, particularly as 65.5% of the cohort had a diagnosis of hypertension with wide  
283 variation in anti-hypertensive agent use being expected in part due to the geographical  
284 variation of study participants.

285 A key strength of this study is the consecutive unselected recruitment strategy, which  
286 provided information on a mixture of unstratified stroke pathologies independent of vascular  
287 imaging. This is crucial, as uncertainty remained due to discordance between findings from  
288 post-hoc analyses of INTERACT2 [3] (only ICH patients), compared with the Controlling  
289 Hypertension and Hypotension Immediately Post Stroke (CHHIPS) [16] and the Continue or  
290 Stop Post-Stroke Antihypertensives Collaboration Study (COSSACS) [17] (which were  
291 largely AIS patients). The findings of this study support those from INTERACT2 where  
292 greater systolic BPV was associated with a poor outcome in acute stroke due to ICH, though  
293 do support those from the mixed CHHIPS and COSSACS patient cohorts where no  
294 significant association was found. The differing study design and timing of BPV assessments  
295 may account for the concordance of the findings of this analysis with the INTERACT2 BPV  
296 analysis and consequent discordance with CHHIPS AND COSSACS BPV analysis [15].  
297 Firstly, this study and INTERACT2 included a comparable number of ICH patients for whom

298 arguably BPV demonstrates greater relevance from a prognostic perspective based on  
299 underlying mechanisms precipitating neuropathological deterioration. In addition, in the  
300 INTERACT2 BPV analysis both diastolic BP and mean arterial pressure appeared to confer  
301 some value in predicting prognosis at 30 days, which was confirmed in the present study.  
302 Secondly, the BPV data from INTERACT2 were gathered in the immediate aftermath of  
303 hyperacute stroke (within 6 hours) as opposed to in the acute period in CHHIPS AND  
304 COSSACS (36-48 hours).

305 Thirdly, as stated in the results section, those excluded were more likely to be female, have a  
306 shorter time between onset and intervention, less likely to have known hypertension and less  
307 likely to be taking aspirin. The reasons for exclusion included a lack of mean systolic BP, 90-  
308 day mRS or a final diagnosis that was indeterminate, stroke mimic, or TIA. The impact of  
309 missing data on the analyses is unclear though it could be argued that these individuals are  
310 healthier and hence the results could have provided an overestimation. However, should they  
311 have had a diagnosis of stroke, the shorter time between onset and intervention may have  
312 provided more robust BPV data in the hyperacute post-stroke period. Furthermore, sex  
313 differences do exist in severity of strokes and survival, and therefore the increased likelihood  
314 of exclusion of females may have attributed to a milder stroke population as stroke is often  
315 more severe in a female population [18]. Importantly, further analyses of patients without AF  
316 (Table VI in Supplementary Files), showed significant associations between pulse pressure  
317 and outcome. These findings suggest that the presence of AF confounds any effect pulse  
318 pressure has on outcome. These findings support those of the Standard Medical Management  
319 in Secondary Prevention of Ischemic Stroke in China (SMART) study that demonstrated  
320 pulse pressure was associated with poor stroke outcome in those over 60 years of age without  
321 AF [19].

322 A key limitation is the heterogeneity posed by assessment of BPV from standard isolated  
323 measurements as opposed to beat-to-beat assessment. However, BP readings were taken  
324 according to standard practice guidelines in participating hospitals, which are likely to be in  
325 accordance with national guidelines in respect of device, positioning and degree of acceptable  
326 measurement error. In addition, the inclusion of patients with atrial fibrillation presents a risk  
327 of excess unquantifiable variation during BPV assessments as compared to those in sinus  
328 rhythm [20].

329 The HeadPoST study generally included strokes of mild to moderate severity (median NIHSS  
330 of 4) and most people recruited had a 90-day mRS of 0-1 [9]. However despite patients  
331 presenting late and the intervention being delivered within 24 hours of admission as opposed  
332 to onset, findings of the study were consistent across all categorical scores on the NIHSS at 7  
333 days [9]. The ability to assess the impact of BPV on early neurological deterioration is  
334 therefore limited, though data presented in this analysis provide 90-day prognostic  
335 information despite this. Prior work demonstrating systolic BPV as a cause for poorer  
336 neurological outcome post AIS showed increased systolic BPV was associated with large  
337 lesion core volume, proximal vessel occlusion and good collaterals [21]. Arguably this study  
338 was not representative of this population, who often fail or are not eligible for reperfusion  
339 therapies, though it provides prognostic information about BPV metrics in less severe strokes.  
340 Therefore, there is inadequate power to examine associations in specific etiological subtypes  
341 of ischemic stroke. Nonetheless, all other data, derived from observational and clinical trial  
342 settings, suggest consistency in risk factors and prognostic variables across such subtypes.

343 This secondary analysis did not assess the BP lowering efficacy of certain anti-hypertensive  
344 agents and the consequent efficacy in preventing adverse cardiovascular outcomes as a  
345 consequence of uncontrolled BPV. Finally, the limited number of patients with large artery  
346 occlusions, with or without mechanical thrombectomy intervention, limits generalizability to



347 those individuals often at the peaks of systolic BP values, though the inclusion of those with  
348 ICH provides some perspectives on stroke severity and extremes of BP. Further work  
349 examining BPV metrics in a more severe subset of AIS patients is warranted including those  
350 undergoing mechanical reperfusion interventions.

351 In conclusion, increased BPV is associated with poor outcome from stroke as determined by  
352 unfavorable shift in mRS at 90 days. Head position has no influence on BPV in the largest  
353 randomized study of nursing care following acute stroke to date.

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373 **Conflicts of interest**

374 The authors declare no conflicts of interest.

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**Table Legend**

Table 1: Baseline characteristics of the 9,156 patients with acute stroke and 4-hourly blood pressure parameters for 24 hours included in the analysis

Table 2: Association of SBP variability with unfavorable shift of the mRS at 90 days

Table 3: Multivariate subgroup analysis by AIS etiology, stroke sub-type, head position and reperfusion therapy

**Table 1: Baseline Characteristics**

|  | <b>Overall (N=9156)</b> |
|--|-------------------------|
| <b>Socio-demographic characteristics</b>                       |                         |
| Female sex   | 3587 (39.2)             |
| Age (years)  | 68.1 (13.5)             |
| <b>Region of Recruitment</b>                                   |                         |
| Australia and UK   | 3383 (36.9)             |
| South America  | 802 (8.8)               |
| China (incl. Taiwan)   | 4281 (46.8)             |
| India and Sri Lanka  | 690 (7.5)               |
| <b>Time from stroke onset to commencing intervention (hrs)</b> | 15.0 (5.0 – 38.0)       |
| <b>Time from admission to commencing intervention (hrs)</b>    | 8.0 (2.0 – 29.0)        |
| <b>Stroke type§</b>  |                         |
| AIS  | 8324 (91.1)             |
| ICH  | 817 (8.9)               |
| <b>Pre-stroke mRS of 0</b>                                     | 5595 (61.1)             |
| <b>NIHSS at admission</b>                                      | 4.0 (2.0 – 9.0)         |
| <b>GCS score on arrival</b>                                    | 15.0 (14.0 – 15.0)      |
| <b>Vital signs and laboratory results</b>                      |                         |
| <b>Systolic BP (mmHg)</b>                                      | 155.5 (27.5)            |
| <b>Diastolic BP (mmHg)</b>                                     | 86.7 (16.6)             |
| <b>Heart Rate (bpm)</b>  | 76.0 (68.0 – 84.0)      |
| <b>Glucose (mmol/l)</b>  | 5.5 (4.9 - 6.1)         |
| <b>Serum Creatinine (mmol/l)</b>                               | 75.0 (63.0 – 90.0)      |
| <b>Medical History</b>   |                         |
| Previous stroke  | 2164 (23.7)             |
| Coronary artery disease  | 1238 (13.6)             |
| Atrial fibrillation  | 960 (10.6)              |
| Heart Failure  | 325 (3.6)               |
| Hypertension   | 5981 (65.5)             |
| Diabetes Mellitus  | 2235 (24.5)             |
| Current Smoker   | 1799 (19.8)             |
| <b>Medications at time of admission</b>                        |                         |
| Aspirin  | 4092 (44.7)             |
| Other antiplatelet agent                                       | 1836 (20.1)             |
| Anticoagulant  | 779 (8.5)               |
| <b>Swallow screen on admission</b>                             | 7155 (78.2)             |
| <b>Swallow assessment on admission</b>                         | 3341 (36.5)             |

Data are n (%), mean (standard deviation) or median (interquartile range). AIS: acute ischemic stroke; ICH: intracerebral hemorrhage; mRS: modified Rankin score; NIHSS: National Institutes of Health stroke scale; GCS: Glasgow coma scale; BP: blood pressure.

§Reported by clinician investigator from brain imaging and other investigations on hospital discharge.

**Table 2 Association of SBP variability with unfavorable shift of the mRS at 90 days**

|      | Univariate analysis |         | Multivariate Model |         |
|------|---------------------|---------|--------------------|---------|
|      | OR(95%CI)           | P value | OR(95%CI)          | P value |
| Mean | 1.26(1.21-1.31)     | <0.0001 | 1.21(1.16-1.25)    | <0.0001 |
| MIN  | 1.18(1.14-1.23)     | <0.0001 | 1.15(1.11-1.20)    | <0.0001 |
| MAX  | 1.28(1.23-1.33)     | <0.0001 | 1.21(1.16-1.26)    | <0.0001 |
| SD   | 1.17(1.12-1.23)     | <0.0001 | 1.10(1.05-1.15)    | <0.0001 |
| CV   | 1.11(1.06-1.15)     | <0.0001 | 1.06(1.02-1.10)    | 0.0065  |
| ARV  | 1.17(1.11-1.22)     | <0.0001 | 1.12(1.06-1.17)    | <0.0001 |
| RSD  | 1.13(1.08-1.18)     | <0.0001 | 1.08(1.04-1.13)    | 0.0002  |
| VIM  | 1.08(1.04-1.13)     | <0.0001 | 1.04(1.00-1.08)    | 0.0533  |

CV: coefficient of variation; ARV: average absolute difference between successive BP measurements; RSD: residual SD; VIM: variation independent of mean.

Data are presented as odds ratio [OR] (95% confidence intervals [95%CI]) for per 1 unit increment of systolic blood pressure [SBP] variability (i.e. for SD, the unit is 1 SD of SD; for CV, the unit is 1 SD of CV; for ARV, the unit is 1 SD of ARV; for RSD, the unit is 1 SD of RSD; and for VIM, the unit is 1 SD of VIM).

Multivariable Model: Adjusted for country, prestroke mRS score, sex, baseline NIHSS score, and history of heart disease, stroke, diabetes mellitus, or hypertension, prior antiplatelet therapy



**Table 3 Multivariate subgroup analysis by AIS etiology, stroke sub-type and head position**

|  |        | Multivariable analysis |               |
|--|--------|------------------------|---------------|
| <b>AIS</b>   |        | OR(95%CI)              | P interaction |
| Large artery occlusion due to significant extracranial internal carotid atheroma | N=654  | 1.05(0.90-1.23)        | 0.333         |
| Large artery occlusion due to significant intracranial cerebral atheroma         | N=2004 | 1.03(0.94-1.13)        |               |
| Small vessel or perforator lacunar disease                                       | N=2580 | 1.06(0.98-1.16)        |               |
| Others   | N=3094 | 1.08(1.01-1.16)        |               |
| <b>Stroke subtype</b>  |        |                        |               |
| AIS  | N=8338 | 1.06(1.01-1.11)        | 0.908         |
| ICH  | N=818  | 1.03(0.94-1.13)        |               |
| <b>Head position</b>   |        |                        |               |
| Lying flat   | N=4375 | 1.04(0.98-1.10)        | 0.120         |
| Sitting up   | N=4781 | 1.08(1.02-1.15)        |               |
| <b>Reperfusion therapy</b>   |        |                        |               |
| No   | N=7183 | 1.05(1.00-1.10)        | 0.139         |
| Yes  | N=1115 | 1.04(0.93-1.17)        |               |

Data are presented as odds ratio [OR] (95% confidence intervals [95%CI]) for per 1 unit increment of systolic blood pressure [SBP] variability. AIS: acute ischemic stroke; ICH: intracerebral hemorrhage.

Adjusted covariates include covariates of country, prestroke mRS score, sex, baseline NIHSS score, and history of heart disease, stroke, diabetes mellitus, or hypertension, and prior antiplatelet therapy

## **Figure Legend**

**Fig. 1: Flowchart of the study procedures**

**Fig. 2: Mean and SD of systolic blood pressure over time**

**Fig. 3: Association between fifths of coefficient of variation of systolic blood pressure and unfavorable shift of mRS at 90 days**

Footnote: Association between fifths of CV of systolic blood pressure at baseline and unfavorable shift of mRS at 90 days









