Thorax artifacts in CT – air embolism or other causes?

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ABSTRACT

Background: The existence of air in hollow organs in the thoracic cavity constitutes a life-threatening situation most of the times. However, sometimes in thoracic Computed Tomography (CT) there are artifacts from different sources that could mimic air densities, disorientating the diagnosis. ***Materials and Methods:*** 100 patients (46 females and 54 males, mean age: 60 years, range: 20-90 years), who had been routinely scanned in the area of thorax using three different imaging protocols (follow up, aorta, pulmonary vessels) were retrospectively studied. In 67 cases, contrast agent was used during the examination. Every case was studied by two specialists. ***Results:*** Artifacts in pulmonary veins were observed in 38 of the cases. Of these artifacts 27 stemmed from contrast agent, calcifications in the vessels, metallic implants, movement of the patient, malfunction of a detector due to the size of field of view (FOV) or due to the existence of contrast agent on the examination table of the CT scanner. In 11 cases, small amounts of air had been inserted into blood circulation during contrast injection. ***Conclusions:*** This study characterized and classified many artifacts related to thorax CT in order to separate them from other serious thoracic pathologies (e.g. aortic dissection, ulcer of veins or arteries). The knowledge and identification of the different types of artifacts is very important in order to avoid the risk of misdiagnosis.

Keywords: *Streak artifacts, CT, air embolism, Air bubble, contrast agent.*

INTRODUCTION

In radiology, an artifact is a structure or an appearance that is not normally present on the radiograph or the tomographic scan images and is produced by artificial means. Radiographic errors may be due to technical errors or processing errors. The most common technical artifacts are noise, beam hardening-streak artifacts, motion artifacts, cone beam effects, helical, ring, partial volume and metal artifacts [1-3]. Those types of artifacts have different sources and they could either degrade image quality or mimic pathologies.

The existence of air in hollow organs is usually reported as a serious pathologic situation (e.g. inflammation that produces aerobic bacteria, pneumothorax, air-bubbles into vessels). Small amounts of air may enter a peripheral vein (and thereby the systemic venous circulation) during injection [4, 5]. Air bubbles may also be injected directly into an artery during angiographic arterial catheterization, for instance during Computed

Tomography (CT) angiography or thorax CT with contrast agent [4, 6-8].

The most common CT examinations that are performed for the thoracic area are the conventional examination as a follow up, examination of the thoracic aorta and examination of the pulmonary vessels. Generally, there are some circumstances during which air could concentrate into pulmonary parenchyma, in vessels, around aorta or near the walls [9].

Artifacts with densities similar to air near thoracic aorta, extra-pericardially or in vessels are usually identified on patients who underwent thorax CT. According to literature this is not a common and known artifact. It is described like air embolism due to contrast injection. However, there are findings indicating that the sources of this artifact are multiple. These artifacts may appear as streaks due to: 1) high contrast density; 2) existence of calcifications in vessels; 3) existence of metallic implants; and 4) respiratory motion of the patient [7, 10-14].

Another technical source for this artifact may be the false response of the reference detectors during the examination of overweight patients (FOV does not include the entire object) or non-cooperative patients (arms in the FOV). Finally, in some cases, where the vein of the patient did not resist the flow of injection resulting in an amount of contrast agent being spilled on the examination table of the CT scanner.

The aim of this study was the differentiation of artifacts and serious thoracic pathologies in order to avoid misdiagnosis. Furthermore, to estimate the frequency of their appearance since this indicates to some extent the impact of this problem in the clinical practice.

MATERIALS AND METHODS

A retrospective study was performed on 100 patients (46 females and 54 males, mean age 60 years, range 20-90 years), who had been routinely scanned from June 2017 to June 2018. The demographic data of the patient cohort are presented in table 1. This study was approved by the local institutional review board and written informed consent was obtained from all the subjects participating in the study protocol. Those patients underwent thorax CT examinations using three different imaging protocols (follow up, aorta, pulmonary vessels). All the examinations were performed using a GE Healthcare multislice 64 scanner and in the 67 of those cases the scans iodine contrast was applied. The parameters of every protocol are summarized in table 2. The CT images were evaluated by a radiologist with 10 years of experience and a radiographer with 20 years of experience and expertise on technical artifacts.

Table 1. Summary of the demographic data and the etiologies for the CT examination.

Demographic data	
Patients	100
Males	54
Females	46
Range of Age (years)	20-90
Mean value of Age (years)	60
Standard Deviation of Age (years)	16
Etiology of scanning	
Follow up (detection of secondary lesions)	52
Suspicion of aneurysm in thoracic aorta	10
Suspicion of primary lesions (e.g. hemoptysis)	10
Dyspnea	10
Feverish / Pneumonia	8
Suspicion of pulmonary embolism	6
Multi – injured patients	2
Thoracic pain	2

Table 2. Scanning parameters for the three CT protocols involved in this study.

	Thorax	**Aorta**	**Pulmonary vessels**
Thick of slices (mm)	1.25	0.625	0.625
Interval of slices (mm)	1.250	0.625	0.625
Time of scanning (sec)	6.37	6.37	14.17
Flow of contrast agent	1.8	2.5	3.5-4.5
kVp	120-140	120-140	120-140
mAs	99-110	99-110	99-110

Statistical section

Descriptive statistics were employed for presenting the data. The average, range, standard deviation, and relative frequency values were calculated according to the

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following mathematical expressions, equations 1-4:

$$mean\ value:\ \bar{x} = \frac{\sum_{i=1}^{N} x_i}{N} \quad (1)$$

range: R=maximum-minimum (2)

$$standard\ deviation: s = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \bar{x})}{N-1}} \quad (3)$$

$$relative\ frequency: f_k = \frac{v_k}{N} \quad (4)$$

Where; x_i is the i^{th} observation, N the total number of observations and v_k the absolute frequency of k event.

Also, an independent samples *t-test* was performed between two subgroups of the patient cohort (CT examinations with and without contrast) using the relative frequencies of the artifacts shown in table 3.

Table 3. Frequency and relative frequency (%) of the observed artifacts in patients who underwent thorax CT examination with and without the use of contrast agent.

Artifact sources	Thorax CT with contrast agent (67%)	Thorax CT without contrast agent (33%)
Air from injection	11 (16.4%)	-
High density of contrast agent	9 (13.4%)	-
Vessel calcifications	7 (10.4%)	-
Metallic implants	6 (9.0%)	-
Patient movement	2 (3.0%)	1 (3.0%)
False detector response	1 (1.5%)	1 (3.0%)

RESULTS

Beside common artifacts like beam hardening, ring, motion, partial volume, cone artifacts caused by metallic implants, motion in non-cooperative patients and other technical or scanner related ones, three additional categories of artifacts were also observed. These artifacts appeared to have air density and either the form of air bubbles produced during the procedure of injection or the form of lines (streak artifacts) caused by: 1) a high density contrast agent; 2) calcifications in vessels; 3) metallic implants; and 4) movement of the patient (table 3). The third category of those artifacts was related to a false response of the reference detectors or the existence of contrast agent on the examination table of the CT scanner. According to our findings over 100 patients, the aforementioned artifacts were observed in 36 cases when contrast agent was used (figures 1, 2, 5) or in 2 cases when contrast was not used during CT scan (figures 3, 4).

More specifically, figure 1 illustrates an artifact with air density in the pulmonary trunk that imitates vessel rupture and a streak artifact in the ascending aorta from the high contrast density in the adjacent superior vena cava. Figure 2 shows a streak artifact caused by the wall calcifications of the ascending thoracic aorta. In figure 3, an artifact with air density in the pulmonary trunk is presented. In this case, the body of the patient was not entirely in the FOV. Figure 4 illustrate four artifacts with air density (in the cardiac muscle and on the top of the pulmonary vessels), which occurred in a case that no contrast agent was used. Finally, figure 4 demonstrates artifacts with air densities in the middle of the pulmonary vessels with the shape of undefined lines.

In table 3, those artifacts are further broken down to the different underlying causes. A statistically significant difference ($p < 0.009$) was observed between the patient groups whose CT examination was conducted with or without contrast.

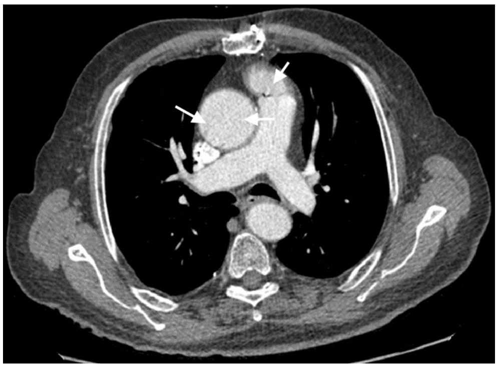

Figure 1. Axial image of thorax CT with contrast agent, which demonstrates an artifact with air density in the pulmonary trunk that imitates vessel rupture. This may have occurred from a false response of the reference detectors due to the existence of a small amount of contrast agent on the examination table of the CT scanner (upper right arrow). In addition, a streak artifact is present in the ascending aorta from the high contrast density in the adjacent superior vena cava.

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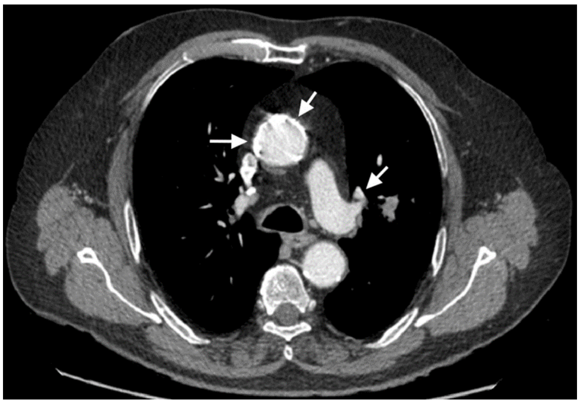

Figure 2. Axial image of thorax CT with contrast agent, which shows a streak artifact caused by the wall calcifications of the ascending thoracic aorta.

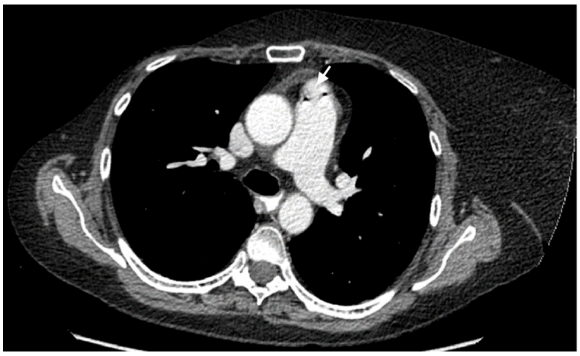

Figure 3. Axial image of thorax CT with contrast agent of an overweighed patient, which indicates an artifact with air density in the pulmonary trunk (not in the highest level). The body of the patient was not entirely in the FOV and the artifact may have been caused by a fault of the reference detectors.

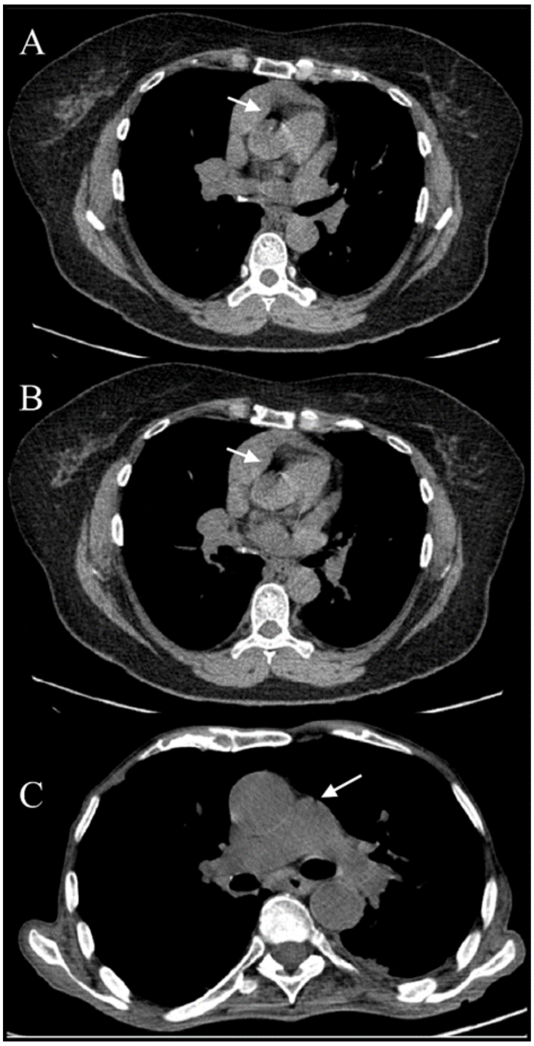

Figure 4. A-C. Axial images of thorax CT without contrast injection. Images **(A)** and **(B)** depict an artifact with air density in the cardiac muscle. Image **(C)** shows a small artifact with air density on the top of the pulmonary vessels. These artifacts may occur due to respiratory movements during scanning.

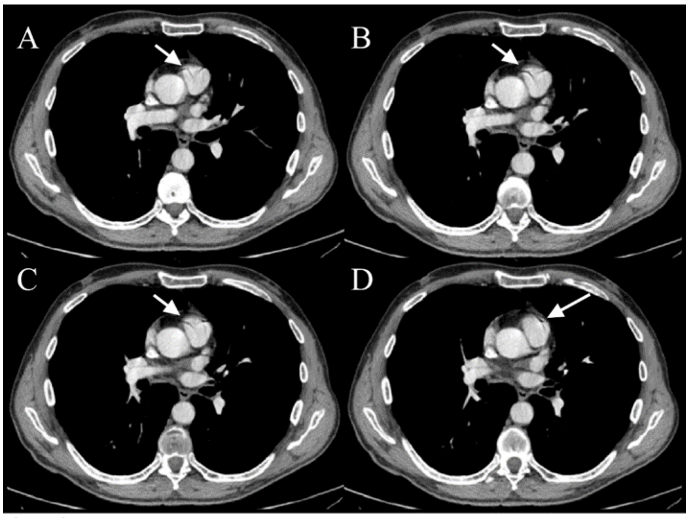

Figure 5. A-D. Axial consecutive images of thorax CT, which illustrate artifacts with air densities in the middle of the pulmonary vessels with the shape of undefined lines and they may be due to the existence of contrast agent on the examination table of the CT scanner.

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DISCUSSION

The technical artifacts in CT could be classified based on their source (patient, scanner or physical factors). The artifacts related to patient factors are those due to metallic implants or movement during scanning. The presence of metallic objects in the scan FOV can cause streak artifacts. The metal itself causes beam hardening, scatter effects, and Poisson noise. Beam hardening and scatter causing dark streaks between metal and surrounding tissue. As patient's movement can be considered any cardiac, respiratory, bowel or unintentionally motion. These movements can cause blurring, double images or even streaks in the final image [1, 3, 15, 16].

Of the most frequent artifacts related to scanner factors are ring artifacts which are caused by incorrectly calibrated or defective detector elements. Those artifacts create a bright or dark ring centered on the center of rotation [1, 3, 17].

In addition there is the "out of field artifact" that occurs when the filter in filtered back-projection is extremely local, meaning that detector measurements far outside the field of view have minimal impact on pixels inside the field of view [1].

Furthermore, cone beam effects and windmill artifacts are often presented during CT examinations. As the detector rows pass by the axial plane of the patient, reconstruction oscillates between taking measurements from a single detector row, and interpolating between two detector rows. If there is a high contrast edge between the two detector rows, the interpolated value may not be accurate. As a consequence, periodic dark and light streaks are produced, which are commonly known as windmill artifacts [1, 3].

Finally, there are artifacts related to physical factors, the most prominent of which are beam hardening-streak artifacts, partial volume effect and cupping artifacts. Briefly, the phenomenon of beam hardening happens when the beam passes through the body, where low energy X-ray photons are attenuated more than the remaining high energy photons. Thus, beam transmission does not follow the simple exponential attenuation of a monochromatic X-ray. This effect is mainly presented in high atomic number materials like bone, metal, or iodine contrast [1, 7]. Beam hardens more during its passage through the middle part of the object than its edges before it reaches the detectors. Therefore, the resultant attenuation profile differs from the ideal profile that would be obtained without beam hardening. These are called cupping artifacts. Partial volume effect occurs when a dense object lying off-center bulges partly into the width of the x-ray beam [3].

An amount of air visualized in mediastinum and especially in its upper region is an alarming sign because it could be related to the existence of a serious disease. These amounts of air could be entering the body as a result of different pathologies or iatrogenically.

The artifacts that were examined here are mentioned in the literature as air bubbles or air embolism and they have been described as amounts of air in vessels due to contrast injection [4, 5, 7, 17]. Systemic air embolism is a severe and potentially fatal complication which occurs in 0.001–0.003% of CT-guided transthoracic lung biopsies. Systemic arterial air embolism from the pulmonary veins into the systemic arterial circulation may be fatal even for small amount of air [8, 9, 18-21]. A reason for those artifacts is the existence of air in the injector.

The present study proves that the causes of all the aforementioned artifacts are numerous. In fact, their most frequent form are streak artifacts. Although, the most common cause of those artifacts is the existence of metallic implants in the patient, there are other reasons too. For example, sometimes contrast agent may have so high density that mimics metal, so it creates streak artifacts especially near superior vena cava (figure 1) [7, 10-12, 14, 22-24]. Also, more rarely, even wall calcifications of the thoracic vessels could mimic metal densities and create streak artifacts (figure 2).

Finally, those artifacts may be caused by a false response of the reference detectors, especially in cases when the arms of patient are shown into the FOV disorientating the detectors

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or in overweight patients where the FOV is not large enough to cover the entire part of the body. In those cases, the reference detectors measure incorrectly and produce artifacts. Further, this artifact was also observed in cases where a small amount of contrast agent was shed on the examination table of the CT scanner after vein rupture during contrast injection (figure 3).

However, these artifacts are not commonly described in the literature despite their frequent appearance as air existence. In the present study, those artifacts were observed not only in cases involving contrast injection, but also in simple scans where no contrast was used. In those contrast agent-free scans, artifacts were caused by respiratory movements (figure 4).

Normally, every amount of air accumulates in the upper part of the anatomic structures. However, in this study, in some cases those artifacts appeared in the middle or lower sections of vessels in the form of lines and other long shapes. These findings indicate that those artifacts were not caused by the existence of air but instead due to the existence of an amount of contrast agent on the examination table of the CT scanner (figure 5).

The present study has some limitations. First, it was performed retrospectively, which as an approach is usually associated with higher heterogeneity between the different subjects. Furthermore, a limited number of subjects was studied, which means that data from another larger patient cohort need to be prospectively collected to validate these findings.

CONCLUSION

Many times, the visualization of small spots with air densities in thoracic vessels are artifacts, which may be caused by contrast agent density, vessel calcifications, metallic implants, patient movement, incorrect detector response. This study characterized and classified many artifacts related to thorax CT in order to separate them from serious thoracic pathologies avoiding the risk of misdiagnosis.

Conflicts of interest*: *Declared none.

REFERENCES

1. Boas FE, Fleischmann E (2012) CT artifacts: Causes and reduction techniques. *Imaging Med, **4:** 229-240*.
2. Lavdas E, Vlychou M, Roka V, Wozniak G, Protogerou G, Fezoulidis I (2009) Artifacts in spiral CT protocols: The importance of the spatial reconstruction. *Eur J Radiography, **1:** 73-79*.
3. Barrett JF and Keat N (2004) Artifacts in CT: Recognition and avoidance. *Radiographics, **24:** 1679–1691.*
4. Emby DJ and Ho K (2006) Air embolus revisited – a diagnostic and interventional radiological perspective (bubble trouble and the dynamic Mercedes Benz sign). *South African J Radiol, **10:** 3-7*.
5. Yu AS, Levy E (1997) Paradoxical cerebral air embolism from a haemodialysis catheter. *Am J Kidney Dis, **29:** 453-455*.
6. Ziser A, Adiry, Lavon H, Shupaka (1999) Hyperbaric oxygen therapy for massive arterial air embolism during cardiac operations. *J Thorac Cardiovasc Surg, **117:** 818-821*.
7. Choi HS, Choi BW, Choe KO, Choi D, Yoo KJ, Kim MI, *et al.* (2004) Pitfalls, artifacts, and remedies in multi– detector row ct coronary angiography. *Radiographics, **24:** 787–800*.
8. Hoang JK, Lee WK, Hennessy OF (2008) Multidetector CT pulmonary angiography features pulmonary embolus. *J Med Imag Radiat Oncol, **52:** 307-317*.
9. Sur BW, Wandtke JC, Hobbs SK (2015) Pneumothorax: How to recognize subtle signs and avoid pitfalls. *Contemp Diagn Radiol, **36:** 1-7*.
10. Lavdas E, Roka V, Protogerou G, Vlychou M, Fezoulidis IV (2006) Elimination of artifacts through spatial reconstitution in thoracic aorta imaging examination. *Archives of Hellenic Medicine, **26:** 384-389*.
11. Setty BN, Sahani DV, Ouellette-Piazzo K (2006) Comparison of enhancement, image quality, cost, and adverse reactions using 2 different contrast medium concentrations for routine chest CT on 16-slice MDCT. *J Comput Assist Tommogr, **30:** 818-822.*
12. Faggioni L and Gabbeloni M (2016) Iodine concentration and optimization in computed tomography angiography current issues. *Invest Radiol, **51:** 816-822.*
13. Sekiguchi R, Nawano S, Satake M, Hayashi T, Murakami K, Nasu K, *et al.* (2001) Multislice CT of the thorax: effects of contrast material pushed with saline solution using a dual power injector on contrast material dose and perivenous artifacts. *Nihon Igaku Hoshasen Gakkai Zasshi, **61:** 484-490*.
14. Kodaira T, Shimamoto K, Hirota H, Itoh S, Itoh K, Kamata N, *et al.* (1995) Optimal concentration of contrast medium in helical CT of the thorax. *Nihon Igaku Hoshasen Gakkai Zasshi, **55:** 138-144.*
15. Chen GTY, Kung JH, Beaudette KP (2004) Artifacts in Computed Tomography of moving objects. *Sem Radiat Oncol,*

***14:** 19-26*.

16. Goldman LW (2007) Principles of CT and CT technology. *J Nucl Med Technol, **35:** 115–128.*
17. Hsieh J (2003) Computed tomography: Principles, design, artifacts, and recent advances. Bellingham, WA: SPIE.
18. Ialongo P, Ciarpaglini L, Tinti MD, Suadoni MN, Cardillo G (2017) Systemic air embolism as a complication of percutaneous computed tomography guided transthoracic lung biopsy. *Ann R Coll Surg Engl, **99:** e174–e176*.
19. Tomiyama N, Yasuhara Y, Nakajima Y, Adachi S, Arai Y, Kusumoto M, *et al.* (2006) CT-guided needle biopsy of lung lesions: a survey of severe complication based on 9783 biopsies in Japan. *Eur J Radiol, **59:** 60–64.*
20. Hare SS, Gupta A, Goncalves TV, Souza CA, Matzinger F, Seely JM (2011) Systemic arterial air embolism after percutaneous lung biopsy. *Clin Radiol, **66:** 589–596.*
21. Hori Y, Yoshimura N, Ozaki T, Takano T, Ooi H, Kimura M, *et al.* (2005) Two-phase CT pulmonary angiography for detection of hilar pulmonary thromboembolism. *Radiat Med, **23:** 414-417.*
22. Haage P, Schmitz-Rode T, Hübner D, Piroth W, Günther RW (2000) Reduction of contrast material dose by a saline flush using a double power injector in helical CT of the thorax. *AJR Am J Roentgenol, **174:** 1049-1053*.
23. Hansmann J, Fink C, Jost G, Pietsch H, Meyer M, Nance JW Jr, *et al.* (2013) Impact of iodine delivery rate with varying flow rates on image quality in dual-energy CT of patients with suspected pulmonary embolism. *Acad Radiol, **20:** 962–971.*
24. Batra P, Bigoni B, Manning J, Aberle DR, Brown K, Hart E, *et al.* (2000) Pitfalls in the diagnosis of thoracic aortic dissection at CT angiography. *Radiographics, **20:** 309-320.*

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