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Predicting acute aortic syndrome using aortic dissection detection risk score, D-dimer, and X-ray

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ABSTRACT

Objective: Acute aortic syndrome (AAS) is a fatal disease with high mortality. There were previous studies using aortic dissection detection risk score (ADD-RS) and D-dimer (DD) to screen AAS. There were screening failures in previous studies, suggesting the need for a more accurate tool. This study investigated the effect of combining ADD-RS and age adjusted D-dimer (DDage-adj) with abnormal findings on chest radiographs on the diagnosis of AAS in patients admitted to emergency department (ED).
Methods: This single-center retrospective case-control study included 93 patients with AAS and 465 with chest pain (CP), diagnosis other than AAS. We attempted to compare the initial clinical presentation and laboratory examination findings.
Results: Age-adjusted DD (DDage-adj), defined as age x 0.01 mg/L in patients ≥50 years, showed sensitivity of 92.5% and specificity of 76.3% for patients with AAS ($p < 0.001$). Positive chest radiography findings were significant with AAS group; sensitivity was 89.2% with a specificity of 80.9% ($p < 0.001$). Multivariate logistic regression analysis was used; widened mediastinum, widening of aortic contour and aortic kinking indicates the probability of AAS in patients with CP ($p < 0.05$).
ADD-RS was used to evaluate the risk of AAS. For low risk group, ADD-RS ≤1, combined use of chest radiography and DDage-adj showed meaningful result. Sensitivity and specificity were 100% and 67.1% with failure rate of 0% ($p < 0.001$). Multivariate logistic regression analysis were made; widening of the mediastinum ($p = 0.035$), widening of the aortic contour ($p < 0.001$) and aortic kinking ($p < 0.001$) showed significant p-value. Combining DDage-adj and these three chest radiography findings in ADD-RS≤1 patients resulted 0% failure rate with 67.8% specificity ($p < 0.001$).
Conclusions: The combination of ADD-RS, DDage-adj and chest radiography could lower the failure rate of AAS exclusion strategy. This combination strategy satisfies low failure rate (<3%) and yields relatively high specificity of 67.8%.

1. Introduction

Acute aortic syndrome (AAS) includes aortic dissection, intramural hematoma, and symptomatic aortic ulcer, among which aortic dissection accounts for approximately 85–95% of all AAS incidences [1,2]. While AAS is a considerably rare disease, with only one in

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12,200 patients admitted to the emergency department (ED) being diagnosed with AAS, it is a fatal disease with a remarkably high rate of mortality [3]. The chief complaint of patients with AAS is chest pain (CP).

CP is very common symptom in ED and accounts for approximately 9% of non-injury-related ED visit for adults every year.

[4] However, as the rate of incidence of AAS is very low, it would be extremely unlikely for the ED staff to suspect AAS in a patient with CP [5]. As a result, many studies have been conducted on the rapid prediction of AAS.

Two well-known tools for rapid prediction of AAS are the aortic dissection detection risk score (ADD-RS) and D-dimer (DD) [6–10]. ADD-RS is a pre-test tool that classifies the patients in 3 (ADD-RS = 0, ADD-RS = 1, ADD-RS>1) or 2 (ADD-RS≤1, ADD-RS>1) categories [8]. However, in the ADvISED Prospective Multicenter Study where the ADD-RS and DD were applied simultaneously, diagnostic failure occurred due to the inability to predict three out of 241 AAS cases, and specificity was also considerably low at approximately 50%, suggesting the need for a more accurate tool [8]. In another study where ADD-RS was combined with chest radiograph to detect AAS, the combination was also shown to be limited in supporting the diagnosis of AAS [11,12]. Increasing the diagnostic accuracy of AAS is critical, given it is a highly fatal disease. Another reason for the need to develop a more accurate tool is to prevent unnecessary computed tomography (CT) due to the low specificity of the conventional tool, which could delay emergency operations such as coronary angiography (CAG). A meta-analysis suggests using age adjusted DD (DDage-adj) over conventional DD cut off value, yielding higher specificity and consistent high sensitivity [13]. Therefore, the present study investigated the effects of combining ADD-RS and DDage-adj with abnormal findings on chest radiographs on the diagnosis of AAS in patients admitted to the ED due to acute CP.

2. Methods

2.1. Study design and data collection

The study was approved by the Institutional Review Board of the Eulji University Hospital. Informed written consent was waived for this study. The subjects in this study were patients aged ≥18 years admitted to a single emergency medical center at a university hospital. A retrospective case–control study was conducted. Among the patients admitted to the ED between January 1st, 2014 and September 30th, 2021, those diagnosed with AAS were defined as the AAS group, and the patients admitted to the ED with CP as the chief complaint during the same period, who did not satisfy the exclusion criteria based on the matching ratio were defined as the CP group. The matching ratio was calculated using Dupont's statistic power calculation. The prevalence of exposure in the control group (P_0) was 0.14 and the correlation coefficient for exposure between cases and their matching controls (phi) was 0.0013. Thus, 1:5 control matching was conducted with P_0 being less than 0.15 [14]. Patients who did not undergo a DD test, were admitted due to trauma, or were readmitted or discharged without an accurate diagnosis were excluded.

2.2. Study variables and definitions

Based on the patient medical record at the time of their first admission to the ED; the general characteristics including age, gender, chief complaint, symptoms, medical history, physical examination and vital signs were investigated.

According to the ADD-RS criteria, the high-risk conditions, pain features, and exam features were analyzed and respective scores were calculated [6]. For the DD test, blood tests performed during the first admission to the ED were analyzed. The DD test results were compared using the conventional positive criterion ≥0.5 mg/L, cut-off values of DDage-adj, and receiver operator characteristic (ROC) curve [15,16]. DDage-adj is defined as age × 0.01 mg/L in patients ≥50 years. Cut-off value of DD ≥ 1.2 mg/L was determined using the ROC curve (AUC 0.928, 95% CI 0.903–0.948). MedCalc software was used to analyze the ROC curve and cut-off value of DD ≥ 1.2 mg/L was suggested.

On the chest radiograph, the findings of widening of the mediastinum, widening of the aortic contour, displaced calcification, aortic kinking, and opacification of the aorticopulmonary window were determined by two raters [17]. In the electrocardiogram (ECG), ST elevation, ST depression, nonspecific ST-T-wave change, and T inversion were defined as abnormal findings.

2.3. Statistical analysis and categorizing continuous variables

The chi-square test was used to compare categorical variables between the two groups. For continuous variables, normality test was performed. If the data were normally distributed, Student's t-test was used to compare the two groups with the results given as mean ± standard deviation. The cut-off value for DD was defined by analyzing the ROC curve.

Logistic regression was performed for ADD-RS>1, DDage-adj, and chest radiograph findings, and the Hosmer–Lemeshow test was performed to assess model fitness.

IBM SPSS software, version 22 (IBM Corp., Armonk, NY, USA) was used to sort and analyze the data in this study and to perform chi-square tests, Student's t-tests, and logistic regression analysis. MedCalc software version 15.8 (Mariakerke, Belgium; https://www.medcalc.org) was used to obtain the cut-off values for the continuous variables. The level of significance was set at a p-value below 0.05.

2.4. Diagnostic workup and follow-up

Computed tomography angiography (CTA) was considered conclusive for the diagnosis of AAS and acute coronary syndrome. Patients suspected for acute coronary syndrome were subjected to CAG for diagnosis and treatment purposes. Patients who were diagnosed with other disease were admitted and treated accordingly. Patients underwent CTA regardless of DD or chest radiography during their admission period if AAS related symptoms persisted despite proper management of the initial diagnosed disease. Patients were discharged directly from ED to the outpatient department as soon as the symptoms passed. Clinical follow-up was scheduled to rule out AAS on their subsequent visit.

3. Results

3.1. General characteristics and test results

The total number of patients admitted to the ED during the study period was 400,739, and the number of patients admitted with CP as the chief complaint was 2888. Among these patients, the number of patients diagnosed with AAS was 165. After excluding 72 who satisfied the exclusion criteria, the remaining 93 patients were categorized as the AAS group. With the exclusion of patients with AAS, those showing a 1:5 matching ratio (n = 465) were categorized as the CP group (Fig. 1).

As AAS group prevailed higher visual analogue scores, normal ECGs and lower diastolic blood pressures; its onset-to-visit time was significantly shorter compared to CP group (Table 1).

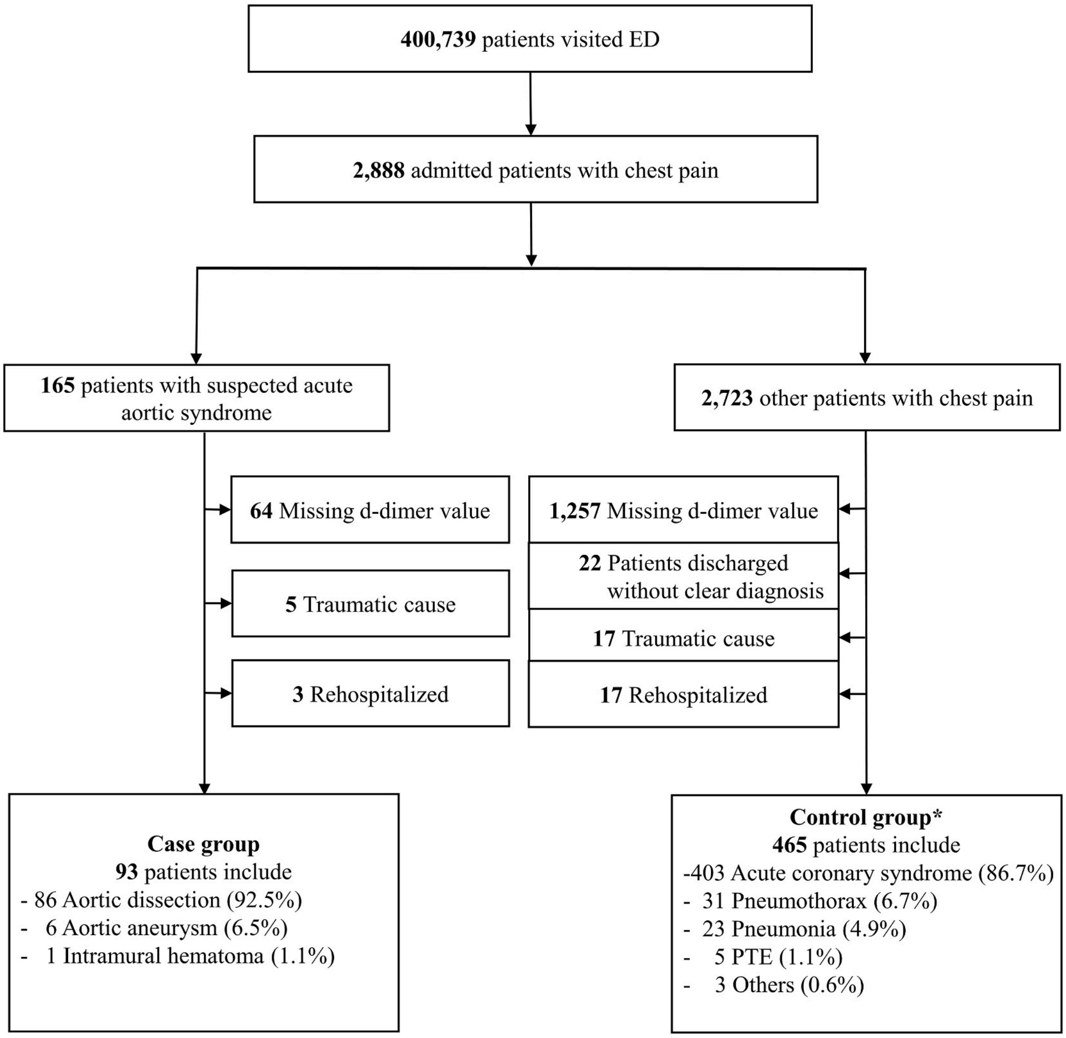

Fig. 1. Study flow chart *1:5 case control ratio ED, emergency department; PTE, pulmonary thromboembolism.

3.2. ADD-RS and DD

The AAS group showed significantly higher levels of DD and ADD-RS category findings compared to CP group ($p < 0.05$) (Tables 1 and 2).

With cut-off value > 1 for ADD-RS, sensitivity was 43.0% (95% confidence interval [CI] 32.8–53.7) with a specificity of 92.9% (95% CI 90.2–95.1). With cut-off value ≥ 1 for ADD-RS, the sensitivity was 96.8% (95% CI 90.9–99.3), while the specificity was 25.2% (95% CI 21.3–29.4) (Area under the curve [AUC] 0.738, 95% CI 0.699–0.774) ($p < 0.001$). With cut-off value ≥ 1.2 mg/L for DD, sensitivity was 86.0% with a specificity of 85.6% ($p < 0.001$). With a cut-off value of 0.5 mg/L for the conventional criterion, sensitivity was 95.7% with a specificity of 68.2%. With the DDage-adj as the criterion, sensitivity was 92.5% with a specificity of 76.3% ($p < 0.001$).

The combination of ADD-RS and DD resulted in sensitivity of 97.8% with a specificity of 64.1% with ADD-RS >1 or ADD-RS≤1 plus DD ≥ 0.5 mg/L; sensitivity was 95.7% with a specificity of 71.2% with ADD-RS>1 or ADD-RS≤1 plus DDage-adj; and sensitivity was 91.8% with a specificity of 80.2% with ADD-RS>1 or ADD-RS≤1 plus DD ≥ 1.2 mg/L ($p < 0.001$) (Table 3).

Of the total 558 patients, 485 patients were classified as low risk after pre-scanning (ADD-RS ≤1). 53 patients were diagnosed AAS and 432 patients were classified as control group. In the cases with ADD-RS ≤1, sensitivity was 96.2% with a specificity of 69% with DD ≥ 0.5 mg/L; sensitivity was 92.5% with a specificity of 76.6% with DDage-adj; and sensitivity was 84.9% with a specificity of 86.3% with DD ≥ 1.2 mg/L ($p < 0.001$) (Table 4).

3.3. Chest radiography

For all the chest radiograph findings known to be abnormal in AAS, significantly higher incidence of positive signs were found in the AAS group than in the CP group ($p < 0.001$). For AAS, sensitivity was 89.2% with a specificity of 80.9% ($p < 0.001$) (Table 5).

3.4. ADD-RS, DD, and chest radiography

For patients satisfying one of the following; ADD-RS >1, DD ≥ 0.5 mg/L or positive chest radiograph findings; *sensitivity was 100% with a specificity of 57.0%. Sensitivity was 100% with a specificity of 62.4% with* ADD-RS >1, DDage-adj or positive chest radiography; and *sensitivity and specificity were 96.8% and 69.0%, respectively with* ADD-RS >1, *DD* ≥ 1.2 mg/L and chest radiography. *($p<0.001$) (Table 3)*.

In cases with ADD-RS ≤1, the sensitivity was 100% and specificity was 67.1% for patients with either DDage-adj or positive chest radiograph findings; sensitivity was 100% and specificity was 61.3% with either DD ≥ 0.5 mg/L or positive chest radiography findings; and the sensitivity was 94.3% and specificity was 74.3% with either DD ≥ 1.2 mg/L or positive chest radiography findings ($p < 0.001$) (Table 4). Four cases showed negative DDage-adg value, but had positive chest radiography finding in the AAS group (Fig. 2).

Multivariate logistic regression analysis of ADD-RS, DDage-adj, and chest radiograph findings revealed that the probability of AAS was indicated by the widening of the mediastinum and aortic contour and aortic kinking in patients with CP ($p < 0.05$) (Table 6).

4. Discussion

4.1. ADD-RS and DD

In previous studies combining ADD-RS and DD, the criterion of DD was set at a cut-off value of ≥0.5 mg/L. The level of DD increases with increasing age; however, the use of the conventional DD cut-off value is disadvantageous as it lowers the specificity in older adults. Thus, some studies apply the age-adjusted cut-off value [15,16,18]. In a study by Kotani, ADD-RS and DDage-adj were used to define a strategy to exclude AAS, and the resulting sensitivity and specificity were 98% and 51%, respectively, in the low-risk group

Table 1
Demographic and clinical characteristics of the study patients.

	AAS group (n = 93)	CP group (n = 465)	p-value
Age (years)	59.6 ± 15.3	60.0 ± 15.7	0.812
Sex (male, %)	55 (59.1)	353 (75.9)	0.001[a]
Onset-to-visit time (h)	12.2 ± 56.3	41.3 ± 116.5	<0.001[a]
Visual analogue scale	6.1 ± 2.8	4.3 ± 1.8	<0.001[a]
Diabetes mellitus	2 (2.2)	115 (24.7)	<0.001[a]
Hypertension	49 (52.7)	206 (44.3)	0.138
Normal ECG	74 (79.6)	267 (54.7)	<0.001[a]
Systolic BP (mmHg)	140.0 ± 32.4	142.5 ± 26.7	0.489
Diastolic BP (mmHg)	78.8 ± 17.5	83.6 ± 17.1	0.018[a]
Heart rate (beats/min)	78.4 ± 17.5	83.6 ± 19.9	0.060
Body temperature (°C)	36.5 ± 0.6	36.5 ± 0.5	0.475
D-dimer (mg/L)	10.66 ± 8.09	0.97 ± 2.30	<0.001[a]

BP, blood pressure; ECG, electrocardiogram; AAS, acute aortic syndrome, CP, chest pain.
[a] p-value <0.05.

Table 2
Aortic dissection detection risk score.

Characteristic	AAS group (n = 93)	CP group (n = 465)	p-value
Predisposing conditions	11 (11.8)	1 (0.2)	<0.001[a]
Marfan syndrome	1 (1.1)	0	0.025[a]
Family history of aortic disease	1 (1.1)	0	0.025[a]
Known aortic valve diseas	3 (3.2)	0	<0.001[a]
Recent aortic manipulation	5 (5.4)	1 (0.2)	<0.001[a]
Known thoracic aortic aneurysm	3 (3.2)	0 (0)	<0.001[a]
Pain features	90 (96.8)	346 (74.4)	<0.001[a]
Abrupt onset of pain	86 (92.5)	301 (64.7)	<0.001[a]
Severe pain intensity	53 (57.0)	100 (21.5)	<0.001[a]
Ripping or tearing pain	61 (65.6)	55 (11.8)	<0.001[a]
Physical exam findings	34 (36.6)	35 (7.5)	<0.001[a]
Perfusion deficit	17 (18.3)	15 (3.2)	<0.001[a]
focal neurologic deficit plus pain	12 (12.9)	10 (2.2)	<0.001[a]
pulse deficit or SBP difference	7 (7.5)	5 (1.1)	<0.001[a]
Murmur of aortic insufficiency	9 (9.7)	6 (1.3)	<0.001[a]
Hypotension or Shock	21 (22.6)	20 (4.3)	<0.001[a]

SBP, systolic blood pressure; AAS, acute aortic syndrome; CP, chest pain.
[a] p-value<0.05.

Table 3
Aortic dissection detection risk score (ADD-RS), D-dimer and chest X-ray.

		AAS group (n = 93)	CP group (n = 465)	p-value
ADD-RS >1 or DDage-adj, chest X-ray (+)	Positive	93 (100)	175 (37.6)	<0.001[a]
	Negative	0 (0)	290 (62.4)	
ADD-RS >1 or D-dimer ≥0.5, chest X-ray (+)	Positive	93 (100)	200 (43.0)	<0.001[a]
	Negative	0 (0)	265 (57.0)	
ADD-RS >1 or D-dimer ≥1.2, chest X-ray (+)	Positive	90 (96.8)	144 (31.0)	<0.001[a]
	Negative	3 (3.2)	312 (69.0)	
ADD-RS >1 or DDage-adj	Positive	89 (95.7)	134 (28.8)	<0.001[a]
	Negative	4 (4.3)	331 (71.2)	
ADD-RS >1 or D-dimer ≥0.5	Positive	91 (97.8)	167 (35.9)	<0.001[a]
	Negative	2 (2.2)	298 (64.1)	
ADD-RS >1 or D-dimer ≥1.2	Positive	85 (91.8)	92 (19.8)	<0.001[a]
	Negative	8 (8.6)	373 (80.2)	

ADD-RS, aortic dissection detection risk score; DDage-adj, age adjusted D-dimer; AAS, acute aortic syndrome; CP, chest pain.
[a] p-value<0.05.

Table 4
D-dimer and chest X-ray in aortic dissection detection risk score (ADD-RS) low risk patients.

		AAS group (n = 53)	CP group (n = 432)	p-value
ADD-RS ≤1, DDage-adj, chest X-ray (+)	Positive	53 (100)	142 (32.9)	<0.001[a]
	Negative	0 (0)	290 (67.1)	
ADD-RS ≤1, D-dimer ≥0.5, chest X-ray (+)	Positive	53 (100)	167 (38.7)	<0.001[a]
	Negative	0 (0)	265 (61.3)	
ADD-RS ≤1, D-dimer ≥1.2, chest X-ray (+)	Positive	50 (94.3)	111 (25.7)	<0.001[a]
	Negative	3 (5.7)	321 (74.3)	
ADD-RS ≤1, DDage-adj, chest X-ray 3 (+)	Positive	53 (100)	139 (32.2)	<0.001[a]
	Negative	0 (0)	293 (67.8)	
ADD-RS ≤1, D-dimer ≥0.5, chest X-ray 3(+)	Positive	53 (100)	165 (38.2)	<0.001[a]
	Negative	0 (0)	267 (61.8)	
ADD-RS ≤1, D-dimer ≥1.2, chest X-ray 3 (+)	Positive	50 (94.3)	107 (24.8)	<0.001[a]
	Negative	3 (5.7)	325 (75.2)	
ADD-RS ≤1, DDage-adj	Positive	49 (92.5)	101 (23.4)	<0.001[a]
	Negative	4 (7.5)	331 (76.6)	
ADD-RS ≤1, D-dimer ≥0.5	Positive	51 (96.2)	134 (31.0)	<0.001[a]
	Negative	2 (3.8)	298 (69.0)	
ADD-RS ≤1, D-dimer ≥1.2	Positive	45 (84.9)	59 (13.7)	<0.001[a]
	Negative	8 (15.1)	373 (86.3)	

ADD-RS, aortic dissection detection risk score; DDage-adj, age adjusted D-dimer; AAS, acute aortic syndrome; CP, chest pain.
Chest X-ray 3 refers to patients with either widened mediastinum, widening of the aortic contour or aortic kinking.
[a] p-value<0.05.

Table 5
Abnormal finding of Chest X-ray.

	AAS group (n = 93)	CP group (n = 465)	Total	p-value
Positive	83 (89.2%)	89 (19.1%)	172 (30.8%)	<0.001*
Widening of the mediastinum	70 (75.3%)	59 (12.7%)	129 (23.1%)	<0.001*
Widening of the aortic contour	73 (78.5%)	55 (11.8%)	128 (22.9%)	<0.001*
Displaced calcification	28 (30.1%)	30 (6.5%)	58 (10.4%)	<0.001*
Aortic kinking	10 (10.8%)	9 (1.9%)	19 (3.4%)	<0.001*
Opacification of the aortopulmonary window	24 (25.8%)	22 (4.7%)	46 (8.2%)	<0.001*
Negative	10 (10.8%)	376 (80.9%)	386 (69.2%)	<0.001*

AAS, acute aortic syndrome; CP, chest pain.
* p-value<0.05.

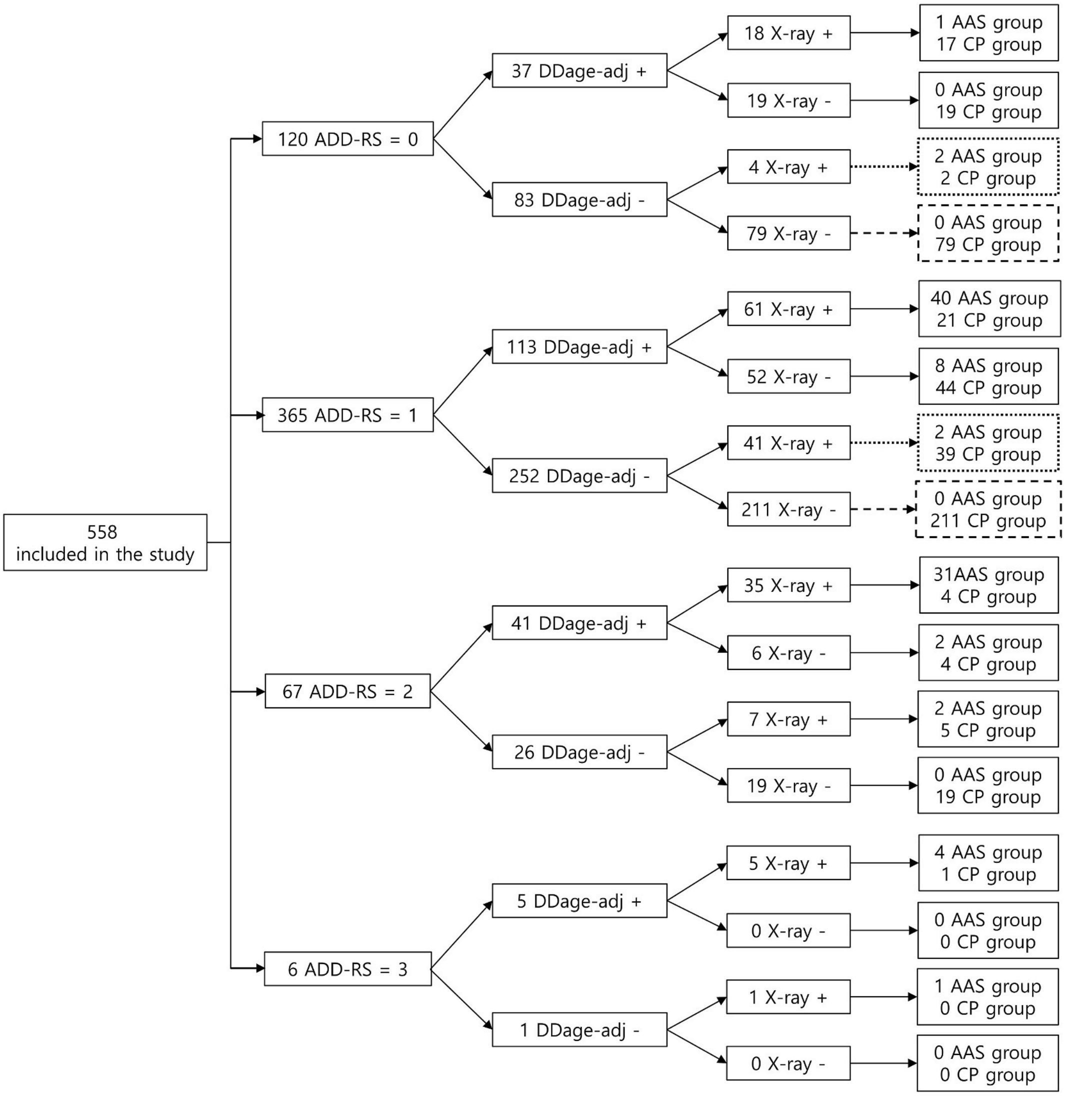

Fig. 2. Distribution of patients. 558 patients were involved in the study, 93 were AAS and 465 were classified as CP group. AAS has been ruled out in 290 patients by ADD-RS score, DDage-adj and chest radiography (marked as dashed line). Four cases showed negative DDage-adg value, but had positive chest radiography finding (marked as dotted line). ADD-RS, Aortic dissection detection risk score; DDage-adj, age adjusted D-dimer; X-ray, chest radiography; AAS, acute aortic syndrome; CP, chest pain.

Table 6
Multivariate logistic regression analysis of ADD-RS, D-dimer and finding of chest X-ray.

Variable	OR	95% CI	p-value
ADD-RS	7.212	3.090–16.832	<0.001[a]
Age-adjusted D-dimer	18.142	7.404–44.456	<0.001[a]
Widening of the mediastinum	2.833	1.076–7.459	0.035[a]
Widening of the aortic contour	6.478	2.471–16.978	<0.001[a]
Displaced calcification	1.589	0.678–3.720	0.286
Aortic kinking	8.786	2.444–31.593	0.001[a]
Opacification of the aorticopulmonary window	0.569	0.210–1.544	0.268

ADD-RS, aortic dissection detection risk score; OR, odd ratio; CI, confidence interval.
[a] p-value<0.05.

[19]. The present study demonstrates DDage-adj to have higher specificity compared to conventional DD cut-off value, while retaining significant failure rate in ADD-RS ≤1 patients. The DDage-adj successfully reduced 7.6% of false positive cases, suggesting DDage-adj to be used over conventional DD in diagnosing AAS (Table 4).

4.2. Chest radiography

Chest radiography is a modality that could raise suspicion for the diagnosis of AAS according to the 2022 American College of Cardiology/American Heart Association guidelines [20]. In a meta-analysis analyzing 13 studies conducted in 2002, the sensitivity of AAS diagnosis for an abnormal chest radiography finding was 90% [21]. In a study conducted by von Kodolitsch et al. chest radiography exhibited a sensitivity of 64% and a specificity of 86% for aortic disease [17]. In the present study, all five radiographic findings indicated statistically significant positive findings in the AAS group. If one or more of these findings were positive, a sensitivity of 89.2% and a specificity of 80.9% were observed. ($p < 0.001$) (Table 5). Chest radiography is relatively less time consuming diagnostic tool that could give brief impression of the disease in short period of time. We suggest use of chest radiography to evaluate chest pain if radiography does not delay critical intervention of the patient such as CTA and CAG.

4.3. ADD-RS, DD, and chest radiography

While the acceptable failure rate has not yet been clearly defined regarding an AAS exclusion strategy, studies on pulmonary embolism mostly adopt approximately a 3% failure rate at 95% CI.[8.] [22,23].

As with other studies, the failure rate of AAS diagnosis in our study was 1–2% using ADD-RS and DD; however, the inclusion of chest radiography resulted in an extremely low failure rate of 0–1%. In this study, patients showing ADD-RS ≤1 were defined as the low-risk group, and those showing ADD-RS >1 as the high-risk group. A CTA evaluation is recommended for the high-risk group. For the low-risk group, the failure rate and specificity according to DD and chest radiography were investigated. 0% failure rate and 67.1% specificity were obtained using DDage-adj and chest radiography. ($p < 0.001$) In addition, when the three significant chest radiography findings from the multivariable logistic regression test were applied, the sensitivity remained 100% with a 0% failure rate; however, the specificity increased to 67.8% (Table 4). Therefore, this study suggests that the flow chart in Fig. 3 should be followed as an AAS exclusion strategy for patients with CP admitted to the ED. When AAS was suspected, the patients' blood pressure (BP) was managed to the lowest BP that maintains adequate end-organ perfusion. Surgical intervention was performed according to ACC/AHA guideline [20].

5. Limitations

This study had several limitations. First, as a single-center retrospective study, only the available medical records of patients could be analyzed without standardization of evaluation. Second, as the present center has a capacity for emergency operations for AAS, the number of patients with AAS is likely to be high compared to general EDs. Third, ADD-RS and DD are useful screening tool, yet the optimal threshold of ADD-RS and DD may depend on the clinical setting [24]. Fourth, not all patients were excluded based on the CTA result. Some patients were diagnosed with other diseases based on the findings of ECG, ultrasound, coronary angiography or other tests. In such cases, AAS was ruled out by using CTA only when the patients continuously complain AAS symptoms during their admission. Fifth, the population of AAS is small. Multicenter study is suggested for bigger population study. Sixth, regarding AAS, no prospective study has yet investigated the use of DDage-adj. Similarly, this study is the first to use ADD-RS, DD, and chest radiography but with a lack of prospective studies. Thus, validation is required through prospective studies in the future.

6. Conclusions

The addition of chest radiography to the AAS exclusion strategy based on ADD-RS and DD could lower the failure rate. In the ADD-RS low-risk patient group, the combination of chest radiography findings with DDage-adj satisfies the requirement for a low failure rate (<3%) and yields the highest specificity (67.8%). Further prospective studies are needed for the evaluation of the algorithm combining DDage-adj and chest radiography.

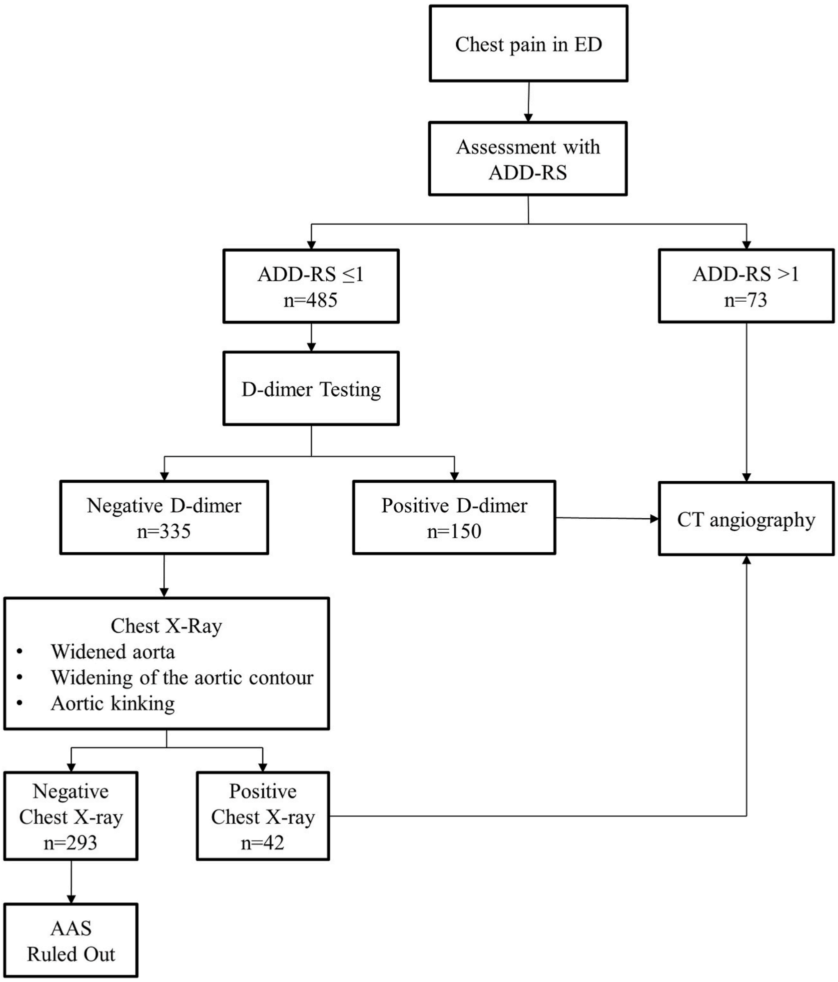

Fig. 3. Proposed diagnostic algorithm based on ADD-RS, chest X-ray and D-dimer. ED, emergency department; ADD-RS, aortic dissection detection risk score; CT, computed tomography; AAS, acute aortic syndrome.

Ethics statement

The study was approved by the Institutional Review Board of the Eulji University Hospital (No 2021-10-010).

Data availability statement

The authors do not have permission to share data.

CRediT authorship contribution statement

Dae Ho Song: Writing – original draft, Validation, Investigation, Data curation, Conceptualization. **Jin Ho Choi:** Writing – review & editing, Validation, Supervision, Conceptualization. **Jang Young Lee:** Writing – review & editing, Visualization, Validation, Supervision, Software, Project administration, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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