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High attenuation pericardial fluid on CT following cardiac catheterization

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Abstract

High-density pericardial fluid may be seen on noncontrast CT performed following cardiac catheterization (CC), raising the possibility of hemopericardium. Our goal was to determine the clinical course and associations of incidentally discovered high-attenuation pericardial fluid on noncontrast CT performed soon after CC. Hospital database search over a 7.5-year period identified 211 patients who underwent CT of the chest and/or abdomen within 60 h before or after CC, 150 having CC first. Pericardial fluid volume and attenuation as well as relevant laboratory and clinical parameters were recorded. Bivariate associations with average pericardial fluid attenuation (HU_{avg}) were assessed. Using the 61 patients with CT before CC as controls, 44 of the patients with CC first had attenuation values greater than the mean+2SD of 22.6 Hounsfield unit (HU) and 19 had attenuation values greater than the maximum control patient value of 39.8 HU. All patients with incidental finding of high-density pericardial fluid followed a benign course. Bivariate correlations showed time gap between CC and CT ($\rho=-0.50$, $p<0.001$), estimated glomerular filtration rate (eGFR) ($\rho=-0.24$, $p=0.004$), and female gender (median (IQR) 17.4 (13.6, 29.6) vs. 15.8 (9.9, 23.7), $p=0.02$) to be associated with HU_{avg} . In multiple linear regression analysis, only time gap and female gender were independently significantly associated with

average attenuation (both $p < 0.001$). The finding that patients with incidentally discovered high-density pericardial fluid followed an uneventful course suggests a benign etiology such as vicarious excretion, and in patients who are otherwise stable, observation rather than immediate intervention should be considered.

Keywords

Vicarious excretion; Pericardium; Hemopericardium; Cardiac catheterization; Pericardial effusion

Introduction

Noncontrast CT of the chest is performed frequently at our institution following cardiac catheterization and prior to coronary artery bypass grafting (CABG) or aortic surgery to evaluate for atheromatous aortic plaques and allow for surgical planning [1, 2]. We have observed high- and intermediate-attenuation fluid within the pericardium, and its recesses on CT scans performed soon after catheterization (Figs. 1 and 2). There had been concern that this was due to procedural complication and hemopericardium; however, we have also observed that these patients followed a benign course. The purpose of this study was to investigate factors associated with high-attenuation pericardial fluid following cardiac catheterization and to determine the clinical course in these patients. We hypothesized that high-attenuation pericardial fluid may be due to vicarious excretion of iodinated contrast into the pericardium rather than hemopericardium.

Methods

Institutional review board approval was obtained for this HIPAA compliant retrospective study. A waiver for informed consent was granted. Clinical Looking Glass (CLG) [3], an interactive software application that integrates demographic, clinical, and administrative databases, was used to identify the patient cohort. The hospital database was searched for all patients who received cardiac catheterization between July 2005 and December 2012. For each patient identified, a search was carried out to determine whether a noncontrast-enhanced CT scan of the chest and/or abdomen was performed in the prior or subsequent 2.5 days (or 60 h). Patients undergoing cardiac catheterization first ("CC first" group) were used for the analysis. Patients receiving CT scan prior to cardiac catheterization were used as controls. For each patient, age, gender, creatinine, albumin, race, and amount and type of contrast used for the cardiac catheterization were obtained from the patient's medical record. The first available creatinine value following catheterization was used. If not available, then the creatinine value with the shortest interval prior to catheterization was used. The above data were used to calculate estimated glomerular filtration rate (eGFR) using the formula: $\text{eGFR (mL/min/1.73 m}^2\text{)} = 175 \times (\text{Serum Creatinine})^{-1.154} \times (\text{Age})^{-0.203} \times (0.742 \text{ if female}) \times (1.212 \text{ if African American})$ [4]. Duration between the cardiac catheterization and CT (time gap) was also calculated for each patient. Reason for catheterization, side of the heart catheterized, and whether a percutaneous coronary intervention (PCI) was performed were also recorded for each patient. Admission and discharge summaries, progress notes, catheterization reports, problem lists, and lab values were reviewed to determine whether

hemopericardium, tamponade, pericarditis, or myocardial infarction was suspected clinically or had been diagnosed. All patient charts were available, with the documents listed above being reviewed for all patients whether they were electronic or hand-written.

For each case, images were reviewed blinded to clinical data on picture archiving and communication system (PACS) (Centricity, GE) to determine whether there was pericardial fluid. If there were no areas or only one measurable area of fluid within the pericardial space, the case was not used, as we were unable to obtain a reliable attenuation measurement. If there were two or more areas of measurable fluid accumulation, the case was used. For each of the largest two or three fluid-containing areas, the largest possible elliptical region of interest (ROI) was drawn using a PACS workstation and the area (mm^2) and average attenuation (Hounsfield unit, HU) of each was recorded. The average HU (HU_{avg}) values from the two or three ROIs and the maximum HU value (HU_{max}) of the two or three ROIs were calculated and tabulated for each patient. Size of the pericardial effusion was measured as the thickest region of pericardial fluid orthogonal to the heart in the axial or coronal planes. If there was only fluid in a pericardial recess [5] but not around the heart itself, then a value of 1 mm was used for calculations.

The CC first patients were compared to the CT first patients. Categorical variables were assessed using chi-square tests. Continuous variables were assessed for normality, t tests were used for normally distributed variables, and Mann-Whitney U tests were used for variables not meeting normality assumptions. Within the CC first group, bivariate associations of HU_{avg} with continuous variables were performed with Spearman rank correlations and associations with categorical variables were assessed with Mann-Whitney tests. HU_{avg} and HU_{max} were found to be not normally distributed and were log-transformed ($\log\text{HU}_{\text{avg}}$ and $\log\text{HU}_{\text{max}}$, which were normally distributed) to confirm associations in categorical variables using t tests and to allow for linear regression modeling. Multiple linear regression models were constructed to identify factors independently associated with $\log\text{HU}_{\text{avg}}$ and $\log\text{HU}_{\text{max}}$ among variables with significant bivariate association with HU_{avg} and HU_{max} . A two-tailed alpha of 0.05 was used to denote statistical significance for all statistical tests. All statistical analyses were performed using SPSS for Windows version 20.

Results

Of the patients, 735 were identified as having a noncontrast CT of the chest and/or abdomen within 60 h before (CT first) and 60 h after CC (CC first). Of these, 524 patients were excluded as follows: 498 did not have pericardial fluid, 13 did not have available imaging on PACS, and 10 had devices (such as LVAD or pericardial drain which caused streak artifact making reliable measurement impossible or a cause of potential bleeding or inflammation in the pericardial space) or a mass within the pericardial space. Three other patients were excluded as follows. One patient (average pericardial fluid attenuation of 69 HU) was excluded as hemopericardium was not an “incidental” imaging finding. Tamponade of uncertain etiology was suspected clinically due to marked hypotension and ultimately diagnosed upon drainage of bloody fluid. One patient had coronary artery perforation during coronary intervention (with no clinical sequela, with an average pericardial fluid attenuation of 31 HU). One patient had a diagnosis of pericarditis on an admission 2 weeks prior to CC

(and on CT, had average pericardial fluid attenuation of 19 HU). Extensive chart review showed no other cases of diagnosed hemopericardium or suspected pericarditis. The remaining 211 patients constituted the study sample.

Of these 211 patients, 150 had CC first while 61 patients had CT first. 104 patients received Omnipaque (iohexol) 350, 64 received Isovue (iopamidol) 370, 1 received Visipaque (iodixanol) 320, and 1 received Omnipaque (iohexol) 140. Forty-one did not have the contrast agent documented in physician or nursing notes. These 41 patients were not used for calculations involving quantity of iodine. One hundred fifty-six patients had creatinine measurements 14.6 ± 16.8 h (mean $\pm$ SD) following catheterization. Fifty patients had creatinine measurements 9.0 ± 8.4 h (mean $\pm$ SD) prior to catheterization. Creatinine values were not available for five patients. For PCI, 39 patients underwent coronary stenting while two had coronary angioplasty only. Table 1 lists the characteristics of the two sets of patients. The CT first group was significantly younger (mean $\pm$ SD, 64 ± 13 vs. 68 ± 12 , $p=0.02$) and had significantly greater proportion of patients with ultimate diagnosis of myocardial infarction (MI) (43 vs. 28 %, $p=0.04$). There were no statistically significant differences regarding gender, creatinine, eGFR, albumin, percent of patients with acute coronary syndrome (ACS), amount of iodine used during CC, percent of patients receiving just left heart versus both right and left heart catheterization, and percent of patients undergoing PCI. No patient underwent just right heart catheterization.

Among the 150 CC first patients, no patient had a follow-up CT of the chest after the initial CT was performed. Regarding echocardiogram follow-up, 17 of the 150 patients received an echocardiogram within 3 days following the initial CT, 12 reported no effusion, 4 reported “minimal” effusion, and 1 reported “small” effusion with “no evidence of diastolic right ventricular collapse.” None of these reports described debris or other evidence of hemorrhage within the pericardium, and no drainage procedure was performed on any of these patients.

Regarding attenuation measurements, three ROIs were able to be drawn in 145/150 (97 %) CC first patients and in 59/61 (97 %) CT first patients. There was no significant difference of pericardial effusion thickness and size of ROIs used for HU measurements between the CC first and CT first groups (Table 1). In the CT first control group the mean attenuation of the individual ROIs was 10.6 ± 6.0 HU, mean + two standard deviations was 22.6 HU, and the maximum value of any ROI was 39.8 HU. Mean HU_{avg} and HU_{max} were significantly greater in the CC first group (HU_{avg} CC first [mean $\pm$ SD] 21.0 ± 15.7 HU, CT first 10.6 ± 6.0 HU, $p<.001$; HU_{max} CC first 27.1 ± 16.4 HU, CT first 16.5 ± 8.7 HU, $p<.001$).

Subsequent analyses were performed only on the CC first group ($n=150$). Bivariate correlations were used to assess associations with CT attenuation of pericardial fluid following CC (HU_{avg} and HU_{max}). For continuous variables, Spearman rank correlations were used. There was statistically significant inverse correlation of HU_{avg} with time gap ($\rho=-0.50$, $p<0.001$) and eGFR ($\rho=-0.24$ $p=0.004$), but not with serum creatinine ($\rho=0.12$, $p=0.13$), serum albumin level ($\rho=-0.16$ $p=0.07$), age ($\rho=-0.13$ $p=0.13$), pericardial fluid thickness ($\rho=0.14$ $p=0.08$), and amount of iodine used ($\rho=0.10$ $p=0.25$). All analyses were repeated using HU_{max} yielding similar results. Associations of categorical

variables of ACS, MI, PCI, gender, and heart side catheterized with HU_{avg} and HU_{max} were tested using Mann-Whitney U tests. HU_{avg} was significantly higher for females than males (median (IQR) 17.4 (13.6, 29.6) vs. 15.8 (9.9, 23.7), $p=0.02$) and was similarly but not significantly higher for HU_{max} (24.4 (20.6, 36.0) vs. 23.1 (14.0, 31.6), $p=0.08$). Neither median HU_{avg} nor HU_{max} differed significantly for ACS (both $p>0.34$), PCI (both $p>0.55$), MI (both $p>0.16$), or heart side catheterized (both $p>0.36$). T tests between the categorical variables of ACS, MI, PCI, gender, and heart side catheterized with $\log HU_{avg}$ and $\log HU_{max}$ were similar.

The parameters for which significant associations were found using bivariate analysis: time gap, eGFR, and gender were tested using multiple linear regression analysis for independent association with HU_{avg} . HU_{avg} was not normally distributed but was log-transformed to $\log HU_{avg}$ (which was normally distributed) to allow for valid integration into a linear regression model. Of these, only time gap between CC and CT and gender were found to be significantly independently associated with HU_{avg} (both $p<0.001$). All analyses were repeated using $\log HU_{max}$, yielding similar results. A scatter plot was constructed showing the relationship between time gap, HU_{avg} , and gender (Fig. 3). Mean and median attenuation values divided by time ranges of time gap between CC and CT are tabulated in Table 2. Table 2 and the regression line in Fig. 3 suggest that the baseline attenuation will be reached by 18–24 h.

Discussion

Small amounts of pericardial fluid measuring up to 50 mL are considered normal [6]. A larger amount of fluid may be considered a pericardial effusion, which may be caused by various processes including heart failure, infection, malignancy, or renal insufficiency [7]. Hemopericardium may also have a variety of causes including blunt or penetrating trauma, bleeding diatheses, nontraumatic aortic or myocardial injury, or iatrogenic injury related to procedures such as cardiac catheterization [8].

In this study, we investigate the phenomenon of increased pericardial fluid attenuation on CT following CC and demonstrate that attenuation is most strongly associated with shorter time gap between CC and CT and also associated with female gender. In this retrospective study, we could not sample and analyze the pericardial fluid in any patient to definitively prove the cause of increased attenuation within the pericardial fluid. Still, extensive chart review failed to demonstrate a dire outcome in any patient with incidentally discovered high-attenuation pericardial fluid, suggesting a benign etiology such as vicarious excretion of contrast into the pericardial space as a likely etiology. Also, since PCI may occasionally cause post-procedural hemorrhagic pericardial effusion (and would not be expected following diagnostic catheterization), yet no association was demonstrated between PCI and fluid attenuation, it would further suggest that the increased attenuation was not complication-related.

In designing this study to investigate high pericardial fluid attenuation following CC, we would have preferred to measure the change in pericardial fluid attenuation prior to and following CC; however, patients undergoing noncontrast CT of the chest prior to and

following CC were rare at our institution. The cohort of clinically stable patients who underwent noncontrast chest CT following CC was largely due to the protocol at our institution of having aortic calcifications assessed by CT prior to surgery requiring aortic cross-clamping [1, 2]. In order to determine a baseline for normal pericardial fluid attenuation, we used a control group of patients who underwent CT prior to the contrast administration during CC. Parameters between the groups were similar aside for age and diagnosis of MI. Neither patient age nor MI was associated with pericardial fluid attenuation (HU_{avg}), so we did not expect either to cause an attenuation difference between the CC first and the control group. Also, there was no difference in pericardial effusion size between the two groups despite the higher percentage of MI patients in the control group (Table 1) [9].

For the control group, the mean attenuation for all the ROIs was 10.6 ± 6.0 HU, mean+2 SD was 22.6 HU, and the maximum value of any ROI was 39.8 HU. Using mean+2 SD as a threshold, 44/150 patients (29 %) had increased pericardial fluid attenuation. Using the maximum value of any ROI as a threshold, 19/150 patients (13 %) had increased pericardial fluid attenuation, ranging up to 105.2 HU. To our knowledge, there has not been a large study evaluating ranges of pericardial fluid attenuation in specific diseases; still, in a small study by Tomoda et. al., they found that CT attenuation of pericardial effusion due to viral pericarditis, lupus, heart failure, renal failure, and hypothyroidism measured up to 30 HU [10]. The large attenuation values in our study would unlikely be due to pericarditis. There has been a single case report presumably describing vicarious excretion of iodinated contrast in a patient with high-iodine volume cardiac catheterization, renal failure, and pericarditis [11]. In that case, the 200 HU value which they measured could not have been due to hemopericardium or pericarditis.

The phenomenon of vicarious excretion of iodinated contrast has been described for the biliary system where it more commonly occurs in patients with renal insufficiency/failure and urologic obstruction (even when unilateral) [12–14]. It has also been described for the peritoneum where increased ascites attenuation was found to be inversely related to time gap between contrast administration and CT imaging [15–18]. Vicarious excretion has also been described for the mucosa of the small bowel [14] and stomach [19]. Proposing a mechanism for vicarious contrast excretion is beyond the scope of our study, but it has been theorized that since this phenomenon occurs even in the absence of exudative processes such as inflammation (although this may facilitate it [11]) or malignancy, passive diffusion of the small contrast molecule may be the cause [15].

There were several limitations to our study. First, we did not directly sample pericardial fluid to prove that high attenuation was due to contrast rather than blood. Still, extensive chart review demonstrated that none of these patients had post-procedural complications to suggest that high attenuation was due to hemopericardium or pericarditis. Even if the high attenuation was caused by blood, our data suggests that it was of a benign variety. Second, we have found pericardial fluid attenuation to be related to patient gender but are not aware of a physiological or clinical explanation of why higher attenuation should be found in women regardless of whether the cause is vicarious excretion or hemopericardium. We are also unaware of such an association in other studies investigating vicarious excretion. The possibility of selection bias was not detected in our analysis but cannot be entirely excluded.

Last, although at 36 h there were no patients with pericardial fluid attenuation greater than the mean+2 SD threshold of 22.6 HU, at 24 h, there were 7 patients above this threshold. Although we suspect that this was related to these patients' low eGFR (average value of 36.9 mL/min/1.73 m² and a range of 4.7–85.8 mL/min/1.73 m²) as an inverse relationship has been shown for vicarious excretion into the peritoneum, bowel, and biliary system [15, 20], we did not have the statistical power to prove this relationship.

In conclusion, we found that all patients with incidentally detected post-CC high-attenuation pericardial fluid followed a benign clinical course suggesting that a benign process such as vicarious excretion of contrast rather than hemopericardium may be responsible. Particularly, in patients with CT performed within 18–24 h after cardiac catheterization, vicarious excretion should be considered as a potential cause, and close observation rather than immediate intervention should be considered in patients who are otherwise stable. Further prospective investigation such as with drainage or imaging with MRI or dual energy CT may be helpful to more definitively characterize the high-attenuation pericardial fluid content as contrast rather than blood.

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Fig. 1.

Axial CTscan obtained 4 h following cardiac catheterization (260 cc of Omnipaque 350 used) in a 62-year-old women with normal eGFR. Image at the level of the cardiac apex demonstrates high-attenuation pericardial fluid (*arrow*) with an average measurement of 89 HU

Fig. 2. Axial CT scan obtained 48 h following cardiac catheterization (198 cc of Visipaque 320 used) in an 83-year-old woman with an eGFR of 31. Image at the level of the left ventricle demonstrates intermediate attenuation pericardial fluid (*arrows*) with an average measurement of 34 HU

Fig. 3.

Scatter plot demonstrating the relationship between HU_{avg} , gender and gap between cardiac catheterization and CT, separately for males (*blue diamonds*) and females (*red squares*)

Table 1

Table listing demographic, clinical, lab value, procedural details, and pericardial measurements and attenuation for the CC first group and (CT first) control group. Data is presented as mean±standard deviation with significance tested with independent sample *t* tests, as median (interquartile range) with significance tested with Mann-Whitney tests, or percent, with significance tested using chi-square tests

	Catheterization first (n=150)	CT first (n=61)	
Age (years)	68±12	64±13	<i>p</i> =0.02
Gender (% male)	59 %	59 %	<i>p</i> =0.97
eGFR (mL/min/1.73 m ²)	69±33	76±32	<i>p</i> =0.15
Albumin (g/dL)	3.6±0.6	3.6±0.5	<i>p</i> =0.61
Creatinine	1.0 (0.8, 1.4)	0.9 (0.8, 1.2)	<i>p</i> =0.23
Acute coronary syndrome	51 %	56 %	<i>p</i> =0.50
Myocardial infarction	28 %	43 %	<i>p</i> =0.04
Iodine administered (g)	47±24	54±35	<i>p</i> =0.12
Left and right heart cath	27 %	21 %	<i>p</i> =0.42
Percutaneous intervention	16 %	28 %	<i>p</i> =0.50
Pericardial fluid thickness (mm)	4.8±4.1	4.8±6.1	<i>p</i> =0.95
ROI measured (mm ²)	115 (71, 190)	126 (70, 192)	<i>p</i> =0.43
HU _{avg} (HU)	21.0±15.7	10.6±6.0	<i>p</i> <0.001
HU _{max} (HU)	27.1±16.4	16.5±8.7	<i>p</i> <0.001

Table 2

Median, mean, and range of HU_{avg} values divided by hour ranges for time gap between cardiac catheterization (CC) and noncontrast CT

Time gap between CC and CT (h)	Number of subjects	Mean (HU)	Median (HU)	Range (HU)
0–6	24	37	35.2	7.9–105.2
>6–12	24	28	24.8	11.5–62.3
>12–18	11	26	19.9	7.7–49.4
>18–24	16	13	13.0	2.6–25.3
>24–30	31	16	14.3	2.9–64.3
>30–36	12	14	13.0	2.7–51.3
>36–42	4	13	13.1	8.3–16.8
>42–48	12	11	11.8	2.3–17.4
>48	16	16	16.4	7.1–25.7