"Air bubble artefact": a new type of artefact on CT head examinations

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Introduction

Artefacts on computed tomography (CT) images have been known for decades. These are usually caused by physical processes (beam hardening and partial volume effect) or by the patient (patient motion) and have been well documented.
We came across an artefact in CT head exams which was inconsistent in occurrence, number and location and mimicked pathologies. It was not initially identified by quality control (QC) checks or phantom studies and led to unnecessary clinical concerns and intervention in some cases.
It was later confirmed by the manufacturer to be due to the presence of air bubbles in the tube oil cooling system.

Quality assurance

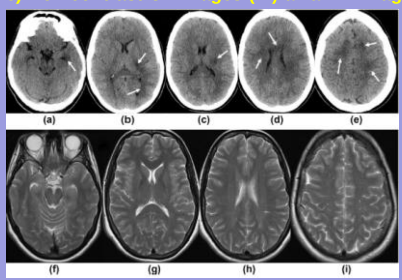
Level A (weekly radiographer led) and Level B (annual physics led) QC tests are performed according to published standards.
The Level A QC protocol uses a GE phantom (22cm diameter, water filled acrylic). CT number and noise (standard deviation) are measured for four axial images and one helical acquired in the water filled portion of the phantom. For each image a region of interest (ROI) is selected with a default size of 675mm^2 and placed in the centre of the image. The mean and standard deviation are recorded and compared with tolerance levels.
Level B QC is performed as recommended by the Institute of Physics and Engineering in Medicine (IPEM) Report 91.

Sequence of events

Initial clinical events

Two patients presented with neurological symptoms and CT demonstrated several ill-defined areas of low attenuation in the cerebral hemispheric white matter (Figure 1: a-e). They then underwent MRI within the next few days. The MRI did not show the changes seen at CT (Figure 1: f-i). It was assumed this was due to a reversible aetiology although the improvement was thought to be too soon. Over the next few days several similar cases presented.

Figure 1 (a-e) Non contrast CT images (f-i) axial T2 images



Initial physics check

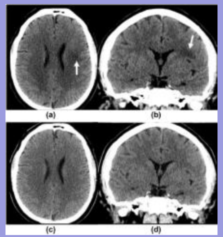
The medical physics expert (MPE) discussed the Level A QA with the radiographer. No issues had been reported and the MPE confirmed all quantitative tests had passed.
CT numbers, noise, and uniformity were tested using the water filled portion of the CATPHAN 424 Series (The Phantom Library Incorporated, NY, USA).
The mean CT number and standard deviation were recorded for ROIs (350mm^2) at the centre, 12, 3, 6, and 9 o'clock. The uniformity was defined as the maximum difference in mean CT number from the peripheral ROIs versus the centre ROI. All tests were found to be within tolerance.
As the suspected artefact was seen on clinical images acquired helically, the artefact was investigated using the CTDI Perspex head phantom (16cm diameter) scanned using the clinical protocol. These images were visually inspected at various window levels and widths; however no artefact was identified.

Subsequent clinical events

As no evidence of an artefact was found the scanner continued to be used for CT head exams. A patient was identified with areas of low attenuation in the left hemisphere (a-b) whilst still on the table and was rescanned on another CT scanner within 15 minutes. The second CT was normal (c-d) and this confirmed that the appearances must be artefactual.

Figure 2 (a-b) Initial non-contrast CT Images with low attenuation

(c-d) Repeat CT within 15 mins is normal.



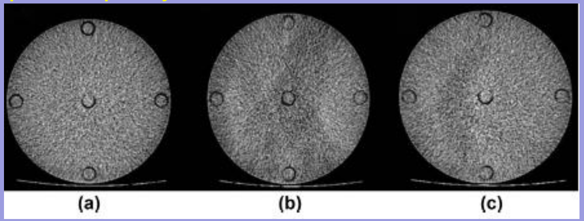
Reporting to equipment manufacturer

GE engineers were immediately contacted. The scanner logs were remotely accessed and the engineers identified that air was present in the tube oil cooling system. This could result in artefacts if the air bubble was within the primary x-ray beam at any point during the rotation. GE identified that scanner had exceeded the tolerance level 4 weeks previously.
The air was removed from the tube oil cooling system by a service engineer.

Subsequent physics checks

All images relating to the investigation were reviewed. Level A QC images were viewed on the CT console at the default window level of 40 HU with a width of 400 HU. The artefact was visible in two images. In one the presentation was subtle and unlikely to be detected, however in the second case the artefact clearly visible even under default viewing conditions.
The CATPHAN and CTDI Perspex head phantom images were reviewed. The artefact was not visible on CATPHAN images but was visible on images of the CTDI Perspex head phantom. In this case the motion of the air bubble could be seen as the tube rotated (Figure 3 a-c). This required a narrow window width (40 HU) in order to clearly identify the artefact. Although the artefact was visible the image passed quantitative tests as the tolerance is ± 3 HU. The small variation in CT number due to the air bubble was sufficient to cause the artefact in CT head exams which may then be mistaken for pathology.

Figure 3 (a) No artefact visible (b-c) Artefact visible as air bubble(s) present in primary beam.



Review of patients, QC and further governance

All patient CT head exams over the 4 week period were reviewed (n=315). There were 56 exams where potential artefacts were present. An addendum was added to those reports requesting a review of those patients.
On a local level, the Level A and Level B QC tests were reviewed. An additional helical acquisition using the clinical CT head protocol on the water filled portion of the GE phantom is included in the weekly QC to be viewed at the full range of window levels and widths. A similar test will be included in Level B tests.

Discussion

As all QC tests were within tolerance and there was an absence of any description of an artefact such as this in the literature, it was initially difficult to call these CT changes artefacts.
The air bubbles lowered the attenuation of the X-ray beam by < 3 HU. The number of air bubbles were variable and they unpredictably crossed the X-ray beam, explaining the inconsistency in the artefacts. Due to the low level of CT numbers involved this was not identified by quantitative tests and visible only on the window setting used for CT head exams.
It is important to realise that CT head exams use a narrow window width and minor changes in CT number can cause significant changes. This has also demonstrated the importance of qualitative as well as quantitative testing.
The issue has been reported to the appropriate regulatory authority and discussions have been held locally with GE. Newer GE scanners have an alert system to warn users of air bubbles in the cooling system before they can cause visible artefacts.

Conclusion

The "air bubble artefact" was identified, caused by air bubbles in the tube oil cooling system. It is inconsistent in appearance and can mimic several aetiologies.
Local QC tests have been modified to detect these changes in future.
It is possible that manufacturers do not have automatic alarms in the system to notify the user of this potential problem. It is important that radiologists, radiographers, MPEs and equipment manufacturers are aware of this artefact and take remedial measures where necessary, for timely detection and rectification.