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(RESEARCH ARTICLE)

Diagnostic efficacy of dual energy CT in differentiating intracerebral hemorrhage from iodinated contrast material staining

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Abstract

Purpose: To evaluate the efficacy of dual energy CT in early differentiating intracerebral hemorrhage from iodinated contrast material staining.

Materials and methods: In this study 46 patients with acute stroke who had undergone recent mechanical thrombectomy and intravenous administration of iodinated contrast material were evaluated on dual energy CT scan (DECT) at 80 and 150kV, to differentiate areas of hyperattenuation secondary to contrast material staining from those representing intracerebral hemorrhage (ICH). Mixed images, virtual unenhanced images (VNC) and iodine overlay maps (IOM) were obtained. Follow up imaging after 24 and 48 hours on conventional CT were used as the standard of reference. A hyperattenuation only seen on VNC image was classified as hemorrhage. A hyperattenuation only seen on iodine map was deemed as contrast.

Results: Mixed images obtained with Dual energy CT showed intra-parenchymal hyperattenuation in 46 patients. Out of these 46 hyperattenuations, iodine staining(n=31,67%), ICH(n=7,15%) and both(n=8,17%)--2 of the 8 areas of hyperattenuation on both VNC and IOM were due to mineralization. The sensitivity, specificity, and accuracy of Dual energy CT in the identifying hemorrhage was calculated as 100 %(7of 7areas), 93 %(31 of 33 areas) and 95 %(38 of 40 areas) respectively.

Conclusion: DECT has high sensitivity and specificity and allows accurate differentiation between ICH and iodine staining after recent stroke intervention without employing extra radiation. Hence, allows prompt administration of anti- platelet therapy in case of no ICH, when clinically indicated.

Keywords: Dual energy CT; Intra-cerebral hemorrhage; Iodine staining; VNC; IOM.

1. Introduction

Mechanical thrombectomy is better option to treat acute ischemic stroke as compared to systemic treatment alone[1]. Iodine staining after mechanical thrombectomy is a common phenomenon [2]. Hemorrhagic transformation and gyriform enhancement of subacute stroke may represent similar imaging appearance and distinguishing them is clinically important. Intracranial hemorrhage, is a significant complication in individuals having acute ischemic stroke, and is

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associated with increased mortality and poor outcome.[1] In ischemic stroke, after MT, the frequency of intra cerebral bleed can reach up to 15.5% in the first 24 to 36 hours[3].

On a routine non-contrast head CT scan performed after contrast administration, it can be difficult to differentiate a hyper-attenuation resulting from iodinated contrast material staining from that arising from intracranial bleed[4,5].This differentiation is extremely important in the setting of acute stroke , when antithrombotic therapy is being considered. The current standard of care for such discrimination is repeat follow-up imaging. Contrast staining generally washes out within 24–48 hours, while hemorrhage persists for days to weeks. Complete resolution of hyperattenuation on follow-up brain imaging can be explained by the phenomenon of temporary extravasation of the contrast medium as a result of ruptured BBB. The density of the contrast medium and that of the hemorrhagic areas being close to one another on conventional brain CT, it may be difficult to distinguish between brain hemorrhage and extravasation of contrast medium just after MT procedure. Early detection of intraparenchymal hemorrhage can lead to adjust platelet anticoagulant/antiaggregant treatment.

Results have shown that DECT can accurately distinguish hemorrhage from iodinated contrast. This discrimination is due to the differences between the photoelectric and Compton scattering effects due to the x-ray attenuation of hemorrhage and iodine. Scanning at 2 energy levels, such as 80kV and 150kv ,) separates different materials spectra that have different attenuation properties. Upon exposure to different X-ray energies we can discriminate the pixel attenuation arising from these photoelectric and Compton effects[6].Previous research has also documented the application of this method in patients undergoing intra-arterial thrombolysis thrombectomy[7].

The sensitivity, specificity, and accuracy of DECT in differentiating hemorrhage from iodinated contrast was assessed.

2. Materials and Methods

2.1. Patient Selection

46 patients were prospectively screened and retrospectively analyzed. Patients with acute stroke who had undergone mechanical thrombectomy with iodinated contrast material were evaluated post procedural on dual energy TOSHIBA AQUILION one 64O slice.

2.2. Study duration

From June 2023 to November 2023, 46 patients (mean age 64years; range 32–74) who underwent DECT scan after Mechanical thrombectomy were included in the study. There were 34 men (mean age 63 years; range 40–74) and 12 women (mean age 68 years; range 32–74).

All patients were scanned within 30 minutes of the end of the interventional procedure.

- Inclusion criteria: All post MT patients
- Exclusion criteria: None

2.3. Ethical committee approval

This study was approved by the institutional review board.

2.4. DECT scanning and image analysis

Patients undergoing DECT imaging were retrospectively analyzed based on the availability of follow-up imaging to establish the status of each observed hyperattenuating focus.

2.5. DECT Scanning

Toshiba Aquillion 640 slice was used for dual-energy scanning. This scanner consists of 2 X-ray tubes and 2 detectors, mounted on a common gantry. The simultaneous acquisition of data at 2 energies in a single scan also minimizes motion artifacts. The dual-energy technique is based on the behaviour of different materials when exposed to x-rays at low and high energy, leading to differences in attenuation. These differences reflect the energy and material dependency of Compton and photoelectric effects

Dual-energy postprocessing was performed using a 3-material decomposition algorithm based on brain parenchyma, hemorrhage, and iodine, producing a mixed images,VNC and an iodine-only overlay image. Virtual Non-Contrast (VNC) imaging and iodine overlay maps (IOM) were recreated on a multi-modality workstation owing to material decomposition. Mixed images were created by merging data acquired at 80 and 150 kV (50% of data at 80kV and 50% of data at 150kV, arbitrarily). VNC images were obtained by subtracting the iodine absorption spectra from each voxel.

2.6. Image analysis

On DECT, we first looked for the absence or presence of hyperattenuation on the mixed images. We then classified these hyperattenuations based on the VNC and IOM images as follows:

- Brain hemorrhage if hyperattenuation was not found on IOM
- BBB rupture (contrast extravasation)if hyperattenuation only existed on Iodine maps
- Brain hemorrhage and BBB rupture if it existed on both VNC and IOM images.

All the hyperattenuated lesions were prospectively analyzed and classified as hemorrhage, contrast, or a combination of the 2, based on the VNC and iodine overlay images.

Table 1 Classification of Hyperattenuating lesions on DECT

Diagnosis	Mixed images	VNC images	Iodine map
Brain haemorrhage	Hyperdensity present	Hyperdensity present	Hyperdensity absent
Blood brain barrier rupture/contrast extravasation	Hyperdensity present	Hyperdensity absent	Hyperdensity present
Brain haemorrhage and blood brain barrier rupture	Hyperdensity present	Hyperdensity present	Hyperdensity present

When using a technique called 3-material decomposition to analyze medical images, it can be difficult to distinguish between areas of calcification and a combination of bleeding and contrast staining. However, one way to tell the difference is by looking at the pattern of hyperattenuation (increased brightness) on both the VNC and iodine overlay images. If the pattern is similar on both images, then it is likely caused by calcification. If the pattern is not similar, then it is more likely a combination of bleeding and contrast staining.

In each case, the analysis of the medical images was completed before the follow-up images were available, and a report was written.

To determine the accuracy of the analysis, the follow-up images were used as a reference point. If the hyperattenuation (increased brightness) cleared up within 24-48 hours on a noncontrast CT scan, it was considered evidence of contrast staining. If the hyperattenuation persisted for longer than 48 hours and showed a rim of hypoattenuation possibly due to edema or infarct, it was classified as hemorrhage.

The 48-hour time cutoff is a standard practice. The follow-up scan was chosen to be a noncontrast CT scan to stay consistent with typical imaging techniques.

2.7. Statistical analysis

To determine how accurate DECT imaging is at detecting hemorrhage in different parts of the brain, the presence or absence of hemorrhage was compared on the DECT images and follow-up images (which are considered the most accurate).

If the DECT images showed pure hemorrhage or a mixture of hemorrhage and iodine, it was considered positive for hemorrhage. The accuracy of DECT was determined by analyzing the statistical relationship between the presence or absence of hemorrhage on the DECT images and the follow-up images. Following are the definitions we used.

- True-positive: A hyperattenuation on the VNC image that persists on the follow-up CT

- False-positive: A hyperattenuation on the VNC image that shows near complete washout on the follow-up CT.
- True-negative: A hyperattenuation on the iodine overlay image without accompanying hyperattenuation on the VNC image that shows near complete washout on the follow-up CT
- False-negative: A hyperattenuation on the iodine overlay image without accompanying hyperattenuation on the VNC image that shows persistent hyperattenuation on the follow-up CT

These values were used to derive the sensitivity, specificity, and accuracy of DECT results.

3. Results

46 foci of intracranial hyperattenuation were identified on the DE images. According to the DECT image interpretation, areas of hyperattenuation were classified as iodinated contrast staining (n = 31; 67%), hemorrhage (n =7 ;15%), or mixed contrast and hemorrhage (n = 8; 17%).

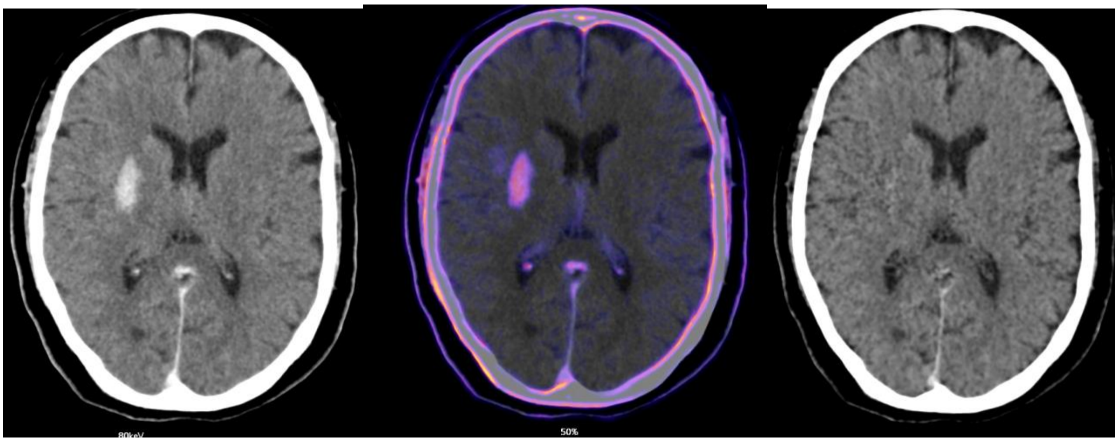
All 31 hyperdensities determined by DECT as contrast were demonstrated to have no hemorrhage by complete washout on follow-up imaging.

All 7 hyperattenuated foci determined by DECT to have hemorrhage only were confirmed as such on follow up imaging. In the 8 cases that were classified as mixed contrast and hemorrhage, 6 were found to have a hemorrhagic component. In 2 cases, there were areas of parenchymal calcifications, as seen on available prior imaging. Metallic streak artifact was evident on both VNC image and iodine overlay image.

The sensitivity, specificity, and accuracy of dual-energy CT in the identification of hemorrhage were 100% (7/7+0 x100), 93% (31/2+31 x 100), and 95% (38/40x100), respectively

- True positive: 7
- True negative:31
- False positive:2
- False negative :0

3.1. Case 1



A B C

Figure 1 These are the mixed images, iodine images and VNC images of a patient acquired on a dual energy scanner;Hyperdensity present on mixed image(A) is present in iodine images(B) but absent on VNC images(C), so this is a case of blood brain barrier rupture and absence of bleed, which was later confirmed on follow up scan

3.2. CASE 2

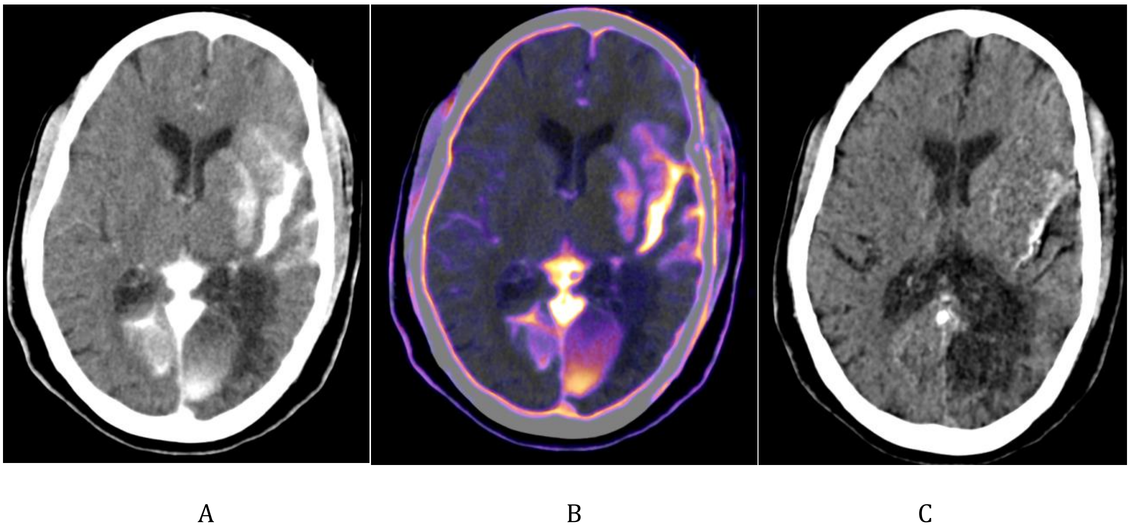


Figure 2 These are the mixed images, iodine images and VNC images of a patient acquired on a dual energy scanner; Hyperdensity present on mixed image(A) is present in iodine image(B) and VNC image(C), so this is a case of blood brain barrier rupture and also bleed, which was later confirmed on follow up scan. Hyperdensity persisted on follow up scan.

3.3. Case 3

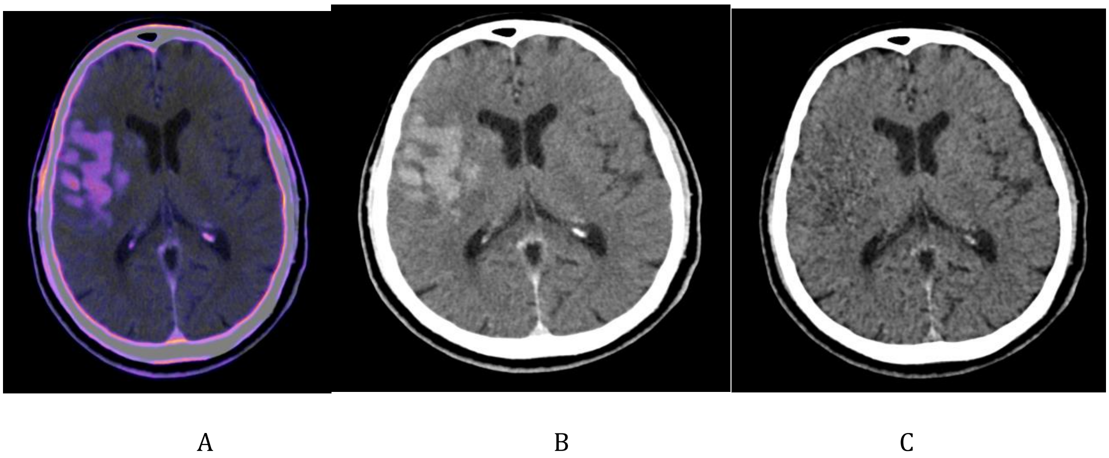


Figure 3 These are the mixed images, iodine images and VNC images of a patient acquired on a dual energy scanner; Hyperdensity present on mixed image(A) is present in iodine image(B) but absent on VNC image(C) so this is a case of blood brain barrier rupture and absence of bleed, which was later confirmed on follow up scan

3.4. Case 4

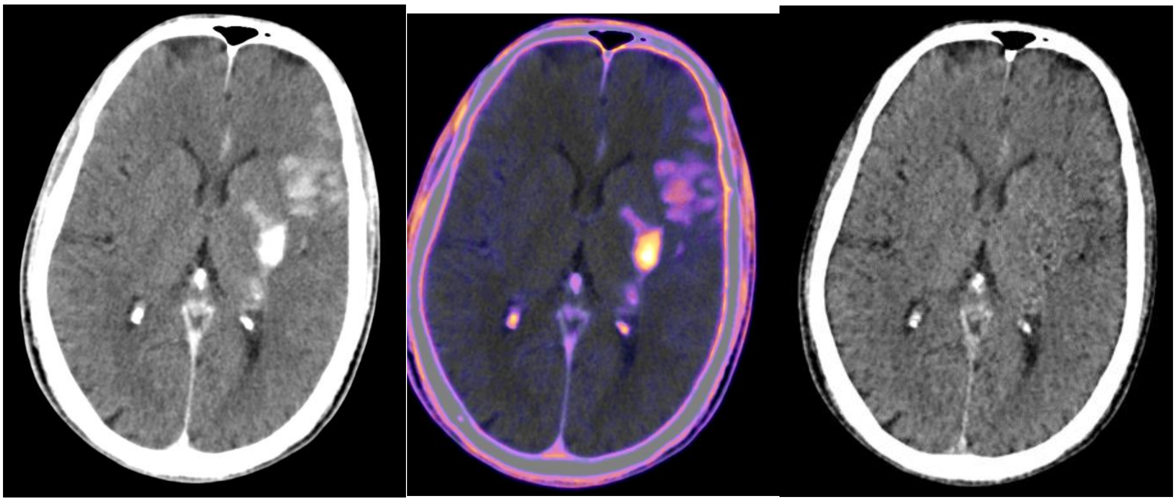


Figure 4 These are the mixed images, iodine images and VNC images of a patient acquired on a dual energy scanner; Hyperdensity present on mixed image(A) is present in iodine image(B) but absent on VNC image(C), so this is a case of blood brain barrier rupture and absence of bleed, which was later confirmed on follow up scan

4. Discussion

This research shows that DECT scanning can effectively differentiate between intracranial hemorrhage and iodinated contrast staining/extravasation in all areas of the brain with high accuracy. The DECT method has the ability to make this distinction without causing any additional radiation exposure to the patient or compromising the quality of the images, as compared to the traditional SE NCCT. The radiation dose from DECT head scans is similar to that of SE head scans. This can be achieved by optimizing the tube current on each source of the dual-source CT scanner. In this study, the total radiation dose was evenly divided between the two x-ray sources, resulting in a dose that is equivalent to a regular head CT scan.

Several prior studies have demonstrated advantages in employing Dual-Energy CT (DECT) within stroke imaging protocols. These benefits encompass a range of areas, such as distinguishing between intracerebral hemorrhage (ICH) and contrast staining (CS) through the utilization of a dual-source DECT method[8], assessing hemorrhagic transformation following endovascular thrombectomy which may influence future antithrombotic strategies[9],quantitatively evaluating the maximum iodine concentration within suspicious hyperdensities, and improving the visualization of early ischemic changes in brain tissue post-mechanical thrombectomy[10].Additionally, DECT finds further applications in neuroradiology, including distinguishing between tumor bleeding and pure hemorrhage

Currently, detecting contrast outside of blood vessels requires multiple imaging sessions to see if the contrast washes out early (within 24-72 hours) from the lesion, indicating it is not a hemorrhage, but just contrast staining. Hemorrhages, on the other hand, persist for several days to weeks. This period of uncertainty in diagnosing the type of lesion can have significant implications for making treatment decisions and may cause delays in providing the most effective medical care. In certain cases, antithrombotic medication is used after endovascular stroke therapy. Anticoagulation may be used to prevent further embolization when there is narrowing or damage to the blood vessels in the neck. However, the presence or absence of intracranial hemorrhage affects the balance between the potential benefits and risks of these therapies.

Quickly diagnosing intracranial hemorrhage (ICH) is crucial in treating acute stroke because significant bleeding tends to happen soon after reperfusion therapy. In a study, it was found that 80% of fatal hemorrhages occurred within 12 hours of receiving tPA (a medication used for stroke treatment), and the rest occurred within 24 hours[11].

However, in cases where the calcification is not readily apparent or there is a high degree of uncertainty, DECT may not be the most accurate method for differentiating between ICH and contrast-enhanced structures. This highlights the importance of utilizing clinical judgement and not solely relying on imaging techniques for accurate diagnosis and treatment decisions.

The current research also brings attention to a limitation of using 3 different materials (brain tissue, bleeding, and iodine) in DECT. This method is not able to accurately detect calcifications, which can be seen on both the virtual non-contrast (VNC) and iodine overlay images. Calcification serves as a potential hindrance when trying to distinguish between intracranial hemorrhage (ICH) and areas of the brain that have been enhanced with iodine contrast. Luckily, in most cases, previous imaging and the distinctive appearance of calcifications can aid in making the correct diagnosis even when using single-energy CT (SECT). However, there are situations where calcifications may not be easily visible or there is uncertainty, and in these cases, DECT may not be the most reliable method for distinguishing between ICH and areas enhanced with contrast. This emphasizes the importance of using clinical judgement and not solely relying on imaging techniques for making accurate diagnoses and treatment decisions.

5. Conclusion

DECT has high accuracy in differentiating bleed versus iodine staining. This is especially important in patients who have received intra-arterial therapy, as the risk of intracerebral hemorrhage is increased in this population. Additionally, DECT can also aid in the diagnosis of other types of intracranial bleeding, such as subarachnoid hemorrhage or traumatic brain injury. This allows for prompt and accurate treatment decisions to be made, leading to improved patient outcomes. Furthermore, the simplicity and accessibility of DECT make it a valuable tool for use in both academic and community hospital settings, providing a wider reach for patients in need of this advanced imaging technique. Overall, the use of DECT in the evaluation of intracranial hemorrhage offers a reliable and efficient method for clinicians to accurately diagnose and manage patients with acute ischemic stroke, ultimately improving patient care and outcomes.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that they have no conflicts of interest.

Statement of ethical approval

We declare that all human studies have been approved by the institutional review board of the University of Toyama and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

Statement of informed consent

No written informed consent was required for the retrospective analysis of clinically acquired data.

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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