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Epicardial halo phenomenon: a guide for pericardiocentesis?

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Abstract The epicardial halo delineates the heart shadow in fluoroscopy. To establish whether the sign is applicable to pericardiocentesis guidance, three investigators evaluated its intensity as absent = grade 0, indistinct = 0.5, clear = 1, intensive = 2 in posterior–anterior (PA) and lateral fluoroscopies recorded before pericardiocentesis or cardiac catheterization (Philips Integris-II BH3000). Three populations were studied: (a) 32 patients with pericardial effusion (PE group), 53.1 % males, aged 53.9 ± 13.9 years; (b) 14 patients with perimyocarditis (PM group), 64.3 % males, aged 51.6 ± 14.4 years; and (c) 46 coronary patients (CAD group), no PE, 95.6 % males, aged 67.3 ± 11.8 years. The intensity of the halo phenomenon was highest in patients with PE, lowest in patients with CAD, and intermediate in patients with PM (median sum of grades in PA/lateral view: 4/5 vs. 2/2.5 vs. 3/3, respectively) ($p < 0.01$). The halo phenomenon correlated well with HR and echocardiographic PE size in both angiographic views. The correlation with body mass index (BMI) and age was significant only in the lateral view and with PE volume only in the PA view. The sensitivity of the halo sign for PE was 84.1 % in PA and 92.0 % in lateral views. In 10/32 PE patients, the evaluation of the sign was repeated after PE drainage, revealing lower grades both in PA and in lateral views ($p < 0.01$). In conclusion, the epicardial halo sign is highly sensitive for the detection of a PE; it correlates well in at least one angiographic projection with the PE volume, HR, age, BMI, and the PE size in echocardiography and could be therefore applied as a safety guide for pericardiocentesis.

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Abbreviations

BMI	Body mass index
HR	Heart rate
PA	Posterior–anterior
PE	Pericardial effusion
PEDMIN	Minimal diastolic size of PE in echocardiography

Introduction

In the emergency setting of pericardiocentesis as a life-saving procedure, the imaging for pericardial access requires echocardiography or both echocardiography and fluoroscopy for guidance of the puncturing needle [1–4]. For the diagnosis of pericardial effusion (PE) in the pre-echocardiography era, the radiological findings were of great importance. One of the most valuable tools was the evaluation of the epicardial halo phenomenon—a radiological sign depicting the borders of the heart shadow [1–3]. However, the correlation of this phenomenon with the presence and/or the size of PE was never resolved. In an effort to improve both the feasibility and safety of pericardiocentesis, we have rediscovered the sign and its applicability for the fluoroscopic guidance of pericardial puncture [5]. Regarding the origin of the sign, two main hypotheses were discussed in previous studies. The first one explains the epicardial halo phenomenon as a radiological projection of the subepicardial fat layer [6–8]. Other experimental and clinical studies, however, have shown that the intensity of the sign correlated with the size of PE [9]. In addition, the phenomenon has not been systematically evaluated in a population of patients without pericardial disease. Therefore, the primary objective of this study was to investigate to what extent the epicardial halo phenomenon is prevalent in patients with pericarditis in order to be routinely used for guidance of pericardiocentesis in the cardiac catheterization laboratory. The secondary objective was to determine whether the intensity of the epicardial halo phenomenon correlates with the amount of PE or other patient-specific parameters such as age, heart rate (HR), and body mass index (BMI).

Methods

Patients

The study population included 92 patients who underwent posterior–anterior (PA) and lateral fluoroscopy (50–150 kV, biplane Philips Integris-II BH3000 cardiac catheterization laboratory) as a part of pericardiocentesis or coronary angiography with or without angioplasty/stent implantation. Three different groups of patients were analyzed according to the presence/size of effusion: The PE group comprised 32 patients with pericarditis and mainly large/moderate PE (Table 1) undergoing fluoroscopically guided subxiphoid pericardiocentesis (mean PE volume: 366.7 ± 449.7 ml; 53.1 % males; mean age, 53.9 ± 13.9 years); the PM group comprised 14 patients with perimyocarditis and a very small PE undergoing cardiac catheterization and endomyocardial biopsy (calculated [10, 11] mean PE volume, 90.5 ± 49.4 ml; 64.3 % males; mean age, 51.6 ± 14.4 years); and the CAD group included 46 patients with coronary artery disease undergoing diagnostic cardiac catheterization with or without coronary angioplasty (no PE; 95.6 % males; mean age, 67.3 ± 11.8 years) (Table 1). The etiology of the underlying pericardial disease in the PE group included neoplastic pericarditis in 12/32 patients (37.5 %), autoreactive/immune mediated PE also in 12/32 patients (37.5 %), viral PE in 3/32 (9.4 %), idiopathic PE in 4/32 (12.5 %), and uremic PE in 1/32 patient (3.1 %). PM group comprised 8/14 patients with idiopathic acute perimyocarditis (57.1 %), 5/14 patients with autoreactive perimyocarditis (35.7 %), and one patient with viral perimyocarditis (7.1 %).

The study was approved by the institutional ethical committee. All patients signed a written informed consent for the procedures they underwent and for the further analysis of the data and images.

Echocardiographic assessment

The size of the PE was defined according to the following criteria: very small PE, < 200 ml; small PE, 200–300 ml; moderate PE, 300–600 ml; and large PE, > 600 ml [2, 3]. The volume of the PE was calculated according to the prolate ellipse model of D'Cruz and Hoffman [10, 11] as a difference between total pericardial sac volume and cardiac volume. The volume of the each prolate ellipse was calculated according to the formula $V = 4\pi/3 \times (L \times D_1 \times D_2)/2$, where L and D_1 are the dimensions of the ellipse in the four-chamber view and D_2 is measured in the parasternal short axis view, both in end-diastole. Maximal and minimal thicknesses of the PE were measured in the four-chamber view in end-diastole as the maximal and

Table 1 Patient populations: baseline clinical data

	N	♂ (%)	Age (years)	PE volume (ml)[a]	PE_{min} (mm)	PE_{max} (mm)	HR (b/min)	BMI (kg/m^2)
PE group	32	53.1	53.9 ± 13.9	366.7 ± 449.7	6.7 ± 5.6	12.8 ± 10.9	85.6 ± 13.9	24.7 ± 3.7
PM group	14	64.3	51.6 ± 14.4	90.5 ± 49.4	2.0 ± 2.0	3.9 ± 2.6	75.8 ± 11.1	27.0 ± 3.1
CAD group	46	95.6	67.3 ± 11.8	n.a.	0	0	68.9 ± 12.5	26.2 ± 2.9

♂ males; *PE* pericardial effusion, PE_{max} maximal thickness of pericardial effusion measured in four-chamber view in diastole, PE_{min} minimal thickness of pericardial effusion measured in four-chamber view in diastole, *HR* heart rate, *BMI* body mass index, *PE group* pericarditis and mainly large/moderate pericardial effusion, *PM group* perimyocarditis and very small pericardial effusion, *CAD group* coronary disease and no pericardial effusion, *n.a.* not applicable

[a] Volume of pericardial effusion in the PE group represents the value obtained by pericardiocentesis, and volume in the PM group was calculated from echocardiography findings according to the method of D'Cruz and Hoffman [10, 11]

minimal distances, respectively, from the epicardial to the parietal pericardial layer in front of one of the four cardiac chambers and the apex of the heart. The CAD group included only the patients in whom no PE was found by echocardiography on the same day or the day before the cardiac catheterization.

Pericardiocentesis: fluoroscopic guidance using the epicardial halo sign

Pericardiocentesis was performed in local anesthesia using the Tuohy-17, blunt-tip introducer needle, via the subxiphoid route [1–3]. Guidance by the epicardial halo assumes that the puncturing needle is oriented in the same direction as it was the echocardiography probe used for verification of the effusion just before the procedure. The needle tip should slowly pass the bony cage, and after passing the diaphragm, the needle is advanced straight to the epicardial halo. The mandrel is then removed, and the needle is attached to a syringe containing angiographic contrast dye solution. The operator intermittently attempts to aspirate fluid and injects a small amount of fluid from the syringe.

The epicardial halo demarks the outer surface of the heart and is used to guide the puncture as a border that the needle tip should not cross during the procedure. It is essential in patients with a small PE to direct the needle approximately tangential to the epicardial halo until the fluid is aspirated. After aspiration of the pericardial fluid, a J-tip guidewire is introduced and after dilatation exchanged for a 7F pigtail catheter for effusion drainage. The intermittent manual drainage was performed until the entire PE was drained, and this volume was used for further calculations. In all patients, echocardiography was performed at the end of the procedure to prove that there was no residual effusion. Patients with loculated or chronic organized effusion, which were not possible to drain completely, were not included in the study. Furthermore, no patient previously treated with steroids was included in the study to avoid the possible influence of the treatment on the thickness of the epicardial fat layer.

Epicardial halo phenomenon

The presence of the epicardial halo sign was evaluated in the PA and lateral fluoroscopic angiograms by three investigators independently using the following classification: no epicardial halo—grade 0; epicardial halo present but indistinct—grade 0.5; epicardial halo clearly present—grade 1; epicardial halo clearly present and intense—grade 2. The sign was considered positive when a demarcation line of higher radiographic density than both the PE and the heart shadow and thicker than 2 mm was observed (Fig. 1). When a PE is present, the epicardial halo is displaced posteriorly by the higher-density fluid, which may be visible as a wide opaque vertical band between the anterior border of the heart and the mediastinum. For each patient, grading was performed from CD recordings by three investigators independently and blindly, regarding the diagnoses and identity of the patients. Findings were correlated with the amount of PE obtained by pericardiocentesis (PE group) and/or the size of PE assessed by echocardiography (group PM), the maximal and minimal thicknesses of PE, the age, the HR, and the BMI. In 10/32 patients in the PE group, the evaluation of the epicardial halo phenomenon was repeated after pericardiocentesis and complete PE drainage, both in PA and in lateral views.

Data analysis and statistics

Results are given as absolute numbers and mean ± standard deviation or frequencies (%). For each patient, separately for PA and lateral views, the sum of grades was calculated from the scores given by the three independent graders, thus providing ranges and median values for further comparison between the groups using the Mann–Whitney *U* test. The correlation of the median sum of grades with the amount of PE, age, HR, and BMI of the patients was performed using Spearman's correlation test, univariate, and multivariate regression analyses. Statistical significance was considered with a p value of <0.05. The analysis was performed in SPSS for Windows 10.0.

Results

The epicardial halo sign was graded positive in the PE group in 26/32 patients (81.3 %) in the PA view by all three graders (Table 2). In the lateral view, the sign was positive in 29/32 patients (90.6 %) by two graders and in 30/32 patients (93.8 %) by one grader.

In the PM group (very small PEs), the halo sign was graded as positive in the range of 11–14/14 patients (78.6–100 %) in the PA view by the different graders. In the lateral view, the sign was positive in 13/14 patients (92.8 %) by all three graders.

In CAD group (coronary artery disease, no PE), the epicardial halo sign was graded as positive in the wide range of 11/46–28/46 patients (23.9–60.9 %) in the PA view. In the lateral view, the sign was positive in 22/46–31/46 patients (47.8–67.4 %).

The sum of grades of all three investigators in the PA view was highest in the PE group (median value, 4; range, 1–6), lowest in the CAD group (median value, 2; range, 1–3), while in the PM group the median value was 3 (range, 2–5) (Table 3). The sum of positive scores for the

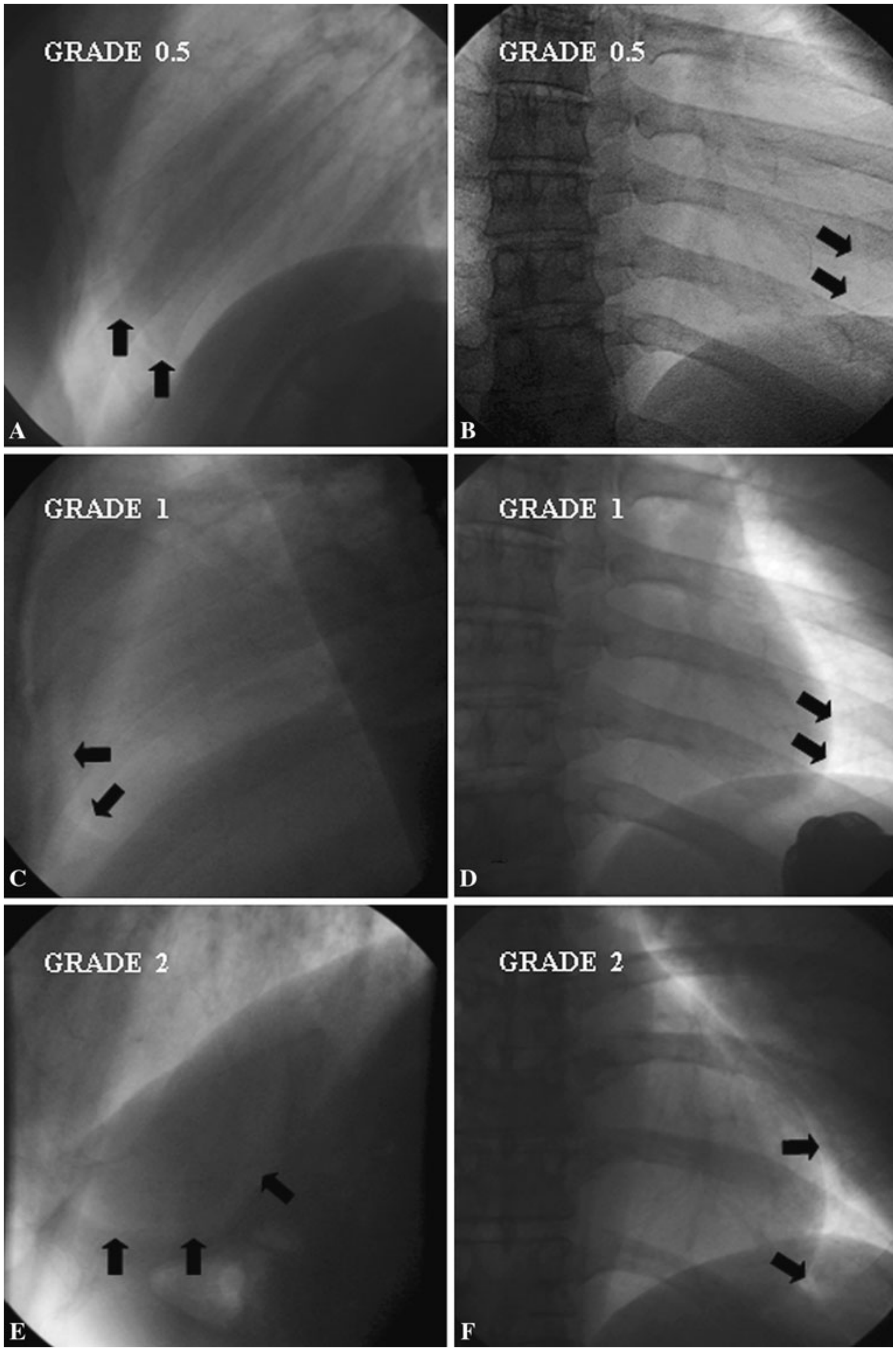

Fig. 1 The epicardial halo phenomenon in the lateral angiographic view (**a**, **c**, **e**) and in the posterior–anterior angiographic view (**b**, **d**, **f**). The intensity of the sign was evaluated by three investigators independently using the following grading system: no epicardial halo—grade 0; epicardial halo present but indistinct—grade 0.5 (**a**, **b**); epicardial halo clearly present—grade 1 (**b**, **c**); epicardial halo clearly present and intensive—grade 2 (**d**, **e**)

epicardial halo sign in the lateral view was also highest in the PE group (median value, 5; range, 2–6), the lowest in the CAD group (median value, 2.5; range, 1–4), while in the PM group the median value was 3 (range, 3–6) (all median values are significantly different, see Table 3).

Table 2 Results of epicardial halo grading by three independent investigators

	Grader 1	Grader 2	Grader 3
PE group ($n = 32$)			
PA view			
Halo sign positive[a]	26 (81.3 %)	26 (81.3 %)	26 (81.3 %)
Mean grade in halo positive patients	1.48 ± 0.50	1.58 ± 0.50	1.54 ± 0.50
Lateral view			
Halo sign positive[a]	29 (90.6 %)	29 (90.6 %)	30 (93.8 %)
Mean grade in halo positive patients	1.45 ± 0.50	1.52 ± 0.51	1.60 ± 0.50
PM group ($n = 14$)			
PA View			
Halo sign positive[a]	13 (92.3 %)	14 (100 %)	11 (78.6 %)
Mean grade in halo positive patients	1.15 ± 0.38	1.07 ± 0.27	1.27 ± 0.47
Lateral view			
Halo sign positive[a]	13 (92.3 %)	13 (92.3 %)	13 (92.3 %)
Mean grade in halo positive patients	1.12 ± 0.30	1.08 ± 0.28	1.31 ± 0.48
CAD group ($n = 46$)			
PA view			
Halo sign positive[a]	20 (43.5 %)	28 (60.9 %)	11 (23.9 %)
Mean grade in halo positive patients	0.98 ± 0.11	1.00 ± 0	1.00 ± 0
Lateral view			
Halo sign positive[a]	23 (50 %)	31 (67.4 %)	22 (47.8 %)
Mean grade in halo positive patients	0.98 ± 0.10	1.00 ± 0	1.09 ± 0.29

[a] The sign was considered positive when a ≥2 mm demarcation line of higher radiographic density than both the pericardial effusion and the heart shadow was observed (sign absent—grade 0; present but indistinct—grade 0.5; clearly present—grade 1; clearly present and intensive—grade 2); The same team of graders evaluated the signs independently of each other. Grader 1 was an experienced interventional cardiologist; grader 2, experienced radiologist; and grader 3, young cardiologist. *PA* posterior–anterior angiographic view, *PE group* pericarditis and mainly large/moderate pericardial effusion, *PM group* perimyocarditis and small pericardial effusion, *CAD group* coronary disease and no pericardial effusion

Table 3 Sum of grades of three investigators for epicardial halo in the investigated patient populations

	Sum of grades in PA view			Sum of grades in lateral view		
	Mean	Median	Range	Mean	Median	Range
PE group* ($n = 32$)	4.19 ± 1.66	4	1–6	4.60 ± 1.40	5	2–6
PM group[†] ($n = 14$)	3.14 ± 1.03	3	2–5	3.50 ± 0.91	3	3–6
CAD group[‡] ($n = 46$)	1.95 ± 0.77	2	1–3	2.31 ± 0.92	2.5	1–4

PA posterior–anterior angiographic view, *PE group* patients with pericarditis and mainly large/moderate pericardial effusion who underwent pericardiocentesis, *PM group* patients with perimyocarditis and a very small pericardial effusion, *CAD group* patients with coronary artery disease and no pericardial effusion

* PE versus CAD group in both PA and lateral views $p < 0.001$

† PE versus PM group in PA view $p = 0.035$, in lateral view $p = 0.014$

‡ PM versus CAD group in PA view $p = 0.012$, in lateral view $p = 0.006$

The diagnostic value of the epicardial halo sign for the detection of a PE is characterized with the sensitivity of 84.1 and 92.0 %, specificity of 57.2 and 44.9 %, positive predictive value of 66.3 and 62.5 %, negative predictive value of 78.2 and 71.4 %, and likelihood ratio to establish the effusion of 1.5 and 1.7 in PA and lateral angiographic views, respectively (Table 4). The values were calculated using echocardiography as a "gold standard."

The intensity of the epicardial halo in the PA view correlated directly with HR ($\rho = 0.41$; $p < 0.01$), PE volume ($\rho = 0.42$; $p < 0.05$), echocardiographic assessment of PE diastolic minimum ($\rho = 0.67$; $p < 0.01$), and maximum diameters ($\rho = 0.66$; $p < 0.01$), while there were no significant correlations with the BMI and the age of the patients (Fig. 2). The intensity of the epicardial halo in the lateral view correlated directly with HR ($\rho = 0.44$;

Table 4 Diagnostic value of the epicardial halo phenomenon in the lateral angiographic view and in the posterior–anterior (PA) angiographic view for the detection of pericardial effusion: specificity, sensitivity, predictive value, and the likelihood ratio

	PA view	Lateral view
Sensitivity	84.1 %	92.0 %
Specificity	57.2 %	44.9 %
Positive predictive value	66.3 %	62.5 %
Negative predictive value	78.2 %	71.4 %
Likelihood ratio	1.5	1.7

$p < 0.01$), the echocardiographic assessment of the PE minimum ($\rho = 0.63$; $p < 0.01$), and the PE maximum ($\rho = 0.62$; $p < 0.01$), but indirectly with the BMI ($\rho = -0.28$; $p < 0.05$) and the age of the patients ($\rho = -0.26$; $p < 0.05$), while there were no correlation with the PE volume obtained by pericardiocentesis (Fig. 3).

In the PE group, pericardiocentesis revealed a hemorrhagic PE in 7/32 patients (21.9 %), serohemorrhagic PE in 15/32 (46.9 %), and serous PE in 10/32 patients (31.2 %). However, the intensity of the halo sign was not significantly different with respect to the presence of a hemorrhagic, serohemorrhagic, or serous PE. In addition, when the intensity of the sign was further analyzed in the PE group with respect to the etiology of the disease (37.5 % neoplastic, 37.5 % autoreactive/immune mediated, 9.4 % viral, 12.5 % idiopathic, and 3.1 % uremic), there were no significant differences between the etiological subgroups. However, if the comparison was extended to the PE and PM group, the intensity of the halo sign in neoplastic PE patients was significantly higher than in autoreactive PE/PM patients ($p = 0.018$).

In 10/32 patients of the PE group, the evaluation of the epicardial halo sign was repeated after complete PE drainage, revealing a significantly lower sum of positive grades both in the PA and in the lateral views ($p < 0.01$). The mean evacuated volume in these 10/32 patients was 515.5 ± 416.6 ml. In fact, after the PE drainage, the halo phenomenon was detectable in the PA view only in 1/10 patient, whereas it was detectable in 9/10 patients in both views before drainage. In the lateral view, the sign was detectable after pericardiocentesis and PE drainage in 4/10 but with a lower sum of grades (median, 1; range, 0.5–1). Grades before drainage were in the PA view—median value of 6, range of 2–6; and in the lateral view—median value of 6, range of 3–6 (for both $p < 0.01$).

Linear univariate and multivariate regression analyses were performed to evaluate the relationship between the amount of the PE, the age, the HR, and the BMI of the patients as independent variables and on the sum of grades in the PA and the lateral views as dependent variables. HR and the minimal diastolic size of PE in echocardiography (PEDMIN) were significantly related to the intensity of the epicardial halo in the PA view in both univariate and multivariate linear regression analyses ($R = 0.64$, $R^2 = 0.41$, $F = 24.47$, $p < 0.01$). The relationship among these variables could be shown with the following regression equation: $y = 0.670 + 0.0024$ HR + 0.175 PEDMIN. Furthermore, in the linear univariate regression model, BMI, HR, and the PEDMIN were found to have a significant effect on the intensity of the epicardial halo in the lateral view. However, in the multivariate regression model, only HR and BMI were found to be significant ($R = 0.62$, $R^2 = 0.38$, $F = 15.26$, $p < 0.01$) in the lateral view. The regression equation was as follows: $y = 3.099 + 0.0027$ HR + 0.139 PEDMIN.

Discussion

This is the first study investigating the presence and intensity of the epicardial halo phenomenon during fluoroscopy/cineangiography of patients with pericarditis or perimyocarditis with various amounts of PE in comparison with patients with coronary artery disease and no PE. The epicardial halo phenomenon was first reported in 1947 [12] and in 1955 [6, 13]. Various terms were used to describe this sign: subepicardial fat line [6], subepicardial-pericardial shadow [13], epicardial fat line [14], epicardial fat pad [15–17], epicardial fat stripe [18, 19], pericardial fat stripe [20], band of density sign [21], and differential density sign of PE [9].

We have previously suggested that this sign might be useful for fluoroscopic guidance of pericardiocentesis using the new tangential approach in the lateral view [1–5]. The intention to further apply the sign for fluoroscopic guidance of pericardiocentesis was the reason to perform a grading of the halo phenomenon in the present study. The grading was performed on the parabolic curve since, even when indistinct (grade 0.5), the sign can be successfully applied for guidance of pericardiocentesis, and therefore, an additional grade was necessary between 0 and 1 in contrast to grading from 1 to 2.

Prevalence of the sign, sensitivity, and specificity for detection of pericardial effusion

In a study by Carsky et al. [15], out of the 100 patients with a PE, the epicardial halo (fat pad sign) was positive in 41 % on lateral radiography, 23 % in the frontal plane, and 12 % of patients in both. Although the diagnostic value of the lateral films was greater, in 11 % of the patients the sign was seen only in the frontal view. Tehranzadeh and Kelly [9] have demonstrated the epicardial halo (differential density) sign in 34 of 50 patients (68 %) with echocardiographically proven PE. Surprisingly, the demonstration was better on

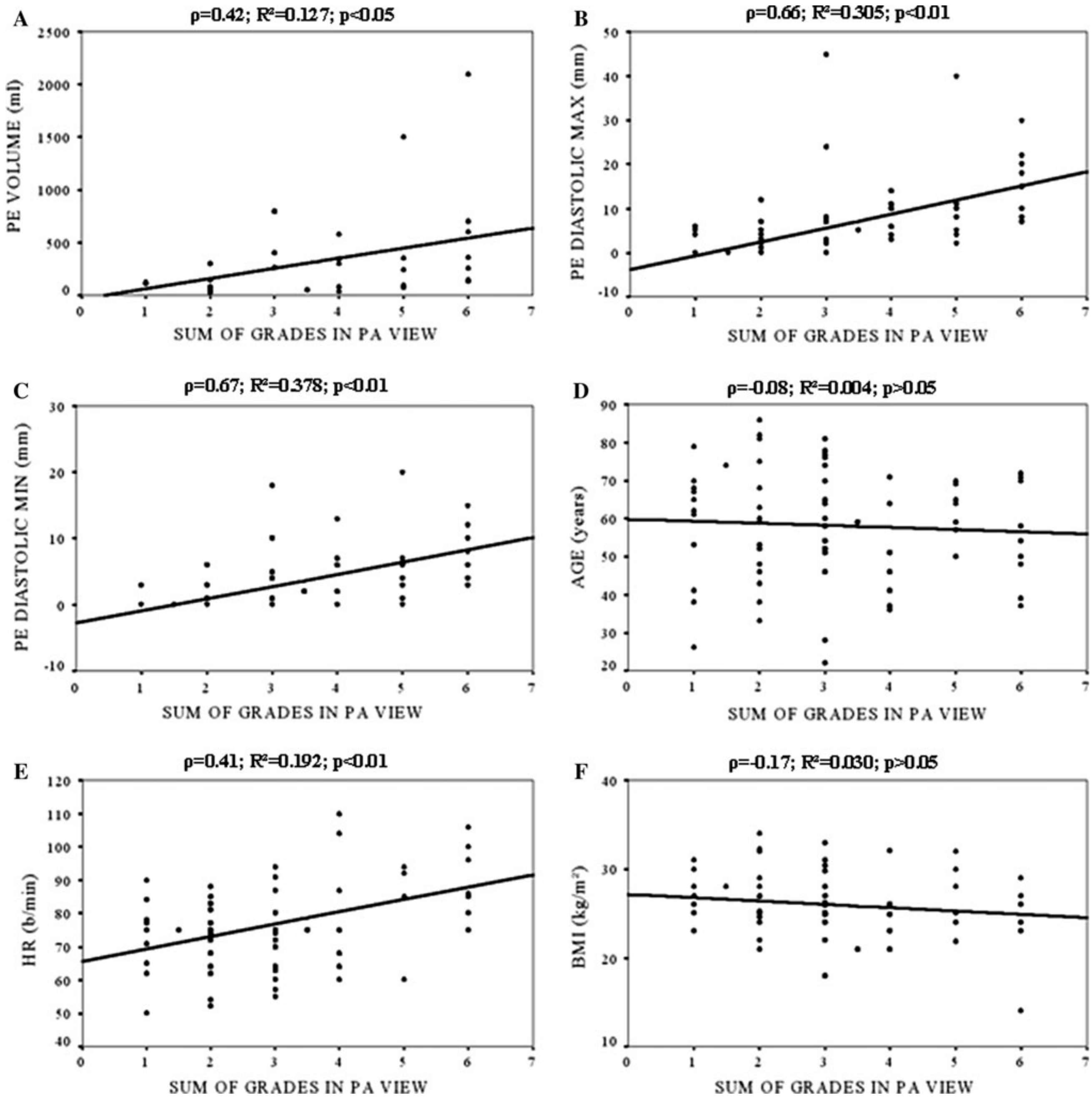

Fig. 2 Spearman's correlations of the sum of grades of epicardial halo in the *PA view* with: **a** pericardial effusion volume (ml) obtained by pericardiocentesis, **b** maximal and **c** minimal thickness of pericardial effusion in echocardiography measured in the four-chamber view in diastole, **d** age, **e** heart rate (HR), and **f** body mass index (BMI)

the frontal radiographs (62 %) than on the lateral films (41 %). The sign was present in 2/50 patients (4 %) in the control group without PE. Furthermore, Lane and Carsky [14] were able to demonstrate the phenomenon in 65 % out of 42 patients with PE, but also in 40 % of routine lateral chest films of patients without PE. In contrast to their and our findings in CAD group, Kremens [13] observed the epicardial halo phenomenon only in 10 % of healthy individuals. However, these studies did not use cineangiography, but plain chest roentgenograms.

In the present study, the sensitivity of the epicardial halo sign for the detection of PE was 84.1 and 92.0 % in PA angiographic view and lateral angiographic view, respectively. As expected, the specificity of the sign for the detection of PE was lower—57.2 and 44.9 % (PA vs. lateral view)—revealing a likelihood ratio to establish the

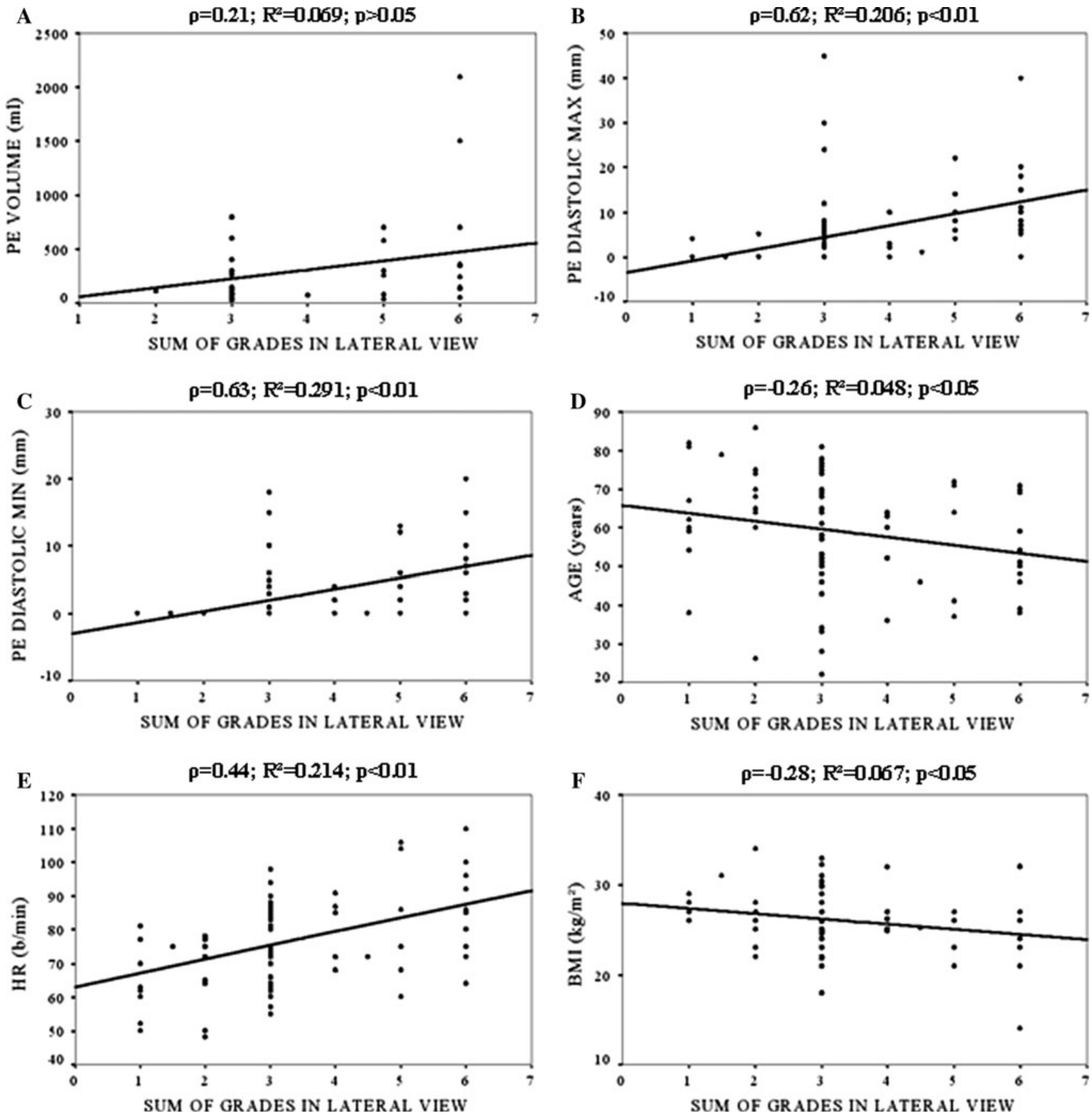

Fig. 3 Spearman's correlations of the sum of grades of epicardial halo in the *lateral view* with: **a** pericardial effusion volume (ml) obtained by pericardiocentesis, **b** maximal and **c** minimal thickness of pericardial effusion in echocardiography measured in the four-chamber view in diastole, **d** age, **e** heart rate (HR), and **f** body mass index (BMI)

effusion of 1.5 and 1.7 in PA angiographic view and lateral angiographic view, respectively. In a contribution by Eisenberg et al. [20], findings of the sign had 94 % specificity, but only 12 % sensitivity in 83 patients with PE and 17 controls with no effusion. The results were better for large and moderate effusions with 92 % specificity and 22 % sensitivity. These findings confirm that epicardial halo sign is sensitive enough to be used for guidance of pericardiocentesis in the large majority of patients. The low specificity of the sign is not a limitation for guidance of pericardiocentesis since all patients undergoing the procedure have to undergo echocardiography for the diagnosis of PE.

Physical origin of the sign

In an attempt to explain the origin of the sign, Tehranzadeh and Kelly [9] constructed a model demonstrating that the difference between the X-ray absorption coefficient of the blood in the cardiac chambers and of the transudate in the pericardial space is the most important contributing factor for the appreciation of the halo phenomenon. Our findings partially support this view, since the intensity of the sign was reduced after evacuation of PE in this study. However, there is still no good explanation for the origin of the sign in patients with coronary artery disease who had no PE on echocardiography, except probably the presence of epicardial fat [22, 23]. Pericardial fat predicts incident coronary heart disease independent of conventional risk factors, including body mass index. The pericardial fat pad may have a direct role in the atherosclerotic process in coronary arteries and inflammatory pericarditis through the local release of inflammation-related cytokines, which could explain the presence of the sign in all three populations of our patients [23, 24].

Parameters determining the intensity of the epicardial halo sign

Our study, as well as the one by Botsch [7], confirms that the intensity of the epicardial halo sign may depend on the size of the PE, the BMI, and the technical features of the radiology equipment. The present study was the first to show a correlation of the intensity of the epicardial halo sign with the age of the patients, their heart rate, and the findings in echocardiography. These parameters are important for the appreciation of the halo sign due to their impact on the features of fluoroscopic image. However, the results of our study were not consistent for both angiographic views, in that they failed to show a good correlation with age and BMI in the PA view and with the PE volume by pericardiocentesis in the lateral view. In a linear univariate regression model, BMI, HR, and PEDMIN were found to have a significant effect on intensity of the epicardial halo in the lateral view. In addition, HR and PEDMIN were significantly related to the intensity of the epicardial halo in the PA view in both univariate and multivariate linear regression analyses. However, in the multivariate regression model, only HR and BMI were found to be significant in the lateral view.

The age of the individuals is thought to be a significant factor affecting the visualization. Increasing pulmonary fibrosis and pulmonary vascular congestion in the older groups may interfere with optimal demonstration of an epicardial halo [13]. Short exposure time [6] and low imaging energy increase the probability of finding the sign [15, 19]. In patients with large breasts, pleural effusion or pulmonary infiltrates visualization of the epicardial halo sign may be difficult [18].

Jorgens et al. [25] described the cinefluoroscopic approach using image intensification, which was considerably more reliable in diagnosing effusions. The same was confirmed in the study of Botsch [7], revealing the positive epicardial halo sign in 29/33 (87.9 %) patients with large/moderate PEs. However, in 4/33 patients (12.1 %) with very large PEs, the epicardial halo sign could be demonstrated only after the initial drainage of PE. This absence of an epicardial halo sign in patients with very large effusions was not confirmed in our study. On the contrary, we demonstrated a clear reduction in intensity of the sign after PE evacuation. The application of cineangiography and technical improvement of the radiology equipment certainly contributed to the high sensitivity of the sign in our study in contrast to previous reports.

An additional advantage of the methodology we used could be the supine position of the patient, which was confirmed as a contributing technical point in the study of Heinsimer et al. [18]. In their experience in 35 patients with PE, the sign was positive in 51 % of the patients using the supine cross-table lateral chest roentgenograms in contrast to 31 % of positive conventional lateral chest roentgenograms in the same patients. The sign was positive using the supine cross-table lateral chest roentgenograms in 20 % of patients with small effusions, in 36 % of patients with moderate effusion, and in 86 % of patients with large effusion. In conventional lateral roentgenograms, the sign was present in 17 % of patients without a PE, in 30 % of patients with a small effusion, in 27 % of patients with a moderate effusion, and in only 36 % of patients with a large PE. The sign was also positive in 22 % of patients with no PE.

Limitations of the study

The epicardial halo phenomenon was assessed in this study by two cardiologists with the large personal experience with the sign and by a consultant radiologist without previous experience with the sign (grader 2). This study was introduced to diminish interobserver variability inherent to all image analyses. The grades obtained for the intensity of the epicardial halo were rather consistent for PE and PM groups, but there was a major interobserver variability in group 3, especially in the PA view. The epicardial halo sign was assessed on the original CD-ROM recordings from the standard fluoroscopy films. No digital image enhancement or extraction was applied. It remains for the future studies to establish whether such a feature could further improve the sensitivity and specificity of the sign and diminish the interobserver variability.

Conclusion

The present study has revealed a high sensitivity of the epicardial halo sign for the detection of PE. The intention of the study was, however, not to recommend this sign either for diagnosis or for follow-up of PE. Due to the low specificity of the sign, doing so would be met with a very limited success and would make little sense in the era of echocardiography. However, the sign is sensitive enough to be used for fluoroscopic guidance of pericardiocentesis as a demarcation line for the "forbidden territory" for the puncturing needle. Seeking for the changes of the sign could also facilitate the recognition of complications during invasive or interventional procedures. Sudden occurrence of an epicardial halo after endomyocardial biopsy or pacemaker lead implantation might indicate cardiac perforation and imminent cardiac tamponade [26]. The contribution of the epicardial halo sign to the safety and feasibility of pericardiocentesis should be further evaluated in a prospective, multicenter study.

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Conflict of interest The authors have no conflicts of interest or financial ties to disclose.

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