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The effects of diffusion and perfusion MRI mismatch on the admission blood glucose and blood pressure values measured in the first 12 hours of acute stroke

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Abstract

Patients with severe stroke and salvageable brain tissue at admission, who have higher glycaemic and blood pressure levels, may have a risk of iatrogenic hypoglycemia/iatrogenic hypotension. In this study, we examined the relationship between the presence of diffusion-weighted imaging (DWI)/perfusion-weighted imaging (PWI) mismatch, admission blood glucose level, and admission blood pressure level in patients who were admitted in the first 12 hours after onset. We studied 212 patients who were prospectively and consecutively registered to the stroke unit from 2006 to 2009. Correlations between mismatch and admission blood pressure level (ABPL) and admission blood glucose level (ABGL) were analyzed using multivariate logistic regression. Mismatch ($P = .064$, adjusted OR = 2.297, 95% CI, 0.953–5.536) was not associated with a high ABGL in the whole group. However, after excluding patients with diabetes mellitus (DM) (n = 67, 35%), mismatch ($P = .033$, adjusted OR = 3.801, 95% CI, 1.110–13.015), an impaired level of consciousness, use of anti-DM medication, glycated hemoglobin levels, and cardioembolic aetiology were independent predictors of a high ABGL. The presence of mismatch or proximal vessel occlusion was not associated with ABPL. Female sex ($P = .048$) and total anterior circulation stroke ($P = .008$) were independent predictors associated with a higher ABPL. We conclude that patients with hyperacute ischemic stroke with PWI/DWI mismatch are more likely to have hyperglycemia.

Abbreviations: AF = atrial fibrillation, DM = diabetes mellitus, DWI = diffusion-weighted imaging, Hba1c = glycated hemoglobin, LACS = lacunar stroke, MR = magnetic resonance, NIHSS score = National Institutes of Health Stroke Scale, PACS = partial anterior circulation stroke, POCS = posterior circulation stroke, PWI = perfusion-weighted imaging, TACS = total anterior circulation stroke.

Keywords: blood glucose, blood pressure, hyperacute ischemic stroke, mismatch, penumbra

1. Introduction

Blood pressure levels are high in approximately 75% of patients who visit emergency clinics with the complaint of acute stroke, and approximately 50% of these patients have a background of hypertension. The highest levels of blood pressure are observed in patients at the early period of stroke, patients with hypertension anamnesis, and patients with hemorrhagic stroke.[1] Among the majority of patients, blood pressure levels are spontaneously reduced in approximately 4 to 10 days. The most prominent decrease is observed among patients who have the highest blood pressure levels. These findings mainly apply to patients who are examined in first 24 to 48 hours in the emergency department. However, the factors affecting blood pressure in the hyperacute state (first couple of hours) are unclear.

Activation of the sympathetic system secondary to a brain lesion and other mechanisms may be a beneficial homeostatic physiological response by increasing blood flow to the ischemic penumbra. Treatments that reduce acute blood pressure may be harmful in such patients.

Hyperglycemia is detected in more than 50% of patients who visit emergency clinics with the complaint of acute stroke.[2] High admission blood glucose levels are thought to be related to a bad prognosis independent of age, severity of stroke, or the subgroup of stroke. Furthermore, admission blood glucose levels negatively affect the probability of recanalization that would be ensured by tissue plasminogen activator.[3,4]

After acute stroke, the glucose requirement (especially in ischemic tissue) becomes sensitive to changes in systemic blood glucose levels. Therefore, high blood glucose levels in the acute period may play a positive role by increasing local glucose levels in ischemic zones of the brain. However, high blood glucose levels may also increase the risk of hemorrhagic transformation and cerebral edema in the zone of the infarct. Even though this appears to be contradictory, protecting the penumbra in ischemic tissue due to an occluded vessel or preventing emergence of new ischemic zones is important in the first couple of hours. Preventing brain edema and hemorrhagic transformation gradually gains importance in the following days after the first 24 hours. A much faster decrease in blood glucose levels is

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observed in patients who have spontaneous recanalization or recanalization developing after thrombolytic treatment compared with those who have no recanalization. This suggests that a reflexive increase in blood glucose levels might develop to prevent ischemic tissue in the first hours of acute ischemia.

In the present study, we investigated the factors affecting blood glucose and blood pressure in the hyperacute period of acute ischemic stroke. We aimed to examine the relationships among proximal vessel occlusion diagnosed by admission cranial magnetic resonance (MR) angiographic imaging, diffusion-weighted imaging (DWI)/perfusion-weighted imaging (PWI) mismatch thought to cover penumbral tissue in admission parenchymal imaging, and admission blood pressure and blood glucose values.

2. Materials and methods

2.1. Selection of patients

In the present study, patients' data that were prospectively and subsequently recorded in the database of Sisli Florence Nightingale Hospital Stroke Unit were examined. The files of 212 patients that were recorded because of acute neurological deficit in the first 12 hours of stroke were reviewed. Among the 212 files, 19 files were excluded because of missing data. Consequently, data of 195 patients (female n = 88, male n = 107) were included in the study.

3. Study protocol and method

3.1. Definition of mismatch

DWI/PWI mismatch that was detected in cranial MR images was considered as mismatch when it was higher than 20% in radiological measurements. Measurements were calculated by the same radiologist to eliminate inter-rater variability.

4. Determining variables

4.1. Dependent variables

Blood pressure levels higher than 140/90 mmHg were diagnosed as hypertension according to the guidelines.[5,6] Systolic blood pressure levels higher than 140 mmHg were considered as hypertension. Systolic blood pressure values above this level were separately categorized. For patients with acute stroke, anti-hypertensive medication was recommended for those who received thrombolysis and had blood pressure higher than 185/110 mmHg, and for those who received no vasodilators and had blood pressure higher than 220/120 mmHg.[7]

For hospitalized patients, hyperglycemia was defined as blood glucose values higher than 140 mg/dL.[8] The dependent variable blood pressure was divided into 2 categories (blood pressure ≥140/90 mmHg and <140/90 mmHg) and the variable blood glucose was divided into 2 categories (≥140 mg/dL and <140 mg/dL).

4.2. Independent variables

Independent variables included proximal vessel occlusion, mismatch, a history of hypertension, localization of the infarct (partial anterior circulation stroke [PACS], total anterior circulation stroke [TACS], posterior circulation stroke [POCS], lacunar stroke [LACS]), severity of stroke (admission National Institutes of Health Stroke Scale [NIHSS score]), and the presence of an impaired level of consciousness according to the NIHSS score (NIHSS Level of Consciousness; scores: 0, 1, 2, 3). Patients who had 2 or 3 points from this question were defined as having an impaired level of consciousness. An NIHSS score of 2 was classified as not alert, requiring repeated stimulation to attend, or obtunded and requiring strong or painful stimulation to make movements. An NIHSS score of 3 was classified as responding only with reflex motor or autonomic effects or totally unresponsive, flaccid and areflexic. Other independent variables that were analysed included sex, age, the time that passed before admission to the emergency room, insular cortex involvement, history of atrial fibrillation (AF), known+new AF, anti-hypertensive medication, aetiology of stroke (cardioemboli, large vessel, small vessel, unknown), history of diabetes mellitus (DM), level of glycated hemoglobin (Hba1c), and use of anti-DM medication.

4.3. Stress hyperglycemia

We examined if the presence of stress hyperglycemia was related to mismatch in the patients who had acute stroke in the first 12 hours. We aimed to better reveal stress hyperglycemia caused by mismatch by also analyzing a group of 132 patients who had HbA1c values <6.5% by excluding patients who were diagnosed with DM.

4.4. Standard protocol approvals, registration, and patients' consent

Written informed consent was signed by all of the participants who enrolled in this study. The research was carried out in conformity with the Declaration of Helsinki and was approved by the Ethics Committee of İstanbul Bilim University School of Medicine.

5. Statistical analysis

5.1. Descriptive analyses and logistic regression

The relationships between selected dependent and independent variables were analyzed using the Chi-square test (when both variables were categorical). If one variable was categorical and the other was continuous, then the Student *t* test was applied. The Mann–Whitney *U* test was performed when the distribution in a *t* test was not homogenous. In these models, variables that showed $P < .25$ were determined as candidate variables for the multivariate model.[9] Multivariate logistic regression analysis was then performed with the determined candidate variables. Statistical analyses were performed using SPSS 17.0 (version 17 SPSS, Inc., Chicago, IL). For exclusion and inclusion of variables in the model, the input value was set as 0.10 and the output value was set as 0.05.

6. Results

6.1. Blood pressure

The relationships of various variables with blood pressure in the whole group and those with the 2 blood pressure categories are shown in Table 1. Women had hypertension significantly more frequently than did men ($P = .045$). The number of patients with TACS was significantly higher in the hypertensive group compared with the normotensive group ($P = .050$). The hypertensive group had significantly more cases with left ventricular

Table 1

Descriptive analysis performed with independent variables determined when blood pressure was dependent variable.

Independent variables	All cases N = 195	Blood pressure <140/90 mm Hg N = 96	Blood pressure >140/90 mm Hg N = 99	Mann Whitney-U Z value	*P* value
Female gender, n (%)	88 (41%)	35 (36%)	53 (55%)	—	.045*
Age, median, (IQR) (mean rank)	73 (62–80)	72 (59–80) (47)	74 (65–80) (51)	−1.398	.162
Duration of admission to emergency, mean (SD)	232 (189)	242 (192)	229 (191)	—	.641
Admission NIHSS, mean (SD)	10 (7)	8 (7)	10 (7)	—	.092
Impaired consciousness, n (%)	25 (12%)	13 (14)	12 (12%)	—	.644
PACS, n (%)	65 (31%)	35 (36%)	30 (30%)	—	.242
TACS, n (%)	65 (31%)	22 (23%)	43 (43%)	—	.050*
POCS, n (%)	33 (16%)	19 (20%)	14 (14.1%)	—	.224
LACS, n (%)	31 (15%)	17 (18%)	14 (14.1%)	—	.401
Proximal vessel occlusion, n (%)	129 (61%)	56 (58%)	73 (74%)	—	.140
Mismatch, n (%)	107 (50%)	46 (48%)	61 (62%)	—	.147
Infarct in insular cortex, n (%)	78 (37%)	34 (35%)	44 (44%)	—	.349
Left ventricle hypertrophy, n (%)	72 (34%)	27 (28.1%)	45 (45%)	—	.021*
EF value in ECO, mean (SD)	55 (8)	55 (9)	54 (8)	—	.714
AF history, n (%)	51 (24%)	20 (21%)	31 (31%)	—	.146
Old + new AF, n (%)	84 (40%)	34 (35%)	50 (51%)	—	.051*
HT history, n (%)	149 (70%)	65 (68%)	84 (85%)	—	.041*
Anti-HT, n (%)	144 (68%)	65 (68%)	79 (80%)	—	.230
Cardioemboli, n (%)	114 (53%)	50 (52%)	64 (64%)	—	.204
Large vessel, n (%)	24 (11%)	8 (8%)	16 (17%)	—	.133
Small vessel, n (%)	9 (4%)	5 (5%)	4 (4%)	—	.629
Unknown cause, n (%)	46 (22%)	27 (28%)	19 (19%)	—	.087

AF = Atrial Fibrillation, ECO = Echocardiogram, EF = Ejection Fraction, HT = Hypertension, LACS = lacunar stroke, NIHSS = National Institutes of Health Stroke Scale, PACS = partial anterior circulation stroke, POCS = posterior circulation stroke, SD = Standard Deviation, TACS = total anterior circulation stroke.

* $P < .05$ indicates statistically significant variables,

hypertrophy compared with the normotensive group ($P = .021$). There were no significant differences in the other variables between the hypertensive and normotensive groups.

Independent variables that showed a *P* value <.25 according to the results of the likelihood ratio test or Wald test statistics were determined as candidate variables for the multivariate model. Female sex ($P = .046$) and presenting with total anterior circulation stroke ($P = .010$) formed the multivariate logistic regression model of having hypertension in this hyperacute stroke patient group. The results of this multivariate model that was established with candidate variables are shown in Table 2.

6.2. Blood glucose

The relationships of variables with blood glucose levels in the whole group and with the 2 blood glucose categories are shown in Table 3. Patients with impaired consciousness had significantly higher blood glucose levels ($P < .001$). Patients with LACS had significantly lower blood glucose levels ($P = .023$). Patients with a history of DM, higher mean Hba1c levels, and use of anti-diabetic medication had significantly higher blood glucose levels on admission (all $P < .001$). Patients who had cardioembolic etiology had significantly higher admission blood glucose levels ($P = .036$). Patients with small vessel disease as the etiological factor had significantly lower admission blood glucose levels ($P = .033$). There were no differences in the other variables between the high admission blood glucose group and the normoglycemic group.

Independent variables that showed a *P* value <.25 according to the results of the likelihood ratio test or Wald test statistics were determined as candidate variables for the multivariate model. Impaired consciousness ($P = .001$), Hba1c ($P < .001$), use of anti-diabetic medication ($P = .003$), and cardioemboli ($P = .002$) formed the multivariate logistic regression model of having hypertension in this hyperacute stroke patient group. The results of this multivariate model that was established with candidate variables are shown in Table 4.

Table 2

Multivariate model parameters for blood pressure of the whole group and their significance level.

Independent variables	Parameter estimation value	Standard error	Wald value	Degree of freedom	Level of significance	Exp (B)	95% Lower confidence limit	95% Upper confidence limit
Female gender	.649	.325	3.979	1	*.046	1.914	1.011	3.620
Left ventricle hypertrophy in ECO	.649	.336	3.723	1	.054	1.913	.990	3.699
HT history	.683	.382	3.197	1	.074	1.980	.936	4.186
TACS	.880	.341	6.651	1	*.010	2.412	1.235	4.709
Constant	−1.308	.409	10.227	1	.001	.270		

ECO = Echocardiogram, HT = Hypertension, TACS = total anterior circulation stroke.

* $P < .05$ indicates statistically significant variables.

Table 3

Descriptive analyses with independent variables determined when blood glucose of whole group is dependent variable.

Independent variables	All cases N = 212-missing value = 193	Blood glucose <140 mg/dL N = 125	Blood glucose >140 mg/dL N = 68	Mann–Whitney *U*: Z	*P* value
Female gender, n (%)	89 (46%)	55 (44%)	34 (50%)	—	.424
Age, median, (IQR) (mean rank)	73 (62–80)	72 (59–79) (63)	74 (66–81) (34)	−1.727	.084
Duration of admission to emergency, mean (SD)	232 (189)	251 (195)	211 (181)	—	.190
Admission NIH, mean (SD)	10 (7)	9 (7)	10 (8)	—	.224
Impaired consciousness, n (%)	24 (12%)	7 (6%)	17 (25%)	—	.000*
PACS, n (%)	65	40	25	—	.458
TACS, n (%)	65 (34%)	44 (35%)	21 (31%)	—	.590
POCS, n (%)	32 (17%)	16 (12.8%)	16 (24%)	—	.05*
LACS, n (%)	30 (16%)	25 (20%)	5 (7%)	—	.023*
Proximal vessel occlusion, n (%)	121 (62%)	76 (60%)	45 (66%)	—	.383
Mismatch, n (%)	106 (55%)	64 (51%)	42 (61%)	—	.159
Insular cortex infarct, n (%)	78 (40%)	52 (42%)	26 (38%)	—	.649
Hba1c, median, (IQR) (mean rank)	5.7 (5.3–6.25)	5.6 (5.3–5.9) (57)	6.0 (5.5–7.25) (31)	−5.012	.000
AF history, n (%)	51 (26%)	28 (22%)	23 (34%)	—	.074
Old+New AF, n (%)	84 (44%)	47 (38%)	37 (54%)	—	.043*
All DM, n (%)	67 (35%)	26 (21%)	41 (60%)	—	.000*
Use of anti-DM medication, n (%)	36 (19%)	10 (8%)	26 (38%)	—	.000*
Cardioemboli, n (%)	114 (59%)	67 (53%)	47 (69%)	—	.036*
Large vein, n (%)	23 (12%)	14 (11%)	9 (13%)	—	.677
Small vein, n (%)	8 (4%)	8 (6%)	0 (0%)	—	.033*
Unknown cause, n (%)	46 (24%)	33 (26%)	13 (19%)	—	.257

AF = Atrial Fibrillation, ECO = Echocardiogram, EF = Ejection Fraction, HT = Hypertension, LACS = lacunar stroke, NIHSS = National Institutes of Health Stroke Scale, PACS = partial anterior circulation stroke, POCS = posterior circulation stroke, SD = Standard Deviation, TACS = total anterior circulation stroke.

* $P < .05$ indicates statistically significant variables.

Table 4

Multivariate model parameters for blood glucose in whole group and the significance levels.

Independent variables in the model	Parameter estimation value	Standard error	Wald value	Degree of freedom	Level of significance	Exp (B)	95% Lower confidence limit	95% Upper confidence limit
Impaired consciousness	2.023	.604	11.209	1	*.001	7.561	2.313	24.715
Hba1c	.972	.277	12.339	1	*.000	2.644	1.537	4.548
Use of anti-DM medication	1.711	.581	8.668	1	*.003	5.532	1.771	17.278
Cardioemboli	1.697	.543	9.771	1	*.002	5.459	1.883	15.823
POCS	1.104	.601	3.379	1	.066	3.017	.929	9.791
Mismatch	.832	.449	3.436	1	.064	2.297	.953	5.536
Constant	−8.896	1.897	21.991	1	*.000	.000		

DM = Diabetes Mellitus, Hba1c = glycated hemoglobin, POCS = posterior circulation stroke.

* $P < .05$ indicates statistically significant variables.

The relationships of variables with blood glucose levels were re-analyzed after patients with DM were excluded (Table 5). In this patient group, the mean admission NIHSS score was significantly higher in the hyperglycemic group compared with the normoglycemic group ($P = .001$). Cases of impaired consciousness were significantly more common in the hyperglycemic group than in the normoglycemic group ($P < .001$). Patients presenting with LACS were significantly more normoglycemic than hyperglycemic ($P = .008$). Patients with proximal vessel occlusion and mismatch were significantly more hyperglycemic than normoglycemic ($P = .037$ and $P = .039$, respectively). Patients with a history of AF, a history of AF+newly diagnosed AF, and an etiology of cardioemboli were significantly more hyperglycemic than normoglycemic ($P = .010$, $P = .007$, and $P = .005$, respectively). There were no differences in the other variables between hyperglycemic and normoglycemic groups.

Independent variables that showed a P value $<.25$ according to the results of the likelihood ratio test or Wald test statistics were determined as candidate variables for the multivariate model. Impaired consciousness ($P = .001$), mismatch ($P = .033$), and an etiology of cardioemboli ($P = .017$) formed the multivariate logistic regression model of having hypertension in this hyperacute stroke patient group. The results of this multivariate model that was established with candidate variables are shown in Table 6.

7. Discussion

7.1. Blood pressure

In our study, among patients who were admitted within the first 12 hours of ischemic stroke, mismatch and proximal vessel occlusion had no significant effect on admission blood pressure.

Table 5

Descriptive analyses performed with independent variables determined when the blood glucose is dependent variable.

Independent variables	All cases N = 125	Blood glucose <140 mg/dL N = 99	Blood glucose >140 mg/dl N = 26	Z value of those taken in Mann Whitney-U	*P* value
Female gender, n (%)	62 (50%)	45 (36%)	17 (65%)	—	.070
Age, median, (IQR) (mean rank)	74 (62–80)	73 (58–80) (50)	76 (65–83) (13)	−1.570	.116
Duration for admission to emergency, mean (SD)	239 (189)	241 (190)	258 (199)	—	.711
Admission NIH, mean (SD)	10 (7)	9 (7)	15 (8)	—	.001*
Impaired consciousness, n (%)	18 (14%)	7 (7%)	11 (42%)	—	.000*
PACS, n (%)	35	27	8	—	.724
TACS, n (%)	45 (36%)	34 (34%)	11 (42%)	—	.451
POCS, n (%)	23 (18%)	16 (16%)	7 (27%)	—	.208
LACS, n (%)	22 (18%)	22 (22%)	0 (0%)	—	.008*
Proximal vessel occlusion, n (%)	85 (68%)	60 (64%)	21 (85%)	—	.037*
Mismatch, n (%)	69 (55%)	50 (51%)	19 (73%)	—	.039*
Infarct in insular cortex, n (%)	54 (43%)	41 (41%)	13 (50%)	—	.432
Hba1c, (SD)	5.4 (0.4)	5.4 (0.4)	5.5 (0.3)	—	.143
AF history, n (%)	41 (33%)	27 (27%)	14 (54%)	—	.010*
Old-new AF, n (%)	60 (48%)	41 (41%)	19 (73%)	—	.007*
Cardioemboli, n (%)	76 (61%)	54 (55%)	22 (85%)	—	.005*
Large vessel, n (%)	13 (10%)	10 (10%)	3 (12%)	—	.831
Small vessel, n (%)	7 (6%)	7 (7%)	0 (0%)	—	.163
Unknown cause, n (%)	28 (22%)	26 (26%)	2 (8%)	—	.043*

AF = Atrial Fibrillation, ECO = Echocardiogram, LACS = lacunar stroke, NIHSS = National Institutes of Health Stroke Scale, PACS = partial anterior circulation stroke, POCS = posterior circulation stroke, SD = Standard Deviation, TACS = total anterior circulation stroke.

* $P < .05$ indicates statistically significant variables.

Our findings suggested that the level of admission blood pressure was not related to vessel occlusion or mismatch. In the present study, female sex and TACS, which is one of the clinical syndromes, were related to the level of acute high blood pressure.

Semplicini et al[10] found that temporary hypertension was present in all of the subtypes of stroke. The best prognosis was found in the LACS subtype, whereas minimum blood pressure and the worst prognosis were found in POCS. In other studies, relatively lower levels of blood pressure were found in severe stroke compared with milder strokes.[11,12] On the basis of these studies, the cases in the present study were classified as LACS, PACS, TACS, and POCS according to the classification developed by Bamford et al[13] using clinical symptoms. In our study, TACS was significantly related to high admission blood pressure levels. This finding is not consistent with previous studies.

Mattle et al[14] reported that systolic blood pressure decreased much more 12 hours after thrombolysis when recanalization of the vessel was ensured by using intravenous thrombolysis compared with no recanalization. Because thrombotic or embolic occlusion is the reason for acute ischemic stroke, it might be the first trigger point leading to high blood pressure. Kvistad et al[15] found that, independent from the stroke subtype and proximal vessel occlusion, hypertensive patients (n = 1067) who were admitted with the complaint of acute stroke within the first 6 hours or later showed a significant decrease in blood pressure in the 24th hour after their admission. The reason for this finding might be because of psychological stress or white coat hypertension. In the present study, no relationship was found between high admission blood pressure and proximal vessel occlusion, which is consistent with Kvistad et al's study.[15]

In the IST study on patients with stroke who were admitted to hospital at a median of 20 hours after onset, female patients had higher blood pressure values than did male patients.[11] This previous finding is consistent with the present study.

The GAIN study showed that a history of hypertension was associated with higher mean blood pressure in the first 60 hours of acute stroke.[16] In the present study, a history of hypertension and the presence of left ventricular hypertrophy were not involved in the final model for explaining admission blood pressure.

Table 6

Multivariate model parameters for blood glucose in non-DM group and the significance levels.

Independent variables in the model	Parameter estimation value	Standard error	Wald value	Degree of freedom	Significance level	Exp (B)	95% Lower confidence limit	95% Upper confidence limit
Impaired consciousness	2.210	.654	11.405	1	*.001	9.118	2.528	32.882
Mismatch	1.335	.628	4.520	1	*.033	3.801	1.110	13.015
Cardioemboli	1.786	.746	5.736	1	*.017	5.966	1.383	25.730
Constant	−4.001	.935	18.312	1	.000	.018		

* $P < .05$ indicates statistically significant variables

In our study, we examined if the state of consciousness, which is an important component of stroke severity, affects admission blood pressure levels. There were no significant relationships between admission blood pressure levels and having an impaired consciousness based on the consciousness category of NIHSS scoring. Previous studies have reported that admission blood pressure levels tend to be higher in patients with no impaired consciousness.[11,15]. However, we found no evidence that the state of consciousness has an effective role in admission blood pressure levels in the present study.

The patients in the present study were divided into etiology groups of large vessel, cardioemboli, small vessel, and unknown causes. We found that this aetiological differentiation was not significantly related to admission blood pressure values. Similarly, no significant relationships were found between admission blood pressure levels and the ejection fraction and presence of AF.

Meyer et al[17] reported that acute ischemia, especially that occurring in the right insular cortex, caused higher than normal systolic and diastolic blood pressure at admission and at the following 5-day period. In another study by Pettersen et al.,[18] no significant relationship was found between insular cortex involvement and increased blood glucose and blood pressure levels. In the present study, no significant relationship was found between insular cortex involvement and admission blood pressure values.

In the present study, high blood pressure was not related to the presence of salvageable penumbral tissue (i.e., presence of mismatch). According to previous literature, high blood pressure negatively affects the prognosis in acute stroke. Based on our findings and previous studies, treatment strategies for patients who are not provided anti-hypertensive therapy in hyperacute or acute stroke because of the possibility of clinical deterioration need to be reconsidered in future studies.

7.2. Blood glucose

In our study, although no relationship was found between acute proximal vessel occlusion and blood glucose levels, there tended to be a relationship between the presence of mismatch and admission blood glucose levels. Impaired consciousness, cardioembolic stroke, use of anti-diabetic medication, and high Hba1c levels were related to high admission blood pressure. For patients who had no history of DM with HbA1c levels lower than 6.5%, mismatch was correlated with high admission blood glucose levels, independent from proximal vessel occlusion. These findings suggest that high admission blood glucose levels are a response to an acute stress factor in hyperacute ischemic stroke. Furthermore, this stress factor might be the presence of mismatch, which can be shown with cranial MR images (i.e., the presence of potentially salvageable penumbral tissue).

Hyperglycaemia was detected in 20% to 50% of patients who were admitted to emergency clinics with the complaint of acute stroke.[2] A total of 8% to 20% of these patients had a history of DM, whereas 6%–42% of them had newly detected DM that was unknown before acute stroke.[2,19,20] The definition of hyperglycemia varies between studies. Hyperglycemia is described as admission blood glucose levels in some studies and as fasting blood glucose levels measured on the next day in other studies. Moreover, the blood glucose limit varies between 108 and 180 mg/dL among studies.

High blood glucose levels measured in individuals with no history of DM or in those with normal Hba1c levels, despite the presence of a history of DM, is called stress hyperglycemia. Stress hyperglycemia is found in 5% to 36% of patients with acute stroke.[21] In the present study, admission hyperglycaemia was detected in 35% of patients. Some previous studies have shown that the severity and intensity of stroke and some stroke subtypes, which are thought to affect admission blood glucose levels, might cause stress hyperglycemia.[22] Some other studies reported that there is no such association.[23]

Allport et al[21] reported that there was a significant relationship between the NIHSS value, which is used in determining the severity of stroke, and admission blood glucose levels. However, in the present study, we did not find a significant difference between admission NIHSS scores and admission blood glucose levels. Our lack of a significant relationship is consistent with the study by Van Kooten et al[23] and the ECASS II study.[24]

Moreover, with regard to the severity of stroke, we also examined how the state of consciousness affects admission blood glucose levels. We found a significant relationship between impaired consciousness in hyperacute stroke and admission blood glucose levels. This finding suggests that impaired consciousness is an important factor that can affect admission blood glucose levels in hyperacute stroke. When we examined the relationships of 4 different clinical syndromes[13] with admission blood glucose levels in multivariate logistic regression analysis, neither of them was included in the final model for explaining blood glucose levels.

Allport et al[21] reported that there was no significant relationship between HbA1c and admission blood glucose levels. This occurred because the response to acute stress causes hyperglycemia independently from 3-month glucose control. In the present study, there was a positive correlation between Hba1c and blood glucose levels in the group of acute stroke. Hba1c was included in the final model of multivariate regression analysis at a high level of significance. In patients without DM with Hba1c levels below 6.5%, Hba1c was not included in the final model in multivariate logistic regression. Therefore, Hba1c was significantly related to admission blood glucose levels in patients with DM, whereas it is not an important factor for determining blood glucose levels in patients without DM.

In the whole patient group, the relationships between admission blood glucose values and the parameters of having DM and using anti-DM medication were significant. These results suggest that blood glucose levels were not well controlled. Therefore, patients with DM and high Hba1c levels and the requirement for using anti-DM medications are more likely to have increased admission blood glucose levels in the hyperacute period of stroke.

In the present study, there was no significant relationship between admission insular cortex infarcts and admission blood glucose levels. This finding is in contrast to that by Allport et al[21] but is consistent with some other studies.[18,25,26]

In the present study, the variable of AF was not significant in the final model of multivariate logistic regression for explaining blood glucose levels. However, some other studies have shown a relationship between AF and hyperglycemia.[27–29]

In our study, there was a significant relationship between blood glucose levels and cardioemboli, which is one of the stroke aetiologies. Among the stroke aetiologies, only cardioembolic stroke was significant in the model for explaining admission blood glucose levels. Cardioembolic stroke was also found to be

an important source of stress that caused an increase in admission blood glucose levels.

Some studies that aimed to explain the reasons of admission hyperglycemia in non-diabetic patients discussed that a factor causing stress hyperglycemia might be impaired glucose metabolism that has not been diagnosed[30–32] or a large size of infarct.[33] In acute stroke, stress hyperglycemia is detected in some patients, but it is not seen in many other patients. Therefore, there might be another stress mechanism for causing differences between these 2 patient groups.

Mismatch tended to be one of the factors that determined blood glucose levels in the multivariate regression model (independently from anti-diabetic medication and HbA1c). Mismatch was also one of the factors that determined blood glucose level in the non-diabetic group, together with the state of consciousness and cardioemboli. For this reason, mismatch is an important source of stress in the hyperacute stroke population and it leads to stress hyperglycemia.

Luitse et al[34] analysed perfusion computed tomographic images of 80 patients with acute stroke in the first 24 hours. These authors also examined the relationship between the area covered by perfusion deficit and admission blood glucose levels. As expected, the authors emphasized that they could not find a large perfusion deficit in individuals who had high admission blood glucose levels. However, in contrast to the present study, only perfusion computed tomography was examined in their study, not diffusion and perfusion MR mismatch. Perfusion computed tomography does not show salvageable penumbral tissue.[34]

Christensen et al[35] showed that patients with the highest tendency towards an increase in blood glucose levels, especially in the first 6 to 12 hours, did not have diabetes. Other studies showed a decrease in blood glucose levels and a plateau phase in the first 24 to 40 hours of stroke.[2,30,32] In patients with and without diabetes, a progressive decrease was reported in blood glucose values that were measured on a daily basis during the first week after stroke.[22,36] An important factor emerging in the first 6 to 12 hours of 2-phase hyperglycemia followed by a return to normal blood glucose levels, with no significant effect on prognosis, might be the presence of mismatch, which disappears after a while. Therefore, managing hyperglycemia in the hyperacute period by distinguishing it from hyperglycemia that is observed in the following period (>12 hours) might be a reasonable approach. How this management should be performed should be investigated by considering the presence of mismatch in a larger number of hyperacute patients.

8. Conclusion

The present study does not show the expected relationship between mismatch and high blood pressure. Investigation and implementation of new treatment strategies for patients with hyperacute stroke with high blood pressure who are not treated might be warranted because of the unproven possibility of clinical deterioration. Our results show the tendency for hyperglycemia at the time of admission in patients with hyperacute ischemic stroke who have mismatch detected in diffusion-perfusion MR images. For this patient group, whether parenteral insulin therapy is safe should be investigated in the future.

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