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Association of blood pressure and hypertension with radiographic damage among the patients with ankyloing spondylitis

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Abstract

To investigate the association of blood pressure and hypertension with disease severity among the patients with ankyloing spondylitis (AS). There were 167 AS patients enrolled in the cross-sectional study. Blood pressure was measured and the presence of hypertension was recorded. Patient's disease severity, including disease activity, functional ability, patient's global assessments, physical mobility and radiographic damage were evaluated. ESR and CRP levels were tested. We recorded patient's medication use of NSAIDs, DMARDs and TNF-α blockers. Smoking, exercise habit, diabetes mellitus, hypercholesterolemia and obesity indices were assessed. Multivariate linear regression showed that systolic blood pressure was associated with TNF-α blocker [standard coefficient (β) = 0.194, $P = .007$], DMARDs (β = 0.142, $P = .046$), age (β = 0.211, $P = .003$), male gender (β = 0.242, $P = .001$) and body mass index (BMI) (β = 0.245, $P = .001$). Diastolic blood pressure was associated with cervical rotation (β = –0.174, $P = .037$), lateral lumbar flexion (β = –0.178, $P = .019$), m-SASSS (β = 0.198, $P = .038$) and BMI (β = 0.248, $P = .003$). Notably, multivariate logistic regression showed that hypertension was associated with m-SASSS (OR = 1.033, $P = .033$), age (OR = 1.098, $P = .0010$) and BMI (OR = 1.210, $P = .003$). Using ROC cure analyses, age, BASMI, BASRI-Total, m-SASSS, waist circumference, BMI and waist-to-height ratio were useful in predicting hypertension, and m-SASSS is the best (AUC = 0.784, $P < .001$). Advanced radiographic damage is an independent risk factor of hypertension in AS, and m-SASSS is the most useful disease severity parameter in predicting the presence of hypertension. Advanced radiographic damage, poor cervical rotation, lateral lumbar flexion, older age, male gender, TNF-α blocker, DMARDs use and obesity are associated with increased blood pressure.

Abbreviations: AS = ankylosing spondylitis, AUC = Area under the curve, BASFI = Bath Ankylosing Spondylitis Functional Index, BASMI = Bath Anklyosing Spondylitis Metrology Index, BASRI = Bath Ankylosing Spondylitis Radiology Index, BMI = body mass index, CRP = C-reactive protein, DM = diabetes mellitus, DMARDs = disease-modifying antirheumatic drugs, m-SASSS = modified Stoke Ankylosing Spondylitis Spinal Score, NSAIDs = non-steroidal anti-inflammatory drugs, OR = odds ratios, ROC = receiver operating characteristic, SpA = Spondyloarthritis, WC = waist circumference, WHtR = waist-to-height ratio.

Keywords: ankylosing spondylitis, blood pressure, hypertension, radiographic damage, TNF-α blocker

1. Introduction

Spondyloarthritis (SpA) is classified as axial SpA, affecting the spine, pelvis and thoracic cage, or peripheral SpA, affecting the extremities. SpA is characterized by inflammatory back pain, sacroiliitis and peripheral arthritis.[1] Axial SpA is divided to radiographic SpA with radiographic sacroiliitis, and non-radiographic SpA without radiographic sacroiliitis, or sacroiliitis on Magnetic Resonance Imaging, or positive HLA-B27 with clinical features. Peripheral manifestations of SpA include arthritis, enthethitis and dactylitis. Patients with SpA can have some extra-articular manifestations, including acute anterior uveitis, bowel inflammation and psoriasis. Ankylosing spondylitis (AS) is the prototype of axial SpA. The most common symptom of AS is chronic back pain and rest stiffness. Chronic inflammation in AS patients can cause syndesmophyte formation and lead to spinal ankylosis, resulting in limitation of spinal mobility.[2]

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The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

The data underlying this article will be shared on reasonable request to the corresponding author.

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Hypertension is a popular health problem in the general population and is an important risk factor of cardiovascular diseases among the patients with AS.[3,4] The patients with AS have increased cardiovascular morbidity and mortality.[4–6] The presence of hypertension was higher in the patients with AS than the health people.[3,7,8] Hypertension is the most prevalent comorbidity among the patients with axial SpA.[8–11] The relationship of blood pressure and hypertension with disease severity have rarely been studied among the patients with AS. To our knowledge, the associations of blood pressure and hypertension with radiographic damage has not yet been reported among the patients with AS. In this study, we measure the blood pressure and record the presence of hypertension among the AS patients, and aim to investigate whether there are independent associations with patient's disease severity, including systemic inflammation, disease activity, functional ability, patient's global assessment, physical mobility and radiographic damage. The associations of blood pressure and the presence of hypertension with patient's demographic data, medication use, life style, comorbidities and obesity indices were also evaluated among the patients with AS.

2. Methods

2.1. Patients

There were 167 AS patients enrolled who fulfilled the 1984 modified New York criteria[12] in the outpatient department of Taipei Tzuchi Hospital, Taiwan during August 1, 2016 to September 30, 2019. We collected these AS patient's demographic and clinical data. The patient's written informed consent was obtained before study. This study was conducted in accordance with the Declaration of Helsinki principles and was approved by the Institutional Review Board of Taipei Tzuchi Hospital (06-XD30-065).

2.2. Blood pressure, hypertension and diabetes mellitus

Patient's blood pressure was measured in the outpatient department of Taipei Tzuchi Hospital. Blood pressure measurement was performed by using a sphygmomanometer in a sitting position after 5 to10 minutes rest. Medical records were reviewed to check the history of hypertension, diabetes mellitus (DM) and hypercholesterolemia in these patients. The presence of hypertension was defined as taking antihypertensive medications for hypertension. DM was defined as taking antidiabetic medications for diabetes. Hypercholesterolemia was defined as taking cholesterol lowering medications for hypercholesterolemia.

2.3. Disease severity

The patient's disease severity was assessed, including systemic inflammation, disease activity, functional ability, patient's global assessments, physical mobility and radiographic damage. Blood erythrocyte sedimentation rate and C-reactive protein (CRP) levels were tested as indices of systemic inflammation. Disease activity was assessed by Bath Ankylosing Spondylitis Disease Activity Index,[13] Ankylosing Spondylitis Disease Activity Index-ESR and Ankylosing Spondylitis Disease Activity Index-CRP.[14,15] Functional ability was assessed by Bath Ankylosing Spondylitis Functional Index (BASFI).[16] Patient's global assessment was assessed by Bath Ankylosing Spondylitis Patient Global Score.[17] Patient's physical mobility was assessed by Bath Anklyosing Spondylitis Metrology Index (BASMI), which was constituted by tragus-to-wall distance, lumbar flexion (Modified Schober index), intermalleolar distance, cervical rotation and lateral lumbar flexion.[18] Fingertip-to-floor distance, chest expansion and occiput-to-wall distance were also measured in the AS patients.

Radiographic damage in the cervical spines, lumbar spine, hip joint and sacroiliac joints were assessed by the Bath Ankylosing Spondylitis Radiology Index (BASRI), modified Stoke Ankylosing Spondylitis Spinal Score (m-SASSS) and modified New York criteria.[12,19,20] Radiographs with anteroposterior and lateral view of cervical and lumbar spine, pelvis and hip were taken in these AS patients. The total BASRI score ranged from 2 to16, and the m-SASSS score ranged from 0 to 72.

2.4. Medication use

The patient's medication use for Non-Steroidal Anti-Inflammatory Drugs (NSAIDs) or Disease-Modifying Antirheumatic Drugs (DMARDs) was recorded. The patients were asked the following question. Do you use NSAIDs during past 3 months: yes almost daily use, occasionally, or no. Patients were subgroup as regular NSAIDs user (yes) and non regular NSAIDs user (occasionally and no). Patients were subgroup as NSAIDs user (yes or occasionally) and non NSAIDs user (no).

Do you use DMARDs (Sulfasalazine or Methotrexate) during past 3 months: yes almost daily use, occasionally, or no. Patients were subgroup as regular DMARDs user (yes) and non regular DMARDs user (occasionally or no). Patients were subgroup as NSAIDs user (yes or occasionally) and non DMARDs user (no).

The patients who were under Tumor Necrosis Factor-α (TNF-α) blocker use were recorded as TNF-α blocker user.

2.5. Life style

The patient's smoking habits were recorded as current smoker, past smoker and nonsmoker. Current and past smoker were grouped as ever smoker.

The patient's exercise habit was recorded. The patients were asked the following questions. Do you have regular exercise during the past 3 months (more than 30 minutes each time of exercise): yes more than 2 times per week, occasionally, or no. The patients were grouped as regular exercise (yes), and non regular exercise (occasionally or no).

2.6. Obesity indices

Patient's obesity indices, including body mass index (BMI), waist circumference (WC) and waist-to-height ratio (WHtR) were estimated. The patient's body weight and height were measured. BMI was determined as the weight divided by the square of the height [weight (kg)/height (m)^2]. WC was measured in the halfway between the lowest rib border and the iliac crest at the end of patient's normal exhalation. WHtR was the WC divided by the height [WC (cm)/height (cm)]. BMI is an index for patient's total obesity. WC and WHtR are indices for patient's central obesity.[2]

2.7. Statistical analysis

We used the SPSS statistical package (SPSS for Windows, Chinese Version 10.0.7C, SPSS Inc., 2000) to carry out the statistical analyses. Continuous variables were described as mean ± standard deviation (SD). Categorical variables were described as ratio (percentages). Univariate linear regression analyses were used to assess correlation of systolic and diastolic blood pressure with independent variables. The results were expressed as regression coefficient [95% confidence intervals (CI)] and standard coefficient (β). Independent variables with a P value < .1 in univariate linear regression analyses were further tested in multivariate linear regression analyses. Univariate logistic regression analyses were used to calculate the odds ratios (OR) (95% CI) for prediction of hypertension. Independent variables with a P value < .1 in univariate logistic regression analyses were further tested in multivariate logistic regression analyses. Receiver operating characteristic (ROC) curve analysis was performed to evaluate each variable in predicting the patients with hypertension. *P* values were regarded as being significant if they were <.05. Listwise deletion was used for missing data.

3. Results

3.1. Clinical features

The clinical characteristics of the 167 AS patients are shown in Table 1. The mean (SD) age were 47.029 (12.720) years, and disease duration were 18.619 (11.595) years in the 167 patients. The male to female ratio was 135:32. There were 20.9% (35/167) patients had hypertension, 6.5% (11/167) patients had DM, and 5.9% (10/167) patients had hypercholesterolemia. There were 10.7% (18/167) patients under TNF-α blocker use, including Etanercept or Adalimumab. The TNF-α blocker use duration were mean (SD), 53.222 (30.907) months.

Table 1

Demographic and clinical features of the 167AS patients.

Characteristic	Total AS patients (n = 167)
Age (yr) (n = 167)	47.029 (12.720)
Male gender (n = 167), male/female	135/32 (80.8%)
Onset age (y/o) (n = 159)	28.506 (11.884)
Disease duration (yr) (n = 159)	18.619 (11.595)
HLA-B27 (+)/(–) (n = 164)	145/19 (88.4%)
ESR (mm/h) (n = 165)	13.472 (14.578)
CRP (mg/dL) (n = 166)	0.706 (1.085)
BASDAI (n = 163)	2.861 (1.724)
ASDAS-ESR (n = 161)	1.968 (0.861)
ASDAS-CRP (n = 162)	2.035 (0.964)
BASFI (n = 165)	1.139 (1.477)
BAS-G (n = 167)	3.465 (2.701)
BASMI (n = 153)	2.841 (1.936)
Tragus-to-wall distance (cm) (n = 166)	13.356 (5.988)
Modified schober index (cm) (n = 166)	4.674 (2.288)
Intermalleolar distance (cm) (n = 167)	113.368 (23.078)
Cervical rotation (degree) (n = 156)	67.868 (28.262)
Lateral lumbar flexion (cm) (n = 167)	12.409 (6.851)
Fingertip-to-floor distance (cm) (n = 167)	17.538 (14.323)
Chest expansion (cm) (n = 167)	3.209 (2.108)
Occiput-to-wall distance (cm) (n = 167)	5.026 (6.047)
BASRI-total (n = 156)	9.198 (2.580)
m-SASSS (n = 156)	28.730 (17.955)
Uveitis (n = 167)	47/120 (28.1%)
TNF-αblocker use (n = 167)	18/149 (10.7%)
Regular NSAIDs use (n = 166)	63/103 (37.9%)
NSAIDs use (n = 166)	137/29 (82.5)
Regular DMARDs use (n = 166)	83/83 (50.0%)
DMARDs use (n = 166)	141/53 (84.9%)
Regular exercise (n = 167)	68/99 (40.7%)
Current smoker (n = 164)	40/124 (24.3%)
Ever smoker (n = 164)	70/94 (42.6%)
Hypertension (n = 167)	35/132 (20.9%)
Diabetes mellitus (n = 167)	11/156 (6.5%)
Hypercholesterolemia (n = 167)	10/157 (5.9%)
Waist circumference (WC) (cm) (n = 165)	90.818 (12.154)
Body mass index (BMI) (kg/m^2) (n = 166)	25.345 (4.501)
Waist to Height Ratio (WtHR) (n = 164)	0.543 (0.073)

Values are shown as mean (standard deviation) or ratio (yes/no) (percentage).
AS = ankylosing spondylitis, ASDAS-CRP = Ankylosing Spondylitis Disease Activity Score with CRP, ASDAS-ESR = Ankylosing Spondylitis Disease Activity Score with ESR, BASDAI = Bath Ankylosing Spondylitis Disease Activity Index, BASFI = Bath Ankylosing Spondylitis Functional Index, BAS-G = Bath Ankylosing Spondylitis Patient Global Score, BASMI = Bath Anklyosing Spondylitis Metrology Index, BASRI = Bath Ankylosing Spondylitis Radiology Index, m-SASSS = modified Stoke Ankylosing Spondylitis Spinal Score.

3.2. Univariate linear regression analyses of clinical factors correlated with systolic and diastolic blood pressure among the 167 AS patients

Univariate linear regression analyses of clinical factors associated with systolic and diastolic blood pressure are shown in Table 2. In the univariate linear regression analyses, systolic blood pressure positively correlated with male gender (standard coefficient (β) = 0.294, *P* < .001) and CRP (β = 0.180, *P* = .020). Systolic blood pressure positively correlated with BASRI-Total (β = 0.159, *P* = .047) and m-SASSS (β = 0.263, *P* = .001). Systolic blood pressure positively correlated TNF-α blocker (β = 0.207, *P* = .007) and DMARDs use (β = 0.178, *P* = .022). Systolic blood pressure positively correlated with WC (β = 0.329, *P* < .001), BMI (β = 0.311, *P* < .001) and WtHR (β = 0.341, *P* < .001). These results suggesting that male gender, active inflammation, advanced radiographic damage, TNF-α blocker, DMARDs use and obesity were significantly associated with increased systolic blood pressure in the AS patients.

In the univariate linear regression analyses, diastolic blood pressure positively correlated with male gender (β = 0.295, *P* < .001). Diastolic blood pressure significantly correlated with BASMI (β = 0.205, *P* = .011), tragus-to-wall distance (β = 0.154, *P* = .048), cervical rotation (β = –0.212, *P* = .008), lateral lumbar flexion (β = –0.201, *P* = .009), chest expansion (β = –0.200, *P* = .010) and occiput-to-wall distance (β = 0.202, *P* = .009). Diastolic blood pressure positively correlated with BASRI-Total (β = 0.204, *P* = .001) and m-SASSS (β = 0.224, *P* = .005). Diastolic blood pressure positively correlated with ever smoker (β = 0.166, *P* = .034). Diastolic blood pressure positively correlated with WC (β = 0.303, *P* < .001), BMI (β = 0.304, *P* < .001) and WtHR (β = 0.294, *P* < .001). These results suggested that male gender, poor physical mobility, particular cervical, lumbar spine and chest expansion, advanced radiographic damage, ever smoker and obesity were significantly associated with increased diastolic blood pressure in the AS patients. Male gender, advanced radiographic damage and obesity were significantly associated with both systolic and diastolic blood pressure.

3.3. Multivariate linear regression analyses of clinical factors correlated with systolic and diastolic blood pressure among the 167 AS patients

Independent variables with a *P* value < .1 in the univariate linear regression analyses were further tested in the multivariate linear regression analyses to assess their correlation with systolic and diastolic blood pressure (Table 3). In the multivariate linear regression analyses, systolic blood pressure positively correlated with TNF-α blocker use (β = 0.194, *P* = .007), after adjusted by age (β = 0.211, *P* = .003), gender (β = 0.242, *P* = .001), DM (β = –0.024, *P* = .745), hypercholesterolemia (β = –0.053, *P* = .460) and BMI (β = 0.245, *P* = .001). Systolic blood pressure positively correlated with DMARDs use (β = 0.142, *P* = .046), after adjusted by age, gender, DM, hypercholesterolemia and BMI. These results suggested that TNF-α blocker and DMARDs use were independently associated with increased systolic blood pressure in the AS patients. Older age, male gender and obesity were also independently associated with increased systolic blood pressure.

In the multivariate linear regression analyses, diastolic blood pressure significantly correlated with cervical rotation (β = –0.174, *P* = .037) and lateral lumbar flexion (β = –0.178, *P* = .019), after adjusted by age, gender, DM, hypercholesterolemia and BMI. Diastolic blood pressure positively correlated with m-SASSS (β = 0.198, *P* = .038), after adjusted by age (β = –0.119, *P* = .177), gender (β = 0.155, *P* = .055), DM (β = –0.106, *P* = .185), hypercholesterolemia (β = 0.008, *P* = .918) and BMI (β = 0.248, *P* = .003). These results suggested

Table 2

Univariate linear regression analyses of clinical factors correlated with systolic and diastolic blood pressure among the 167 AS patients.

Clinical factors	Systolic blood pressure			Diastolic blood pressure		
	Regression coefficient (95% CI)	Standard coefficient (β)	P value	Regression coefficient (95% CI)	Standard coefficient (β)	P value
Age (yr) (n = 167)	0.209 (0.041–0.377)	0.100	.015*	−0.0299 (−0.172 to 0.112)	−0.032	.677
Male gender (n = 167)	10.545 (5.272–15.817)	0.294	<.001*	8.791 (4.416–13.166)	0.295	<.001*
Onset age (y/o) (n = 159)	0.0738 (−0.106 to 0.254)	0.064	.420	−0.0291 (−0.159 to 0.153)	−0.033	.971
Disease duration (yr) (n = 159)	0.139 (−0.045 to 0.322)	0.118	.138	−0.0558 (−0.215 to 0.103)	−0.055	.489
ESR (mm/h) (n = 165)	0.113 (−0.037 to 0.263)	0.116	.137	0.0706 (−0.053 to 0.195)	0.088	.263
CRP (mg/dL) (n = 166)	2.350 (0.369–4.332)	0.180	.020*	1.245 (−0.408 to 2.897)	0.115	.139
BASDAI (n = 163)	−1.044 (−2.320 to 0.232)	−0.126	.108	−0.636 (−1.690 to 0.418)	−0.093	.235
ASDAS-ESR (n = 161)	−1.398 (−3.989 to 1.192)	−0.084	.228	−0.367 (−2.495 to 1.761)	−0.027	.734
ASDAS-CRP (n = 162)	−0.386 (−2.695 to 1.924)	−0.026	.742	0.713 (−1.175 to 2.601)	0.059	.457
BASFI (n = 165)	0.995 (−0.447 to 2.467)	0.104	.184	0.875 (−0.348 to 2.098)	0.110	.159
BAS-G (n = 167)	−0.721 (−1.519 to 0.078)	−0.137	.077	−0.0076 (−0.677 to 0.622)	−0.002	.982
BASMI (n = 153)	0.737 (−0.434 to 1.909)	0.101	.215	1.260 (0.291–2.229)	0.205	.011*
Tragus-to-wall distance (cm) (n = 166)	0.108 (−0.256 to 0.472)	0.046	.558	0.302 (0.003–0.602)	0.154	.048*
Modified Schober index (cm) (n = 166)	−0.199 (−1.156 to 0.759)	−0.032	.683	−0.399 (−1.191 to 0.394)	−0.077	.322
Intermalleolar distance (cm) (n = 167)	0.0441 (−0.034 to 0.122)	0.087	.266	0.0087 (−0.086 to 0.103)	0.014	.855
Cervical rotation (degree) (n = 156)	0.0460 (−0.125 to 0.003)	−0.092	.253	−0.0887 (−0.154 to −0.024)	−0.212	.008*
Lateral lumbar flexion (cm) (n = 167)	−0.281 (−0.596 to 0.034)	−0.136	.080	−0.345 (−0.603 to −0.087)	−0.201	.009*
Fingertip-to-floor distance (cm) (n = 167)	0.120 (−0.031 to 0.271)	0.121	.119	0.0665 (−0.059 to 0.192)	0.081	.298
Chest expansion (cm) (n = 167)	−0.573 (−1.602 to 0.456)	−0.085	.273	−1.115 (−1.955 to −0.275)	−0.200	.010*
Occiput-to-wall distance (cm) (n = 167)	0.138 (−0.221 to 0.498)	0.059	.448	0.394 (0.101–0.686)	0.202	.009*
BASRI-Total (n = 156)	0.843 (0.010–1.677)	0.159	.047*	0.925 (0.218–1.632)	0.204	.001*
m-SASSS (n = 156)	0.201 (0.083–0.318)	0.263	.001*	0.146 (0.045–0.247)	0.224	.005*
Uveitis (n = 167)	−1.609 (−6.431 to 3.212)	−0.051	.511	−0.310 (−4.317 to 3.697)	−0.012	.879
TNF-α blocker use (n = 167)	9.434 (2.585–16.283)	0.207	.007*	3.395 (−2.393 to 9.182)	0.090	.248
Regular NSAIDs use (n = 166)	0.419 (−4.047 to 4.884)	0.014	.853	2.477 (−1.228 to 6.182)	0.103	.189
NSAIDs use (n = 166)	1.040 (−4.665 to 6.745)	0.028	.719	2.629 (−2.114 to 7.372)	0.085	.275
Regular DMARDs use (n = 166)	1.976 (−2.348 to 6.300)	0.070	.368	1.675 (−1.931 to 5.280)	0.071	.360
DMARDs use (n = 166)	5.395 (0.805–9.985)	0.178	.022*	3.767 (−0.061 to 7.595)	0.150	.054
Regular exercise (n = 167)	1.023 (−3.393 to 5.439)	0.036	.648	−1.423 (−5.084 to 2.238)	−0.060	.444
Current smoker (n = 164)	4.849 (−0.155 to 9.944)	0.149	.057	3.896 (−0.301 to 8.093)	0.143	.069
Ever smoker (n = 164)	4.182 (−0.204 to 8.568)	0.146	.062	3.937 (0.306–7.567)	0.166	.034*
Diabetes mellitus (n = 167)	4.636 (−4.087 to 13.360)	0.081	.296	0.923 (−6.340 to 8.187)	0.020	.802
Hypercholesterolemia (n = 167)	1.909 (−7.237 to 11.054)	0.032	.681	1.343 (−6.250 to 8.935)	0.027	.727
Waist circumference (WC) (cm) (n = 165)	0.385 (0.214–0.556)	0.329	<.001*	0.294 (0.151–0.437)	0.303	<.001*
Body mass index (BMI) (kg/m^2) (n = 166)	0.981 (0.519–1.443)	0.311	<.001*	0.797 (0.412–1.182)	0.304	<.001*
Waist to height ratio (WtHR) (n = 164)	65.886 (37.732–94.039)	0.341	<.001*	47.054 (23.286–70.822)	0.294	<.001*

Listwise deletion for missing data.

AS = ankylosing spondylitis, ASDAS-CRP = Ankylosing Spondylitis Disease Activity Score with CRP, ASDAS-ESR = Ankylosing Spondylitis Disease Activity Score with ESR, BASDAI = Bath Ankylosing Spondylitis Disease Activity Index, BASFI = Bath Ankylosing Spondylitis Functional Index, BAS-G = Bath Ankylosing Spondylitis Patient Global Score, BASMI = Bath Anklyosing Spondylitis Metrology Index, BASRI = Bath Ankylosing Spondylitis Radiology Index, m-SASSS = modified Stoke Ankylosing Spondylitis Spinal Score.

*Statistical significances.

that poor cervical rotation, lateral lumbar flexion and advanced radiographic damage were independently associated with increased diastolic blood pressure in the AS patients. Obesity was independently associated with increased diastolic blood pressure.

Systolic blood pressure showed the trend to have association with CRP levels after multivariate adjustment (β = 0.125, *P* = .090). Diastolic blood pressure showed the trend to have association with BASMI (β = 0.163, *P* = .055), chest expansion (β = −0.139, *P* = .068), BASRI-Total (β = 0.164, *P* = .058) and DMARDs use (β = 0.121, *P* = .097), after multivariate adjustment.

3.4. Univariate logistic regression analyses of clinical factors for hypertension among the 167 AS patients

Univariate logistic regression analyses of clinical factors for hypertension are shown in Table 4. In univariate logistic regression analyses, hypertension was associated with age [OR (95% CI), *P* value; 1.093 (1.050–1.137), *P* < .001] and disease duration [OR = 1.055 (1.020–1.091), *P* = .002]. Hypertension was associated with BASFI [OR = 1.300 (1.035–1.623), *P* = .024], BASMI [OR = 1.341 (1.096–1.641), *P* = .004], tragus-to-wall distance [OR = 1.065 (1.002–1.132), *P* = .041], intermalleolar distance [OR = 0.972 (0.955–0.989), *P* = .001], cervical rotation [OR = 0.986 (0.973–0.999), *P* = .031], lateral lumbar flexion [OR = 0.919 (0.866–0.975), *P* = .005], chest expansion [OR = 0.782 (0.614–0.996), *P* = .046], and occiput-to-wall distance [OR = 1.079 (1.017–1.145), *P* = .012]. These results suggested that the presence of hypertension was increased in the AS patients with older age, longer disease duration, poor functional ability and physical mobility.

Hypertension was associated with BASRI-Total [OR = 1.219 (1.051–1.413), *P* = .009] and m-SASSS [OR = 1.053 (1.030–1.077), *P* < .001]. The presence of hypertension was increased in the AS patients with advanced radiographic damage.

Hypertension was associated with DM [OR = 5.255 (1.500–18.405), *P* = .009], hypercholesterolemia [OR = 4.233 (1.152–15.562), *P* = .030], WC [OR = 1.059 (1.024–1.095), *P* = .001], BMI [OR = 1.185 (1.080–1.301), *P* < .001], and WtHR [OR = 142,906.709 (390.072–52,355,269.7), *P* < .001]. The

Table 3

Multivariate linear regression analyses of clinical factors correlated with systolic and diastolic blood pressure among the 167 AS patients.

Clinical factors	Systolic blood pressure			Diastolic blood pressure		
	Regression coefficient (95% CI)	Standard coefficient (β)	*P* value	Regression coefficient (95% CI)	Standard coefficient (β)	*P* value
CRP (mg/dL) (n = 165)	1.633 (−0.255 to 3.521)	0.125	.090	0.441 (−1.166 to 2.048)	0.041	.589
BAS-G (n = 166)	−0.544 (−1.248 to 0.197)	−0.104	.149	0.107 (−0.524 to 0.737)	0.024	.739
BASMI (n = 152)	−0.362 (−1.582 to 0.857)	−0.049	.558	1.007 (−0.023 to 2.036)	0.163	.055
Tragus-to-wall distance (cm) (n = 165)	−0.333 (−0.699 to 0.033)	−0.141	.074	0.0421(−0.271 to 0.355)	0.021	.791
Cervical rotation (degree) (n = 155)	0.0282 (−0.053 to 0.109)	0.057	.494	0.0729 (−1.41 to −0.005)	−0.174	.037*
Lateral lumbar flexion (cm) (n = 166)	−0.0778 (−0.385 to 0.230)	−0.038	.618	−0.306 (−0.562 to −0.050)	−0.178	.019*
Chest expansion (cm) (n = 166)	0.169 (−0.829 to 1.167)	0.025	.738	−0.777 (−1.613 to 0.060)	−0.139	.068
Occiput-to-wall distance (cm) (n = 166)	−0.278 (−0.639 to 0.083)	−0.119	.130	0.193 (−0.113 to 0.499)	0.099	.215
BASRI-total (n = 156)	−0.0236 (−0.923 to 0.876)	−0.004	.959	0.745 (−0.025 to 1.515)	0.164	.058
m-SASSS (n = 156)	−0.0640 (−0.078 to 0.206)	0.084	.374	0.129 (0.007 to 0.250)	0.198	.038*
TNF-αblocker use (n = 166)	8.850 (2.487 to 15.212)	0.194	.007*	2.050 (−3.454 to 7.554)	0.054	.463
DMARDs use (n = 166)	4.323 (0.070 to 8.577)	0.142	.046*	3.058 (−0.557 to 6.673)	0.121	.097
Current smoker (n = 163)	1.798 (−3.139to6.735)	0.055	.473	0.781 (−3.423 to 4.984)	0.029	.367
Ever smoker (n = 163)	0.0679 (−4.296to4.432)	0.002	.976	0.874 (−2.835 to 4.582)	0.037	.642

Variables were adjusted by age, gender, diabetes mellitus, hypercholesterolemia, body mass index.
Listwise deletion for missing data.
AS = ankylosing spondylitis, BAS-G = Bath Ankylosing Spondylitis Patient Global Score, BASMI = Bath Anklyosing Spondylitis Metrology Index, BASRI = Bath Ankylosing Spondylitis Radiology Index, m-SASSS = modified Stoke Ankylosing Spondylitis Spinal Score.
*Statistical significances.

presence of hypertension was increased in the AS patients with DM, Hypercholesterolemia and obesity.

3.5. Multivariate logistic regression analyses of clinical factors for hypertension among the 167 AS patients

Independent variables with a *P* value < .1 in the multivariate logistic regression analyses were further tested in the multivariate logistic regression analyses to assess their association with hypertension (Table 5). Most importantly, in multivariate logistic regression analyses, hypertension was associated with m-SASSS [OR = 1.033 (1.003–1.065), *P* = .033], adjusted by age [OR = 1.098 (1.039–1.160), *P* = .001], gender [OR = 0.447 (0.111–1.801), *P* = .258], DM [OR = 1.849 (0.427–8.007), *P* = .411], hypercholesterolemia [OR = 5.020 (0.970–25.967), *P* = .054], and BMI [OR = 1.210 (1.096–1.370), *P* = .003]. The above results suggested that advanced radiographic damage with m-SASSS scoring was independently associated with the presence of hypertension among the AS patients. Older age and obesity were also independently associated with hypertension in AS.

3.6. ROC curve analysis to evaluate clinical variables in predicting the AS patients with hypertension

Continuous variables that showed significant associations with hypertension in univariate logistic regression analyses were further assessed by ROC curve analyses, including age, disease duration, BASFI, BASMI, BASRI-Total, m-SASSS, WC, BMI, and WtHR (Table 6). We used ROC curve analyses to evaluate the clinical variables in predicting the AS patients with hypertension. The variables which showed significant in predicting the presence of hypertension among the AS patients were age [Area under the curve (AUC) = 0.756, *P* < .001], BASMI (AUC = 0.699, *P* = .001), BASRI-total (AUC = 0.687, *P* = .003), m-SASSS (AUC = 0.784, *P* < .001), WC (AUC = 0.699, *P* = .001), BMI (AUC = 0.622, *P* = .010), and WtHR (AUC = 0.731, *P* < .001). Older age, poor physical mobility, advanced radiographic damage and obesity were useful in predicting the patients with hypertension. The m-SASSS demonstrated the highest AUC value in predicting the presence of hypertension among the patients with AS.

4. Discussion

4.1. Radiographic damage associated with blood pressure and hypertension

Our study showed that 20.9% patients with AS had hypertension. Hypertension was the most prevalent comorbidity among the patients with AS, compatible with previous studies.[8–11] Radiographic damage, particular the m-SASSS positively correlated with diastolic blood pressure in multivariate liner regression analysis. Only the m-SASSS was associated with the presence of hypertension in multivariate logistic regression analysis. These results in our study indicate that radiographic damage is an independent risk factor associated with increased blood pressure and the presence of hypertension in AS. The AS patients with advanced radiographic damage have increased the risk of hypertension, and possibly have more incidences of cardiovascular morbidity and mortality.

4.2. Male gender and older age associated with blood pressure and hypertension

In our study, male gender positively correlated with increased systolic blood pressure in multivariate linear regression analyses. Yao-Min et al[9] showed that male AS patients had an increased risk for all cardiovascular diseases than the general population. Male AS patient may have increased blood pressure and higher incidence of cardiovascular diseases. Older age increased the risk of hypertension in multivariate logistic regression analysis. Older age was associated with carotid intima-media thickness and atherosclerotic plaques in chronic arthritis patients.[21] Older AS patients have increased risk for all cardiovascular diseases as compared to the general population.[9] Older age was associated with the presence of hypertension in the patients with AS.

Table 4

Univariate logistic regression analyses of clinical factors for hypertension among the 167 AS patients.

Clinical factors	Hypertension	
	Odds ratio (OR) (95% CI)	*P* value
Age (yr) (n = 167)	1.093 (1.050–1.137)	<.001*
Male gender (n = 167)	1.185 (0.446–3.153)	.733
Onset age (y/o) (n = 159)	1.028 (0.996–1.060)	.084
Disease duration (yr) (n = 159)	1.055 (1.020–1.091)	.002*
ESR (mm/h) (n = 165)	1.023 (0.999–1.047)	.061
CRP (mg/dL) (n = 166)	1.018 (0.726–1.427)	.917
BASDAI (n = 163)	0.895 (0.712–1.125)	.342
ASDAS-ESR (n = 161)	1.154 (0.748–1.783)	.517
ASDAS-CRP (n = 162)	0.926 (0.622–1.378)	.926
BASFI (n = 165)	1.300 (1.035–1.623)	.024*
BAS-G (n = 167)	1.027 (0.896–1.178)	.700
BASMI (n = 153)	1.341 (1.096–1.641)	.004*
Tragus-to-wall distance (cm) (n = 166)	1.065 (1.002–1.132)	.041*
Modified Schober index (cm) (n = 166)	0.902 (0.755–1.079)	.259
Intermalleolar distance (cm) (n = 167)	0.972 (0.955–0.989)	.001*
Cervical rotation (degree) (n = 156)	0.986 (0.973–0.999)	.031*
Lateral lumbar flexion (cm) (n = 167)	0.919 (0.866–0.975)	.005*
Fingertip-to-floor distance (cm) (n = 167)	1.018 (0.992–1.044)	.175
Chest expansion (cm) (n = 167)	0.782 (0.614–0.996)	.046*
Occiput-to-wall distance (cm) (n = 167)	1.079 (1.017–1.145)	.012*
BASRI-total (n = 156)	1.219 (1.051–1.413)	.009*
m-SASSS (n = 156)	1.053 (1.030–1.077)	<.001*
Uveitis (n = 167)	1.446 (0.651–3.211)	.365
TNF-αblocker use (n = 167)	2.069 (0.716–5.975)	.179
Regular NSAIDs use (n = 166)	0.520 (0.225–1.202)	.126
NSAIDs use (n = 166)	0.381 (0.245–1.542)	.300
Regular DMARDs use (n = 166)	0.743 (0.348–1.586)	.443
DMARDs use (n = 166)	1.444 (0.624–3.345)	.391
Regular exercise (n = 167)	2.011 (0.947–4.270)	.069
Current smoker (n = 164)	0.292 (0.231–1.588)	.308
Ever smoker (n = 164)	0.793 (0.366–1.719)	.556
Diabetes mellitus (n = 167)	5.255 (1.500–18.405)	.009*
Hypercholesterolemia (n = 167)	4.233 (1.152–15.562)	.030*
Waist circumference (WC) (cm) (n = 165)	1.059 (1.024–1.095)	.001*
Body mass index (BMI) (kg/m^2) (n = 166)	1.185 (1.080–1.301)	<.001*
Waist to Height Ratio (WtHR) (n = 164)	142,906.709 (390.072–52,355,269.7)	<.001*

Listwise deletion for missing data.
AS = ankylosing spondylitis, ASDAS-CRP = Ankylosing Spondylitis Disease Activity Score with CRP, ASDAS-ESR = Ankylosing Spondylitis Disease Activity Score with ESR, BASDAI = Bath Ankylosing Spondylitis Disease Activity Index, BASFI = Bath Ankylosing Spondylitis Functional Index, BAS-G = Bath Ankylosing Spondylitis Patient Global Score, BASMI = Bath Anklyosing Spondylitis Metrology Index, BASRI = Bath Ankylosing Spondylitis Radiology Index, m-SASSS = modified Stoke Ankylosing Spondylitis Spinal Score.
* Statistical significances.

Table 5

Multivariate logistic regression analyses of clinical factors for hypertension among the 167 AS patients.

	Hypertension	
Clinical factors	Odds ratio (OR) (95% CI)	*P* value
ESR (mm/h) (n = 164)	1.016 (0.983–1.050)	.346
BASFI (n = 164)	1.053 (0.787–1.407)	.730
BASMI (n = 152)	1.068 (0.834–1.367)	.602
Tragus-to-wall distance (cm) (n = 165)	1.010 (0.936–1.091)	.796
Intermalleolar distance (cm) (n = 166)	0.991 (0.968–1.015)	.453
Cervical rotation (degree) (n = 155)	0.999 (0.984–1.015)	.936
Lateral lumbar flexion (cm) (n = 166)	0.994 (0.877–1.016)	.122
Chest expansion (cm) (n = 166)	0.864 (0.656–1.136)	.295
Occiput-to-wall distance (cm) (n = 166)	1.034 (0.961–1.112)	.376
BASRI-total (n = 156)	1.059 (0.871–1.288)	.564
m-SASSS (n = 156)	1.033 (1.003–1.065)	.033*
Regular exercise (n = 166)	2.055 (0.766–5.516)	.153

Variables were adjusted by age, gender, diabetes mellitus, hypercholesterolemia, body mass index.
AS = ankylosing spondylitis, BASFI = Bath Ankylosing Spondylitis Functional Index, BASMI = Bath Anklyosing Spondylitis Metrology Index, BASRI = Bath Ankylosing Spondylitis Radiology Index, m-SASSS = modified Stoke Ankylosing Spondylitis Spinal Score.
*Statistical significances.
Listwise deletion for missing data.

Table 6

Area under the ROC curve (AUC) of clinical parameters in predicting the AS patients with hypertension.

	Hypertension	
Parameters	**AUC**	***P* value**
Age	0.756	<.001*
Disease duration	0.619	.057
BASFI	0.603	.099
BASMI	0.699	.001*
BASRI-total	0.687	.003*
m-SASSS	0.784	<.001*
Waist circumference (WC)	0.699	.001*
Body mass index (BMI)	0.622	.010*
Waist to height ratio (WtHR)	0.731	<.001*

Null hypothesis: true area = 0.5.
Listwise deletion for miss data (n = 133).
AS = ankylosing spondylitis, BASFI = Bath Ankylosing Spondylitis Functional Index, BASMI = Bath Anklyosing Spondylitis Metrology Index, BASRI = Bath Ankylosing Spondylitis Radiology Index, m-SASSS = modified Stoke Ankylosing Spondylitis Spinal Score, ROC = receiver operating characteristic.
*Statistical significance.

4.3. CRP associated with blood pressure

CRP levels positively correlated with systolic blood pressure in univariate linear regression analysis, and showed the trend after multivariate adjustment. Active systemic inflammation may be associated increased systolic blood pressure among the AS patients. Patients with higher CRP levels were associated with the increased risk of hypertension.[22,23] In the AS patients, there was a positive association between ASDAS-CRP and carotid intima-media thickness.[24] The carotid intima-media thickness had been shown as a predictor of developing hypertension.[25] Higher inflammation may cause increased arterial stiffness and lead to the presence of hypertension in the AS patients.

4.4. M-SASSS associated with blood pressure and hypertension

BASRI-Total and m-SASSS positively correlated with systolic/diastolic blood pressure in univariate linear regression analyses. Only the m-SASSS significantly correlated with diastolic blood pressure after multivariate linear regression adjustment. Importantly, there was increased risk of developing hypertension for the AS patients with higher m-SASSS in multivariate logistic regression. Advanced radiographic damage with m-SASSS scoring could be associated with the presence of hypertension among the patients with AS. Notably, radiographic damage was independently associated with increase in diastolic blood pressure and the presence of hypertension in our study. The presence of syndesmophytes was independently associated with an accelerated atherosclerosis in patients with SpA.[26] Increased carotid intima-media thickness has a positive association with higher blood pressure.[25,27,28] Radiographic damage, including the syndesmophytes formation and ankyloisng of spine, may possibly has strong relation to vascular intima-media thickness in patients with AS. The BASRI-Total score did not show significant association with elevated blood pressure and the presence of hypertension, after multivariate linear/logistic regression adjustment. The BASRI-Total score contains cervical, lumbar spine, sacroiliac and hip joint, as the m-SASSS score contains only cervical and lumbar spine. Increased blood pressure and the presence of hypertension may predominately related to the spinal radiographic damage in AS.

4.5. Physical mobility associated with blood pressure

Cervical rotation and lateral lumbar flexion were positively correlated with diastolic blood pressure in multivariate linear regression adjustment. Poor physical mobility, particular cervical rotation and lateral lumbar mobility may be associated with increased blood pressure in the AS patients. Active inflammation and advanced radiographic damage could lead to patient's poor physical mobility. The association of blood pressure with physical mobility may be due to higher inflammation and advanced radiographic damage in these AS patients.

4.6. TNF-α blocker and DMARDs associated with blood pressure

TNF-α blocker and DMARDs use had associations with increased systolic blood pressure among the AS patients in multivariate linear regression analyses. Sizheng Steven et al[29] showed that comorbidities were associated with disease activity in axial SpA. The patients with DMARDs use may possibly have higher inflammation and associated with increased systolic blood pressure. In a meta-analysis study, TNF-α blocker was associated with increased risk of developing hypertension in rheumatoid arthritis.[30] TNF-α blocker use may possibly also induce elevated systolic blood pressure among the AS patients, but the pathological mechanisms needs further investigation. A further larger prospective cohort is required to assess the association between TNF-α blocker use and the elevation of blood pressure.

4.7. Obesity, DM and hypercholesterolemia associated with hypertension

WC, BMI, and WtHR were positively correlated with systolic/diastolic blood pressure in multivariate linear regression analyses. Obesity was significantly associated with the presence of hypertension in multivariate logistic analyses. Our study suggested that obesity could be associated with increased systolic/diastolic blood pressure and presence of hypertension among the patients with AS. DM and hypercholesterolemia were associated with the presence of hypertension in univariate logistic regression analyses. The presence of DM is frequently associated with developing hypertension.[31] Hypertension is commonly observed in patients with hypercholesterolemia, due to the accelerated atherosclerosis.[32] The association between obesity and hypertension has been well demonstrated in most racial groups.[33,34] Presence of DM and hypercholesterolemia have associations with hypertension among the patients with AS.

4.8. Age, BASMI, BASRI-total, m-SASSS, WC, BMI, and WtHR in predicting hypertension

In the ROC curve analyses, age, BASMI, BASRI-Total, m-SASSS, WC, BMI and WtHR were significant parameters in predicting the presence of hypertension among the patients with AS. Older age, poor physical mobility, advanced radiographic damage and obesity could predict the presence of hypertension. Advanced radiographic damage with m-SASSS scoring was the most useful disease severity parameter to predict the presence of hypertension in AS.

This study has some limitations. The patients with DM, hypertension and hypercholesterolemia but without the medications use were not classified as having these comorbidities. The associations of blood pressure and hypertension with radiographic damage could not be established on such a small cross sectional cohort. A larger-scale study to assess the associations of blood pressure and hypertension with longitudinal radiographic change is needed in the AS patients.

5. Conclusion

Advanced radiographic damage with m-SASSS is an independent risk of increased blood pressure and presence of hypertension among the patients with AS. Older age, male gender, poor cervical rotation, lateral lumbar flexion, TNF-α blocker and DMARDs use are independently associated with increased blood pressure. Obesity increases the risk of elevated blood pressure and presence of hypertension in AS. Older age, poor physical mobility, advanced radiographic damage and obesity are useful indices in predicting the AS patients with hypertension, and m-SASSS is the best.

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