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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.

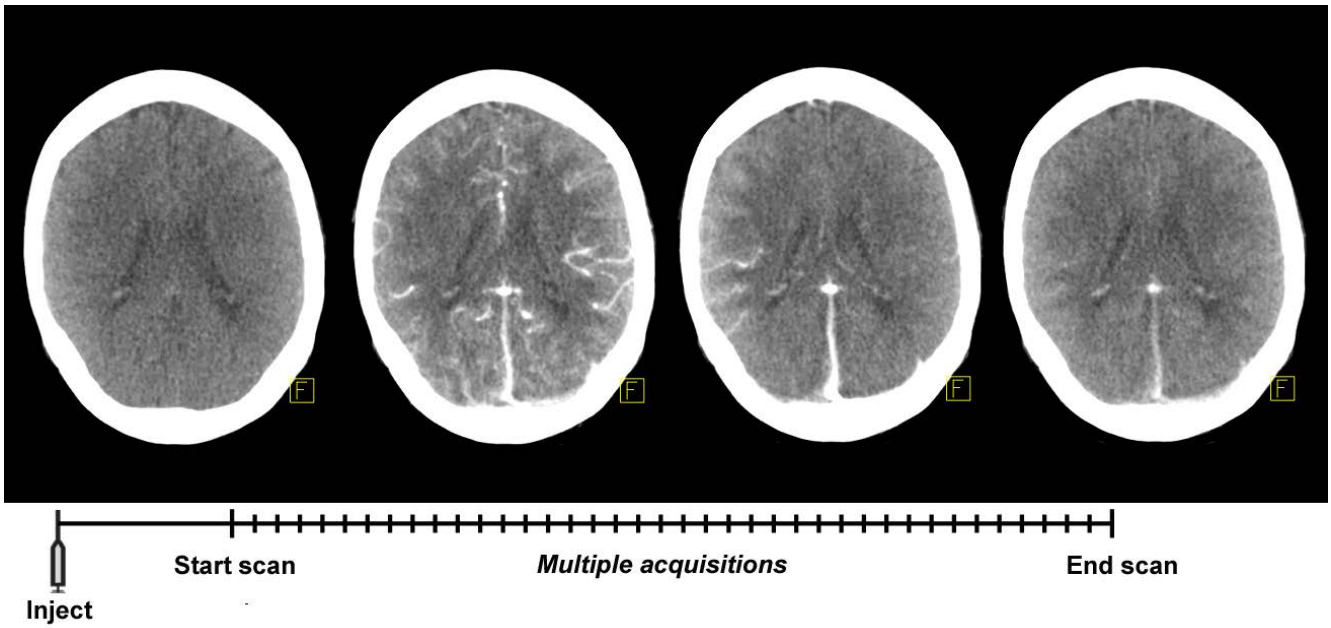
Dose Management

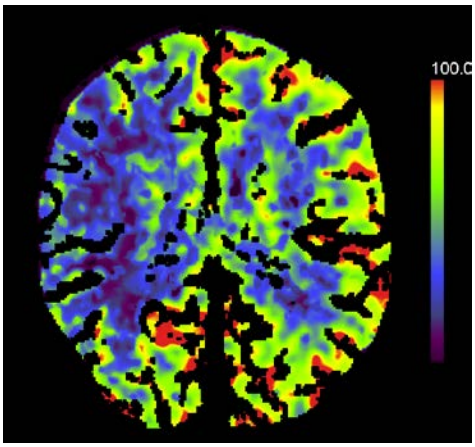
- 80 kV should be used to increase iodine signal brightness;
- Low dose per single scan (i.e. one tube rotation) is critical, since repeated scanning will result in a relatively high cumulative dose;
- Time interval between scans, and hence the total number of scans over the exam duration, should be 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

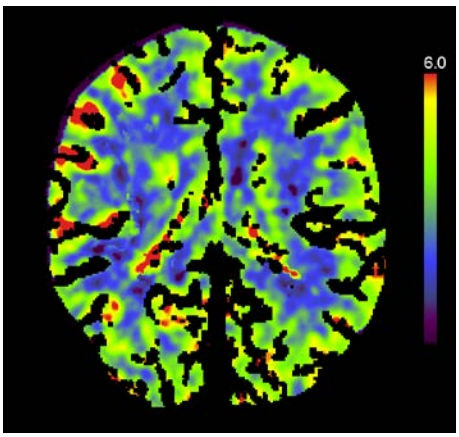
- ACR Practice Guideline for the Performance of Computed Tomography (CT) Perfusion in Neuroradiologic Imaging. (www.acr.org/Quality-Safety/Standards-Guidelines/Practice-Guidelines-by-Modality/CT);
- AJNR Special Collection. Radiation Dose in Neuroradiology CT Protocols. Collection Editors: Max Wintermark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

BRAIN PERFUSION CT: Sample Images

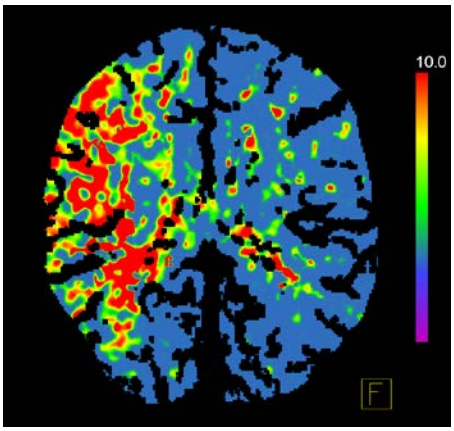




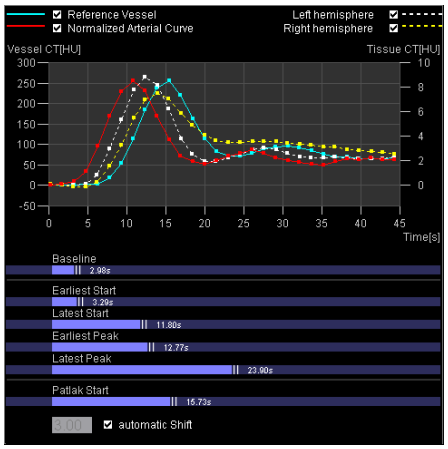
Cerebral Blood Flow (CBF, in mL/100 g/min)



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



Mean Transit Time (MTT, in seconds)



Peak Enhancement Curves

INDEX OF ADULT BRAIN PERFUSION CT PROTOCOLS (by manufacturer)

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.

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)

Scanogram: Lateral and PA: Scan from base of skull to vertex.

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)

Scout: PA and Lateral, 200 mm coverage, 120kV at 3mA for both views.

NEUROLOGICA	Ceretom	BodyTom
Acquisition Mode /collimation	8 x 1.25 mm / 10mm	8 x 1.25 mm / 10mm
Scan Voltage (kV)	100	100
Scan Current (mA)	6	6
Scan Time (s)	30-40	25
Rotation Time (s)	1	1
Slice Thickness (mm)	10	10
Increment / Table feed (mm)	0	0
Field of View (FOV) (cm)	25.3	30
Gantry Tilt (°)	0	0
Primary Reconstruction Kernel	Soft Tissue	Post Fossa / Vessel
Image Format	DICOM	DICOM
Contrast Agent	Yes	Yes
Dose (CTDIvol) (mGy)	328	408
Reference Scan	Yes	Yes
Views	CBF, MTT, CBT and axial	CBF, MTT, CBT and axial
Scan Coverage (mm)	10	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: 50m of 370 mg/cc of contrast media at 4-6 ml/sec followed by a 30 ml saline flush at 4ml/sec.
Preferred injection site: 18-20 gauge IV placed in right antecubital vein

SCOUT (NV 16): Lateral and PA, Base of skull through vertex. 250 mm in length, 40 mA, 90 kVp

SCOUT (NV 64): Lateral and PA, base of skull through vertex. 250 mm in length, 40 mA, 80 kVp

BRAIN PERFUSION CT:

This scan is performed for a continuous 40 seconds.
The radiologist will determine the scan range, referring to any previously acquired (optional) scanned series.

After perfusion scan is complete, load perfusion images to the Brain Perfusion Application.

NEUSOFT	NeuViz 64i/e	NeuViz 16
Scan Type	Axial	Axial
Rotation Time (s)	0.5	0.6
Collimation	32 x 0.625	16 x 1.5 mm
kVp	80	90
Reference mAs	150	96
Pitch	n/a	n/a
DFOV (mm)	250	250
Resolution	Standard	Standard
Dose Modulation	OFF	n/a
ClearView	20%(optional)	n/a
Cycle Time	1 sec	1.5 sec.
Scan Coverage	20	24
Cycles	40	40
CTDIvol	260	249

RECON 1

Type	Axial	Axial
Filter	F10	SA
Thickness (mm)	5	6
Increment (mm)	5	6

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

SURVIEW: Lateral, 120 kVp, 30 mA. From vertex to base of skull

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: 35 to 50 mL of at least 300 mg/cc concentration injected with an iodine delivery rate of at least 1.75 g/s and an injection time not longer than 8s followed by 20 to 30 mL of saline injected with the same flow rate.
An example fulfilling these restrictions would be: 35 ml contrast media (370mg/ml iodine, preheated to body temperature), injection rate 5 ml/s followed by 20-30 ml saline with identical flow rate.

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.

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	Emotion 16	Scope Power	Perspective 64 Perspective 128	Sensation 64
Scan Mode	Multiscan	Multiscan	Multiscan	Multiscan
Rotation Time (s)	1.0	1.0	1.0	1.0
Table Motion	None	None	None	None
Detector Configuration (mm)	6 x 3	16 x 1.2	32 x 1.2	24 x 1.2
Coverage per Rotation (mm)	18	19.2	38.4	28.8
Scan Range (mm)	18	19.2	38.4	28.8
Cycle Time (s)	3.75	3	3	1.0 (continuous)
Feed (mm/rot)	-	-	-	-
kV	80	80	80	80
mAs	150	150	150	200
Scan Field (mm)	200	200	200	200
Scan time (s)	40	40	40	40
CARE Dose4D	OFF	OFF	OFF	OFF
CARE kV	-	-	-	-
CTDIvol (mGy)	394	394	391	297
RECON 1				
Kernel	H31s	H31s	H31s	H31s
Slice (mm)	9.6	9.6	9.6	9.6
Increment (mm)	9.6	9.6	9.6	9.6

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

BRAIN PERFUSION CT (Selected SIEMENS Scanners) (*Continued*)

SIEMENS	Definition (Dual Source)	Definition AS64	Definition Edge Definition AS+	Definition Flash (Dual source 128-slice)	Force (Dual source 192-slice)
Scan Mode	4D Spiral	4D Spiral	4D Spiral	4D Spiral	4D Spiral
Rotation Time (s)	0.33	0.33	0.28 - 0.33	0.28	0.25
Table Motion	Yes	Yes	Yes	Yes	Yes
Detector Configuration (mm)	24 x 1.2	16 x 1.2	32 x 1.2	32 x 1.2	48 x 1.2
Coverage per Rotation (mm)	28.8	19.2	38.4	38.4	57.6
Scan Range (mm)	62	84	86-100	100	114
Cycle Time (s)	1.5	1.5	1.5	1.5	1.5
Pitch	variable	variable	variable	variable	variable
kV	80	80	80	80	70
Effective mAs	200	180	200	180	200
Scan Field (mm)	200	200	200	200	200
Scan time (s)	45	45	45	45	45
CARE Dose4D	OFF	OFF	OFF	OFF	OFF
CARE kV	OFF	OFF	OFF	OFF	OFF
CTDIvol (mGy)	220.0	281	211 - 222	235	148
RECON 1					
Kernel	H20f	H20f	H20f	H20f	Hr36
Slice (mm)	5.0	5.0	5.0	5.0	5.0
Increment (mm)	3.0	3.0	3.0	3.0	3.0

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.

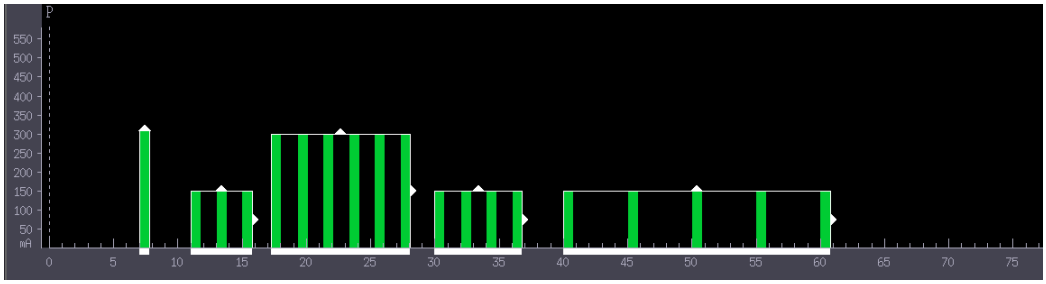
CONTRAST: **Oral:** None.
IV: 50 mL of 370 mg/cc concentration contrast media @ 5-6 mL/sec followed by 50 mL saline at 5-6 mL/sec
Preferred injection site: 18–20 gauge IV placed in right antecubital vein.

SCANOGRAM: PA and Lateral, 240 mm coverage, 120 kV, 50 mA, caudal-cranial direction.

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.

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.



TOSHIBA	Aquilion PRIME	Aquilion Premium	Aquilion ONE
Scan Type	Dynamic Volume Continuous	Dynamic Volume Intermittent	Dynamic Volume Intermittent
Rotation Time (s)	1.5	0.75	0.75
Table Motion	None	None	None
Detector Configuration	10 x 4 mm	160 x 0.5 mm	320 x 0.5 mm
Coverage per Rotation (mm)	40	80	160
Scan Range (mm)	40	80	160
Acquisition Interval (s)*	Continuous	2 s initially, then 5 s	2 s initially, then 5 s
kV	80	80	80
mA	40	310 (mask), 300 (arterial phase), 150 (elsewhere)	310 (mask), 300 (arterial phase), 150 (elsewhere)
SUREExposure	No	No	No
SFOV (mm)	240mm (S)	240mm (S)	240mm (S)
Delay after injection (s)	5	7	7
Scan Time (s)	49.5	53	53
CTDI-vol (mGy)	128.8	196.8	214.6
RECONSTRUCTION			
Kernel	43	41	41
Thickness (mm)	10	0.5	0.5
Interval (mm)	10	0.5	0.5
DFOV (cm)	240	240	240