Brain perfusion made easy : CT/MR ?
Vienna ECR 2011

Techniques for CT and MR, post processing, radiation

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Learning Objectives:

1. To understand and compare the different techniques for brain perfusion imaging.
2. To learn about the methods of acquisition and post-processing of brain perfusion by first pass of contrast agent for CT and MR.
3. To learn about non contrast MR methods (arterial spin labeling).

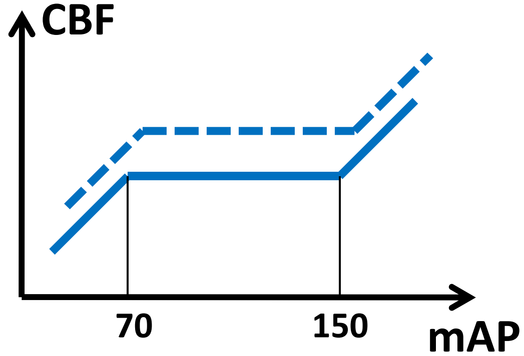
Plan of the presentation

- Essential of cerebral blood flow (CBF)
- Brain perfusion methods
- CT
  - Xenon-CT, First pass of Contrast
  - Radiation Protection
- MR
  - First pass of Contrast
  - Arterial Spin Labelling (ASL)

Essential of cerebral blood flow

- Brain is highly depend of blood flow
- CBF is 15% of the cardiac output at rest
- ~ 750 ml/min, ~ 50 ml/min/100g
- ~ 80 ml/min/100g in grey matter
- ~ 20 ml/min/100g in white matter
- Blood brain barrier (unique to the brain)
  - Can be altered by various conditions (stroke, tumours, inflammation,…)

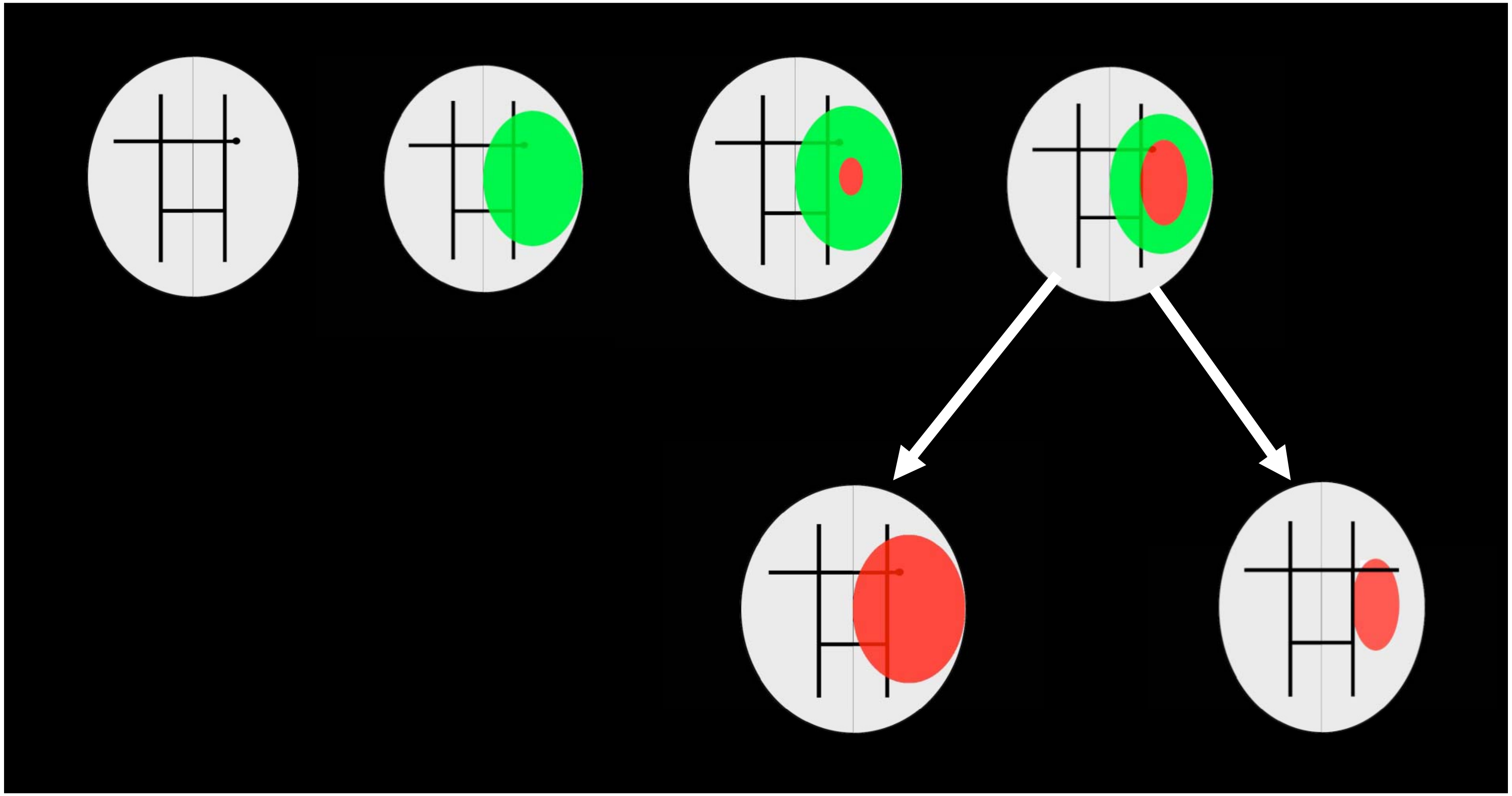
Essential of cerebral blood flow



- Strong auto regulation
- CBF < 20, loss of neuronal function, penumbra
- CBF < 10, ischemic cascade, infarct
- CBF modulated by $PaCO_2$, PaO_2, metabolic needs, acetazolamid
- CBF reserve can by challanged by $PaCO_2$ or acetazolamid

Essential of cerebral blood flow

Infarct - penumbra



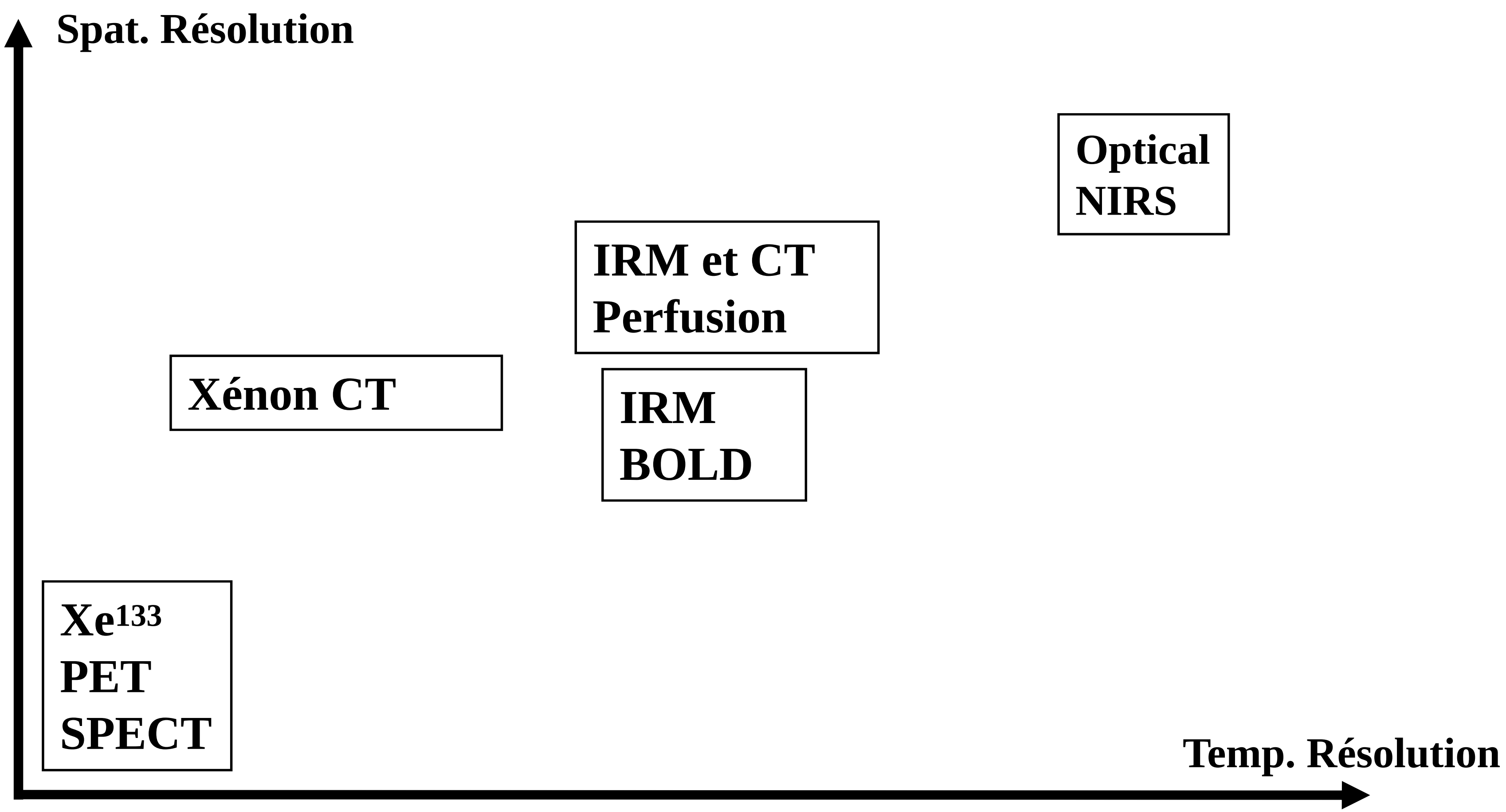
Brain perfusion methods

- Needs
  - Easy to perform ?
  - Quantitative and accurate or semi quantitative ?
  - Non invasive (contrast agent, radiation) ?
  - Repeatable (min, days,..) ?
  - High spatial resolution ?

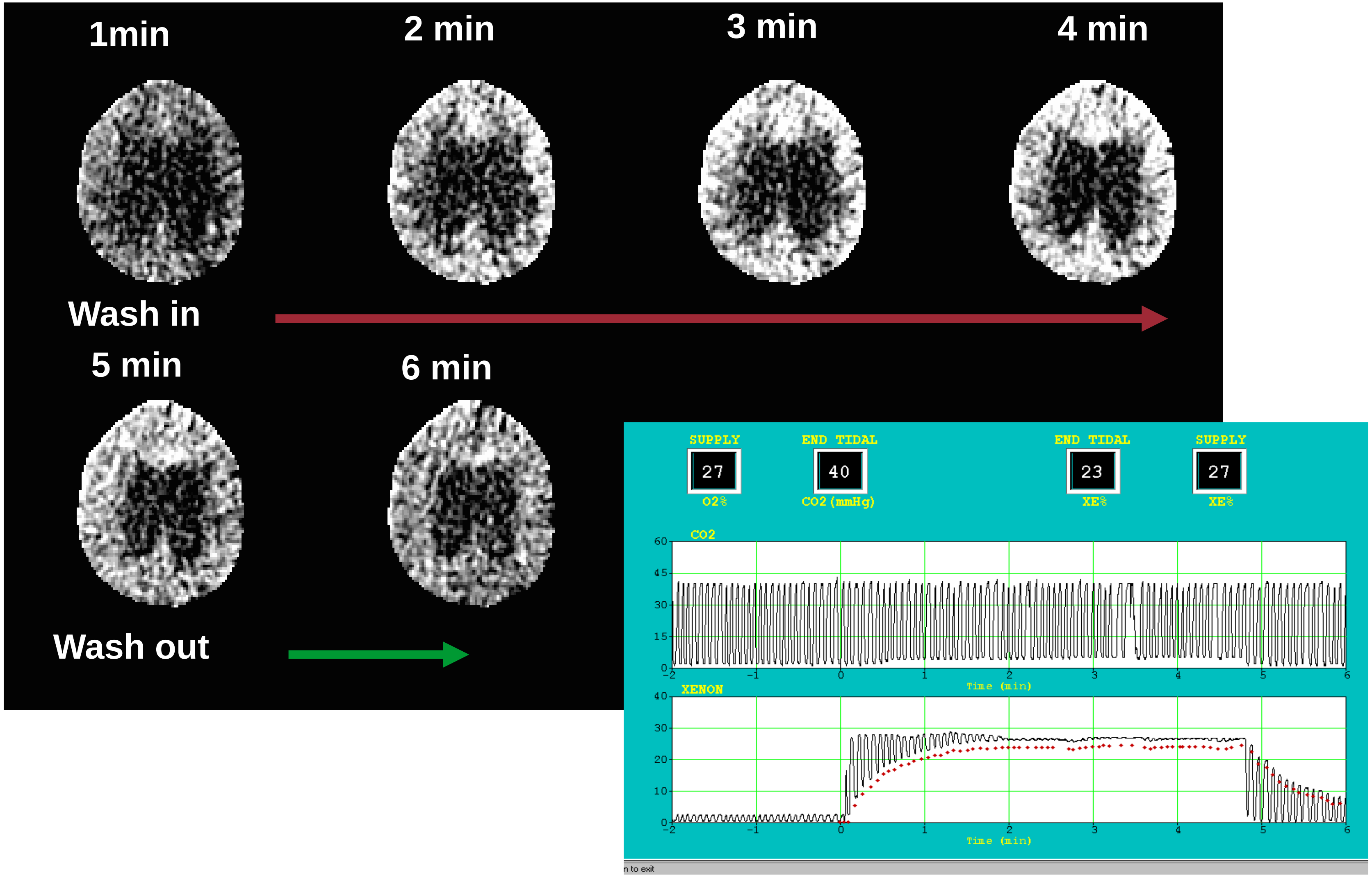
Brain perfusion methods

- Classification by modalities:
  - CT, MRI, US, Nuc, Infra read,..
- Tracer
  - Stable Xe, Iodine, Gd, BOLD, small b DWI, endogenous, microbubble, microspheres, HMPAO, O15, Xe 133
- CBF Model
  - Extraction at first pass, equilibrium, maximal sloop, central volume principle.

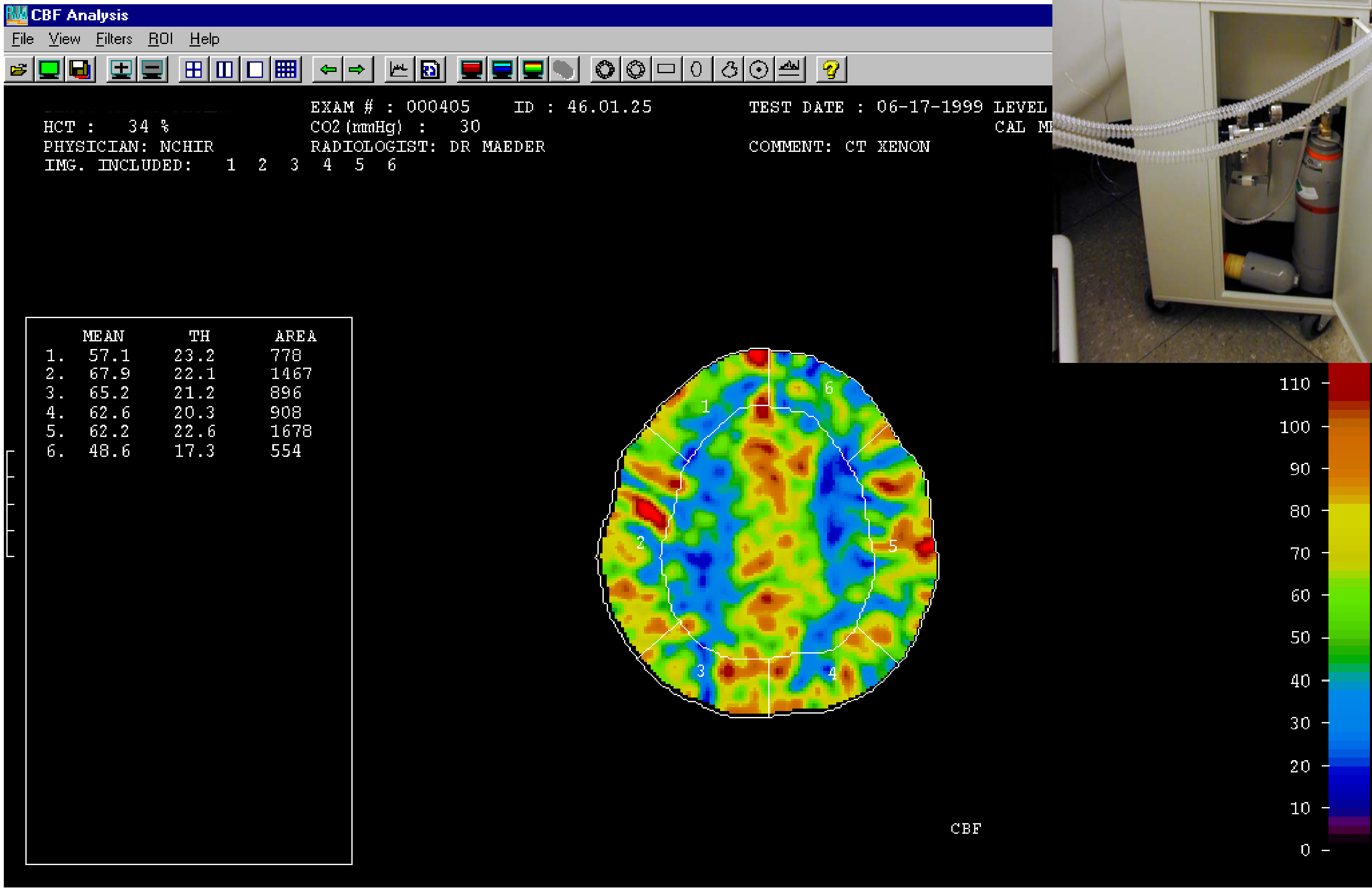
Brain perfusion methods



Stable Xe CT


1min
2 min
3 min
4 min
Wash in
5 min
6 min
Wash out
SUPPLY
27
O2%
END TIDAL
40
CO2 (mmHg)
END TIDAL
23
XE%
SUPPLY
27
XE%
CO2
Time (min)
XENON
Time (min)
n to exit

Stable Xe CT


CBF Analysis
File View Filters ROI Help
EXAM # : 000405 ID : 46.01.25 TEST DATE : 06-17-1999 LEVEL
HCT : 34 %
CO2 (mmHg) : 30
PHYSICIAN: NCHIR
RADIOLOGIST: DR MAEDER
COMMENT: CT XENON
IMG. INCLUDED: 1 2 3 4 5 6
MEAN TH AREA
1. 57.1 23.2 778
2. 67.9 22.1 1467
3. 65.2 21.2 896
4. 62.6 20.3 908
5. 62.2 22.6 1678
6. 48.6 17.3 554
110
100
90
80
70
60
50
40
30
20
10
0
CBF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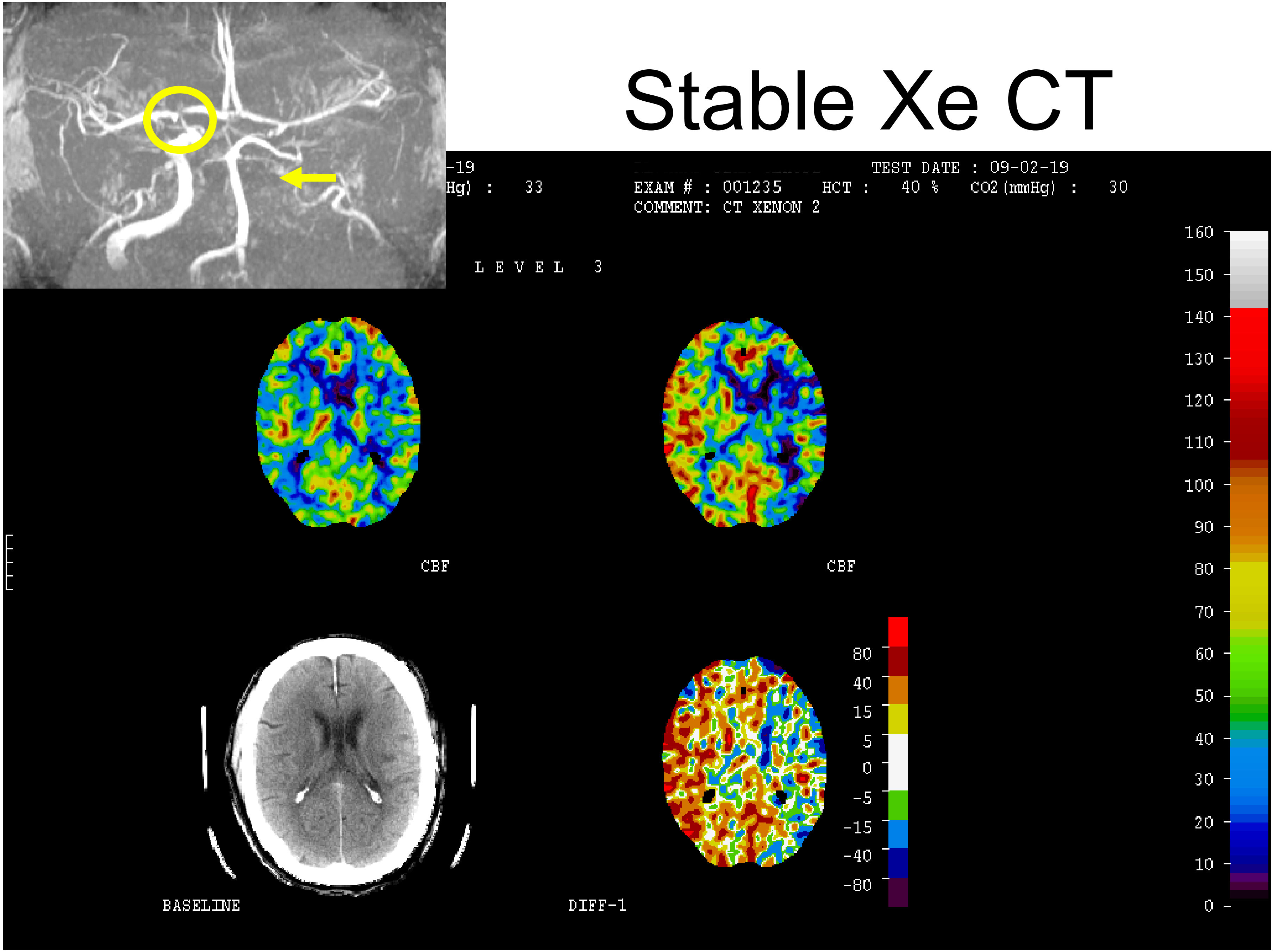
DIVERSIFIED DIAGNOSTIC PRODUCTS, INC.

Stable Xe CT



-19
Hg) : 33
TEST DATE : 09-02-19
EXAM # : 001235 HCT : 40 % CO2 (mmHg) : 30
COMMENT: CT XENON 2
L E V E L 3
CBF
CBF
BASELINE
DIFF-1
80
40
15
5
0
-5
-15
-40
-80
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

Perfusion CT technique

Principle:

- Intravenous administration of iodinated contrast material (40-50cc at 4-5 cc/s)
- Acquisition of sequential images with the cine mode (20 to 50 images, 1 image every 1 or 3 seconds)
- Multi-detector arrays = 2-16 adjacent 10-5 mm sections
- 80 KVp, 200 mAs
- stochastic dose = 3 mSv < standard cerebral CT (4 à 6 mSv)
- rCBF, rCBV, MTT calculation through the central volume principle model

Perfusion CT

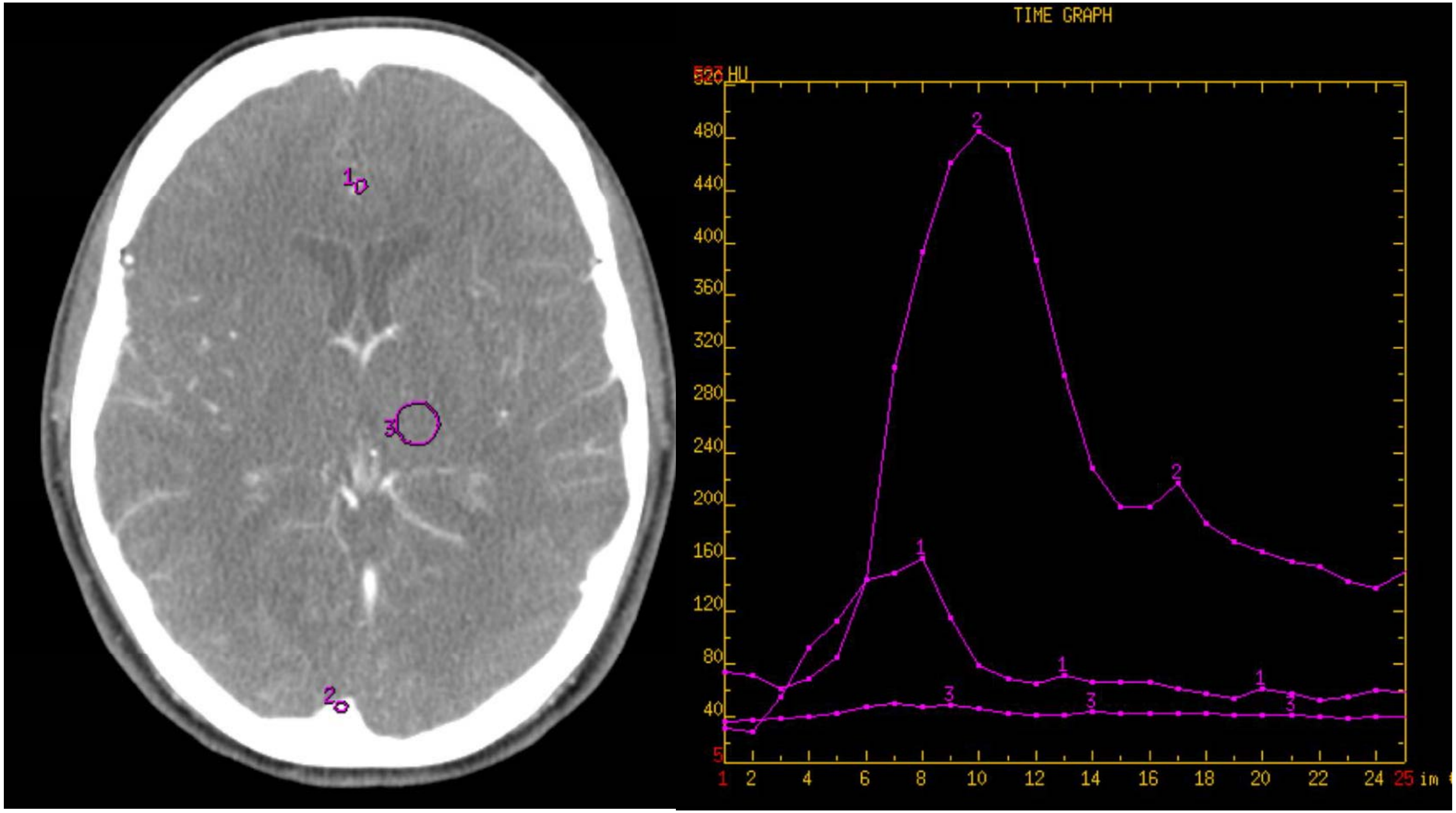
2 slab, 2 injections

2 X 40cc at 4 cc/s
2X 8 5 mm sections every 2 s
Cine mode 400 images, 16 X 25, 50s acq
80 KVp, 120 mA, 1S rotation time, ISD 1s
CTDI vol 150 mGy   DLP 1200 mGy-cm
~ 3 msV

Shuttle mode, 1 injection

40cc at 4 cc/s
16 5 mm sections every 2.8 s
Shuttle cine mode 288 images, 16 X 18, 50s acq
80 KVp, 240 mA, 0,4s rotation time, ISD 2s
Iterative reconstruction (ASIR 40%)
CTDIvol 100 mGy DLP 800 mGy-cm
~ 2 msV

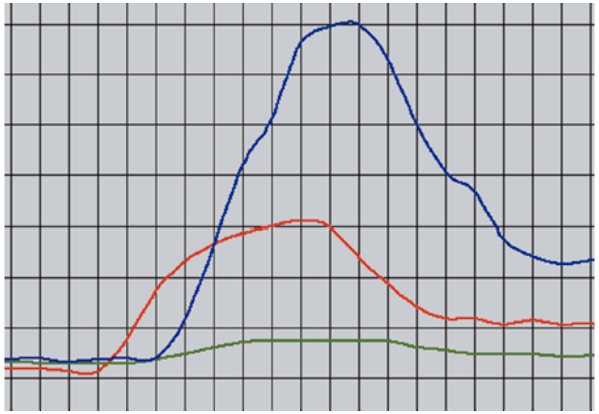
Perfusion CT



Perfusion CT Central Volume Principle

MTT is obtained by a deconvolution :

$$rCBF = \frac{rCBV}{MTT}$$

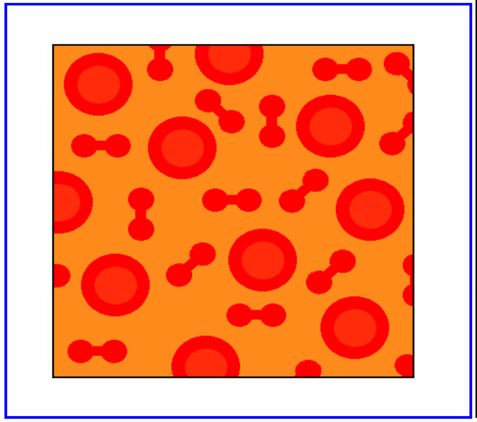


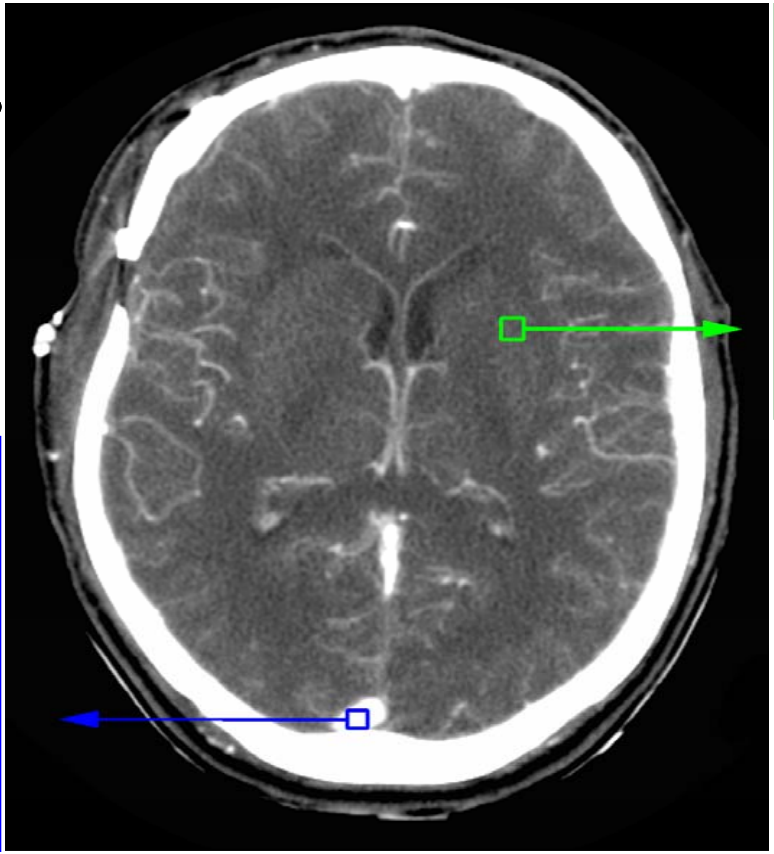
Theoretic basis and technical implementations of CT perfusion in acute ischemic stroke, part 1: Theoretic basis. Konstas AA at al AJNR Am J Neuroradiol. 2009 Apr;30(4):662-8.

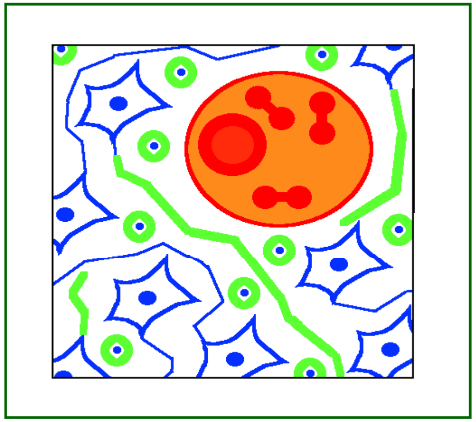
Quantitative assessment of regional cerebral blood flows by perfusion CT studies at low injection rates: a critical review of the underlying theoretical models. Wintermark M, Maeder P, Thiran JP, Schnyder P, Meuli R Eur Radiol. 2001;11(7):1220-30.

Regional Cerebral Blood Volumes rCBV

rCBV in venous sinus = 100%
100 cc per 100 cc
100 cc per 100 g







rCBV in parenchyma = 5%
5 cc per 100 cc
5 cc per 100 g

Optimal perfusionCT coverage ?

Optimal brain perfusion CT coverage in patients with acute middle cerebral artery stroke.
Furtado AD at all. AJNR Am J Neuroradiol. 2010 Apr;31(4):691-5.

CONCLUSIONS:

Seventy-five millimeters is the minimal PCT coverage required to use PCT as a tool to select patients with acute stroke for reperfusion therapy by using a mismatch of 0.5. A z-axis coverage of 50 mm was sufficient for a mismatch of 0.2; and 55 mm, for the size of PCT infarct relative to MCA territory (one-third or more).

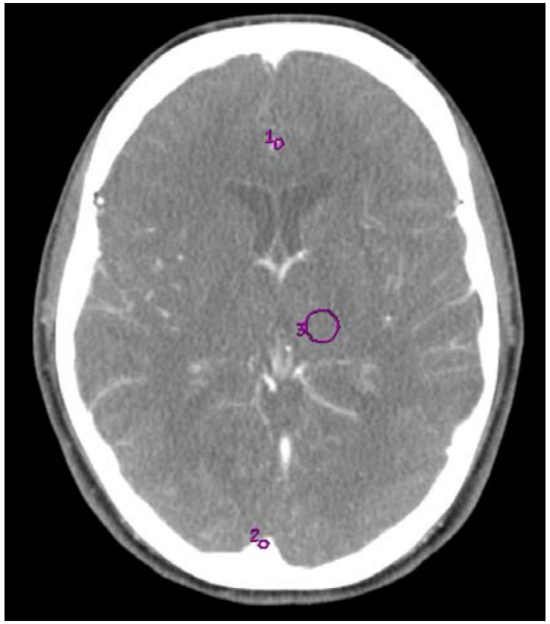
80 mm also needed is dementia, epilepsy, trauma, vasospasm post SAH, …

Witch artery should be used for the arterial input function ?

1. Partial volume effect dose not affect the result of the deconvolution process
2. Central volume principle require to take the arterial input function as close as possible to the volume of interest, but in practice MCA or ACA are adequate for AIF measurement

The anterior cerebral artery is an appropriate arterial input function for perfusion-CT processing in patients with acute stroke.
Wintermark at al Neuroradiology. 2008 Mar;50(3):227-36.

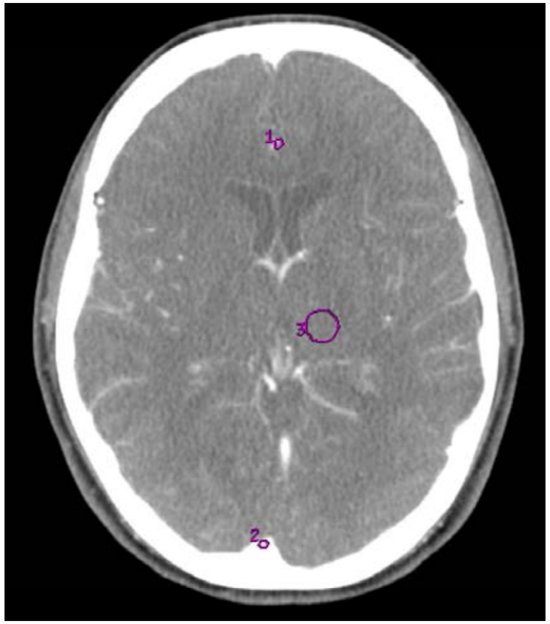
CONCLUSION: In acute stroke patients, the selection of the AIF has no statistically significant impact of the PCT results; standardization of the PCT postprocessing using the ACA as the default AIF is adequate.



Witch vein should be used for the reference venous output function ?

$$\mathbf{rCBF} = \frac{\mathbf{rCBV}}{\mathbf{MTT}}$$

1. CBV values are affected   by the choice of the reference vein
2. Quantification is strongly dependent on partial volume effect in the reference venous pixel
3. Sagittal sinus in it vertical lower part should be preferred when ever possible



What is the optimal temporal resolution and contrast volume ?

Dynamic perfusion CT: optimizing the temporal resolution and contrast volume for calculation of perfusion CT parameters in stroke patients. Wintermark M at al AJNR Am J Neuroradiol. 2004 May;25(5):720-9.

RESULTS: Increasing temporal sampling intervals lead to significant overestimation of rCBV, rCBF, and TTP and significant underestimation of MTT compared with values for an interval of 1 second. Maximal allowable intervals to avoid these effects were 2, 3, 3, and 4 seconds for 30, 40, 50, and 60-mL boluses, respectively. Venous exit of contrast material occurred in 97.5% of patients after 36, 42, 42, and 48 seconds, respectively, for the four volumes. SNRs did not differ with volume.
CONCLUSION: Temporal sampling intervals greater than 1 second can be used without altering the quantitative accuracy of PCT. Increased sampling intervals reduce the radiation dose and may allow for increased spatial coverage.

Is perfusionCT really quantative ?

Which KVp and mA should be used ?

Using 80 kVp versus 120 kVp in perfusion CT measurement of regional cerebral blood flow. Wintermark M, Maeder P, Verdun FR, Thiran JP, Valley JF, Schnyder P, Meuli R AJNR Am J Neuroradiol. 2000 Nov-Dec;21(10):1881-4.

Perfusion CT, radiation protection

The NEW ENGLAND JOURNAL of MEDICINE

REVIEW ARTICLE

N Engl J Med 2007;357:2277-84.

CURRENT CONCEPTS

Computed Tomography — An Increasing Source of Radiation Exposure

David J. Brenner, Ph.D., D.Sc., and Eric J. Hall, D.Phil., D.Sc.

The NEW ENGLAND JOURNAL of MEDICINE

Perspective

JULY 1, 2010

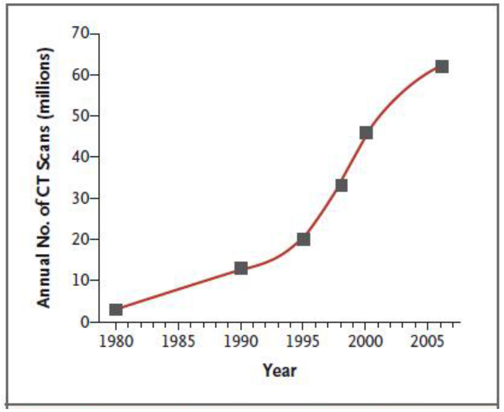
Is Computed Tomography Safe?

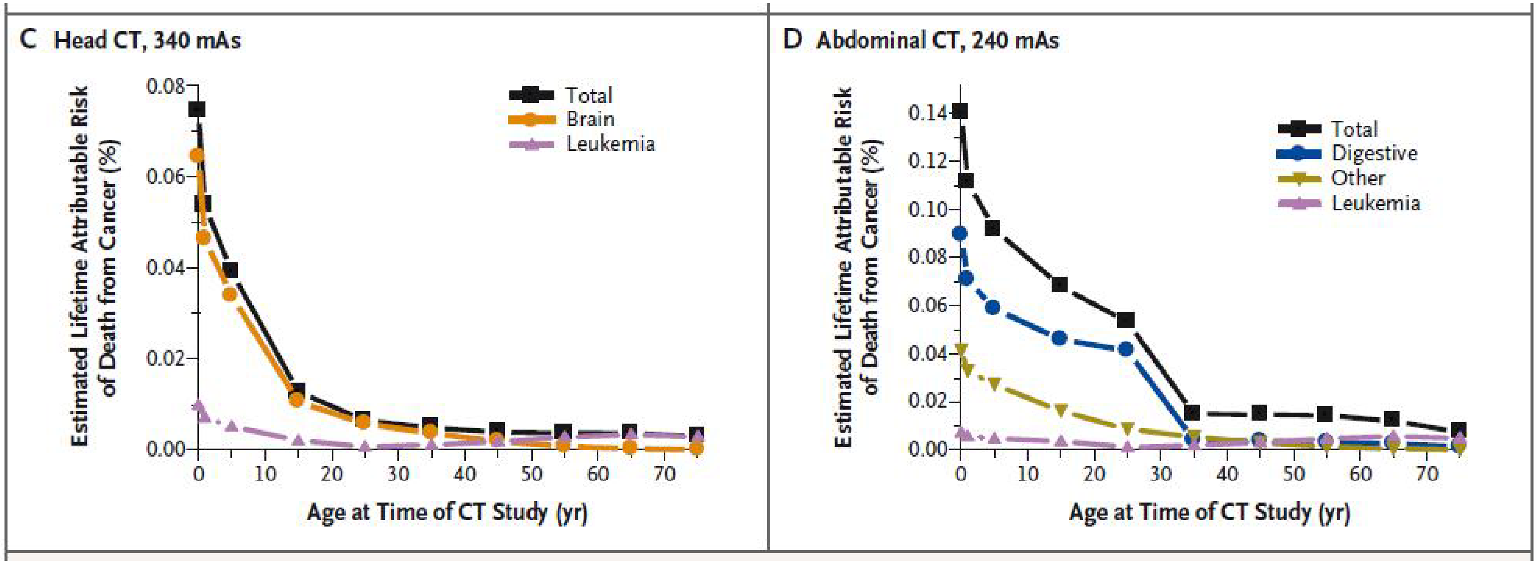
Rebecca Smith-Bindman, M.D.

Perfusion CT, radiation protection

Computed Tomography — An Increasing Source of Radiation Exposure

David J. Brenner, Ph.D., D.Sc., and Eric J. Hall, D.Phil., D.Sc.





Perfusion CT, radiation protection

THE RADIATION BOOM

After Stroke Scans, Patients Face Serious Health Risks

By WALT BOGDANICH
Published: July 31, 2010

The New York Times August 1, 2010

The New York Times August 1, 2010

Monica Almeida/The New York Times, bottom

☑ RECOMMEND

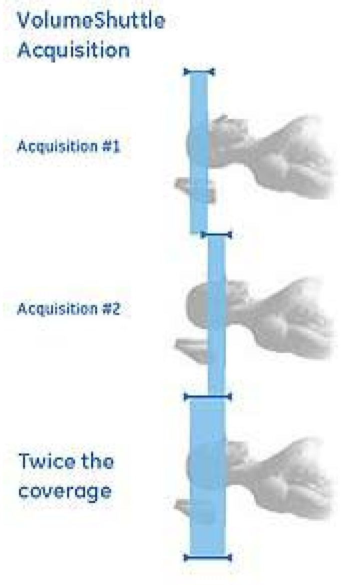
H. Michael Heuser lost clumps of hair and had other problems after receiving a radiation overdose at Cedars-Sinai Medical Center in Los Angeles. Mr. Heuser, a 52-year-old executive producer of films, received CT perfusion scans after exhibiting stroke symptoms.

But an examination by The New York Times has found that radiation overdoses were larger and more widespread than previously known, that patients have reported symptoms considerably more serious than losing their hair, and that experts say they may face long-term risks of cancer and brain damage.

Officials there said they intentionally used high levels of radiation to get clearer images, according to an inquiry by the company that supplied the scanners,

Experts say that is unjustified and potentially dangerous.

Perfusion CT, radiation protection



Shuttle mode, 1 injection

40cc at 4 cc/s
16 5 mm sections every 2.8 s
Shuttle cine mode 288 images, 16 X 18, 50s acq
80 KVp, 240 mA, 0,4s rotation time, ISD 2s
Iterative reconstruction (ASIR 40%)
CTDIvol 100 mGy, DLP 800 mGy-cm
~ 2 msV

2 slab, 2 injections

2 X 40cc at 4 cc/s
2X 8 5 mm sections every 2 s
Cine mode 400 images, 16 X 25, 50s acq
80 KVp, 120 mA, 1S rotation time, ISD 1s
CTDI vol 150 mGy, DLP 1200 mGy-cm
~ 3 msV

1 slab, 1 injections

40cc at 4 cc/s
8 5 mm sections every 2 s
Cine mode 240 images, 8 X 30, 60s acq
140 KVp, 300 mAs, 1S rotation time, ISD 1s
CTDIvol 2500 mGy, DLP 10000 mGy-cm
~ 25 msV

TRANSIENT HAIR LOSS WITH A CUMULATIVE EXPOSURE > 3 Gy

Perfusion CT, radiation protection

80 KVp, 120 mA, 1S rot, ISD 1s
CTDI vol 150 mGy, DLP 1200 mGy-cm
~ 3 msV

80 KVp, 240 mA, 0,4s rot, ISD 2s
Iterative reconstruction (ASIR 40%)
CTDIvol 100 mGy, DLP 800 mGy-cm
~ 2 msV

140 KVp, 300 mAs, 1S rot, ISD 1s
CTDIvol 2500 mGy, DLP 10000 mGy-cm
~ 25 msV

Perfusion CT, radiation protection

Shuttle mode, 1 injection

40cc at 4 cc/s

16 5 mm sections every 2.8 s

Shuttle cine mode 288 images, 16 X 18, 50s acq

80 KVp, 240 mA, 0,4s rotation time, ISD 2s

Iterative reconstruction (ASIR 40%)

CTDIvol 100 mGy, DLP 800 mGy-cm

~ 2 msV

GE web proposal

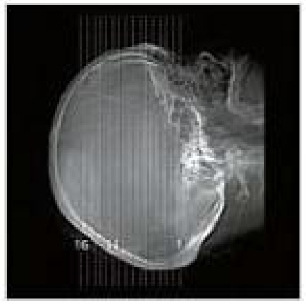


Figure 1: Demonstrating Volume Perfusion acquisition over 8cms coverage on scout views.

Protocol for all patients

Technical parameters

- Scan Type: Volume Shuttle
- Rotation time: 0.4 secs
- Prospective Slice thickness:
  5mm 8i - (Retro Recon 2.5mm, 1.25mm & 0.625mm)
- Coverage: 8 cms total (40mm x 2 - shuttle mode)
- SFOV: Head
- KVp: 80
- mA: 500 (200mAs)
- Prep Delay: 5 secs
- Shuttle: 19 x 8 cms passes
- Total scan duration: 52.2 secs

Injection parameters for - Dual Headed Injector

- Contrast + Saline Injection Rate: 4.0 ml/ second
- Total Contrast Amount:
  50 ml (350 Strength Non-Ionic Contrast 350mgI/ml)
- Saline: 50 ml Saline chase

http://www.gehealthcare.com/euen/ct/products/products_technologies/products/lightspeed-vct-xt/26552_VCT_XT_05_shuttle-clinical-case.html

Perfusion CT, radiation protection

Shuttle mode, 1 injection

40cc at 4 cc/s
16 5 mm sections every 2.8 s
Shuttle cine mode 288 images, 16 X 18, 50s acq
80 KVp, 240 mA, 0,4s rotation time, ISD 2s
Iterative reconstruction (ASIR 40%)
CTDIvol 100 mGy, DLP 800 mGy-cm
~ 2 msV

MGH proposal

35 cc at 4 cc/s
16 5 mm sections every 2.8 s
Shuttle cine mode 512 images, 16 X 32, 90s acq
80 KVp, 375 mA, 0,4s rotation time, ISD 2s
CTDIvol 280 mGy, DLP 2250 mGy-cm
~ 5 msV

GE web proposal

40cc at 4 cc/s
16 5 mm sections every 2.8 s
Shuttle cine mode 304 images, 16X 19, 52s acq
80 KVp, 500 mA, 0,4s rotation time, ISD 2s
CTDIvol 220 mGy, DLP 1760 mGy-cm
~ 4 msV

TRANSIENT HAIR LOSS WITH A CUMULATIVE EXPOSURE > 3 Gy

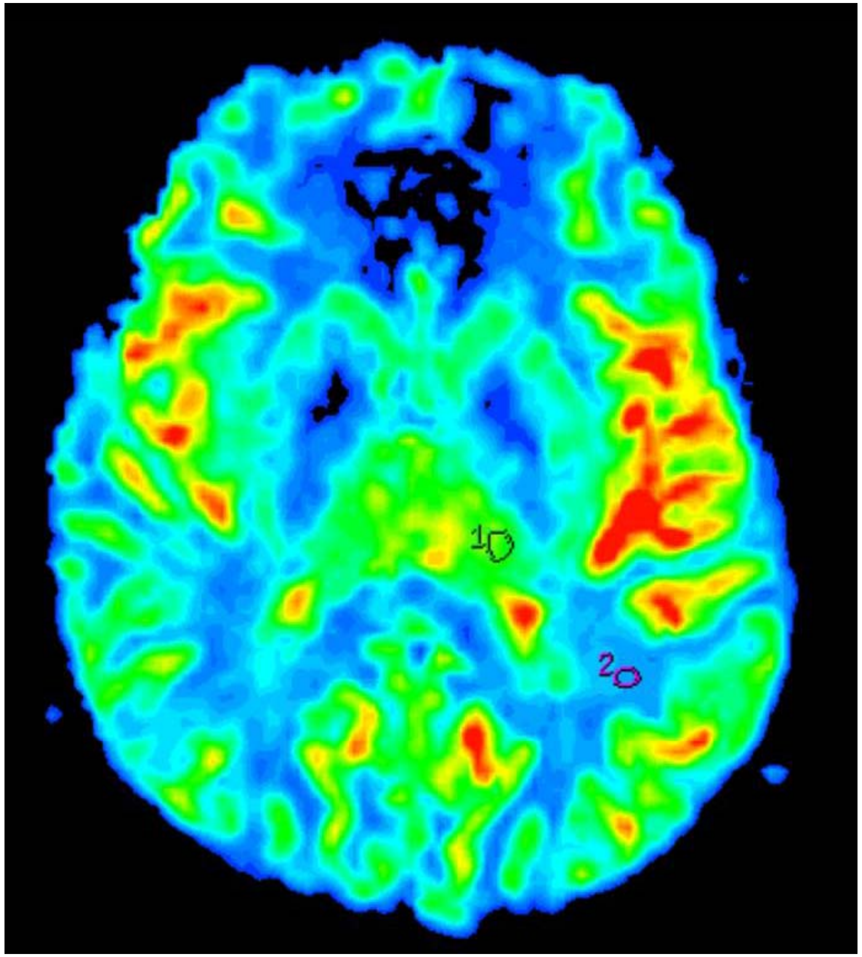
http://www.mghradrounds.org/index.php?src=gendocs&ref=2010_june

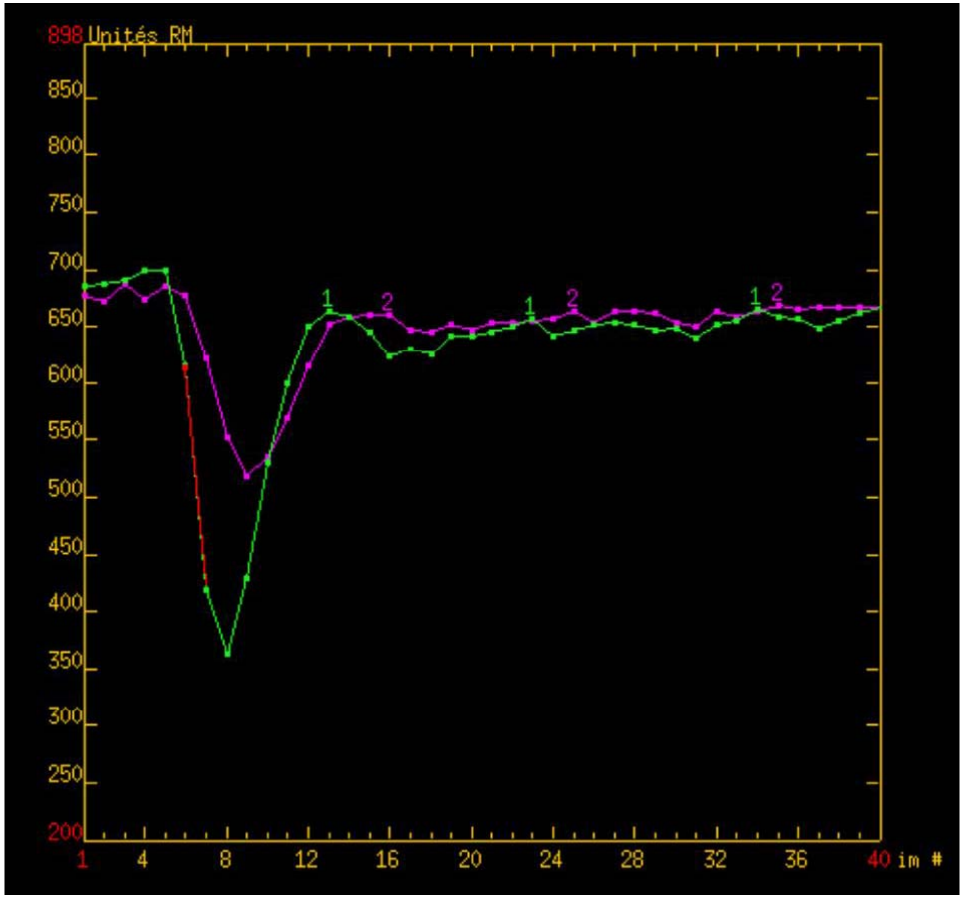
Perfusion MR technique

Principle:

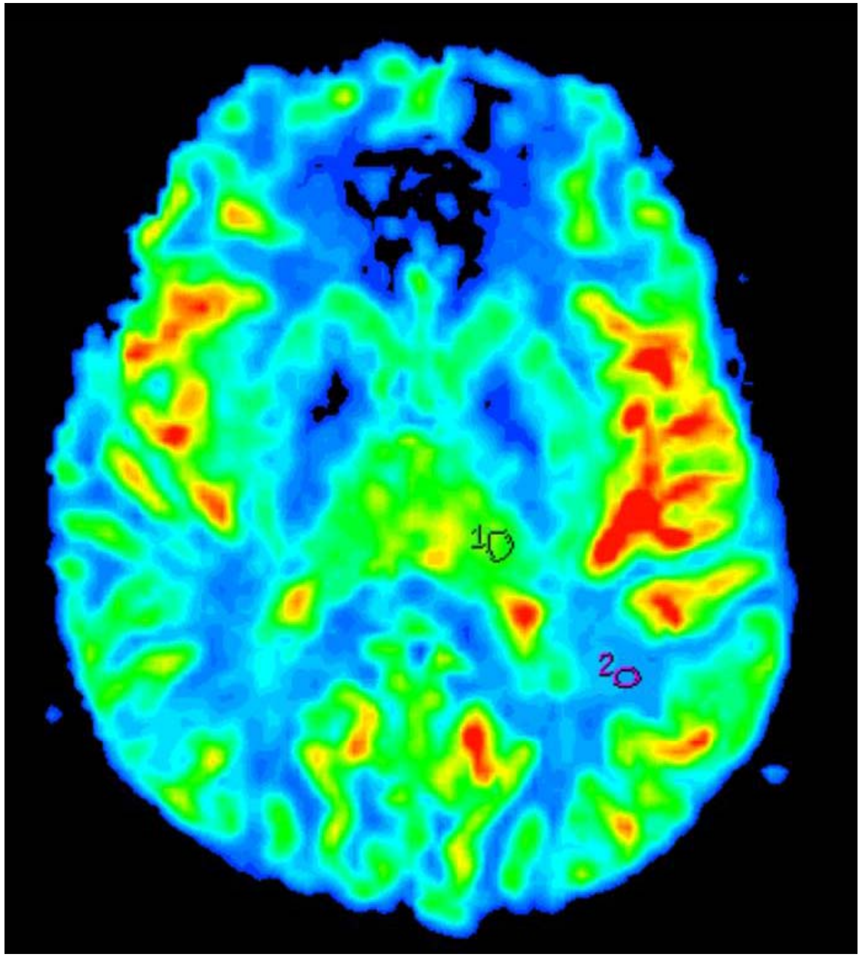
- Intravenous administration of Gd contrast (10-20cc at 4-5 cc/s)
- Multisclice, gradient echo echoplanar (16X40 5 mm, every 2 or 3 s)
- rCBF, rCBV, MTT calculation through the central volume principle model
- rCBF, rCBV, estimated by the maximal sloop and negative enhancement integral.

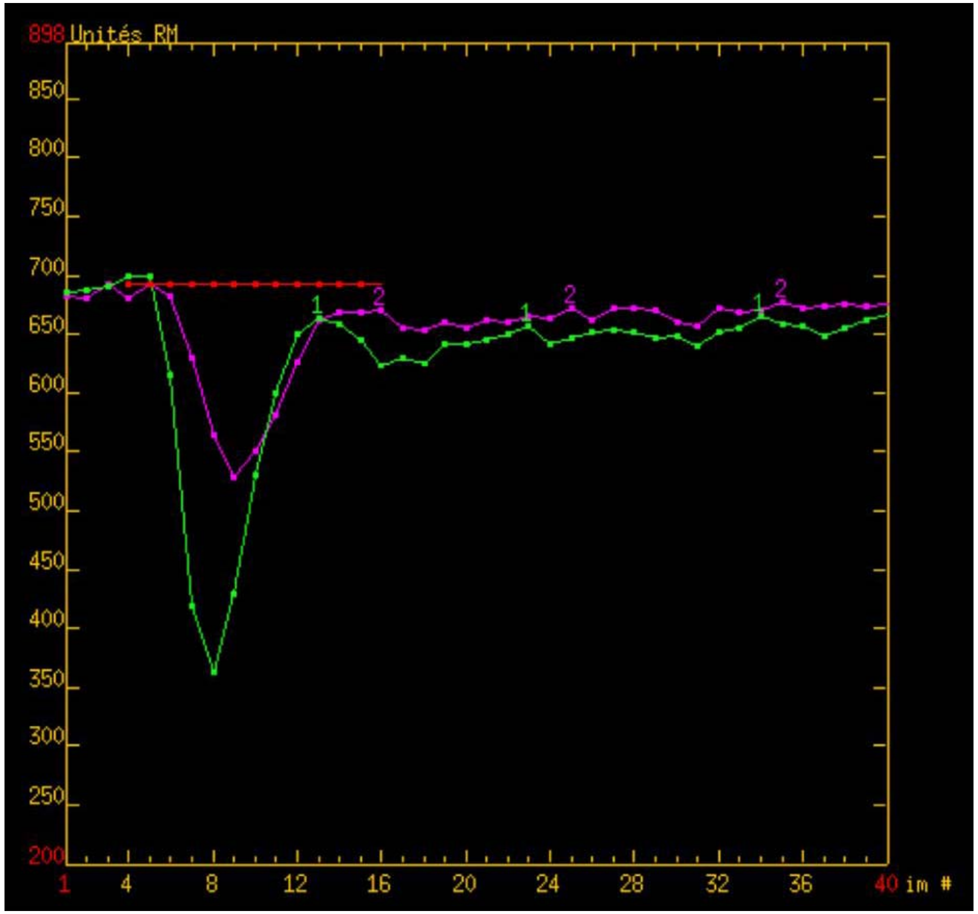
rCBF ~ maximal sloop of decrease





rCBV ~ negative enhancement $\int$





Arterial Spin Labelling (ASL)

1. Arterial spin labelling 2. Labelled image acquisition. 3. Reference image acquisition