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TECHNICAL REPORT

A rare cause of tube arcing artifact seen in computed tomography image of a positron emission tomography/computed tomography scanner

Sneha Mithun, Ashish Kumar Jha, Ketan Panchal, Nilendu C Purandare, Sneha Shah, Archi Agrawal, Venkatesh Rangarajan

Department of Nuclear Medicine and Molecular Imaging, Tata Memorial Hospital, Parel, Mumbai, Maharashtra, India

Correspondence: Dr. Venkatesh Rangarajan, Department of Nuclear Medicine and Molecular Imaging, Tata Memorial Hospital, Parel, Mumbai - 400 012, Maharashtra, India. E-mail: drvrangarajan@gmail.com

Abstract

Tube arcing artifact is known to be caused by a temporary short circuit in the X-ray tube causing momentary loss of X-ray output. It is seen as near-parallel and an equidistant streak pattern on transaxial computed tomography (CT) images and as a "horizontal" hypodense band on the coronal and sagittal CT images. This artifact can be a random occurrence and was caused in this particular case due to voltage fluctuations in the high-voltage supply transformer supplying the rotor of the anode in the X-ray tube. This problem was initially corrected by reducing the tube voltage to 120 kV from the original 140 kV and, subsequently, replacing the faulty transformer. This kind of artifact, which is a very rare situation, can affect the image quality, and could also be an early sign of equipment failure. To the authors' knowledge, such an artifact has not been reported till date in a clinical scenario. Hence, we would like to report a rare situation of tube arcing artifact along with a unique remedy.

Key words: Artifact; computed tomography image quality; positron emission tomography/computed tomography tube arcing; X-ray tube

Introduction

An artifact in a computed tomography (CT) image can be described as any discrepancy in the Hounsfield unit (HU) seen in the image obtained as opposed to what is expected.[1] Artifacts in CT can be either patient related, equipment related, or due to image processing.[2-4] Most of the patient-related and image processing–related artifacts can be minimized, corrected, or avoided by being alert, properly instructing the patient, and applying software corrections. The equipment-related artifacts can lead to errors in attenuation distribution calculation.[5] However, equipment-related artifacts require active intervention, and early identification of the same is important to enable prompt resolution by the equipment support team. Tube arcing CT artifact is an equipment-related artifact and rarely cited in literature. It is usually attributed to temporary short circuit in the X-ray tube.[6] The short circuit is normally said

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to be caused due to presence of impurities obstructing the path of electrons emitted by cathode before they reach the anode, leading to momentary loss of X-ray output.[5] In our case, we discovered that the tube arcing artifact did not occur due to the reasons described in literature.

Technical Note

Our department has a positron emission tomography/computed tomography (PET/CT) scanner (Discovery IQ PET; GE Medical Systems, Milwaukee, USA). This equipment is used to perform PET/CT as well as routine CT procedures. On a busy afternoon, we encountered an artifact on two to three consecutive slices of the CT transaxial images of a patient, which showed near-parallel streaks across the transaxial image and a hypodense band with parallel bars on the corresponding sagittal and coronal images [Figure 1]. On careful examination and, in particular, viewing the CT images in the "lung window," it became apparent that the streaks in the transaxial slices were not parallel, but appeared to converge at a point outside the circumference of the gantry. The remaining slices did not show this kind of artifact. When we measured the HU of the tissues, we found that it was lower than that of neighboring slices. We felt that the probable reason for the artifact could be disruption of X-ray production in those slices possibly because of failure of voltage generation. Literature search suggested this could be the rarely encountered tube arcing artifact. For confirmation of the artifact, we reviewed CT series of all other PET/CT studies performed on that day. However, none of the other images had any such artifact. We immediately brought this occurrence to the vendor's support team, who also suspected voltage failure to be the possible cause. The next day, we were more vigilant and found more frequent occurrences of this artifact. We also observed something new which intrigued us. These artifacts had not occurred in any other dedicated CT images. Preliminary investigation by the vendor's support personnel revealed very short-lived, erratic drops in voltage corresponding in time with the seen artifacts. This drop in voltage as seen on a graph did not touch zero at any of the instances; the voltage graph showed high standard deviations in the voltages [Figure 2], and hence, the system did not generate any error or abruptly stop scanning. However, this observation still did not explain why these artifacts were not occurring in any of the other CT images acquired. We performed repetitive phantom scan in dedicated CT protocol and did not observe such an artifact. So, we performed the phantom CT scan in PET/CT whole body protocol and streak artifact was observed [Figure 3A and B]. Thus, we decided to review the CT acquisition parameters for diagnostic CT and CT in PET/CT protocols. Our review revealed a difference in kV used in both protocols, i.e., 140 kV used in PET/CT protocol and 120 kV used in diagnostic CT protocol. Service engineer changed the HEMIT tank (which is a transformer supplying voltage to the rotor of the rotating anode), considering the faulty current supply to the CT tube. After replacement, we performed repetitive CT scans of phantom in PET/CT protocol at 140 kV and did not observe any tube arcing artifact [Figure 3C and D].

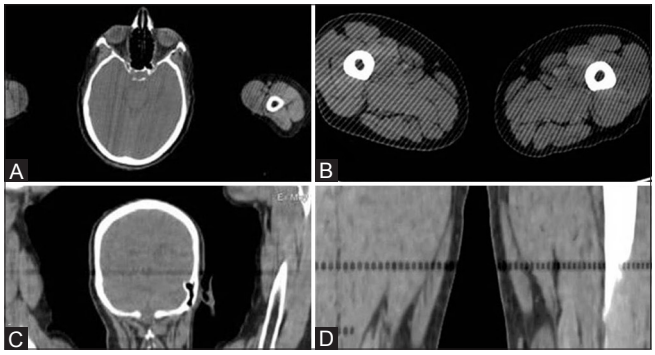

Figure 1 (A-D): Clinical image: CT tube arcing artifact seen in the head region on the transaxial image (A) and corresponding coronal image (B); in the thigh region on the transaxial image (C) and corresponding coronal image (D)

Discussion

X-ray tubes used in medical devices work at high voltages and are susceptible to electrical breakdown or short circuits. Various sources of arcing are mentioned in the literature, namely, insulator surface flashover, insulator breakdown, and vacuum flashover. Insulator surface flashover is tube design dependent; vacuum flashover is a very common phenomenon and is generally caused due to the presence of particulate impurities resulting from tungsten evaporation or imperfect surface of the target.[7] Overheating of the focal spot and tungsten evaporation can result due to faulty anode rotor.[8] In this particular case, short circuit was caused due to the defective transformer supplying voltage to the rotor of the rotating anode (HEMIT tank). There were sudden drops in the voltage causing disruption of X-ray output. However,

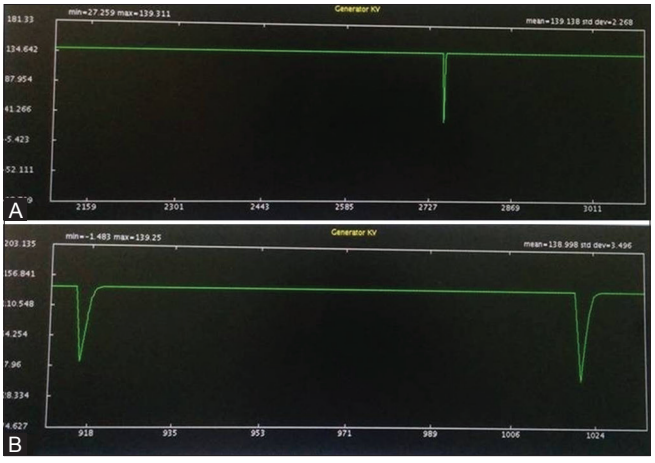

Figure 2 (A and B): Plot of generator kV versus time in images showing drop of voltage corresponding to appearance of tube arcing artifact (A and B)

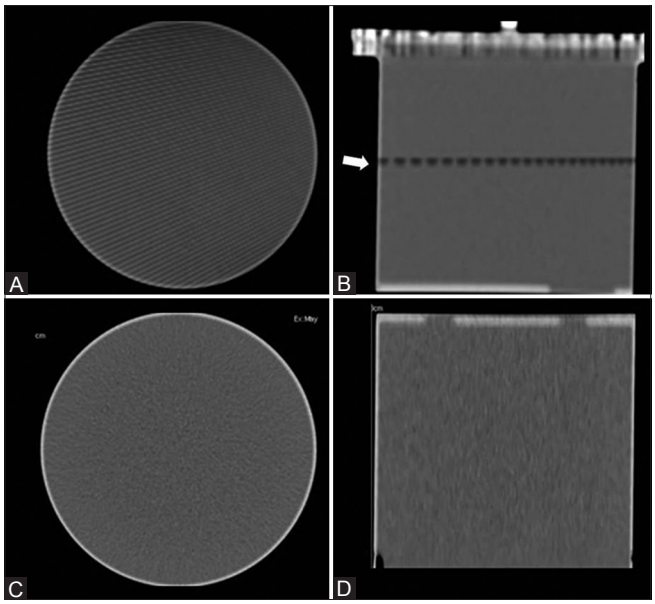

Figure 3 (A-D): Phantom image: CT image of uniformity phantom in PET/CT whole body protocol showing streak artifact, transaxial image (A); arrow shows alternating lucent bands seen on the coronal image (B). CT images, transaxial image (C) and corresponding coronal image (D) of uniformity phantom in PET/CT whole body protocol after replacing the HEMIT tank (no tube arcing artifact seen)

there was no abrupt termination of the CT scan as there was no error generated by the system. This was because at no point did the drop in voltage reach the threshold (0 kV) to generate an error. The resulting artifact was seen as alternating hypodense streaks throughout the transaxial image, which corresponded with a horizontal hypodense band in sagittal and coronal images also. Tube arcing artifact can normally be corrected by applying correction algorithms. The correction algorithm could either use synthesized projections generated by using the neighboring unaffected slices or an adaptive filtering scheme or a partial data interpolation method.[6,9] However, these methods are capable of correcting only moderate streak artifacts and not to the extent mentioned here.[5] Frequent tube arcing or tube spit of this magnitude can only be resolved by replacing the tube,[5] which would have been very costly, considering that it had only been 6 months since installation of the PET/CT. However, in our case, the reason for disruption of X-ray was different. The most probable reason for disruption in X-ray production leading to the artifact was the disrupted current supply to the rotor of the rotating anode at 140 kV. Hence, simply replacing the HEMIT tank could resolve the issue. Although tube arcing artifact and its causes have been described in the literature, we have described a unique cause and remedy for it.

Conclusion

The described tube arcing artifact seen in CT images was caused by a fault with the transformer supplying voltage to the rotor connected to the anode in the X-ray tube, which involved sudden transient drops in voltage generated whenever acquisition was done at 140 kV. Using the CT at a relatively lower voltage of 120 kV could prevent such an occurrence, and in case such an artifact does occur, it would save time and cost if this reason is ruled out before proceeding to tube replacement.

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Conflicts of interest
There are no conflicts of interest.

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