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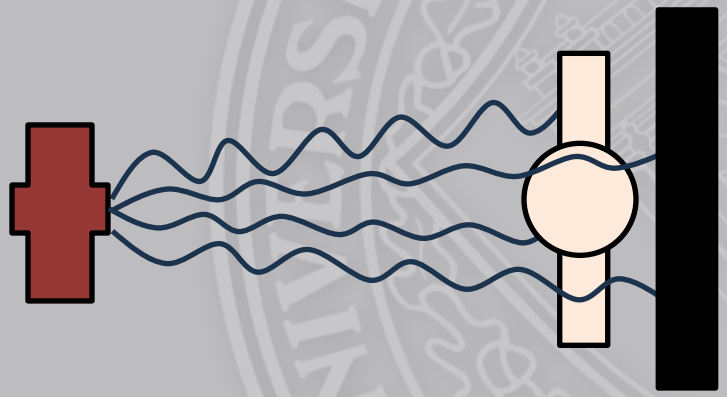
Dual-Energy CT in Head Imaging:

Practical Pearls for the Emergency and Inpatient Setting

Luis Nunez MD, Emily Lawrence MD, Prashanth Damalcheruvu MD

Principles

- Diagnostic information is the result of the quantity of x-rays that are not removed from the incident x-ray beam, or non-interacting photons.



The AAPM/RSNA physics tutorial for residents. X-ray interactions. J T Bushberg. RadioGraphics 1998 18:2, 457-468
10.1148/radiographics.18.2.9536489

Principles

- Types of X-ray Interaction:
  - Rayleigh scattering
  - Compton scattering
  - Photoelectric absorption
  - Pair production

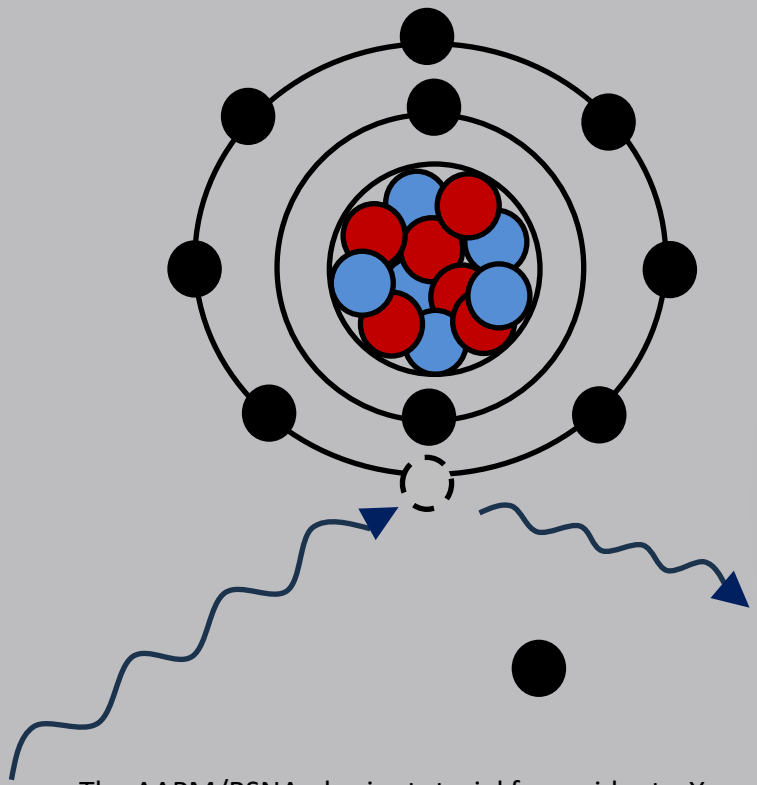
Photon energy

Tissue composition

The AAPM/RSNA physics tutorial for residents. X-ray interactions. J T Bushberg. RadioGraphics 1998 18:2, 457-468
10.1148/radiographics.18.2.9536489

Principles

Compton Scatter

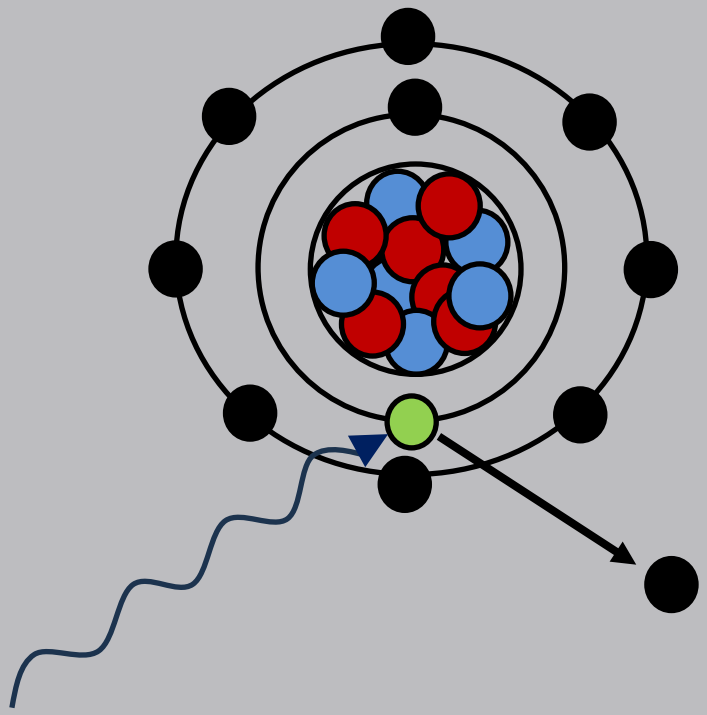


- Interaction between photons and free/loose E-
- Predominates in soft tissue
- Does not depend on Z

The AAPM/RSNA physics tutorial for residents. X-ray interactions. J T Bushberg. RadioGraphics 1998 18:2, 457-468
10.1148/radiographics.18.2.9536489

Principles

Photoelectric absorption

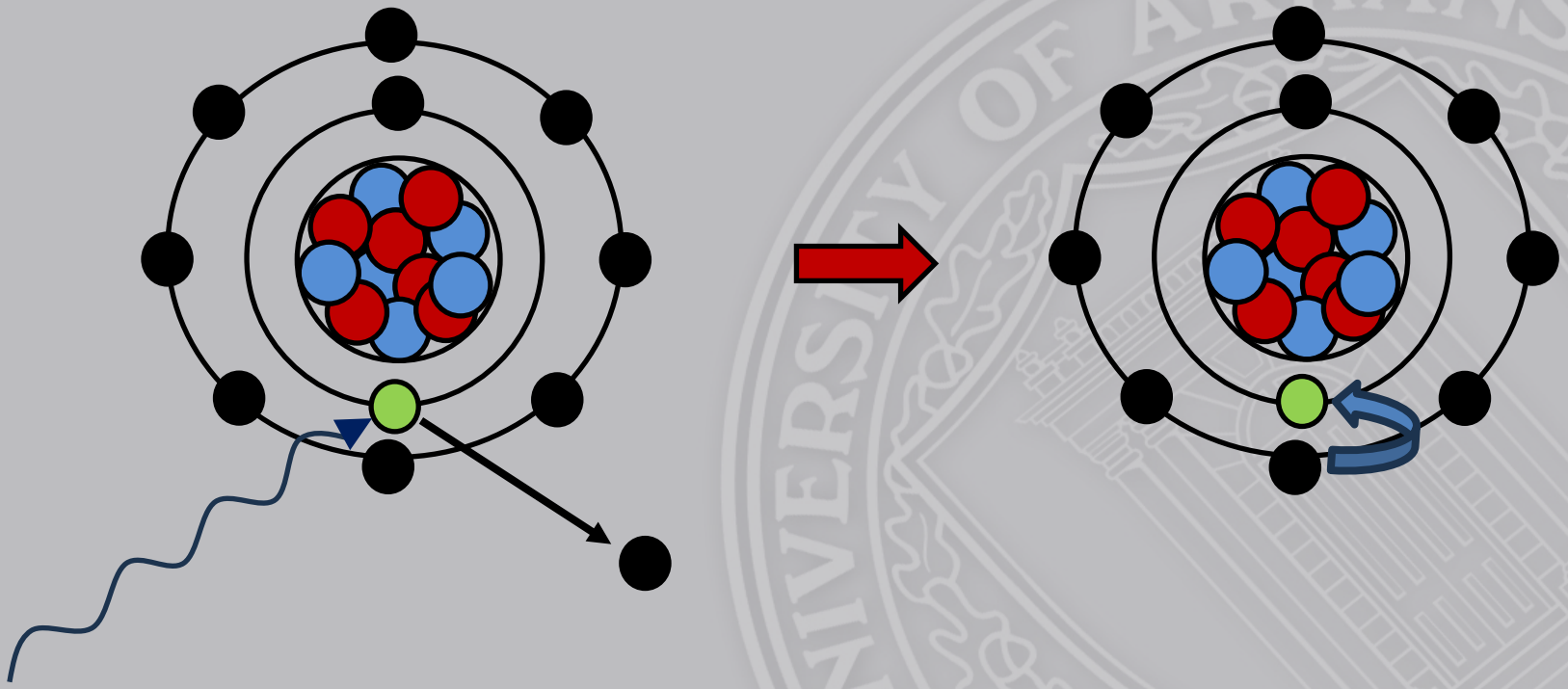


- Interaction between photons and tightly bound E-
- Photon is completely absorbed and E- is ejected
- Depends on Z

The AAPM/RSNA physics tutorial for residents. X-ray interactions. J T Bushberg. RadioGraphics 1998 18:2, 457-468
10.1148/radiographics.18.2.9536489

Principles

Photoelectric Effects



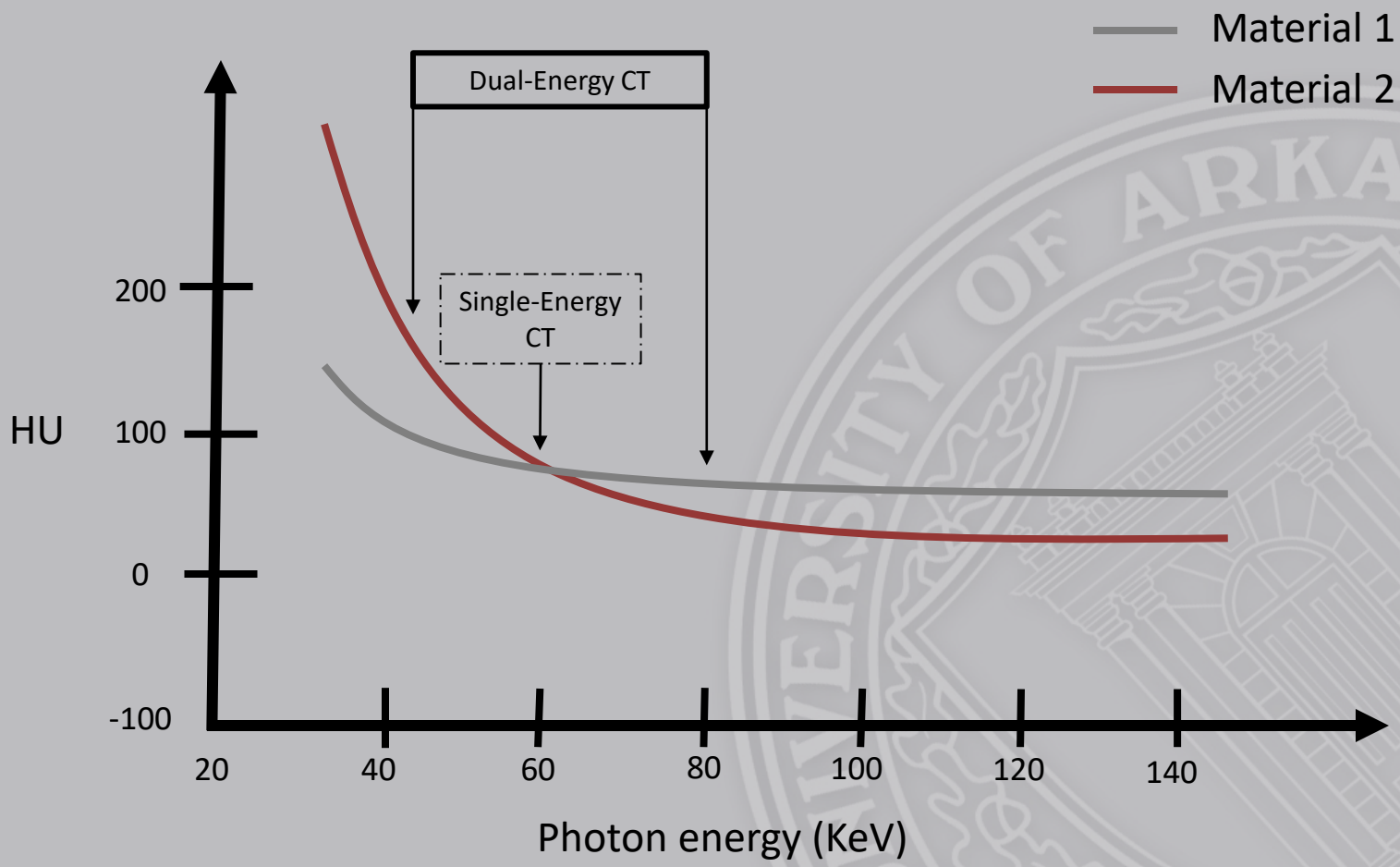
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10.1148/radiographics.18.2.9536489

Conventional CT

- Linear attenuation coefficient (**μ**): fraction of photons scattered/absorbed by a specific material
- **Hounsfield unit** is a measure of the **μ**.
- **HU** can change depending on photon energy

Greffier J, et al. Spectral CT imaging: Technical principles of dual-energy CT and multi-energy photon-counting CT. Diagn Interv Imaging. 2023 Apr;104(4):167-177.

Conventional CT



Greffier J, et al. Spectral CT imaging: Technical principles of dual-energy CT and multi-energy photon-counting CT. Diagn Interv Imaging. 2023 Apr;104(4):167-177.

Dual-Energy CT

- 2 photon spectra (high & low energy)
- Simultaneous acquisition (temporal & spatial)
- Imaging analysis and post-processing
  - Raw data: lower beam hardening, more accurate, more applications
  - Image-based: postprocessing after reconstruction

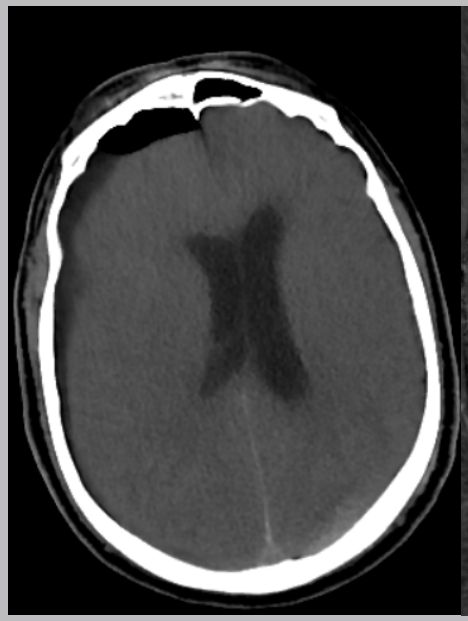
Tatsugami F, Higaki T, Nakamura Y, Honda Y, Awai K. Dual-energy CT: minimal essentials for radiologists. Jpn J Radiol. 2022 Jun;40(6):547-559. doi: 10.1007/s11604-021-01233-2. Epub 2022 Jan 4. PMID: 34981319; PMCID: PMC9162973.

Dual-Energy CT

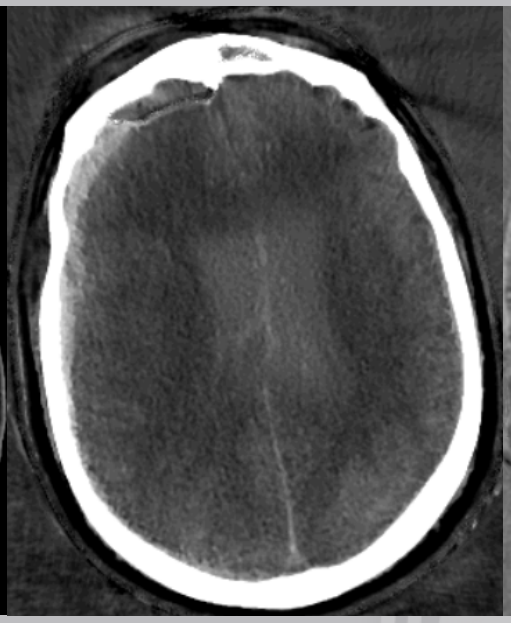
- **Material decomposition**: yield qualitative and quantitative information about the tissue composition.
  - **Virtual monocromatic images**
  - **Virtual non-contrast-enhanced**
  - **Iodine map**
  - **Calcium map**
  - **Fat map**

Tatsugami F, Higaki T, Nakamura Y, Honda Y, Awai K. Dual-energy CT: minimal essentials for radiologists. Jpn J Radiol. 2022 Jun;40(6):547-559. doi: 10.1007/s11604-021-01233-2. Epub 2022 Jan 4. PMID: 34981319; PMCID: PMC9162973.

Dual-Energy CT



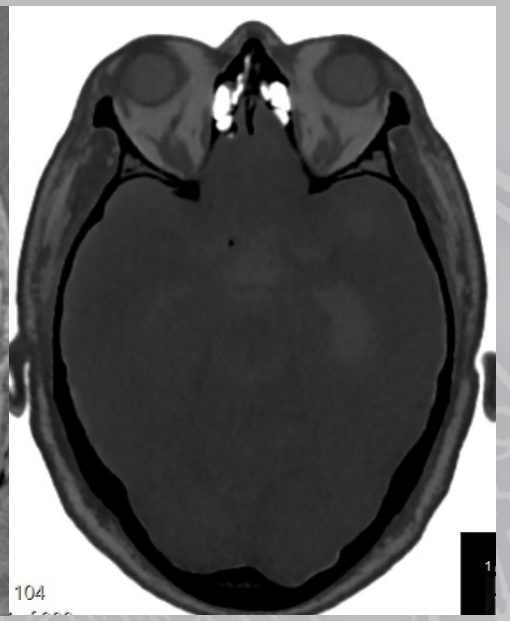
Water map



Iodine map



Fat map



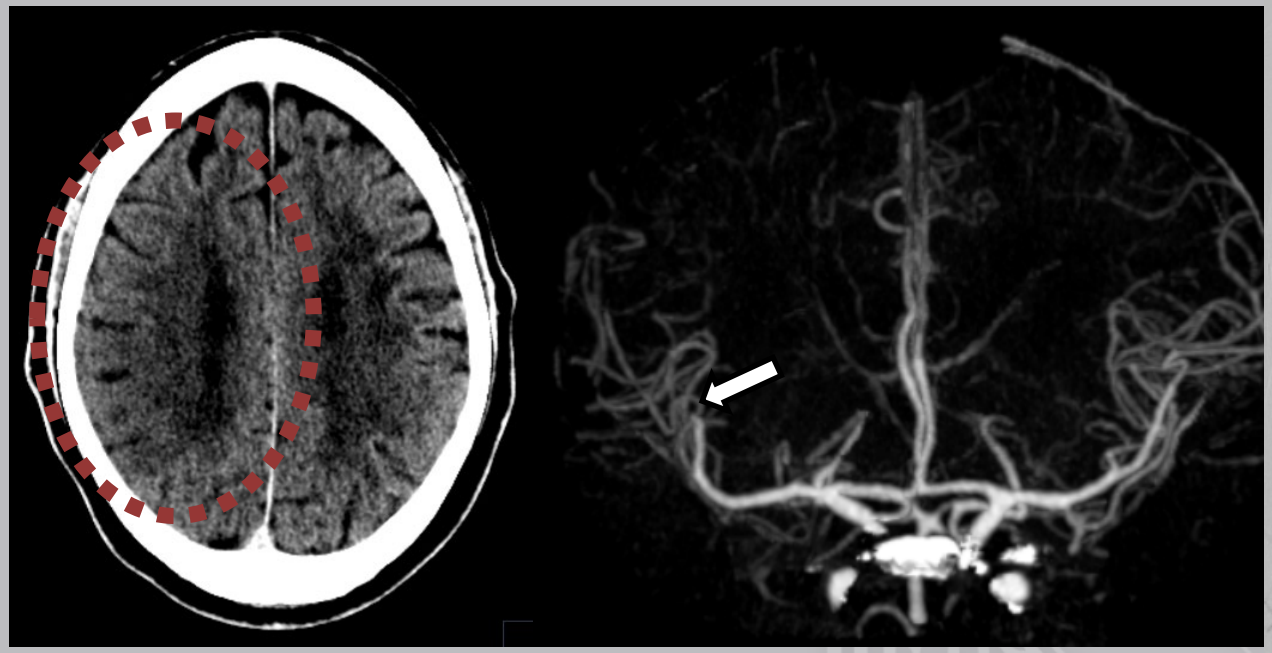
Calcium map

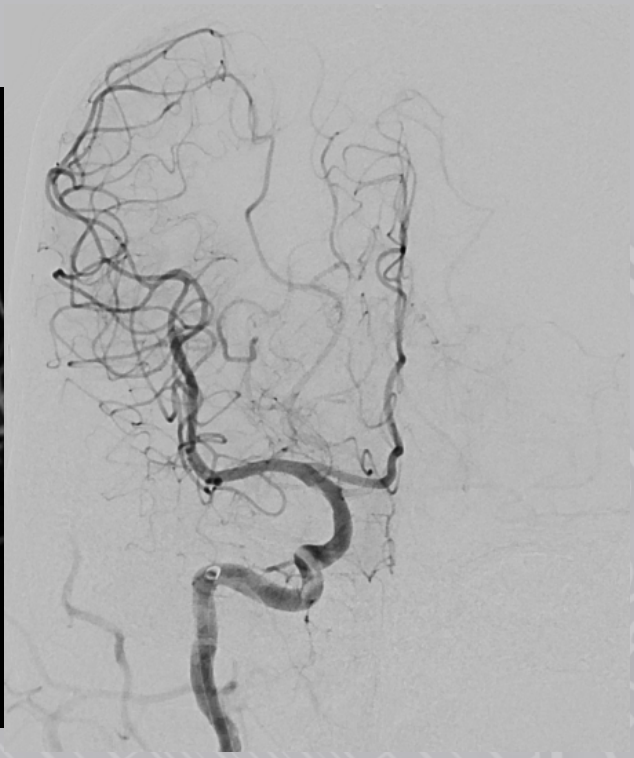
Applications

- Minimization beam hardening at posterior fossa
- Artifact reduction from aneurysm clips / metal artifact
- Ischemic stroke
- Contrast staining vs hemorrhage
- Hemorrhage vs calcification
- Bone subtraction – aneurysm visualization / Dural sinus thrombosis / carotid stenosis

Roele ED, Timmer VCML, Vaassen LAA, van Kroonenburgh AMJL, Postma AA. Dual-Energy CT in Head and Neck Imaging. Curr Radiol Rep. 2017;5(5):19. doi: 10.1007/s40134-017-0213-0. Epub 2017 Mar 29. PMID: 28435761; PMCID: PMC5371622.

Case 1



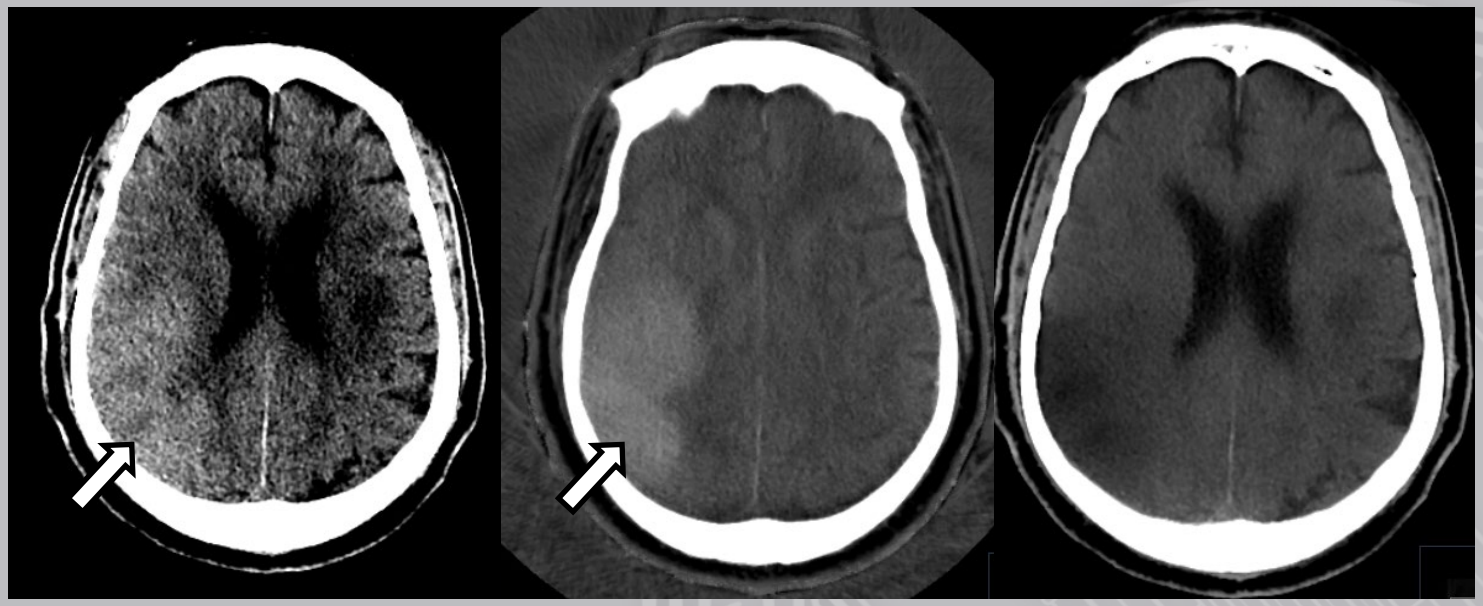


Non-Contrast head CT

CTA Reconstruction

DSA

Case 1

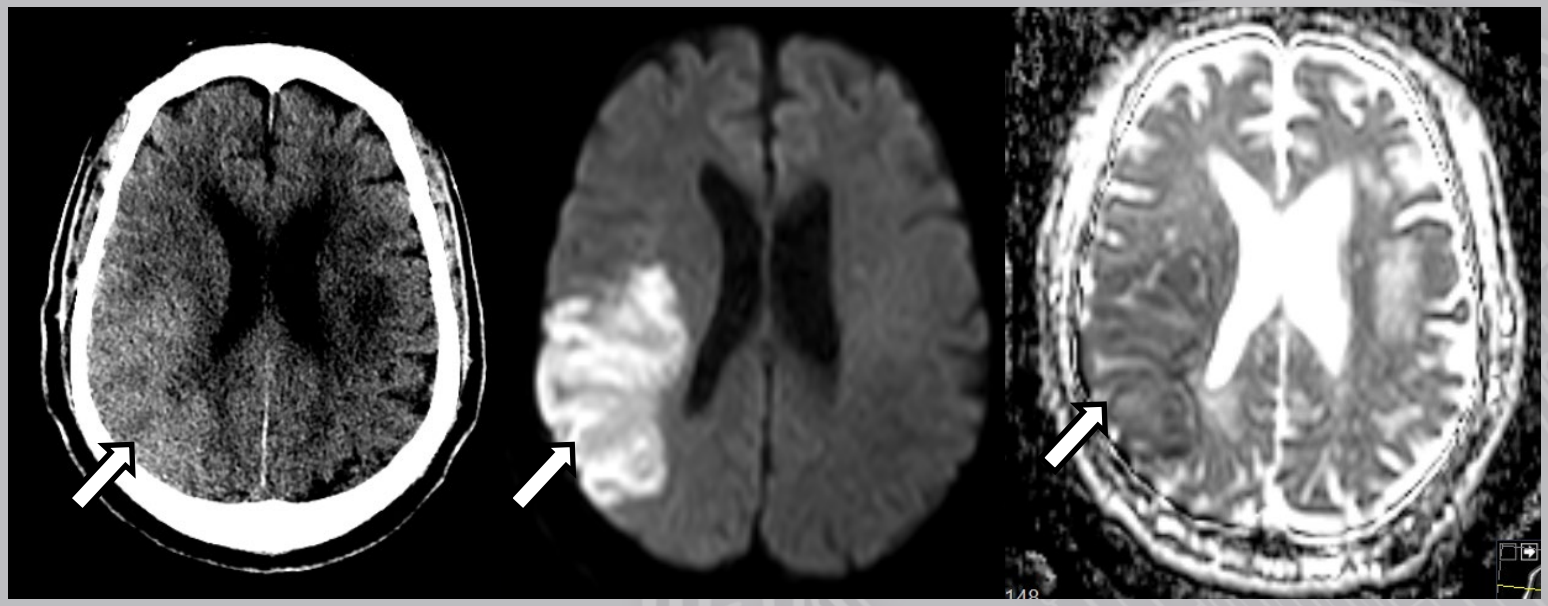


Non-Contrast head CT

Iodine map

Water map

Contrast Staining



Non-Contrast head CT DWI ADC map

DECT in Contrast Staining

Diagnostic accuracy of dual-energy CT in distinguishing intracerebral hemorrhage from contrast staining: a systematic review and meta-analysis with radiation dose assessment



La radiologia medica

Aims and scope →

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Computed Tomography | Open access | Published: 11 February 2026

Volume 131, pages 772–796 (2026) Cite this article

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Luigi Asmundo, Moreno Zanardo, Domenico Albano, Mariachiara Basile, Massimo Cressoni, Attilio Prato, Francesco Sardanelli, Luca Maria Sconfienza & Paolo Vitali

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Sections Figures

Abstract

Introduction

DECT in Contrast Staining

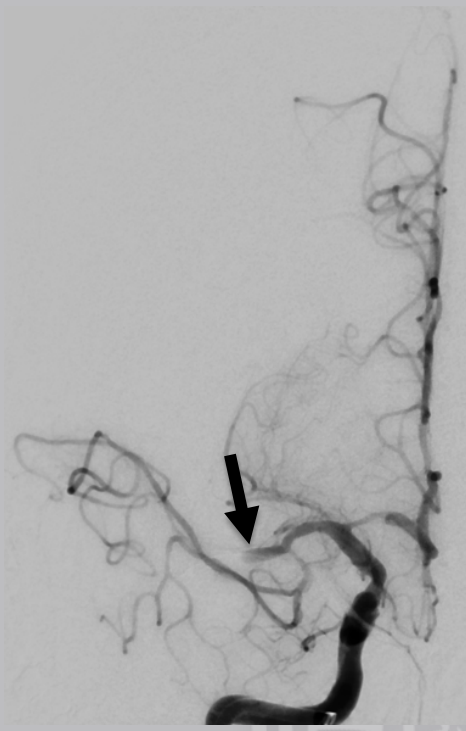
- Meta-analysis that evaluated 68 studies including 5530 patients.
- Sensitivity: 96.1%
- Specificity: 97.8%
- Radiation dose was comparable to conventional single-energy CT

Asmundo L, Zanardo M, Albano D, Basile M, Cressoni M, Prato A, Sardanelli F, Sconfienza LM, Vitali P. Diagnostic accuracy of dual-energy CT in distinguishing intracerebral hemorrhage from contrast staining: a systematic review and meta-analysis with radiation dose assessment. Radiol Med. 2026 May;131(5):772-796. doi: 10.1007/s11547-026-02180-6. Epub 2026 Feb 11. PMID: 41670887; PMCID: PMC13201350.

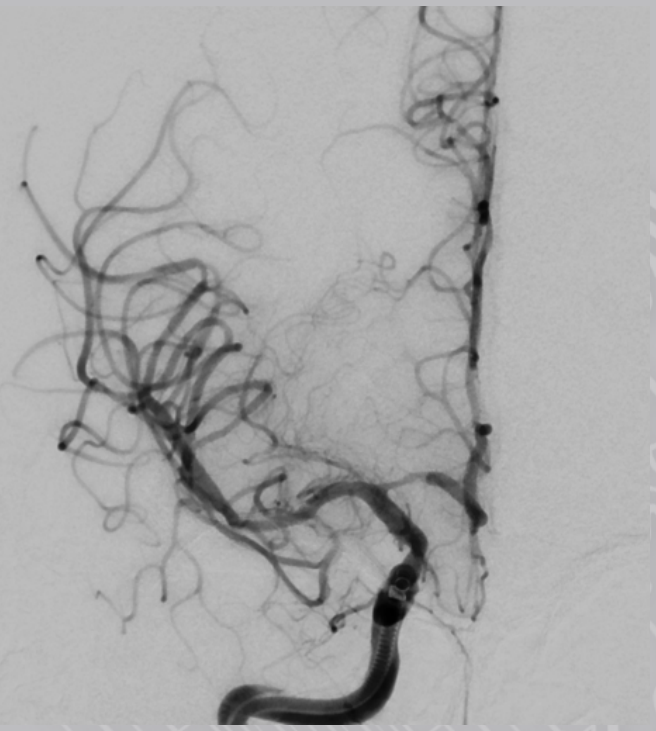
Case 2



Non-Contrast head CT



DSA - Initial



DSA - Final

CTA Reconstruction

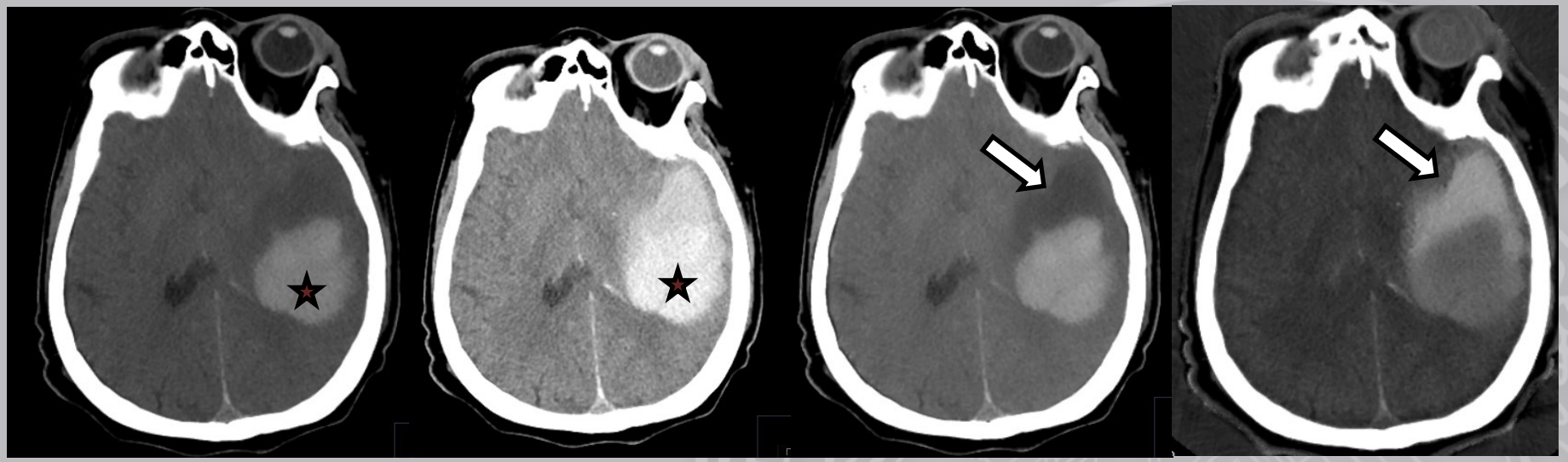
Case 2



Initial Head CT

Follow-up Head CT

Hemorrhage + Contrast Staining



140 KeV | 70 KeV | Water map | Iodine map

★ Parenchymal Hemorrhage

↘ Contrast Staining

Iodine Attenuation

New contrast injection strategies for low kV and keV imaging

Applied Radiology — Vol. 47, Issue 1, pp. 7-11
DOI: 10.37549/AR2447
Published: December 31, 2017

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[1] Division of Cardiovascular Imaging, Department of Radiology and Radiological Science, at the Medical University of South Carolina, Charleston, SC

[2] institutional research support from Astellas, Bayer, GE

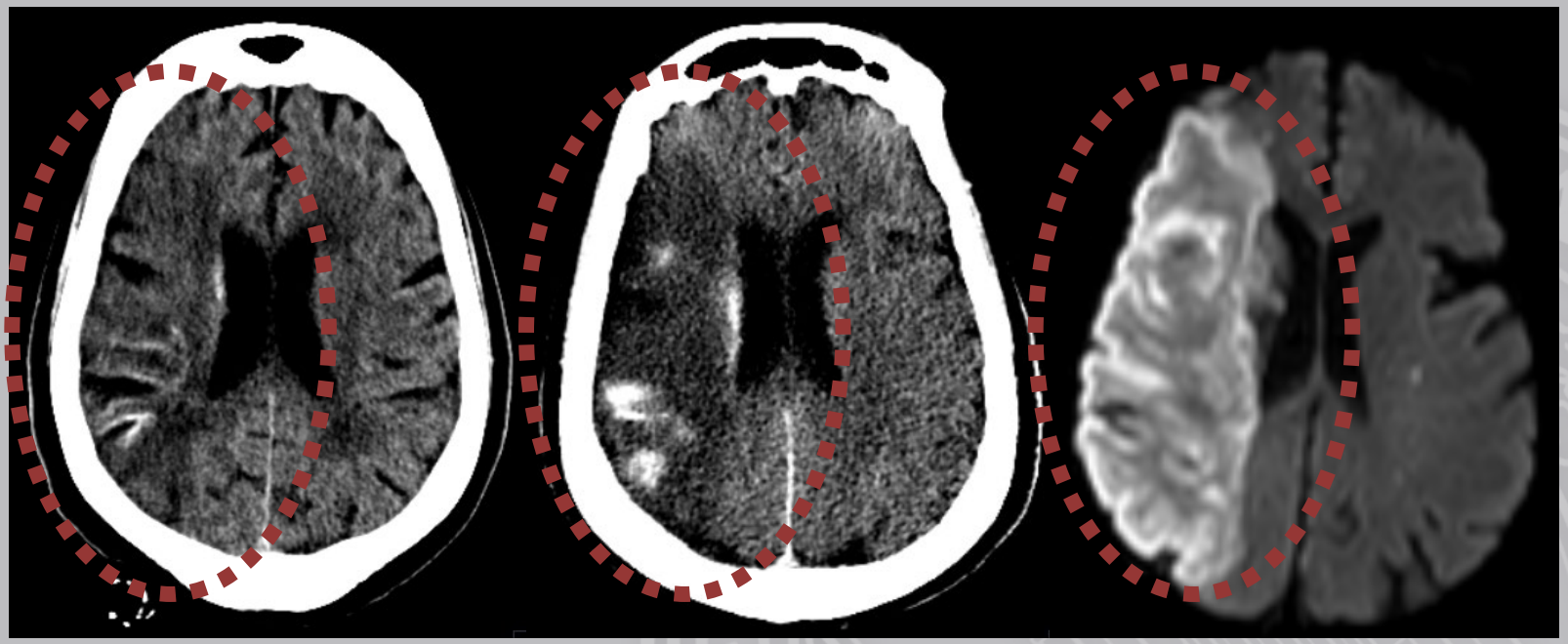
"Iodine attenuation increases at lower tube potentials due to decreased Compton scattering and greater photoelectric effect when photon energy approaches the k-edge of iodine"

VM Reconstructions

- Virtual monoenergetic (VM) reconstructions allow selection of beam energy
- Low-energy images increase contrast-to-noise ratio optimization.
  - Increasing ischemic brain edema visibility.
- High-energy images reduce artifacts
  - Posterior fossa visualization

Dodig D, Matana Kaštelan Z, Bartolović N, Jurković S, Miletić D, Rumboldt Z. Virtual monoenergetic dual-energy CT reconstructions at 80 keV are optimal non-contrast CT technique for early stroke detection. Neuroradiol J. 2022 Jun;35(3):337-345. doi: 10.1177/19714009211047449. Epub 2021 Sep 22. PMID: 34550827; PMCID: PMC9244738.

Acute Stroke



Non-Contrast Head CT | Low-Energy | DWI

Posterior Fossa



Non-Contrast head CT | High-energy | DWI | ADC map

Intracranial Calcification

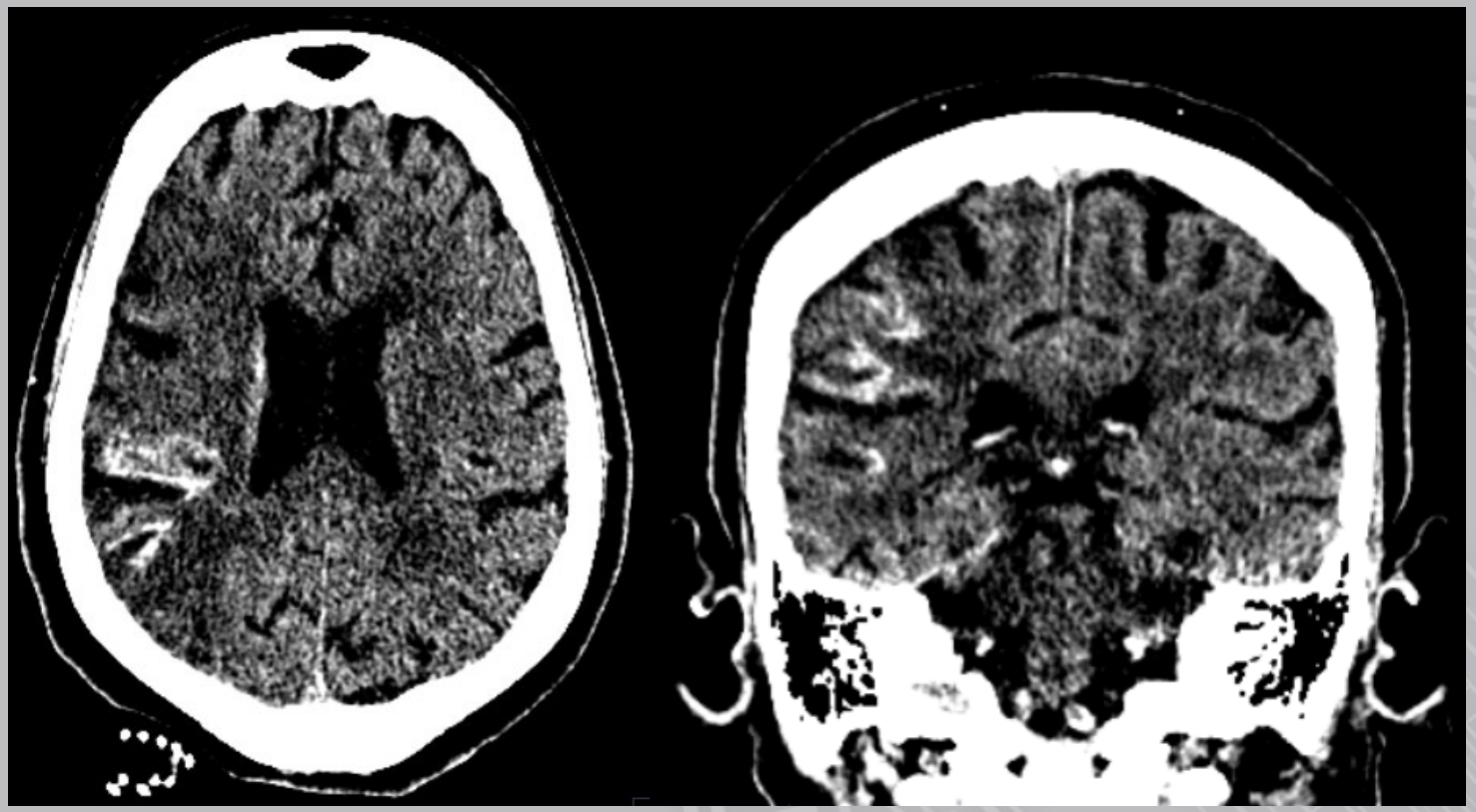
- Intracranial calcification may mimic hemorrhage
- Sequelae of dystrophic process
  - Basal ganglia
  - Choroid plexus
- Pathologic
  - Neurocysticercosis
  - Sturge-Weber
- Calcium decomposition images

Hu R, Daftari Besheli L, Young J, Wu M, Pomerantz S, Lev MH, Gupta R. Dual-Energy Head CT Enables Accurate Distinction of Intraparenchymal Hemorrhage from Calcification in Emergency Department Patients. Radiology. 2016 Jul;280(1):177-83. doi: 10.1148/radiol.2015150877. Epub 2016 Jan 25. PMID: 27322974.

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Case 3

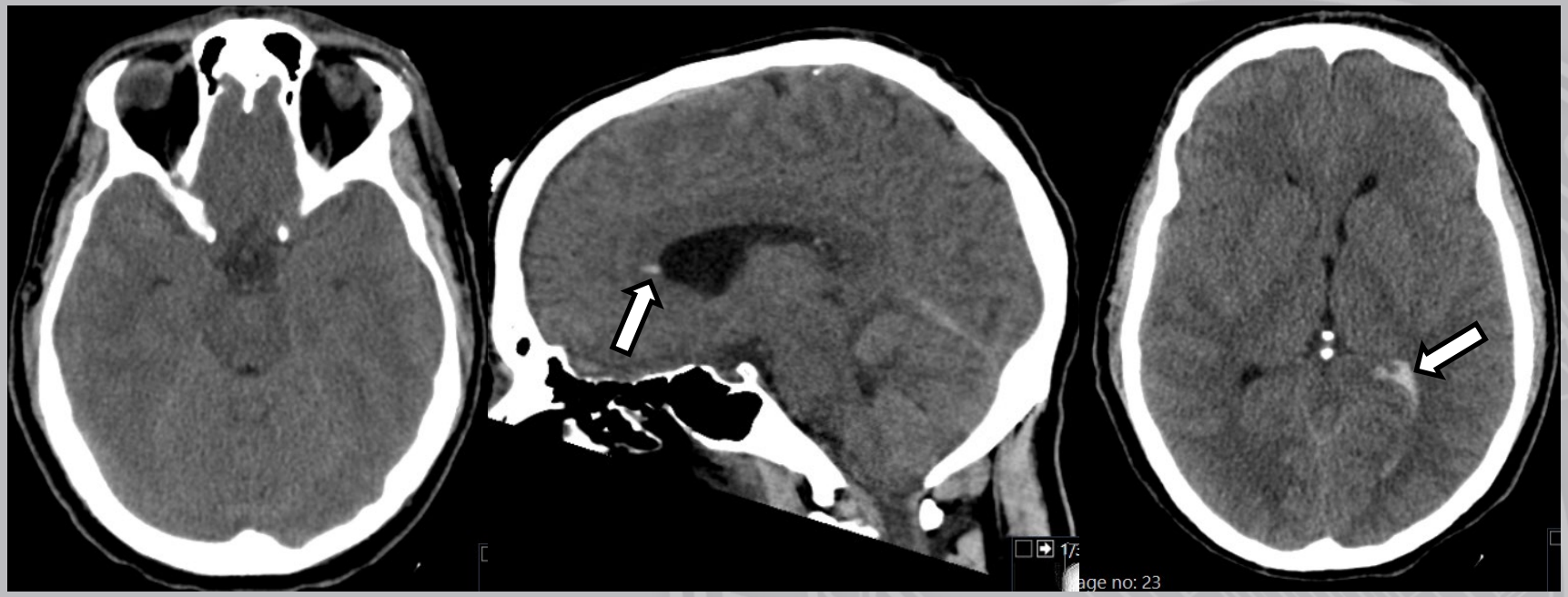


Case 3



Cortical Laminar Necrosis

Case 4

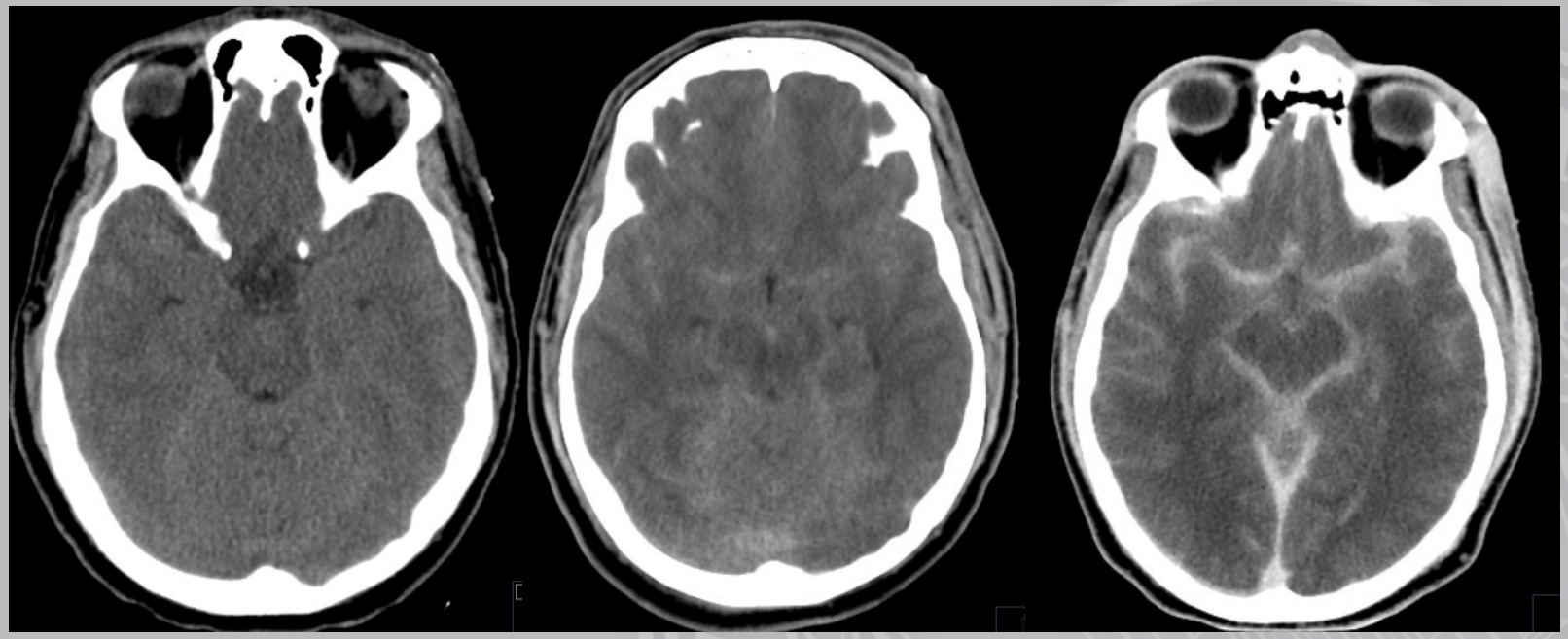


Non-Contrast Head CT

Non-Contrast Head CT

Non-Contrast Head CT

Case 4

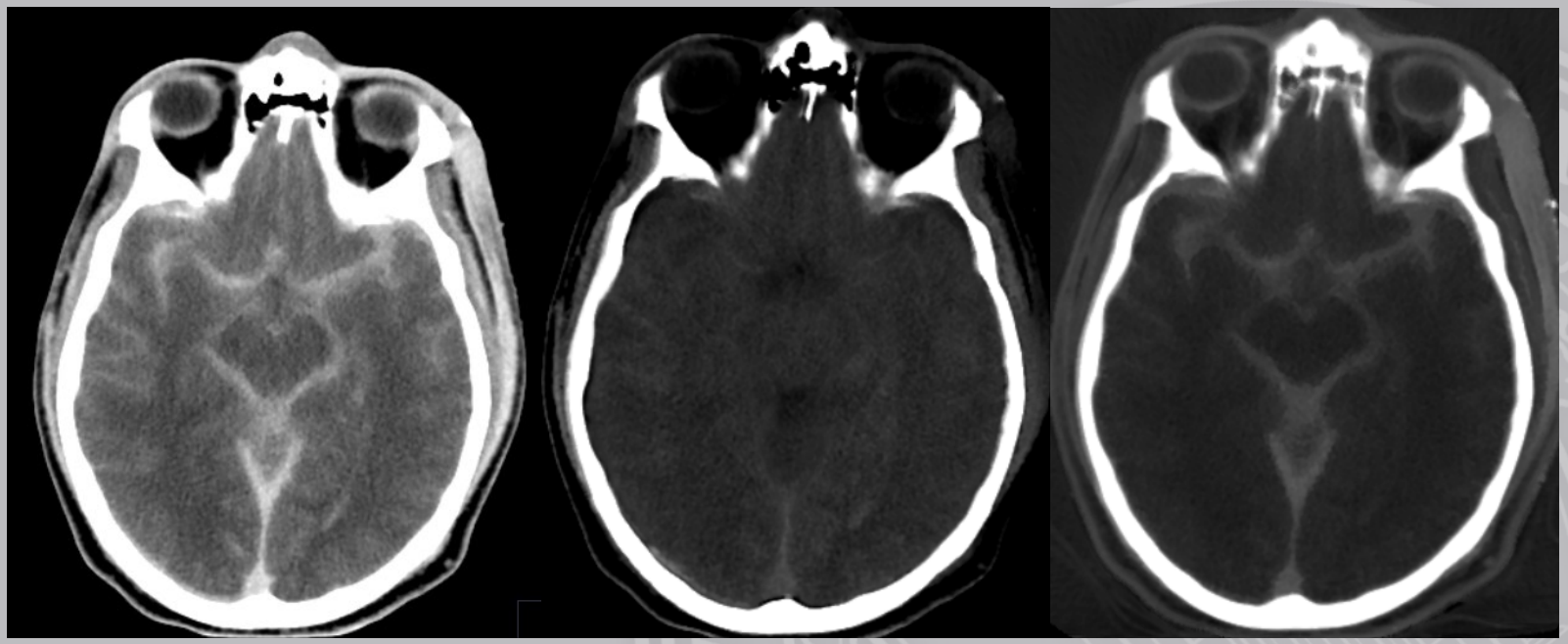


Initial Head CT

10-hour follow-up

12-hour follow-up

Case 4



Head CT

Water map

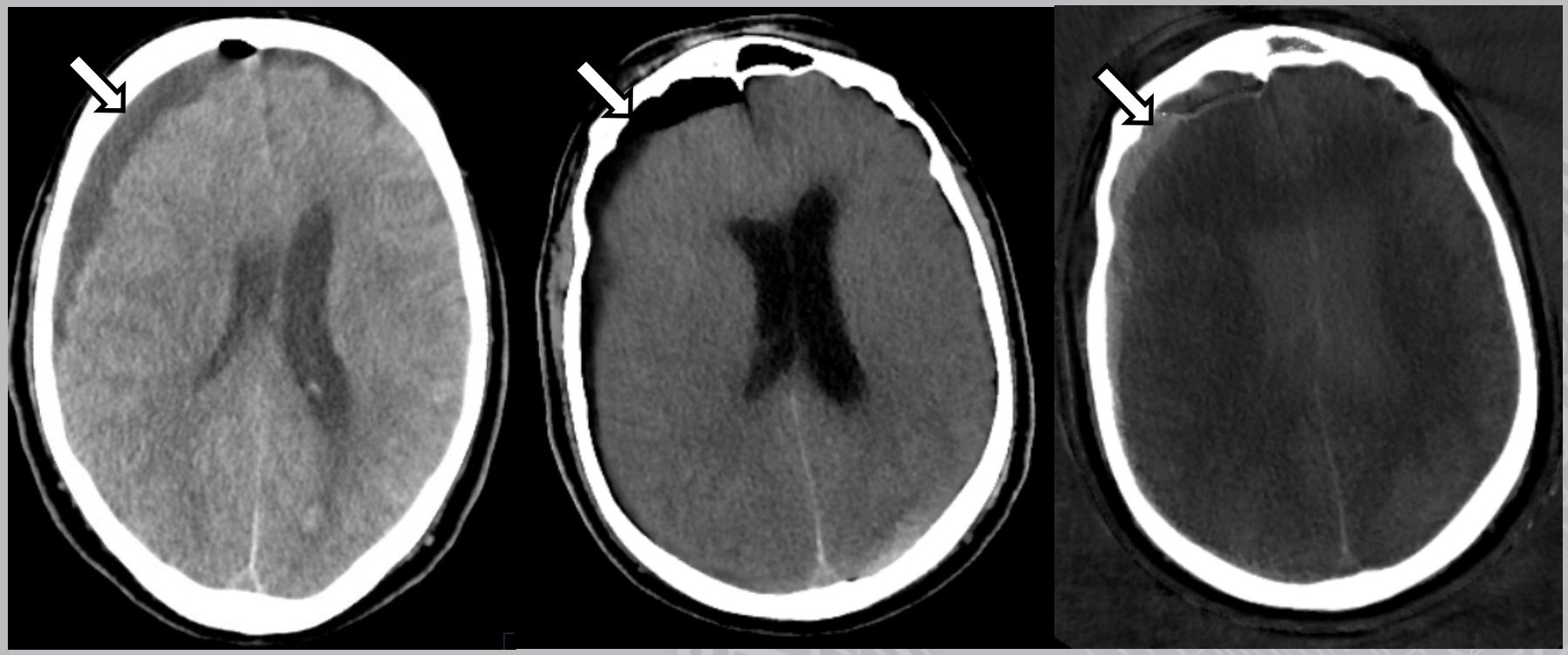
Iodine map

Contrast Extravasation

- Leakage of contrast in subdural or subarachnoid spaces
  - Unclear mechanism
  - Disruption of blood-brain barrier
  - Neurotoxic effects
  - Risk factors: renal insufficiency, large volume of contrast

Chen J, Xie P, Huang J, Sheng E, Liu K. Subdural contrast extravasation after percutaneous coronary intervention mimicking acute subdural hematoma: A case report. Medicine (Baltimore). 2021 Apr 30;100(17):e25583. doi: 10.1097/MD.0000000000025583. PMID: 33907109; PMCID: PMC8084036.

Contrast Extravasation

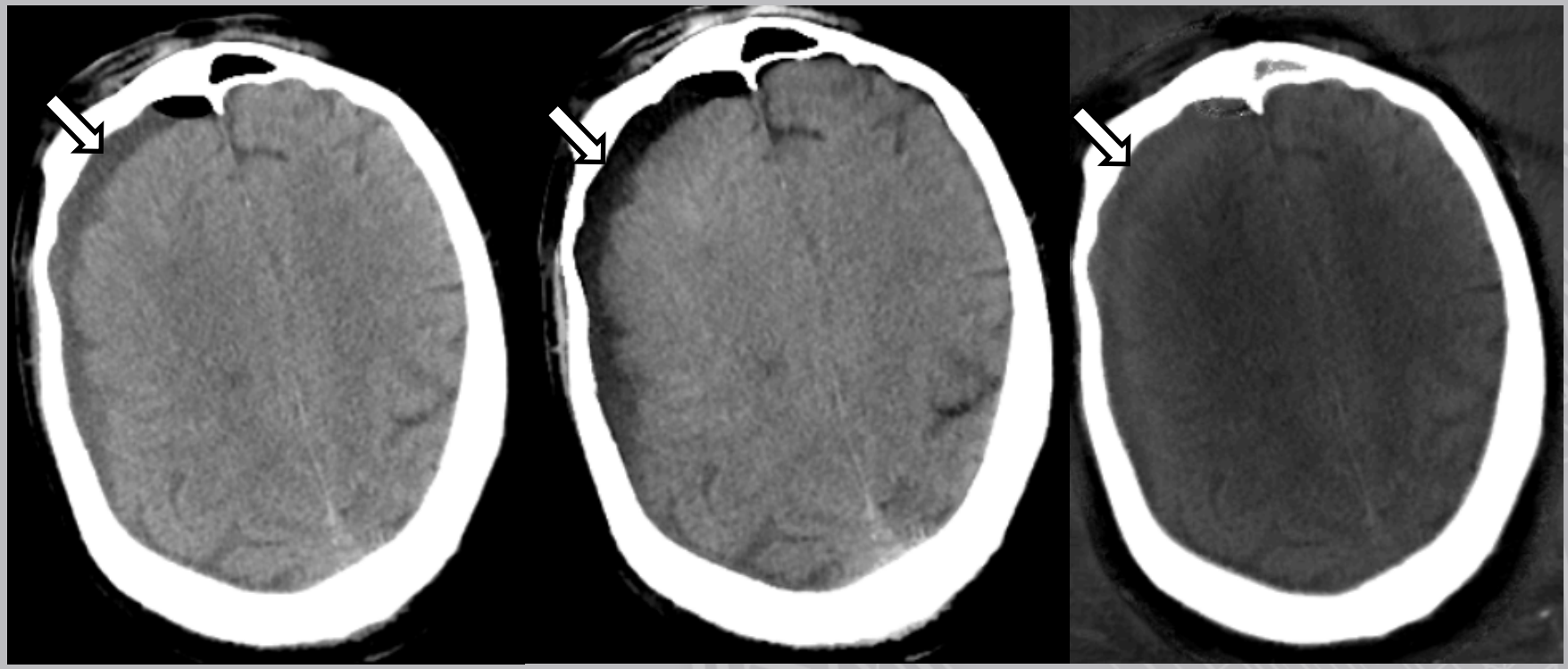


Head CT

Water map

Iodine map

Contrast Extravasation



Follow-up Head CT | Water map | Iodine map

Limitations

- Hardware and software costs.
- Technologist- or radiologist-driven workflows, which may require added time before image interpretation.
- Artifacts in regions of photon starvation, usually in regions of overlying metal or high-attenuating regions such as the shoulders.
- Iodine concentrations too low or too high.

Tatsugami F, Higaki T, Nakamura Y, Honda Y, Awai K. Dual-energy CT: minimal essentials for radiologists. Jpn J Radiol. 2022 Jun;40(6):547-559. doi: 10.1007/s11604-021-01233-2. Epub 2022 Jan 4. PMID: 34981319; PMCID: PMC9162973.

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