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ADULT BRAIN PERFUSION CT

Indications

Suspected acute infarction;
Assessment of reperfusion after treatment of acute stroke;
Vasculitis;
New neurological symptoms after subarachnoid hemorrhage suggesting vasospasm;
Evaluation of the hemodynamic significance of a carotid stenosis;
Transient ischemic attack;
Evaluation of the cerebral vascular reserve using acetazolamide challenge;
Evaluation of brain perfusion after significant head trauma;
Brain tumor.

Diagnostic Task

- Detect brain ischemia in stroke, transient ischemic attack, vasculitis;
- Distinguish already-infarcted brain from brain at risk of infarction;
- Identify regions of brain made ischemic by vasospasm;
- Detect altered brain perfusion downstream a significant carotid stenosis;
- Assess altered cerebral vascular reserve in patients with ischemic symptoms;
- Assess altered cerebral perfusion after traumatic brain injury;
- Identify early brain tumor recurrence and higher-grade tumor components.

Key Elements

- Time-resolved scans are used to track the flow of iodinated contrast media through the brain;
- Multiple images (20-40) are acquired over the same section of anatomy;
- Patients must be able to remain still during the exam in order to avoid motion misregistration;
- The table may remain stationary during the entire exam, or move back and forth between a few table positions;
- Whole-brain perfusion CT can be accomplished using CT systems with wide detector arrays (8-16 cm); alternatively, scan modes that move the patient back and forth over the desired scan volumes can be used;
- Acquisitions are repeated at predetermined time intervals (e.g. every second to every 2-3 seconds) for a predetermined duration (e.g. 40-90 seconds);
- Relatively thick image widths are used to minimize image noise (5-10 mm is common);
- Image quality is inferior to a routine head CT. That is, images are noisier and thicker.
- Data are used to generate color maps of hemodynamic significance:
  --Blood volume (BV) and flow (BF), mean transit time (MTT), time to peak perfusion (TPP);
- A non-contrast-enhanced head CT and/or a CT angiogram may be combined with a perfusion CT scan.

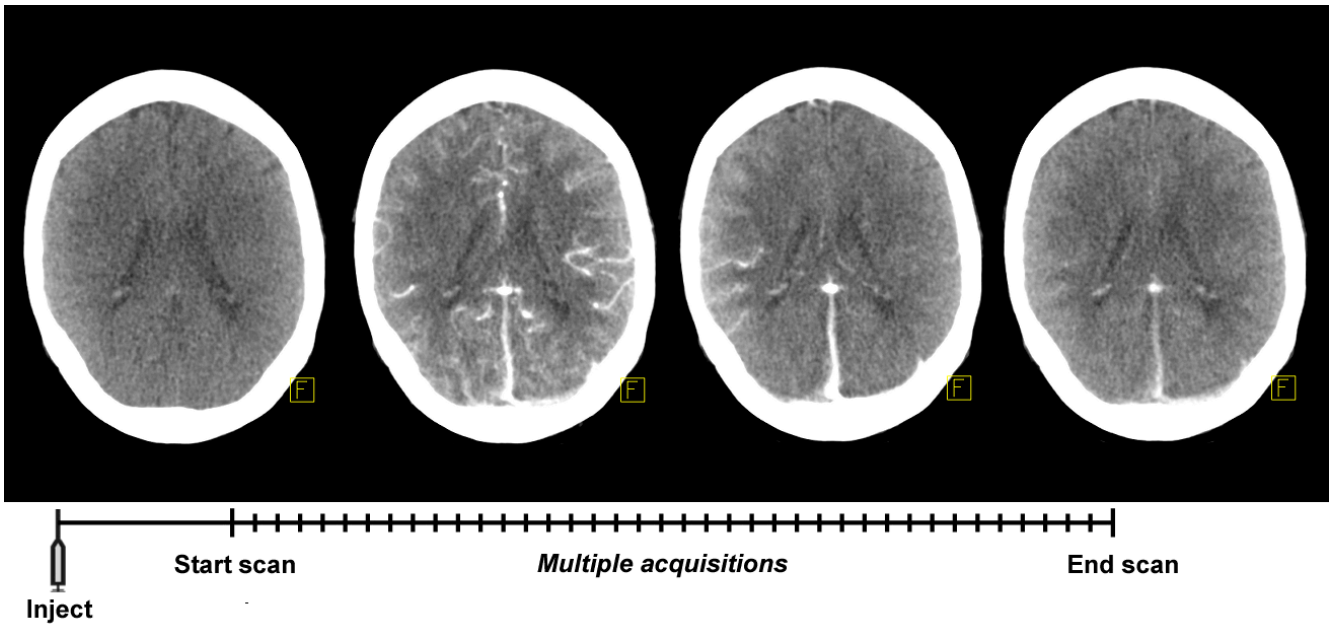
Dose Management

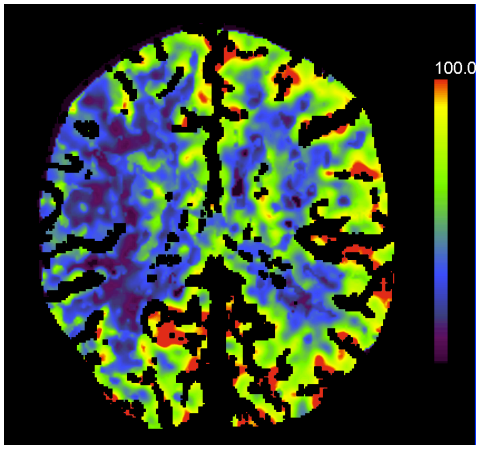
- 80 kV should be used to increase iodine signal brightness;
- Low dose per single scan (i.e. one tube rotation) is critical, since repeated scanning will result in a relatively high cumulative dose;
- Time interval between scans, and hence the total number of scans over the exam duration, should be set carefully, taking into account the analysis algorithm (some approaches require relatively dense data points);
- Dose (tube current) modulation should not be used, as it may interfere with the calculation of the BV and BF parameters;

Additional Resources

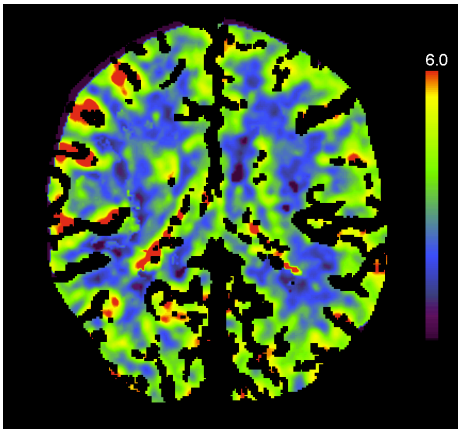
- ACR Practice Guideline for the Performance of Computed Tomography (CT) Perfusion in Neuroradiologic Imaging. (www.acr.org/Quality-Safety/Standards-Guidelines/Practice-Guidelines-by-Modality/CT);
- AJNR Special Collection. Radiation Dose in Neuroradiology CT Protocols. Collection Editors: Max Wintermark and Michael H. Lev (available at www.ajnr.org/specCol/specCollPCTToc.dtl).

BRAIN PERFUSION CT: Sample Images

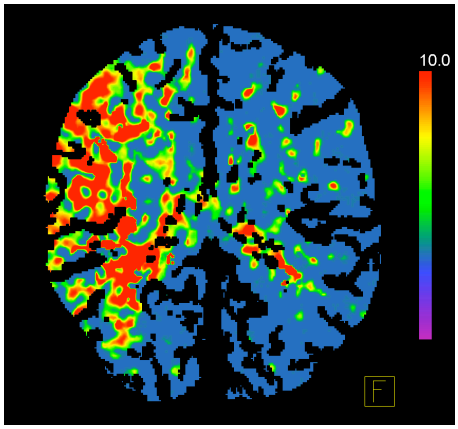




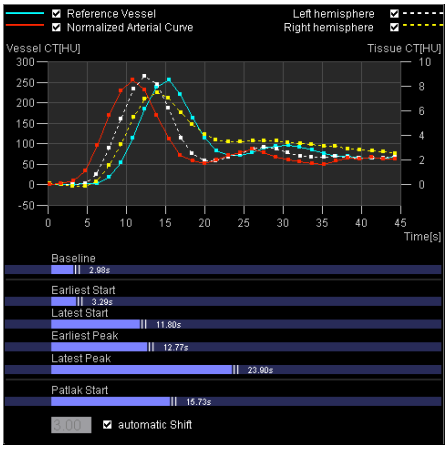
Cerebral Blood Flow (CBF, in mL/100 g/min)



Cerebral Blood Volume (CBV, in mL/100 g)



Mean Transit Time (MTT, in seconds)



Peak Enhancement Curves

BRAIN PERFUSION CT (Selected GE Scanners)

GENERAL: This protocol may include an optional, non-contrast-enhanced head scan and/or an optional head CT angiogram. Center the table height, such that the external auditory meatus is located at the center of the gantry and the landmarked at the level of the canthomeatal line (S0). The patient's chin should be tilted toward the chest (i.e. in a "tucked" position) to minimize the amount of tilt needed to better avoid the eyes especially for modes that do not support tilt. Perfusion protocols are for adults; modifications must be done for pediatrics.

CONTRAST: **Oral:** None.
IV: 40 ml of 350 -370 mg/cc concentration contrast media at 4 ml/sec, followed by 25 ml saline flush at same rate.
Preferred injection site: 18–20 gauge IV in right antecubital vein or central line capable of a 4 ml/sec injection.
Optional second level can be examined after a 5 to 10 min delay.

SCOUT: PA and Lateral, 200 mm coverage, 120 kV, 10 mA.
(CT Radiograph)

BRAIN PERFUSION CT:

The radiologist will determine the scan range, referring to any previously acquired (optional) scanned series.
The injection rate and volume of contrast directly affects the duration of the scan. Consideration needs to be given to these factors and patient cardiac output for appropriate scan delays and duration.
If a second location is desired, the start location of this group will be 1.5-2mm above the end of the first location.

Perfusion computations are performed on an image-processing workstation or scan console after scan completion.

Option 1: Axial mode (non-continuous axial acquisitions).

GE	LightSpeed and BrightSpeed 4/8 slice	LightSpeed and BrightSpeed 16 slice	LightSpeed VCT and Discovery CT750 HD
Scan Type	Axial	Axial	Axial
Rotation Time (s)	1	1	1
Detector Rows	16	16	64
Exam Duration (s)	44	44	44
Total Exposure Time (s)	22	22	22
kVp	80	80	80
Manual mA	150	150	150
AutomA/SmartmA	OFF	OFF	OFF
SFOV	Head	Head	Head
Prep Delay (s)	5	5	5
ISD (s)	1	1	1
DFOV (cm)	25	25	25
Image Thickness	5mm x 4i	5mm x 4i	5mm x 8i
Interval (mm)	0	0	0
Reconstruction Algorithm	Standard	Standard	Standard
ASiR			SS30-50 (optional, if available)
Coverage (mm)	20	20	40
Temporal Sampling (s)	2	2	2
CTDI-vol (mGy)	200 @ 150 mA	220 @ 150 mA	216 @ 150 mA

Continued

BRAIN PERFUSION CT (Selected GE Scanners) (continued)

Option 2: Cine mode (continuous axial acquisition).

GE	LightSpeed and BrightSpeed 4/8 slice	LightSpeed and BrightSpeed 16 slice	LightSpeed VCT and Discovery CT750 HD
Scan Type	Cine	Cine	Cine
Rotation Time (s)	1	1	1
Detector Rows	16	16	64
Exam Duration (s)	45	45	45
Total Exposure Time (s)	45	45	45
kVp	80	80	80
Manual mA	150	150	150
Auto-mA/Smart -mA	OFF	OFF	OFF
SFOV	Head	Head	Head
Prep Delay (s)	5	5	5
DFOV (cm)	25	25	25
Image Thickness	5mm x 4i	5mm x 4i	5mm x 8i
Interval (mm)	0	0	0
Reconstruction Algorithm	Standard	Standard	Standard
ASiR			SS30-50 (optional, if available)
Coverage (mm)	20	20	40
Time interval between reconstructed images (s)	0.5 - 1	0.5 - 1	0.5 - 1
CTDI-vol (mGy)	407 @ 150 mA	452 @ 150 mA	441 @ 150 mA

Continued

BRAIN PERFUSION CT (Selected GE Scanners) (continued)

Option 3: Volume mode (table moves in and out of the gantry to increase coverage).

GE	**LightSpeed VCT and Discovery CT750 HD**	**LightSpeed VCT and Discovery CT750 HD**
Scan Type	Volume Shuttle **Axial**	Volume Shuttle **Helical**
Rotation Time (s)	0.4	0.4
Detector Rows	64	64
Total Exposure Time	13.6 sec	47.38 sec
Pitch	N/A	0.984:1
Passes	17	28
kVp	80	80
Manual mA	400	200
AutomA/SmartmA	OFF	OFF
SFOV	Head	Head
Prep Group	5	5
ISD	N/A	N/A
DFOV	25	25
Image Thickness	5mm x 8i	5 mm
Interval (mm)	40	10
Reconstruction Algorithm	Standard	Standard
ASiR	SS50 (optional, if available)	SS50 (**ON**)
Coverage (mm)	80	110-120
Temporal Sampling (s)	3 sec	3 sec
CTDI-vol (mGy)	178 @ 400 mA	261 @ 200 mA

BRAIN PERFUSION CT (Selected HITACHI Scanners)

Dynamic scan (intermittent axial acquisitions at the same table location)

HITACHI	Scenaria 64 slice
Scan Type	Dynamic Scan
Rotation Time (s)	1
Detector Rows	64
Total Exposure Time (s)	20
kVp	80
mA	150
IntelliEC (AEC)	OFF
Scan FOV (mm)	500
Sequence delay (s)	5 sec.
ISD (s)	1 sec.
DFOV (mm)	230
Image Thickness	5 mm x 8i
Interval (mm)	0
Filter	11
Intelli IP	C
Coverage (mm)	40
CTDI-vol (mGy)	166

Images obtained using this Dynamic Scan protocol can be processed using TeraRecon iNtuition™ TDA clinical application to obtain quantitative perfusion parameters.

Use of other manufacturer's perfusion software applications may be appropriate, but the accuracy of the results has not been validated by either Hitachi or the AAPM. Users should work with the software vendor to determine whether the data obtained with this scan protocol are appropriate for the specific algorithm used to calculate perfusion parameters.

BRAIN PERFUSION CT (Selected NEUROLOGICA Scanners)

NEUROLOGICA	Ceretom
Acquisition Mode /collimation	8 x 1.25 mm / 10mm
Scan Voltage (kV)	100
Scan Current (mA)	6
Scan Time (s)	30-60
Rotation Time (s)	1
Slice Thickness (mm)	10
Increment / Table feed (mm)	0
Field of View (FOV) (cm)	25.3
Gantry Tilt (°)	0
Primary Reconstruction Kernel	Soft Tissue
Image Format	DICOM
Contrast Agent	Yes
Dose (CTDIvol) (mGy)	328
Reference Scan	Yes
Views	CBF, MTT, CBT and axial
Scan Coverage (mm)	10

Notes:
1. Scan voltage is limited to 100kV and cannot be changed by the CT technologist.
2. Maximum scan current is set to 6 mA.
3. Default scan time is 30 seconds. Lower mA setting is recommended for longer scans.
4. Low dose reference scan is available for scan localization prior to CTP scan.

BRAIN PERFUSION CT (Selected NEUSOFT Scanners)

GENERAL: Protocols are designed and intended for adult patients only. The gantry should be tilted to position the scan field parallel to the Frankfort horizontal plane. Functional Imaging is used measure physiological processes in the brain. Using a continuous or sequentially acquired dataset, at one anatomical position, the absorption of contrast material into the brain tissue can be measured and quantified.

CONTRAST: **Oral:** None.
IV: 40m of 300 mg/cc of contrast media a 4 ml/sec followed by a 20 ml saline flush at 4ml/sec.

SCOUT (Nuevz DUAL): Lateral Surview 250mm in length, 80kV, 40mA.

SCOUT (Nuevz 16): Lateral Surview 250mm in length, 90kV, 40mA.

BRAIN PERFUSION CT:

NEUSOFT	Neuviz DUAL	Neuviz 16
Scan Type	Axial	Axial
Rotation Time (s)	1.5	0.6
Detector Rows	2	16
Exam Duration (s)	65	50
Total Exposure Time (s)	60	45
kVp	80	90
manual (mA)	120	150
DoseRight	OFF	OFF
Cycles	40	30
SFOV (mm)	250	250
Prep Delay (s)	5	5
DFOV (mm)	250	250
Image Thickness (mm)	10	6
Interval (mm)	0	0
Resolution	Standard	Standard
Reconstruction Algorithm	SA	SA
WC/WL	350/80	95/40
Coverage (mm)	20	24
Temporal Sampling (s)	1.5	1.5
CTDI vol (mGy)	308.20	291.42

BRAIN PERFUSION CT (Selected PHILIPS Scanners)

GENERAL: These protocol parameters should not be used for pediatric patients.

CONTRAST: **Oral:** None.
IV: For Non-Jog scans: 40–50 mL contrast, followed by 20–40 mL saline
For Jog Mode scans: 70 mL contrast, followed by 45 mL saline
For all scans: Injection rate of 4–6 mL per second, 18–20 gauge IV placed in right antecubital vein

Option 1: Non-Jog Mode.

PHILIPS	Brilliance 16 slice	Brilliance 40/64 slice	Brilliance iCT SP	Brilliance iCT
Rotation Time (s)	0.5	0.5	0.4	0.4
Collimation	16 × 1.5 mm	32 × 1.25 mm	32 × 1.25 mm	64 × 1.25 mm
Coverage (mm)	24	40	40	80
kVp	90	80	80	80
mAs	125	125	100	100
ACS/DOM	OFF	OFF	OFF	OFF
Cycle Time (s)	2.0	2.0	1.5	1.5
Cycles	30	30	40	40
Thickness (mm)	6.0	5.0	5.0	5.0
Increment (mm)	0.0	0.0	0.0	0.0
Resolution	Standard	Standard	Standard	Standard
FOV (mm)	250	250	220	220
Filter	UB	UB	UB	UB
WC/WL	80/40	80/40	80/40	80/40
CTDI-vol (mGy)	240	132	160	148

Option 2: Jog Mode (Table moves back and forth between two positions).

PHILIPS	Brilliance 16 slice	Brilliance 40/64 slice	Brilliance iCT SP	Brilliance iCT
Rotation Time (s)	0.5	0.5	0.4	0.4
Collimation	16 × 1.5 mm	32 × 1.25 mm	32 × 1.25 mm	64 × 1.25 mm
Coverage (mm)	48	80	80	160
kVp	90	80	80	80
mAs	125	125	100	100
ACS/DOM	OFF	OFF	OFF	OFF
Cycle Time (s)*	4	4	4	4
# of Jog Cycles	15	15	15	15
Thickness (mm)	6.0	5.0	5.0	5.0
Increment (mm)	0.0	0.0	0.0	0.0
Resolution	Standard	Standard	Standard	Standard
FOV (mm)	250	250	220	220
Filter	UB	UB	UB	UB
WC/WL	80/40	80/40	80/40	80/40
CTDI-vol (mGy)	120	66	80	72

* Cycle time represents the time from the start of one scan to the start of the next scan over the same piece of anatomy (i.e., the sampling interval of the time attenuation curve). For the 4 s cycle time, the manufacturer's perfusion analysis software reports relative, rather than absolute, perfusion parameters. Absolute, quantitative perfusion parameters are reported for cycle times less than or equal to 2.5 s.

BRAIN PERFUSION CT (Selected SIEMENS Scanners)

GENERAL: This protocol may include an optional, non-contrast-enhanced head scan and/or an optional head CT angiogram
Center the table height, such that the external auditory meatus is located at the center of the gantry.
The patient's chin should be tilted toward the chest (i.e. in a "tucked" position).

CONTRAST: **Oral:** None.
IV: 40 mL of 350 mg/cc concentration contrast media at 4 mL/sec followed by 30 mL saline at 4 mL/sec
Preferred injection site: 18–20 gauge IV placed in right antecubital vein

TOPOGRAM: PA and Lateral, 512 mm coverage, 120 kV, 100 mA. Craniocaudal direction.
(CT Radiograph)

BRAIN PERFUSION CT:
This scan is performed for a continuous 40 or 45 seconds.
The radiologist will determine the scan range, referring to any previously-acquired (optional) scanned series.
No Gantry Tilt for the periodic spiral (adaptive 4D spiral).

SIEMENS	Sensation 64	Definition DS (64)	Definition AS+ (128)	Definition Flash (128)
Scan Type	Multiscan (Cine)	Periodic Spiral	Periodic Spiral	Periodic Spiral
Rotation Time (s)	1.0	0.33	0.30	0.28
Table Motion	None	In & Out of Gantry	In & Out of Gantry	In & Out of Gantry
Collimation	24 x 1.2 mm	24 x 1.2 mm	32 x 1.2 mm	32 x 1.2 mm
Coverage per Rotation (mm)	28.8	28.8	38.4	38.4
Scan Range (mm)	28.8	62	96	100
Cycle Time	1.0 (continuous)	1.5 s	1.5 s	1.5 s
Pitch	---	---	---	---
Feed (mm/rot)	---	---	---	---
kVp	80	80	80	80
Effective mAs	270	200	200	200
CARE Dose 4D	OFF	OFF	OFF	OFF
Scan Field (mm)	200	200	200	200
Prep Delay (s)	5	5	5	5
Scan time (s)	40	45	45	45
CTDI-vol (mGy)	433	220	220	259
Base Protocol	NeuroPCT	NeuroVPCT	NeuroVPCT	NeuroVPCT

RECONSTRUCTION	Sensation 64	Definition Scanners
Kernel	H20	H20
Slice (mm)	7.2	10.0
Increment (mm)	7.2	4.0
FOV (mm)	200	200
Window width/window center	150/50	150/50

Perfusion computations are performed on an image-processing workstation after scan completion.

BRAIN PERFUSION CT (Selected TOSHIBA Scanners)

GENERAL: This protocol may include an optional, non-contrast-enhanced head scan and/or an optional head CT angiogram
Center the table height, such that the external auditory meatus is located at the center of the gantry.

CONTRAST: **Oral:** None.
IV: 50 mL of 370 mg/cc concentration contrast media @ 5-6 mL/sec followed by 50 mL saline at 5-6 mL/sec
Preferred injection site: 18–20 gauge IV placed in right antecubital vein.

SCANOGRAM: PA and Lateral, 240 mm coverage, 120 kV, 50 mA, caudo-cranial direction.
(CT Radiograph)

BRAIN PERFUSION CT:
This scan is performed for 60 seconds.
The radiologist will determine the scan range, referring to any previously-acquired (optional) scanned series for the Aquilion Premium. For the Aquilion ONE, the entire head is covered.

TOSHIBA	Aquilion Premium	Aquilion ONE
Scan Type	Dynamic Volume Intermittent	Dynamic Volume Intermittent
Rotation Time (s)	0.75	0.75
Table Motion	None	None
Collimation	160 x 0.5mm	320 x 0.5 mm
Coverage per Rotation (mm)	80	160
Scan Range (mm)	80	160
Acquisition Interval*	2 s initially, then 5 s	2 s initially, then 5 s
kVp	80	80
mA*	150	300 (arterial phase), 150 (elsewhere)
SUREExposure	OFF	OFF
Scan Field (mm)	240	240
Delay after injection (s)	7	7
Scan Time (s)	53	53
CTDI-vol (mGy)	122	162

RECONSTRUCTION	Aquilion Premium	Aquilion ONE
Start	Radiologist selects location	Below base of skull
End		Vertex
Kernel	41	41
Slice (mm)	0.5	0.5
Increment (mm)	0.5	0.5
FOV (mm)	240	240

Perfusion computations are performed on an image-processing workstation after scan completion.

*The image below shows the scan protocol for the Aquilion ONE. Each green bar represents a volume scan. The mA is increased for the arterial portion of the scan to provide improved image quality for the digitally subtracted angiogram (DSA) image.