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A CASE OF MASSIVE TRANSIENT REDUCTION OF ATTENUATION OF IODINE CONTRAST BOLUS DURING COMPUTED TOMOGRAPHY PULMONARY ANGIOGRAPHY: WHY AND HOW TO AVOID IT

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We report an incidental case of combined disproportionate deep inspiration and breath-old artifacts producing during computed tomography pulmonary angiography performed to exclude pulmonary embolism in a 69 year-old patient. These known but unwelcome cumulated artifacts may cause transient major attenuation or interruption of the contrast bolus which may occasionally obscure or mimic an embolus. We shortly review the mechanisms of these classical artifacts and the adequate breathing instructions to avoid them are remembered.

Key-word: Embolism, pulmonary.

Case report

A 69-year-old smoker suffering from chronic obstructive pulmonary disease presented to our emergency department with complaints of unproductive cough and increasing dyspnea. There was a recent history of bronchitis treated with amoxicillin and clarithromycine. Arterial gasometry confirmed moderate respiratory acidosis. D-dimers were moderately elevated at 65 mcg/100 ml (nl < 50). CT pulmonary angiography was asked to specifically rule out associated pulmonary embolism.

CT pulmonary angiography was performed with a 64-row MDCT (Lightspeed Ultra, GE Medical System, and Milwaukee, WI) and following our local classical protocol.

During this protocol non ionic contrast (Optiray 300, Guerbet, France) is injected at a rate of 3,5 ml/s via a 18-20-gauge needle. The technical parameters are 100 Kv, 0.5 sec rotation time, auto mA regulation and a pitch of 0,984. The delay before starting the acquisition varies from 12 to 30 sec. It is determined by a compromise between the level of HU automatically measured on a reference cut positioned in the main pulmonary artery (SmarPrep, General Electric, Wisc) and/or by the operator's visual appreciation of the whiteness of this artery . The acquisition time requires a technical delay of 9 seconds followed by a mean time of 4 seconds to scan the entire chest. With these parameters the total examination time varies from 25 to 43 sec and the amount of injected contrast from about 85 cc to an automatically blocked maximum of 120 cc. Saline injection of 20 cc automatically follows.

The inspiratory and breath hold instructions are given to the patient during the technical delay of 9 seconds before scanning. Thus the required time of breath hold is about 12 seconds. The patient's arms are positioned above the head but comfortably lying on a big cushion, a positioning classically guarantying in our experience a minimum compression of the veins entering the chest.

Immediate analysis of the pulmonary arteries (Fig. 1 to 3) revealed an unusual phenomenon characterized by massive prograde irruption of unenhanced blood within the previously intensely enhanced pulmonary arteries. The pulmonary arterial iodine appeared acutely diluted by volutes of unenhanced blood and a nearly complete and premature wash out of the main pulmonary artery was drastically observed contrasting with the high density of the aorta. An unusual collapse of the superior vena cava was also found in association with massive blockage and retrograde reflux of contrast within dilated cervical veins.

These abnormalities were finally attributed to massive and combined "deep inspiration" and "breath-hold" artifacts. Retrospectively it appears that these caricature artifacts were probably the result of a combination of inadequate breathing instructions and disproportionately exaggerated respiratory maneuvers performed of the patient.

Discussion

For CT pulmonary angiography, optimal contrast opacification of the vessels depends on several factors including adequate injection delay and duration, scan duration, injection rate, total volume of contrast administrated and concentration of iodine content of the contrast medium (1-3). Strictly adequate breathing instructions also appear essential for optimal diagnosis.

A transient attenuation or interruption of the contrast bolus has been described as a physiologic artifact associated with initial inspiration immediately before the scan . This artifact can sometimes result in poor opacification of the pulmonary arteries during CT pulmonary angiography (1-3). This unwelcome artifact can have negative consequences for the diagnosis of pulmonary embolism: an embolus may potentially be obscured or hidden within an insufficiently opacified pulmonary artery; reciprocally a focal interruption of the contrast medium column can mimic an embolus (4).

It has been suggested that transient attenuation or interruption of the contrast bolus during CT pulmonary angiography might be related to inappropriate suspended deep inspiration through several mechanisms including an altered contrast medium flow dynamics during forced inspiration and resulting in the passage of a bolus of non opacified blood from the inferior vena cava entering the right heart (suction mechanism), an acutely reduced delivery of contrast medium via the superior vena cava to the right atrium secondary to a sudden rise in intrathoracic pressure during end-inspiratory breath-hold and/or inappropriate simultaneous Valsalva maneuver, and accessorily a preferential flow of contrast medium

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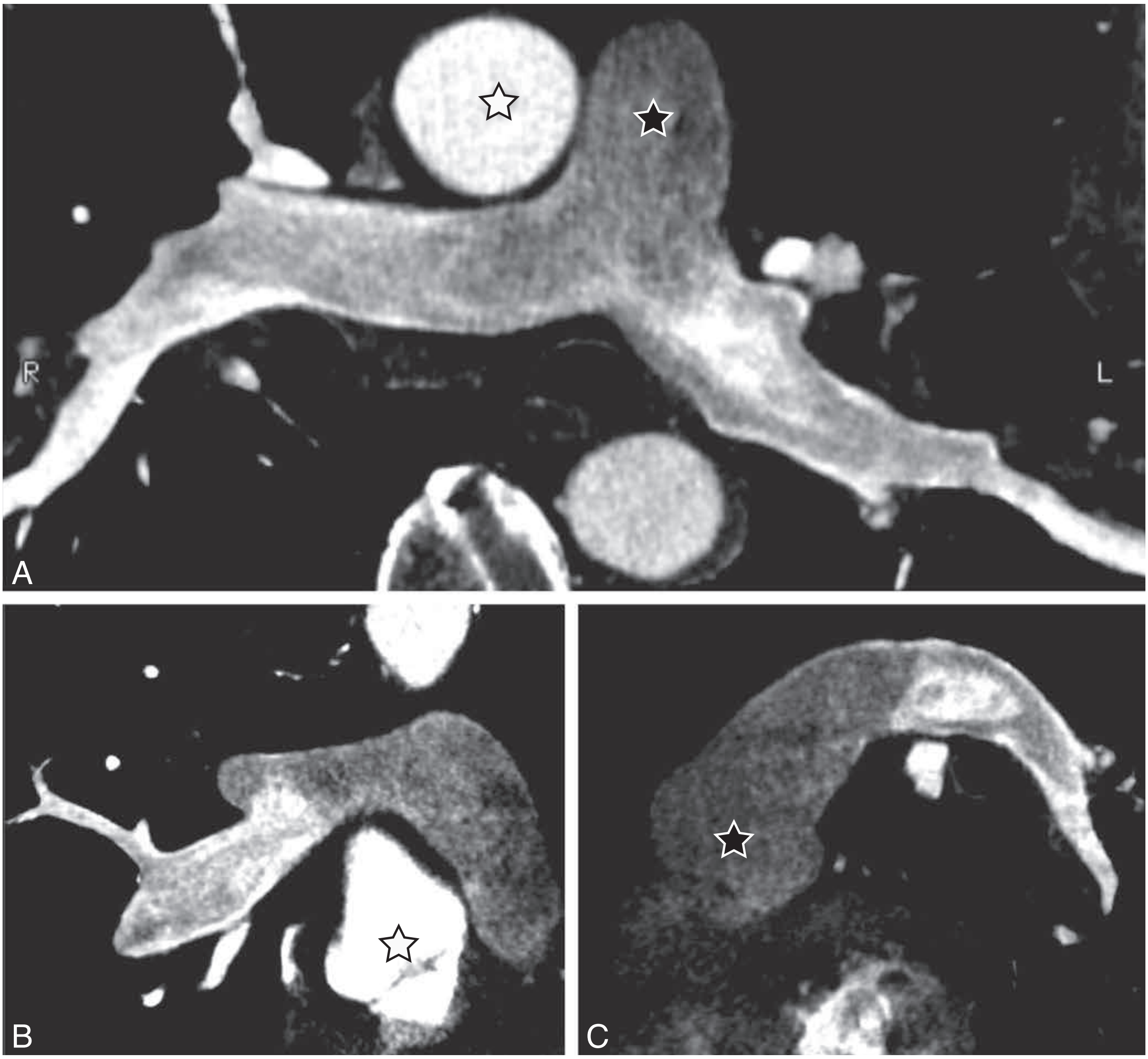

Fig. 1. — Curvilinear MPR views of the pulmonary arteries – bifurcation (A), right (B) and left (C) arteries – illustrate a massive prograde irruption of unenhanced blood within the previously enhanced arteries. Volutes of unenhanced blood acutely dilute the iodine contrast. The nearly complete wash out of the pulmonary artery (black star) drastically contrasts with the high density of the aorta (white star).

through a patent foramen ovale from the right to the left heart on inspiration and subsequent Valsalva maneuver (1-6).

This artifact has been reported in 3% of the patients in the study of Wittram & Yoo (3). In the paper of Gosselin et al., it was present in 37% of patients (7). This major but interesting discrepancy might be mostly explained by the differences in the instructions given to the patients in the two studies: the patients of Wittram & Yoo (3) were instructed to "take a breath in and hold it" before image acquisition; on the contrary, those of Gosselin et al. (7) were instructed to first have five respiratory cycles of hyperventilation before being invited to take a full inspiration two seconds before scanning. This sequence of hyperventilation before deep inspiration and breath-hold probably drastically exacerbates the artifact and validates the predominantly influence of inadequate excessive inspiration in the phenomenon.

In a recent study MRI has been used for noninvasive evaluation of the manner in which the superior vena cava (SVC) and inferior vena cava (IVC) contributions to systemic venous return to the thorax vary with different respiratory maneuvers (1). When intrathoracic pressure remains constant, as during breath-holds at end-inspiration and end-expiration, the IVC to SVC flow ratio is very similar to that during free breathing, the ratio of IVC flow to SVC flow being approximately 2:1.

This flow ratio reduces during Valsalva maneuver which produced also the greatest decrease in venous return from the IVC and therefore would be expected to result in the best contrast opacification of the pulmonary arteries through the SVC. In daily practice it would be difficult, however, for most patients to sustain

Fig. 2. — This very thick coronal MIP reconstruction of the full thoracic CT pulmonary angiography clearly illustrates the dynamic mechanism of the "deep strained continuous inspiration" and "breath-hold" associated artifacts. During "deep strained inspiration" massive unenhanced blood is pumped from the abdomen through the IVC (grey arrow) causing acute prograde dilution of the iodine contrast in the pulmonary artery (black star). Nearly concomitantly the "breath hold" maneuver - very similar to an acute Valsalva maneuver - generates acute positive intrathoracic pressure which induces a collapse of the SVC (white arrow) with acute blockage and retrograde reflux of contrast within the dilated cervical veins (black arrows). This collapse of the SVC reduces delivery of contrast medium to the right atrium and amplifies the dilution due to inspiration.

a Valsalva maneuver for the entire length of a pulmonary CT angiogram (1). Moreover this maneuver is susceptible to collapse the SVC causing a reduction of the delivery of contrast medium (6, 8).

During deep strained continuous inspiration intrathoracic pressure becomes negative (1). This change in pressure gradient increased venous return to the right atrium for nearly 50% by a mechanism of suction of blood from the extra-thoracic areas. The percentage of increase in IVC flow during inspiration is significantly greater than the increase in SVC flow: the "abdomino-thoracic pump" predominates (4). Therefore the contribution of IVC flow to total systemic venous return is transiently greater during inspiration, the IVC to SVC flow ratio being 2.4:1. Because contrast material is almost always administered through an arm vein, this relative increase of unopacified blood from the IVC dilutes contrast medium injected at a constant rate.

Individual variation in the manner in which patients follow breathing instructions and the forcefulness of their inspiratory effort may explain why this artifact is seen on some but not all pulmonary CT angiograms. The inspiratory IVC flow may increase only 15% in a subject but 140% in another in the series of Kuzo (1).

A possible mechanism may be that diaphragmatic descent during inspiration increases intraabdominal pressure. With positive intraabdominal pressure and negative intrathoracic pressure, the greater pressure gradient along the IVC than along the SVC results in greater augmentation of IVC flow (9).

In our caricature reported case the intense inspiratory attenuation artifact has probably been amplified by an involuntary concomitant equivalent of Valsalva maneuver during the "breath-hold" at the end of the exaggerated deep inspiration. This "breath hold" produced acute positive intrathoracic pressure after the initial negative pressure generated by the inspiration (8). The result was an immediate collapse of the superior vena cava and a blockage of the contrast column with intense reflux in the cervical and jugular venous system (8) (Fig. 2, 3). In other words, the dilution of the contrast caused by the augmentation of the unenhanced IVC flow during the deep inspiration has been amplified by the nearly simultaneous blockage of the enhanced SVC flow by the Valsalva maneuver.

High-flow injection – 5 to 7 cc/sec – could represent an alternative to avoid the described artifact but this type of injection which requires constant high quality and safe intravenous catheters, a condition not easily achievable seven days a week in current clinical practice especially in elderly or altered patients.

To reduce inspiration and breath-hold associated artifacts authors have promoted expiratory CT pulmonary angiography and have concluded that expiratory scanning could be used as an optimal protocol for dedicated pulmonary artery imaging. However, this protocol suffers from inferior parenchymal imaging and should probably be reserved for failed inspiratory breath-hold CT pulmonary angiography (4,10).

We conclude that, in clinical practice, breathing instructions would be unambiguously appropriate to avoid the inspiration artifact as much as possible. Instructions such as "stop breathing" or "hold your breath" appear the most appropriate but others such as "take a deep breath and hold it" or "take a deep breath and block your breath" would be absolutely avoid.

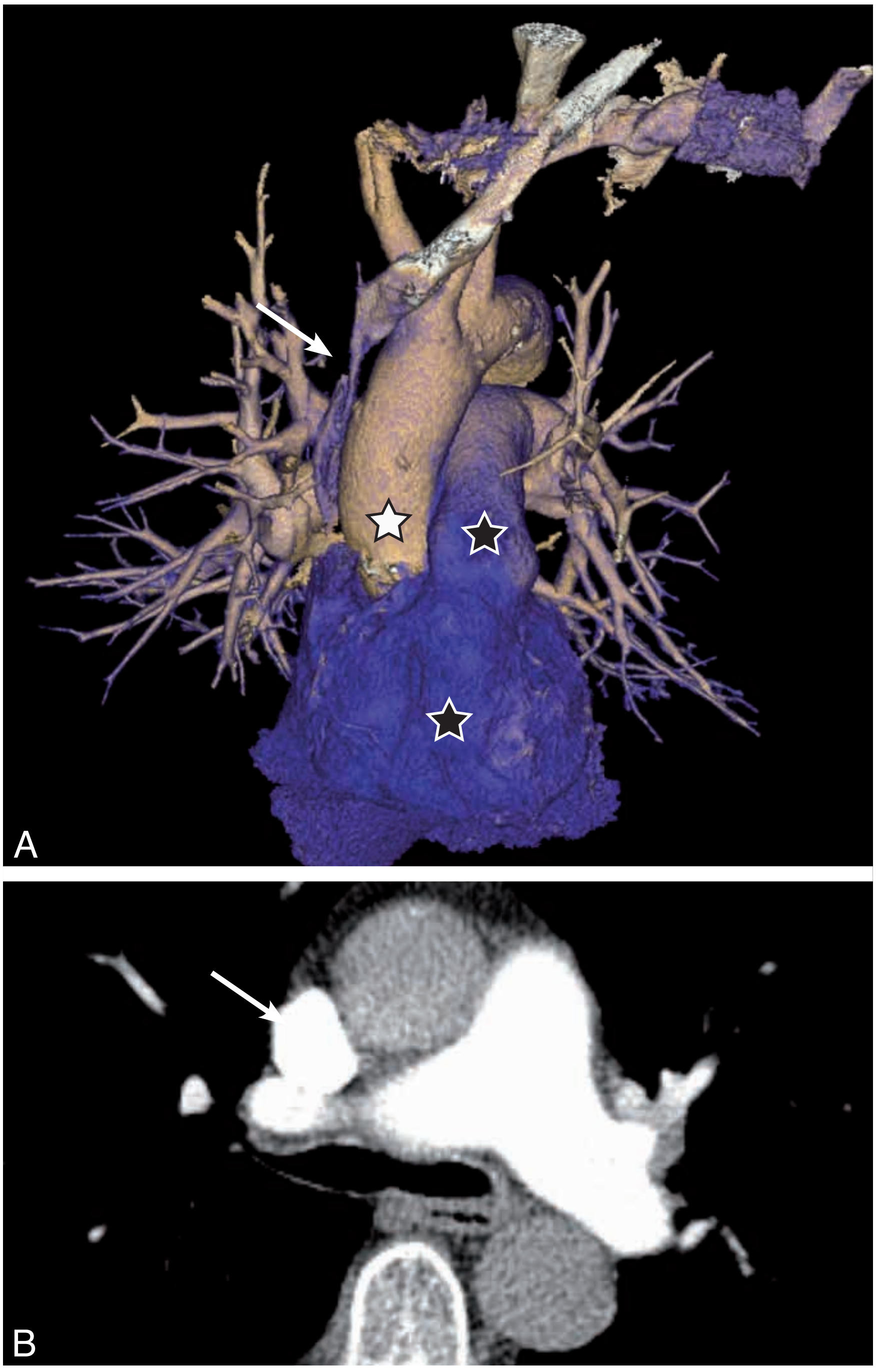

Fig. 3. — Global volume rendering view of the CT angiogram (A). The acute dilution of the iodine vascular contrast is clearly illustrated in dark blue. A complete "wash out" of the iodine contrast of the right cavities of the heart and of the main pulmonary artery is clearly visible (black star) when compared with the aorta (white star). The complete collapse of the SVC induced by the "breath-hold" (white arrow) is obvious when compared with the diameter of this vein (white arrow on B) during the "bolus tracking" phase of the angio-CT.

References

1. Kuzo R.S., Pooley R.A., Crook J.E., Heckman M.G., Gerber T.C.: Measurement of Caval Blood Flow with MRI During Respiratory Maneuvers: Implications of Vascular Contrast Opacification on Pulmonary CT Angiographic Studies. *AJR*, 2007, 188: 839-842.
2. Wittram C.: How I Do It: CT Pulmonary Angiography. *AJR*, 2007, 188: 1255-1261.
3. Wittram C., Yoo A.J.: Transient interruption of contrast on CT pulmonary angiography: proof of mechanism. *J Thorac Imaging*, 2007, 22: 125-129.
4. Mortimer A.M., Singh R.K., Hughes J., Greenwood R., Hamilton M.C.: Use of expiratory CT pulmonary angiographyto reduces inspiration and breath-hold associated artifact: contrast dynamics and implications for scan protocol. *Clin Radiol*, 2011, 66: 1159-1166.
5. Henk C.B., Grampp S., Linnau K.F., et al.: Suspected pulmonary embolism : enhancement of pulmonary arteries in deep-inspiration CT angiography - influence of patent foramen ovale and atrial-septal defect. *Radiology*, 2003, 226: 749-755.
6. Eichenberger A.C., Schwitter J., McKinnon G.C., Debatin J.F., von Schulthess G.K.: Phase-contrast echo-planar MR imaging: real-time quantification of flow and velocity patterns in the thoracic vessels induced by Valsalva's maneuver. *J Magn Reson Imaging*, 1995, 5: 648-655.
7. Gosselin M.V., Rassner U.A., Thieszen S.L., Phillips J., Oki A.: Contrast dynamics during CT pulmonary angiogram: analysis of an inspiration associated artifact. *J Thorac Imaging*, 2004, 19: 1-7.
8. Attubato M.J., Katz E.S., Feit F., Bernstein N., Schwartzman D., Kronzon I.: Venous Changes Occuring During the Valsalva Maneuver: Evaluation by Intravacualr Ultrasound. *Am J Cardiol*, 1994, 74: 408-410.
9. Takata M., Robotham J.L.: Effects of inspiratory diaphragmatic descent on inferior vena caval venous return. *J Appl Physiol*, 1992, 72: 597-607.
10. Chen Y.H., Velayudhan V., Weltman D.I., et al.: Waiting to exhale: salvaging the nondiagnostic CT pulmonary angiogram by using expiratory imaging to improve contrast dynamics. *Emerg Radiol*, 2008, 15: 161-169.