Diagnostic accuracy of dual-energy CT after intraarterial treatment in acute stroke to differentiate intracerebral hemorrhage from iodinated contrast

Poster No.: C-0395
Congress: ECR 2012
Type: Scientific Paper
Authors: M. A. Domingo, D. Gutierrez, O. Chirife, L. Oleaga Zufiría, S. Capurro, L. San Roman; Barcelona/ES
Keywords: Neuroradiology brain, Interventional vascular, Management, CT, CT-Angiography, MR, Computer Applications-Virtual imaging, Decision analysis, Comparative studies, Ischaemia / Infarction, Embolism / Thrombosis, Haemorrhage
DOI: 10.1594/ecr2012/C-0395

Any information contained in this pdf file is automatically generated from digital material submitted to EPOS by third parties in the form of scientific presentations. References to any names, marks, products, or services of third parties or hypertext links to third-party sites or information are provided solely as a convenience to you and do not in any way constitute or imply ECR's endorsement, sponsorship or recommendation of the third party, information, product or service. ECR is not responsible for the content of these pages and does not make any representations regarding the content or accuracy of material in this file.

As per copyright regulations, any unauthorised use of the material or parts thereof as well as commercial reproduction or multiple distribution by any traditional or electronically based reproduction/publication method is strictly prohibited.

You agree to defend, indemnify, and hold ECR harmless from and against any and all claims, damages, costs, and expenses, including attorneys' fees, arising from or related to your use of these pages.

Please note: Links to movies, ppt slideshows and any other multimedia files are not available in the pdf version of presentations.

www.myESR.org
1. BASIC PRINCIPLES of DE-CT

Acquisition of **2 datasets** from the same anatomic location with **different kVp** (usually 80 and 140 kVp)

- 2 tubes (A and B) use different kVp (80 and 140 kVp) (Siemens)
- 1 tube switches kVp from 80 to 140 in less than 0.5 ms (GE)

Dual-energy software (three-material decomposition algorithm) allows the **separation of iodine from the image** to obtain

- Virtual unenhanced CT images
- Iodine map images
- Mixed (adjustable blending of 80 and 140-kVp data) images

DUAL-SOURCE CT SCANNER

It is composed of two x-ray tubes and two corresponding detectors (FOV of detector A: 50 cm, FOV of detector B: 26 cm)

The two acquisition systems are mounted on the rotating gantry with an angular offset of **90°**

Each tube can be operated independently with regard to their kilovoltage and milliamperage settings

For dual-energy CT acquisition, the tube voltages are set at 140 kVp (tube A) and 80 kVp (tube B). Tube currents are adjusted depending on x-ray output (3.4 times higher for tube A) to result in similar noise levels: 50 mAs for tube A and 200 mAs for tube B (Table 1 on page 9)
Basic principles of DE-CT

<table>
<thead>
<tr>
<th>Tube voltage (kVp)</th>
<th>Tube current (mAs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tube A</td>
<td>140</td>
</tr>
<tr>
<td>Tube B</td>
<td>80</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>80 kVp dataset</th>
<th>140 kVp dataset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhancement of vessels</td>
<td>Maximized</td>
<td>Lower</td>
</tr>
<tr>
<td>Noise</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td>FOV</td>
<td>26 / 33 cm</td>
<td>50 cm</td>
</tr>
</tbody>
</table>

Table 1: Features of datasets

References: Radiology, Hospital Clinic de Barcelona - Barcelona/ES

To decrease noise in the images of low kVp

- Collimation of 1 mm rather than 0.625 mm
- A combination of 140/100 kVp rather than 140/80 kVp

Advantages of second generation dual-source CT

- A wider FOV of tube B: 33 cm
- A tin filter used to filter the high-energy spectrum in order to improve the separation of the two energy spectra to increase the image contrast and the discrimination abilities
- Significant reduction in imaging noise increasing the low kVp level from 80 to 100 kVp without losing discrimination abilities

ADVANTAGES of DE-CT

1. Material decomposition by the acquisition of two image series with different kVp (80 and 140 kVp): thanks to attenuation differences of substances at
two different energy levels, DE software is able to detect and differentiate these substances

2. Elimination of misregistration artifacts (almost simultaneous acquisition of two image series with different kVp)

3. Avoidance of non-contrast (unenhanced) images: iodine removal from the image and generation of virtual non-contrast image leading to a reduction of radiation dose (up to 50%, depending on the protocol used)

4. Higher image contrast of 80 kVp data, therefore improved detection of iodine-containing substances on low-energy images

Remember that Hounsfield unit (HU) measurements depend on the kVp used for the acquisition (at different keV)

2. PHYSICAL PRINCIPLES

X-Ray photons interact with tissues by means of photoelectric effect and Compton scatter

PHOTOELECTRIC EFFECT

An incident photon ejects an electron from the K shell (the innermost shell) of an atom; an electron from an adjacent shell fills the void and energy is released in the form of a photoelectron

It takes place when the incident photon has sufficient energy to overcome the K-shell binding energy of an electron

Therefore, it is energy dependent: its likelihood increases as the energy of the incident photon approximates the K-shell binding energy of an electron

It affects organic substances with a high atomic number

K-shell binding energy varies for each element and it increases as the atomic number increases

COMPTON SCATTER

It affects organic substances with a low atomic number
Depending on the energy of these photons (that is related to kVp) and on the composition of tissues (elements with different atomic numbers Z and k-edge values), the photoelectric effect would take place or not

- The probability of photoelectric absorption increases as Z of material increases (proportional to $Z^3$) and decreases as x-ray photon energy $E_0$ increases (proportional to $1/E_0^3$)
- K-edge refers to the spike in attenuation that occurs at energy levels just greater than that of the K-shell binding because of the increased photoelectric absorption at these energy levels
- K-edge values vary for each element and they increase as the Z increases

The basis of DE techniques are formed by

- The energy dependence of the photoelectric effect
- The variability of K-edges

If a tissue is submitted to two different kVp (keV, energies), each substance with different k-edge would produce two different attenuation (UH) values that would let differentiate them (Fig. 1 on page 9)
**Basic principles of DE-CT**

The closer the energy level is to the K edge of a substance, the more the substance attenuates.

**Fig. 1**: Attenuation values according to keV values

**References**: Radiology, Hospital Clinic de Barcelona - Barcelona/ES

Human tissues are made up of many different elements, arranged in many different combinations:

- Hydrogen, carbon, nitrogen, phosphorous and oxygen have similar K edges (ranging from 0.01 to 0.53 keV).
  - K-edges values are below the energies currently used (80 kVp and 140 kVp), thus these elements are not well appreciated or differentiated between them.
- K-edges of calcium (4.0 keV) and iodine (33.2 keV) are higher than K-edges of soft tissues and lower than K-edges of inorganic elements.
  - Calcium and iodine K-edges are sufficiently different from soft tissues; K-edges that calcium and iodine can be distinguished from soft-tissues.
  - The K-edge of iodine (33.2 keV) is closer to 80 kVp, therefore the attenuation of iodine-containing substances is higher at 80 kVp (increase by a factor of approximately two at 80 kVp compared with 140 kVp).
3. NEURORADIOLOGICAL APPLICATIONS

A. VIRTUAL NON-CONTRAST (VNC) IMAGES for the detection of brain hemorrhages in contrast-enhanced CT angiography (CTA)

Sensitivity, specificity and accuracy >90%

CNR (contrast to noise ratio) of vnc images < CNR of conventional non-contrast images

The generation of vnc images are complex because attenuation differences between 80 kVp and 140 kVp vary depending on

• Tissue vascularity (high vascularity: greater attenuation differences)
• Tissue perfusion (high perfusion: greater attenuation differences)
• Phase of enhancement (arterial, portal, excretory)

B. REMOVAL of BONE from the carotid and brain CTA

DE technique is superior to automatic bone removal and digital substraction CTA, particularly at the level of the skull base where there is a close proximity between vascular territories and bone

C. REMOVAL OF CALCIUM from the carotid and brain CTA

The accuracy is high for calcified plaques with a good correlation between DECT and DSA in stenosis grading of carotid arteries

However, the accuracy is low for poor calcified plaques, poor luminal enhancement and presence of small vessel diameters, conditions in which DE technique leads to an overestimation of the degree of stenosis when compared to DSA

PURPOSE

To evaluate Dual-energy CT (DECT) images to differentiate intracerebral hemorrhage from iodinated contrast material staining after intra-venous pharmacological and/or mechanical thrombolysis treatment in patients with acute stroke
Basic principles of DE-CT

<table>
<thead>
<tr>
<th>Tube voltage (kVp)</th>
<th>Tube current (mAs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tube A</td>
<td>140</td>
</tr>
<tr>
<td>Tube B</td>
<td>80</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>80 kVp dataset</th>
<th>140 kVp dataset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhancement of vessels</td>
<td>Maximized</td>
<td>Lower</td>
</tr>
<tr>
<td>Noise</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td>FOV</td>
<td>26 / 33 cm</td>
<td>50 cm</td>
</tr>
</tbody>
</table>

Table 1: Features of datasets
Basic principles of DE-CT

The closer the energy level is to the K edge of a substance, the more the substance attenuates.

**Fig. 1:** Attenuation values according to keV values

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Methods and Materials

This is a retrospective analysis of Dual-energy CT studies performed in a group of 29 patients with acute middle cerebral artery and/or internal carotid artery stroke (<4.5 hours) after intra-venous pharmacological and/or mechanical thrombolysis, combined or not with thrombus aspiration and carotid stent.

All patients underwent a Dual-energy CT study 24 hours after the treatment to rule out bleeding for treatment decision (antiplatelet therapy, thrombolytic therapy with heparin or a combination of both).

A second generation dual-energy CT scanner (Siemens) was used for imaging at 100 kVp and 140 kVp.

Virtual unenhanced images and iodine overlay images were obtained by a three-material decomposition algorithm.

Follow-up MRI or CT images were used as the standard of reference.
Results

The arterial location of thrombus diagnosed by CTA are shown in Table 2 on page 49.

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>NUMBER of PATIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>RIGHT MCA</td>
<td>10</td>
</tr>
<tr>
<td>LEFT MCA</td>
<td>12</td>
</tr>
<tr>
<td>RIGHT ICA +/- CMA</td>
<td>3</td>
</tr>
<tr>
<td>LEFT ICA +/- CMA</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 2: Arterial location of thrombus

References: Radiology, Hospital Clinic de Barcelona - Barcelona/ES

The endovascular treatments performed in our patient population are the following (Table 3 on page 49, Table 4 on page 50, Table 5 on page 51, Table 6 on page 52)
Table 3: Mechanical thrombectomy with different devices have been performed in 9 patients

References: Radiology, Hospital Clinic de Barcelona - Barcelona/ES
**ENDOVASCULAR TREATMENT**

<table>
<thead>
<tr>
<th>RTPA + MECHANICAL THROMBECTOMY</th>
<th>NUMBER of PATIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTPA + TREVO</td>
<td>10</td>
</tr>
<tr>
<td>RTPA + TREVO + SOLITAIRE</td>
<td>2</td>
</tr>
<tr>
<td>TOTAL</td>
<td>12</td>
</tr>
</tbody>
</table>

*Table 4:* Intravenous rTPA followed by mechanical thrombectomy with different devices have been performed in 12 patients

*References:* Radiology, Hospital Clinic de Barcelona - Barcelona/ES
# ENDOVASCULAR TREATMENT

<table>
<thead>
<tr>
<th>RTPA + MECHANICAL THROMBECTOMY + ASPIRATION</th>
<th>NUMBER of PATIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTPA + TREVO + ASPIRATION</td>
<td>1</td>
</tr>
<tr>
<td>RTPA + TREVO + SOLITAIRE + MERCI + ASPIRATION</td>
<td>1</td>
</tr>
<tr>
<td>TOTAL</td>
<td>2</td>
</tr>
</tbody>
</table>

**Table 5:** Intravenous rTPA followed by mechanical thrombectomy and aspiration have been performed in 2 patients

**References:** Radiology, Hospital Clinic de Barcelona - Barcelona/ES
**ENDOVASCULAR TREATMENT**

<table>
<thead>
<tr>
<th>OTHERS TREATMENTS</th>
<th>NUMBER of PATIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTPA + TREVO + STENT</td>
<td>1</td>
</tr>
<tr>
<td>TREVO + ASPIRATION</td>
<td>2</td>
</tr>
<tr>
<td>TREVO + SOLITAIRE + STENT</td>
<td>1</td>
</tr>
<tr>
<td>STENT</td>
<td>1</td>
</tr>
<tr>
<td>RTPA</td>
<td>1</td>
</tr>
<tr>
<td>TOTAL</td>
<td>6</td>
</tr>
</tbody>
</table>

**Table 6:** Other treatments with different combined modalities have been performed in 6 patients

*References:* Radiology, Hospital Clinic de Barcelona - Barcelona/ES

We performed a DE-CT study 24 hours after the endovascular treatment to detect hemorrhage. The DE-CT results are shown in Table 7 on page 53.
### DECT RESULTS

<table>
<thead>
<tr>
<th>DECT RESULTS</th>
<th>NUMBER of PATIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO HYPERDENSITIES</td>
<td>9</td>
</tr>
<tr>
<td>HYPERDENSITIES</td>
<td>20</td>
</tr>
<tr>
<td>- IODINE</td>
<td>8</td>
</tr>
<tr>
<td>- BLOOD</td>
<td>2</td>
</tr>
<tr>
<td>- IODINE + BLOOD</td>
<td>10</td>
</tr>
</tbody>
</table>

**Table 7:** DE-CT studies have shown hiperdensities in 20 patients and no anormalities in 9 patients

**References:** Radiology, Hospital Clinic de Barcelona - Barcelona/ES

The treatments decided by neurologists after DE-CT studies are shown in **Table 8** on page 54
## POSTERIOR TREATMENT

<table>
<thead>
<tr>
<th>TREATMENTS</th>
<th>NUMBER of PATIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANTIPLATELET</td>
<td>6</td>
</tr>
<tr>
<td>- ASPIRIN</td>
<td>4</td>
</tr>
<tr>
<td>- CLOPIDOGREL</td>
<td>1</td>
</tr>
<tr>
<td>- ASPIRIN + CLOPIDOGREL</td>
<td>1</td>
</tr>
<tr>
<td>HEPARIN</td>
<td>13</td>
</tr>
<tr>
<td>ANTIPLATELET + HEPARIN</td>
<td>5</td>
</tr>
<tr>
<td>NO TREATMENT</td>
<td>5</td>
</tr>
</tbody>
</table>

**Table 8**: Treatment decision after performance of DE-CT studies

**References**: Radiology, Hospital Clinic de Barcelona - Barcelona/ES

To verify the results of DE-CT, we have compared DE-CT studies with different modalities depending on the clinical setting (MRI disponibility, clinical state of patient, contraindications for MRI)

Follow-up MRI has been performed in 19 patients. The correlation between DECT and MRI is shown in **Table 9** on page 55.
DECT-MRI CORRELATION

<table>
<thead>
<tr>
<th></th>
<th>DECT</th>
<th>BLOOD</th>
<th>BLOOD + IODINE</th>
<th>IODINE</th>
<th>NO HYPER-DENSITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BLOOD T2* EG</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>NO BLOOD T2* EG</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>TOTAL</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>7</td>
<td>19</td>
</tr>
</tbody>
</table>

DECT sensibility in diagnosing blood existence in relation to T2* 7/11
DECT specificity in diagnosing blood absence in relation to T2* 8/8
DECT accuracy after endovascular treatment in relation to T2* 15/19

Table 9: The accuracy of DECT studies to detect hemorrhage compared to MRI studies is 15/19 (79%)

References: Radiology, Hospital Clinic de Barcelona - Barcelona/ES

In these cases, if T2* sequences (very sensitive to presence of hemorrhage) showed a low signal, presence of hemorrhage was diagnosed and correlated with the results of DECT studies.

Follow-up DE-CT has been performed in 6 patients. The correlation between the first DECT and the second DECT is shown in Table 10 on page 56
Table 10: The accuracy of the first DECT studies to detect hemorrhage compared to the second DECT studies is 6/6 (100%)

References: Radiology, Hospital Clinic de Barcelona - Barcelona/ES

In these cases, if DE-CT studies performed days after were consistent with the results of first DE-CT studies, we considered a positive correlation. If second DE-CT studies showed different results, we considered a negative correlation giving more relevance to the results of the second DE-CT studies for being our standard of reference.

Follow-up unenhanced CT has been performed in 4 patients. The correlation between DECT and unenhanced CT is shown in Table 11 on page 57
DECT- UNENHANCED CT CORRELATION

<table>
<thead>
<tr>
<th>DECT CT</th>
<th>BLOOD</th>
<th>BLOOD + IODINE</th>
<th>IODINE</th>
<th>NO HYPER-DENSITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>HYPER-DENSITY</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>NO HYPER-DENSITY</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>TOTAL</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

DECT sensibility in diagnosing blood existence in relation to CT: 2/2
DECT specificity in diagnosing blood absence in relation to CT: 2/2
DECT accuracy after endovascular treatment in relation to CT: 4/4

Table 11: The accuracy of DECT studies to detect hemorrhage compared to unenhanced CT is 4/4 (100%)

References: Radiology, Hospital Clinic de Barcelona - Barcelona/ES

In these cases, if the unenhanced CT showed a rapid resolution of hiperdensity, we have considered that the hiperdensity corresponds to iodine. In the contrary, if there was a persistence in time of hiperdensity in the unenhanced CT, we have considered that the hiperdensity corresponds to blood.

DECT sensibility in diagnosing blood existence in relation to follow-up studies: 12/16 (75%)

DECT specificity in diagnosing blood absence in relation to follow-up studies: 13/13 (100%)

DECT accuracy after endovascular treatment in relation to follow-up studies: 25/29 (86%)
To exemplify the electronic poster, different clinical cases are shown

CASE 1 (Fig. 2 on page 58, Fig. 3 on page 59, Fig. 4 on page 60)

Fig. 2
References: Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Case 1

DECT: Absence of hyperdensities → absence of iodine and absence of blood

Hypertension under treatment as the only cardiovascular risk factor
Absence of clinical and imaging contraindications to begin thrombolytic therapy with sodic heparin

Fig. 3

References: Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Fig. 4

**References:** Radiology, Hospital Clinic de Barcelona - Barcelona/ES

**CASE 2** (Fig. 5 on page 61, Fig. 6 on page 62, Fig. 7 on page 63)
Fig. 5

References: Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Case 2

**DECT:** Absence of hyperdensities → absence of iodine and absence of blood

Multiple cardiovascular risk factors and chronic atrial fibrillation without medical treatment

Absence of clinical and imaging contraindications to begin thrombolytic therapy with sodic heparin

Fig. 6

References: Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Fig. 7

References: Radiology, Hospital Clinic de Barcelona - Barcelona/ES

CASE 3 (Fig. 8 on page 64, Fig. 9 on page 65, Fig. 10 on page 66, Fig. 11 on page 67, Fig. 12 on page 68)
Fig. 8

References: Radiology, Hospital Clinic de Barcelona - Barcelona/ES
**Case 3**

**Fig. 9**

**References:** Radiology, Hospital Clinic de Barcelona - Barcelona/ES

**DECT:** Hyperdensity in right basal ganglia corresponding to iodine
Hyperdensity in right temporal pole corresponding to blood

Patient has a right ICA stenosis and an unknown atrial fibrillation
Thrombolytic therapy (sodic heparin) + Antiplatelet therapy (aspirin)
**Fig. 10**

**References:** Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Case 3

**DECT:** Hyperdensity in right basal ganglia corresponding to iodine

Patient has a right ICA stenosis and an unknown atrial fibrillation
Thrombolytic therapy (sodium heparin) + Antiplatelet therapy (aspirin)

Fig. 11

**References:** Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Case 3

Fig. 12

References: Radiology, Hospital Clinic de Barcelona - Barcelona/ES

CASE 4 (Fig. 13 on page 69, Fig. 14 on page 70, Fig. 15 on page 71, Fig. 16 on page 72)
Fig. 13

References: Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Case 4

Fig. 14

References: Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Fig. 15

References: Radiology, Hospital Clinic de Barcelona - Barcelona/ES

MRI (12 hours after DECT): Hyperintensity T2 in right basal ganglia, in relation to acute ischemic infarct

Diffusion restriction cannot be valued due to blood presence

Bleeding in right basal ganglia in T2* EG sequence

GOOD CORRELATION between DECT and MRI
Case 4

MRI (12 hours after DECT):
Bleeding in right basal ganglia and in right centrum semiovale in T2* EG sequence

GOOD CORRELATION between DECT and MRI

Clinicians have decided to begin sodic heparin because the patient has an atrial fibrillation debut.
They have valued the pros and cons of no treatment and they considered that the two little bright spots in VNC were of little relevance and the risk of no treatment was assessed as higher for other embolic events than the risk of bleeding due to treatment.

Fig. 16
References: Radiology, Hospital Clinic de Barcelona - Barcelona/ES

CASE 5 (Fig. 17 on page 73, Fig. 18 on page 74, Fig. 19 on page 75)
Case 5

CTA: Occlusion of left MCA in M1 segment

Cerebral perfusion:
A decrease in rCBV at the level of left basal ganglia
A delay in TTP at the territory of left MCA
Mismatch +

Fig. 17

References: Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Case 5

DECT: Absence of hyperdensities → absence of iodine and absence of blood
Little hypodensity next to left caudate head compatible with acute infarct

Inexistence of cardiovascular risk factors
Double antiplatelet therapy (aspirin + clopidogrel)

Fig. 18

References: Radiology, Hospital Clinic de Barcelona - Barcelona/ES
**Case 5**

**Fig. 19**

**References:** Radiology, Hospital Clinic de Barcelona - Barcelona/ES

**CASE 6** (Fig. 20 on page 76, Fig. 21 on page 77, Fig. 22 on page 78)
Fig. 20

References: Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Case 6

DECT: Hyperdensity in right basal ganglia, insula and Sylvian fissure corresponding to iodine (basal ganglia) and blood (insula and Sylvian fissure)

Hypertension as the only cardiovascular risk factor
Patient has a left ICA suboclusive stenosis
Thrombolytic therapy (sodic heparin) + Antiplatelet therapy (aspirin)

Fig. 21

References: Radiology, Hospital Clinic de Barcelona - Barcelona/ES
DECT (3 days after)
Hyperdensity in right basal ganglia, insula and Sylvian fissure corresponding to blood
Iodine is reabsorbed in a few days and disappears quickly in iodine images, but blood lasts
more days in being absorbed and persists in VNC images

GOOD CORRELATION between both DECT

Fig. 22
References: Radiology, Hospital Clinic de Barcelona - Barcelona/ES

CASE 7 (Fig. 23 on page 79, Fig. 24 on page 80, Fig. 25 on page 81)
Case 7

CTA: Occlusion of right MCA in distal M1 segment

Cerebral perfusion:
A light decrease in rCBV at the level of right centrum semiovale
A delay in TTP at the territory of right MCA
Mismatch+

Fig. 23

References: Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Case 7

**DECT:**
- Hyperdensity in right lenticular nucleus and right inferior frontal circunvolution corresponding to iodine
- Hypodensity in right inferior frontal circunvolution compatible with acute infarct

Patient has a hypertrophic cardiomyopathy, hypertension and an atrial fibrillation without treatment.
No thrombolytic or antiplatelet therapies after mechanical thrombectomy due to a recent low digestive haemorrhage.

**Fig. 24**

**References:** Radiology, Hospital Clinic de Barcelona - Barcelona/ES
CASE 8 (Fig. 26 on page 82, Fig. 27 on page 83, Fig. 28 on page 84)
Fig. 26

References: Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Case 8

DECT: Light hyperdensity in right basal ganglia corresponding to iodine
Light hypodensity in right basal ganglia corresponding to acute infarct

Absence of cardiovascular risk factors
Antiplatelet therapy (aspirin) is decided because of an episode of haematuria during the hospital stay

Fig. 27
References: Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Case 8

Unenhanced CT (1 day after)
Light hypodensity in right basal ganglia (lenticular nucleus and caudate head) corresponding to acute infarct

GOOD CORRELATION between DECT and unenhanced CT

Fig. 28
References: Radiology, Hospital Clinic de Barcelona - Barcelona/ES
### Table 2: Arterial location of thrombus

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>NUMBER of PATIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>RIGHT MCA</td>
<td>10</td>
</tr>
<tr>
<td>LEFT MCA</td>
<td>12</td>
</tr>
<tr>
<td>RIGHT ICA +/- CMA</td>
<td>3</td>
</tr>
<tr>
<td>LEFT ICA +/- CMA</td>
<td>4</td>
</tr>
</tbody>
</table>

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
ENDOVASCULAR TREATMENT

<table>
<thead>
<tr>
<th>MECHANICAL THROMBECTOMY</th>
<th>NUMBER of PATIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TREVO</td>
<td>5</td>
</tr>
<tr>
<td>SOLITAIRE</td>
<td>2</td>
</tr>
<tr>
<td>TREVO + SOLITAIRE</td>
<td>1</td>
</tr>
<tr>
<td>TREVO + BONNET + MERCI</td>
<td>1</td>
</tr>
<tr>
<td>TOTAL</td>
<td>9</td>
</tr>
</tbody>
</table>

**Table 3:** Mechanical thrombectomy with different devices have been performed in 9 patients

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
### Table 4: Intravenous rTPA followed by mechanical thrombectomy with different devices have been performed in 12 patients

<table>
<thead>
<tr>
<th>RTPA + MECHANICAL THROMBECTOMY</th>
<th>NUMBER of PATIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTPA + TREVO</td>
<td>10</td>
</tr>
<tr>
<td>RTPA + TREVO + SOLITAIRE</td>
<td>2</td>
</tr>
<tr>
<td>TOTAL</td>
<td>12</td>
</tr>
</tbody>
</table>

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
**Table 5**: Intravenous rTPA followed by mechanical thrombectomy and aspiration have been performed in 2 patients.

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
### Table 6: Other treatments with different combined modalities have been performed in 6 patients

<table>
<thead>
<tr>
<th>OTHERS TREATMENTS</th>
<th>NUMBER of PATIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTPA + TREVO + STENT</td>
<td>1</td>
</tr>
<tr>
<td>TREVO + ASPIRATION</td>
<td>2</td>
</tr>
<tr>
<td>TREVO + SOLITAIRE + STENT</td>
<td>1</td>
</tr>
<tr>
<td>STENT</td>
<td>1</td>
</tr>
<tr>
<td>RTPA</td>
<td>1</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>6</strong></td>
</tr>
</tbody>
</table>
Table 7: DE-CT studies have shown hiperdensities in 20 patients and no anormalities in 9 patients

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
## POSTERIOR TREATMENT

<table>
<thead>
<tr>
<th>TREATMENTS</th>
<th>NUMBER of PATIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANTIPLATELET</td>
<td>6</td>
</tr>
<tr>
<td>- ASPIRIN</td>
<td>4</td>
</tr>
<tr>
<td>- CLOPIDOGREL</td>
<td>1</td>
</tr>
<tr>
<td>- ASPIRIN + CLOPIDOGREL</td>
<td>1</td>
</tr>
<tr>
<td>HEPARIN</td>
<td>13</td>
</tr>
<tr>
<td>ANTIPLATELET + HEPARIN</td>
<td>5</td>
</tr>
<tr>
<td>NO TREATMENT</td>
<td>5</td>
</tr>
</tbody>
</table>

**Table 8:** Treatment decision after performance of DE-CT studies

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
## DECT-MRI Correlation

<table>
<thead>
<tr>
<th>MRI</th>
<th>DECT</th>
<th>Blood</th>
<th>Blood + Iodine</th>
<th>Iodine</th>
<th>No Hyper-Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>BLOOD</td>
<td>T2* EG</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>NO BLOOD</td>
<td>T2* EG</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>7</td>
</tr>
</tbody>
</table>

DECT sensibility in diagnosing blood existence in relation to T2* 7/11
DECT specificity in diagnosing blood absence in relation to T2* 8/8
DECT accuracy after endovascular treatment in relation to T2* 15/19

**Table 9:** The accuracy of DECT studies to detect hemorrhage compared to MRI studies is 15/19 (79%)

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
**DECT-DECT CORRELATION**

<table>
<thead>
<tr>
<th>1st DECT</th>
<th>BLOOD</th>
<th>BLOOD + IODINE</th>
<th>IODINE</th>
<th>NO HYPER-DENSITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>BLOOD</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>BLOOD + IODINE</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>IODINE</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>NO HYPER-DENSITY</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>TOTAL</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

DECT sensibility in diagnosing blood existence in relation to DECT 3/3
DECT specificity in diagnosing blood absence in relation to DECT 3/3
DECT accuracy after endovascular treatment in relation to DECT 6/6

**Table 10**: The accuracy of the first DECT studies to detect hemorrhage compared to the second DECT studies is 6/6 (100%)

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
### Table 11: The accuracy of DECT studies to detect hemorrhage compared to unenhanced CT is 4/4 (100%)

<table>
<thead>
<tr>
<th>CT</th>
<th>DECT</th>
<th>BLOOD</th>
<th>BLOOD + IODINE</th>
<th>IODINE</th>
<th>NO HYPER-DENSITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>HYPER-DENSITY</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>NO HYPER-DENSITY</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>TOTAL</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

DECT sensibility in diagnosing blood existence in relation to CT 2/2
DECT specificity in diagnosing blood absence in relation to CT 2/2
DECT accuracy after endovascular treatment in relation to CT 4/4

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Fig. 2

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Case 1

DECT: Absence of hyperdensities → absence of iodine and absence of blood

Hypertension under treatment as the only cardiovascular risk factor
Absence of clinical and imaging contraindications to begin thrombolytic therapy with sodium heparin

Fig. 3

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Case 1

MRI (24 hours after DECT): Diffusion restriction in left lenticular nucleus, in relation to acute ischemic infarct

No signs of bleeding in T2* EG sequence

GOOD CORRELATION between DECT and MRI

Fig. 4

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Case 2

CTA: Occlusion of left MCA in M1 segment

Cerebral perfusion:
A decrease in rCBV at the level of left subcortical frontal white matter
A delay in TTP at the territory of left MCA

Fig. 5

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Case 2

**DECT:** Absence of hyperdensities → absence of iodine and absence of blood

Multiple cardiovascular risk factors and chronic atrial fibrillation without medical treatment
Absence of clinical and imaging contraindications to begin thrombolytic therapy with sodium heparin

**Fig. 6**

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Fig. 7

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Case 3

CTA: Occlusion of right MCA in M1 segment

Cerebral perfusion:
A decrease in rCBV at the level of right basal ganglia and thalamus
A delay in TTP at the territory of right MCA
Missmatch

Fig. 8

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Case 3

**DECT:** Hyperdensity in right basal ganglia corresponding to iodine
Hyperdensity in right temporal pole corresponding to blood

Patient has a right ICA stenosis and an unknown atrial fibrillation
Thrombolytic therapy (*sodic heparin*) + Antiplatelet therapy (*aspirin*)

**Fig. 9**

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Fig. 10

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Fig. 11

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Case 3

MRI (4 days after DECT):
Diffusion restriction in right lenticular nucleus and caudate head, in relation to acute ischemic infarct

No signs of bleeding in T2* EG sequence

GOOD CORRELATION between DECT and MRI

Fig. 12

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Case 4

CTA: Thrombosis of right ICA and occlusion of right MCA in M1 segment

Cerebral perfusion:
A decrease in rCBV at the level of right deep fronto-temporal white matter

A delay in TTP at the territory of right MCA

Missmatch +

Fig. 13

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Case 4

DECT: Hyperdensity in right basal ganglia corresponding to iodine. There are two little bright pots in VNC (↑) probably corresponding to blood. Patient has an unknown atrial fibrillation. Absence of clinical contraindications → thrombolytic therapy (sodic heparin).

Fig. 14

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Case 4

MRI (12 hours after DECT): Hyperintensity T2 in right basal ganglia, in relation to acute ischemic infarct

Diffusion restriction cannot be valued due to blood presence

Bleeding in right basal ganglia in T2* EG sequence

GOOD CORRELATION between DECT and MRI

Fig. 15

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Case 4

**MRI (12 hours after DECT):**

Bleeding in right basal ganglia and in right centrum semiovale in T2* EG sequence

**GOOD CORRELATION between DECT and MRI**

Clinicians have decided to begin sodic heparin because the patient has an atrial fibrillation debut. They have valued the pros and cons of no treatment and they considered that the two little bright spots in VNC were of little relevance and the risk of no treatment was assessed as higher for other embolic events than the risk of bleeding due to treatment.

---

**Fig. 16**

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Case 5

CTA: Occlusion of left MCA in M1 segment

Cerebral perfusion:
- A decrease in rCBV at the level of left basal ganglia
- A delay in TTP at the territory of left MCA

Mismatch +

Fig. 17

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Case 5

DECT: Absence of hyperdensities → absence of iodine and absence of blood
Little hypodensity next to left caudate head compatible with acute infarct

Inexistence of cardiovascular risk factors
Double antiplatelet therapy (aspirin + clopidogrel)

Fig. 18

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Case 5

DECT (3 days after)
Absence of hyperdensities → absence of iodine and absence of blood
Hypodensity in centrum semiovale compatible with acute infarct

GOOD CORRELATION between both DECT

Fig. 19

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Case 6

CTA: Occlusion of left ICA with extension to M1 segment of left MCA

Cerebral perfusion:
A decrease in rCBV at the level of left basal ganglia, thalamus and insular white matter
A delay in TTP at the territory of left MCA
Mismatch +

Fig. 20

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
DECT: Hyperdensity in right basal ganglia, insula and Sylvian fissure corresponding to iodine (basal ganglia) and blood (insula and Sylvian fissure)

Hypertension as the only cardiovascular risk factor
Patient has a left ICA subocclusive stenosis
Thrombolytic therapy (sodic heparin) + Antiplatelet therapy (aspirin)

Fig. 21
Case 6

DECT (3 days after)

Hyperdensity in right basal ganglia, insula and Sylvian fissure corresponding to blood
Iodine is reabsorbed in a few days and disappears quickly in iodine images, but blood lasts
more days in being absorbed and persists in VNC images

GOOD CORRELATION between both DECT

Fig. 22

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Fig. 23

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Case 7

**DECT:**
- Hyperdensity in right lenticular nucleus and right inferior frontal circunvolution corresponding to iodine
- Hypodensity in right inferior frontal circunvolution compatible with acute infarct

Patient has a hypertrophic cardiomyopathy, hypertension and an atrial fibrillation without treatment
No thrombolytic or antiplatelet therapies after mechanical thrombectomy due to a recent low digestive haemorrhage

**Fig. 24**

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Case 7

DECT (4 days after)
Absence of hyperdensities $\Rightarrow$ This fast resolution of hyperdensities (disappearance in 4 days) confirms that the hyperdensity corresponds to iodine
Hypodensity in right inferior frontal circunvolution compatible with subacute infarct

GOOD CORRELATION between both DECT

Fig. 25

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Fig. 26

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
**Case 8**

**Fig. 27**

DECT: Light hyperdensity in right basal ganglia corresponding to iodine
Light hypodensity in right basal ganglia corresponding to acute infarct

Absence of cardiovascular risk factors
Antiplatelet therapy (aspirin) is decided because of an episode of haematuria during the hospital stay
Case 8

Unenhanced CT (1 day after)
Light hypodensity in right basal ganglia (lenticular nucleus and caudate head) corresponding to acute infarct

GOOD CORRELATION between DECT and unenhanced CT

Fig. 28

© Radiology, Hospital Clinic de Barcelona - Barcelona/ES
Conclusion

Dual-energy CT can differentiate intracranial hemorrhage from iodinated contrast material with high sensitivity and specificity in patients with acute ischemic stroke after the initial thrombolytic therapy.

It is a useful tool to decide subsequent treatment in this group of patients, depending on the existence or absence of blood.
References

Personal Information

For any doubt, write to the following e-mail direction:

montse.domingo.ayllon@gmail.com

Montse Domingo Ayllón, MD