The ONE Guides

Aquilion ONE

Series

4D Neurological Imaging

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Clinical results may vary due to clinical settings, patient preparation and other factors.

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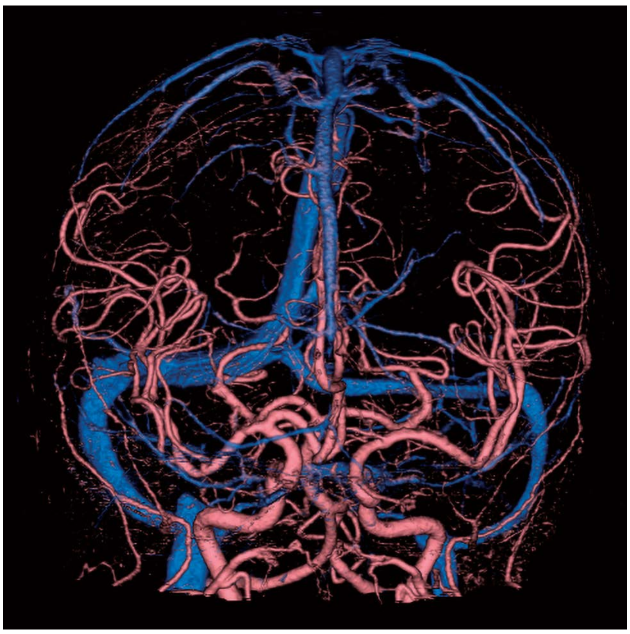
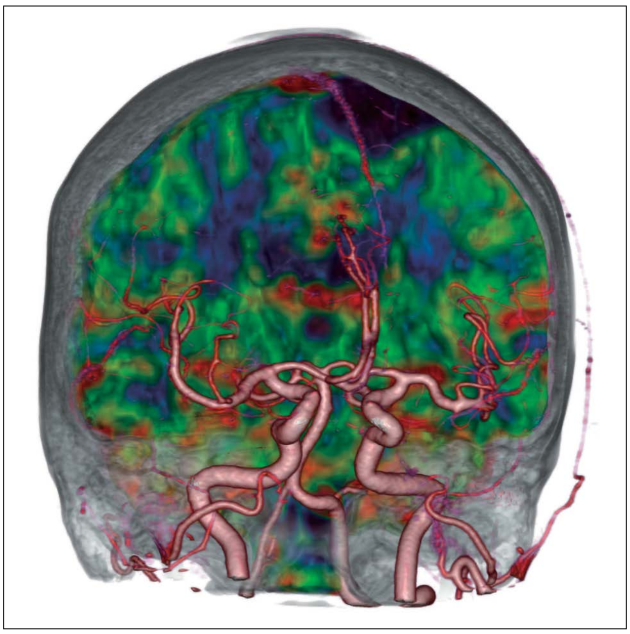
Preface

Cerebrovascular disease is the second leading cause of death worldwide. What's more, the social and economic burden associated with stroke continues to increase – not only for survivors, but also for families, caregivers and the healthcare system as a whole.[1] When it comes to the diagnosis of stroke, it is often said that "time is brain." The faster the clinician can detect areas of decreased blood flow, and determine the optimal treatment pathway, the better the patient's chances are for survival and recovery.

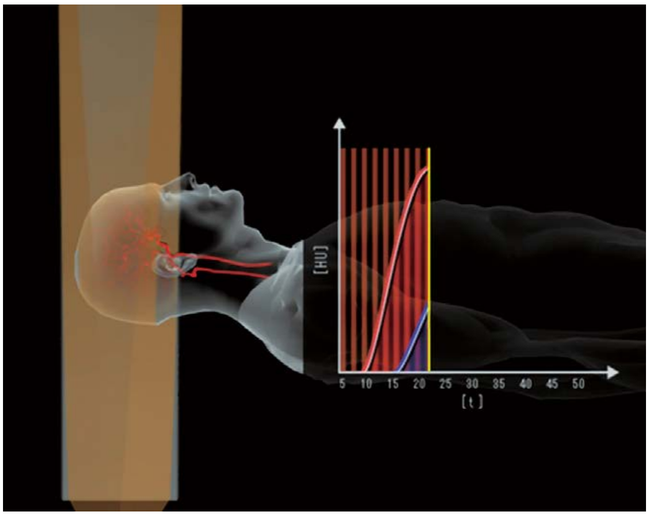
Improving the management of patients with stroke has been a decades long area of intense research and development at Canon Medical. In fact, stroke imaging was a key driver in the development of the Aquilion ONE family. The Neuro ONE protocol is designed specifically for comprehensive stroke assessment of the entire brain in one intermittent 60-second scan sequence. The advanced post processing applications on the Vitrea workstation deliver a comprehensive stroke assessment that can be completed in under 5 minutes from the start of the scan to image review.

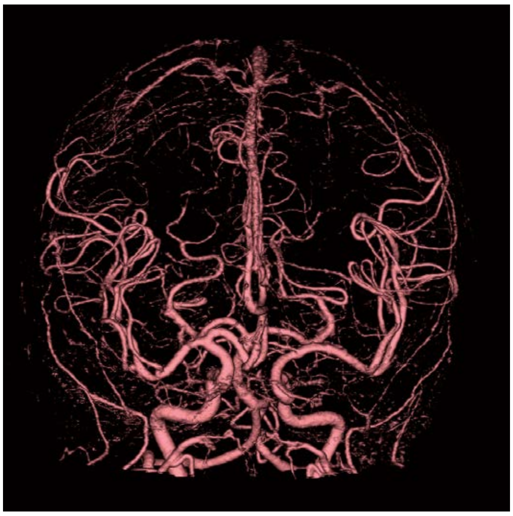




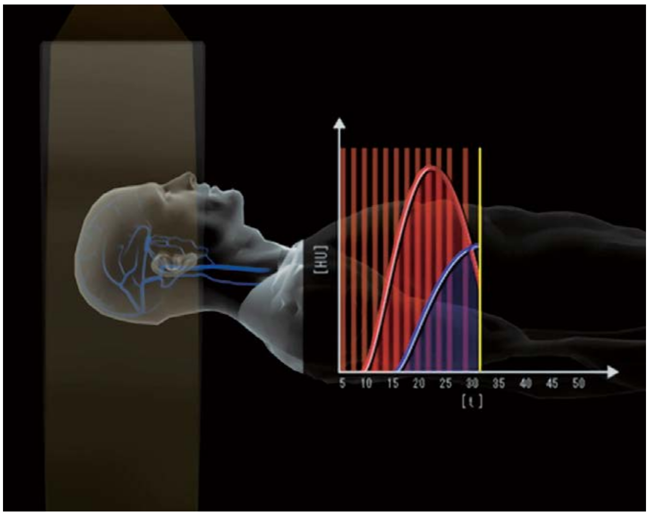
This guide provides instructions for scanning:

- Neuro ONE brain perfusion protocol: Comprehensive stroke evaluation
- 4D CT DSA protocol: The new standard in cerebrovascular imaging





Arterial



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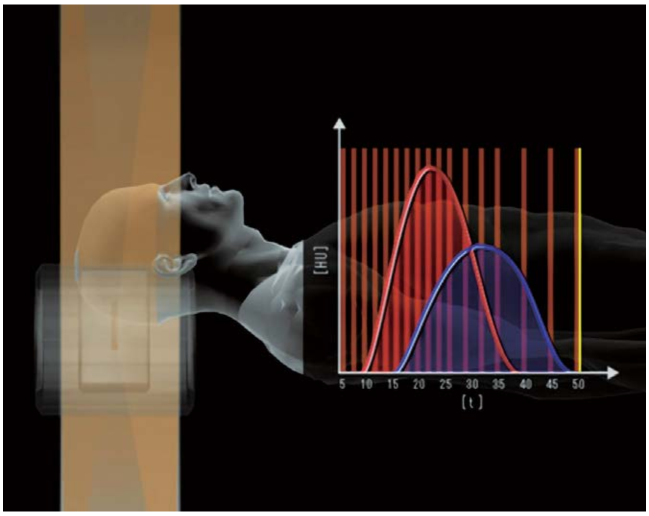
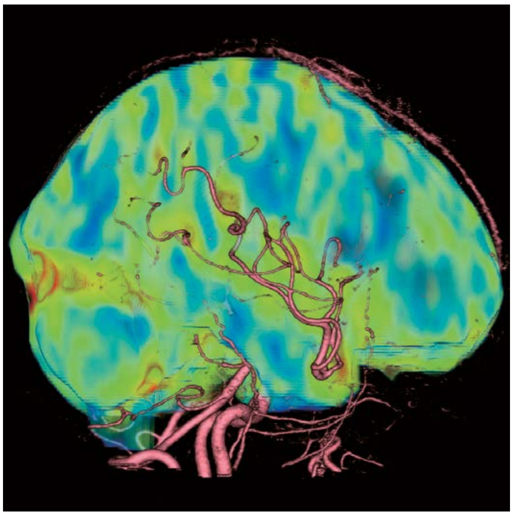




Whole-brain perfusion & DSA

Neuro ONE Brain Perfusion for Stroke

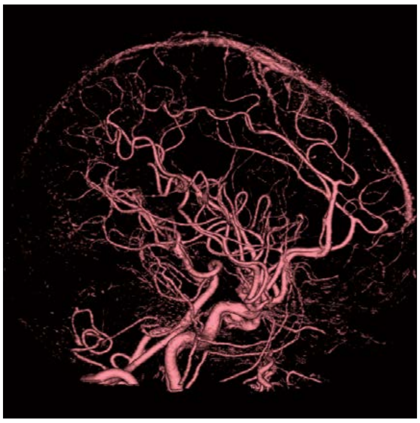
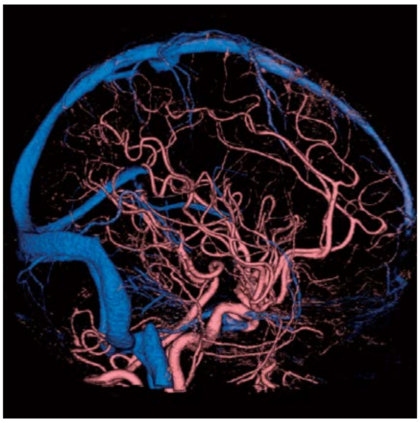
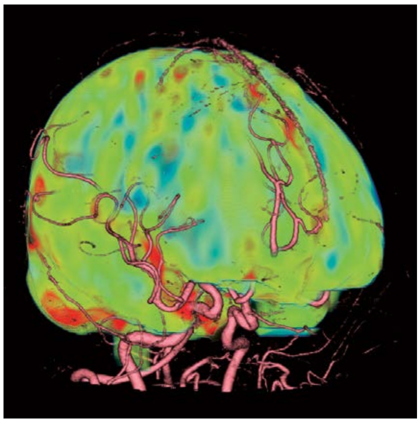
Introduction

The Neuro ONE scan protocol provides:

- CT angiography: To visualize the intra-cranial vascular anatomy and identify occlusion, stenosis and aneurysm.
- CT venography: To visualize the intra-cranial venous anatomy and identify occlusion and stenosis.
- 4D CT digital subtraction angiography (DSA): To assess flow direction and gauge collateralization.
- Whole-brain perfusion: Provides several metrics (time to peak, mean transit time, blood volume and blood flow) that allows quantification of an area of low blood flow.

Dynamic volume imaging with the Neuro ONE protocol provides a comprehensive examination of the intracranial vasculature to evaluate for stenosis and aneurysm, with the dynamic flow images permitting accurate visualization of collateral circulation. Whole-brain perfusion images are calculated to quantify the functional consequences of any vascular pathology. This complete evaluation can be completed in less than 5 minutes.

In acute stroke imaging, the time to diagnosis and treatment directly affects the degree of injury to brain tissue. Complete and rapid diagnosis of cerebral ischemia can directly influence the patient's quality of life. Aquilion ONE provides the new standard for imaging stroke patients using CT.

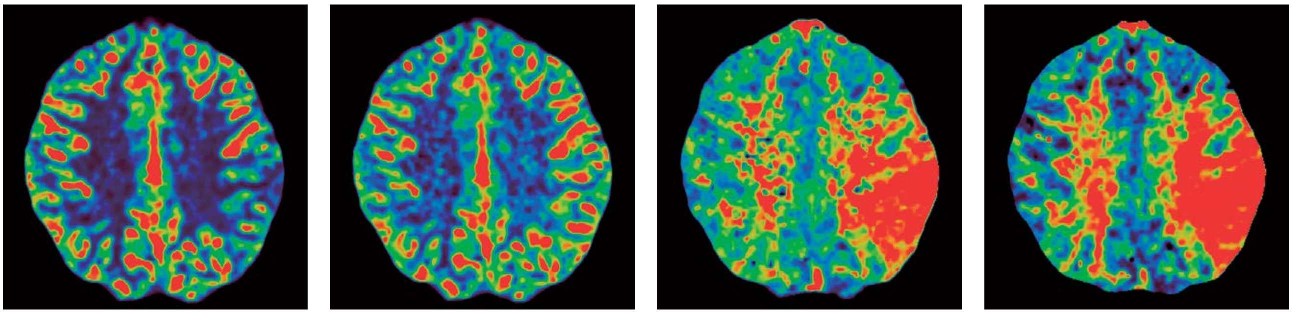




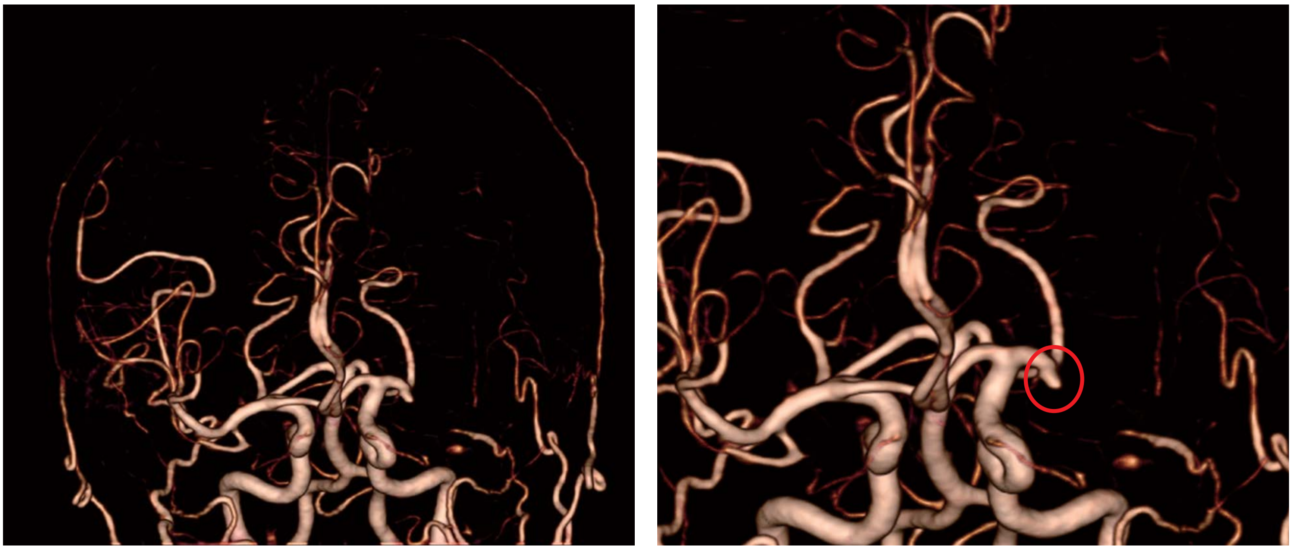
Clinical examples using Bayesian processing

Acute Stroke

In this case the perfusion maps demonstrate low cerebral blood flow, decreased blood volume, prolonged mean transit time and delayed time to peak. Close analysis of the CT angiographic images demonstrate an embolic occlusion of the temporal branch of the middle cerebral artery.

CBF CBV MTT TTP





Acute Stroke

Acute Stroke:

In this case, the perfusion maps demonstrate an area of decreased perfusion in the temporal lobe. The CTA demonstrates occlusion of the artery supplying this region.

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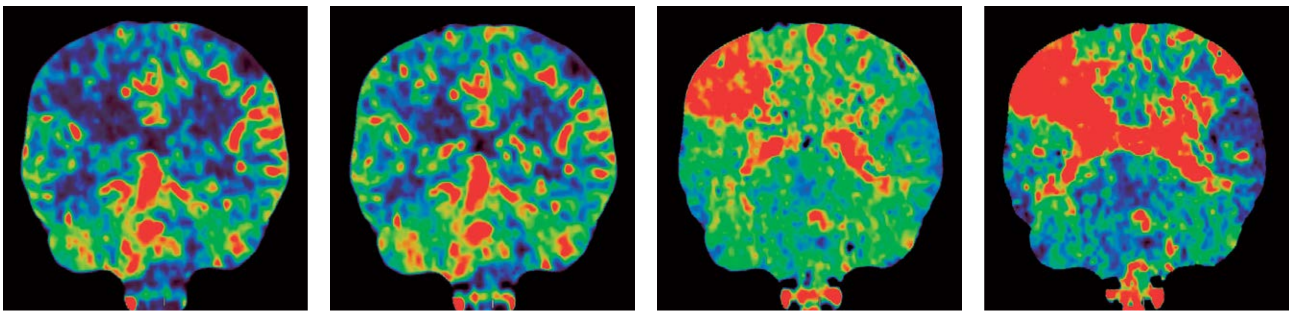

Neuro ONE Brain Perfusion for Stroke

Carotid Occlusion:
In this case, an occlusion of the right carotid artery is shown. The perfusion images demonstrate no perfusion defects. Close examination of the DSA images show that the right MCA is supplied by the basilar artery via the posterior communicating artery.

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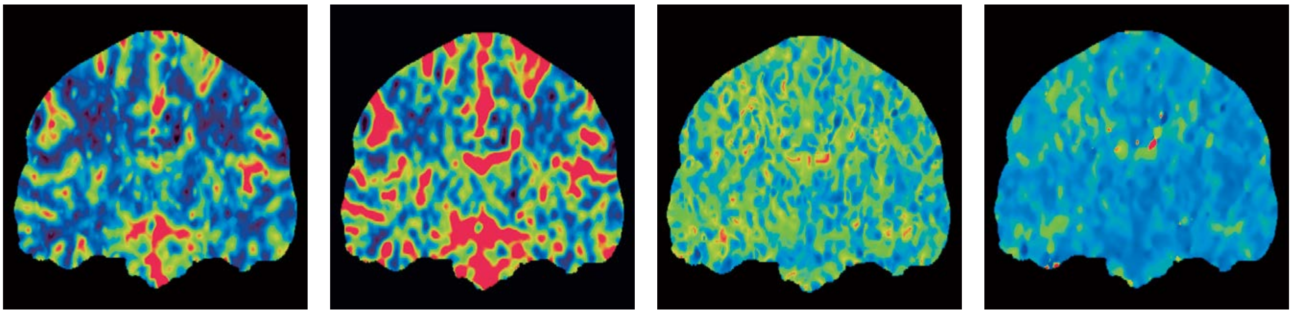
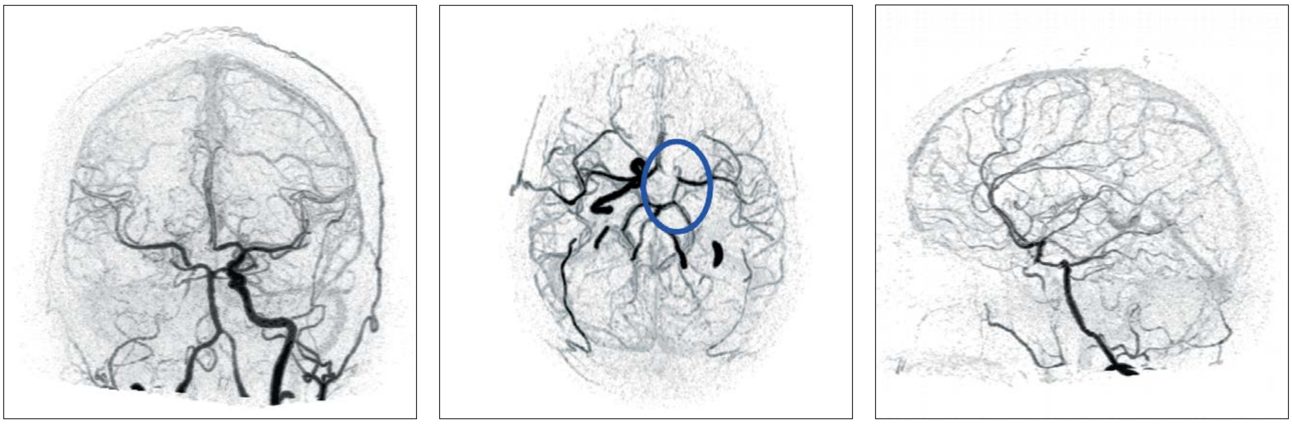


Anterior Superior Left Lateral (Cut)



"Canon Medicals Neuro ONE protocol is a one minute CT examination that enables comprehensive diagnostic imaging analyses in acute cerebral stroke, which is crucial for adequate treatment decision making. Featuring whole brain coverage, it provides dynamic evaluation of the full intra-cranial circulation shown on the Vitrea application as a non-invasive 4D-DSA. In addition, superior quality whole brain perfusion maps are computed by an advanced probabilistic model using the Bayesian method. With Canon's new stroke imaging solution we are able to offer a faster and more confident diagnosis, which contributes to improving the outcome of our stroke patients."

Dr. Anton Meijer MD, PhD
Neuro radiologist team lead neuro radiology
Radboud University Medical Center
Nijmegen, the Netherlands.

"Bayesian based perfusion significantly improves the diagnostic confidence in our primary stroke center. With better image quality, perfusion deficits are more easily depicted. Also by non-experts. We especially value that all perfusion parameter maps are now of diagnostic quality allowing for a confident distinction of perfusion patterns, where in the past diagnosis could remain uncertain because of ambiguity between these maps. This allows for a better separation into infarct core and penumbra regions."

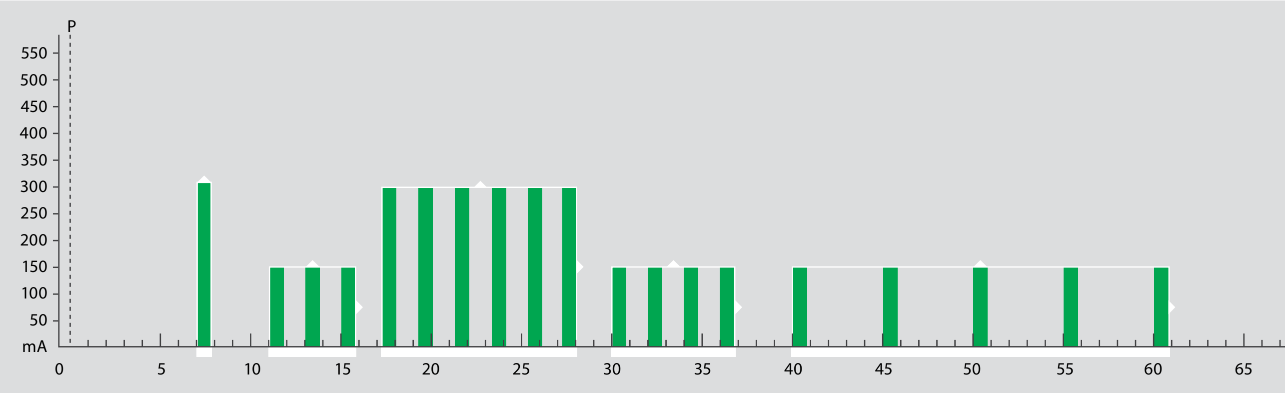
Ewoud Smit MD, PhD
Radiologist
Radboud University Medical Center
Nijmegen, the Netherlands

Protocol Outline

The Neuro ONE protocol performs a series of intermittent volume scans over a period of 60 seconds. The first volume is used as the mask for the dynamic subtraction, much like a mask in DSA.

A series of low-dose scans are performed, first for every two seconds during the arterial phase, and then spaced out to every 5 seconds to capture the slower venous flow. The exposure is increased during the peak arterial enhancement to provide superior 3D images of the intracranial arteries. These images are often preferred for evaluation of the fine peripheral arteries in 3D volume rendering.

Scan	kV	mA	Rotation Time	Sample Time	Acquisition Interval
1	80	430	0.75 s	7 s	-
2	80	300	0.75 s	11-15 s	2 s
3	80	420	0.75 s	17-27 s	2 s
4	80	300	0.75 s	30-37 s	2 s
5	80	300	0.75 s	40-60 s	5 s



The above protocol is standard in Aquilion ONE CT systems. Canon Application Specialists can also help you to create and use custom protocols.

Examination Guidelines

Patient Preparation and Positioning

- Give the patient a full explanation of the procedure (if possible).
- Place an 18- or 20-gauge cannula in the right arm.
- Position the patient for a lateral scanogram.
- Position the head as symmetrically as possible.
- Position the head so that the OM baseline (mid-orbit to EAM) is perpendicular to the floor (or as close as possible).
- Immobilize the patient with the head strap and pads to ensure that the patient remains still during the examination.

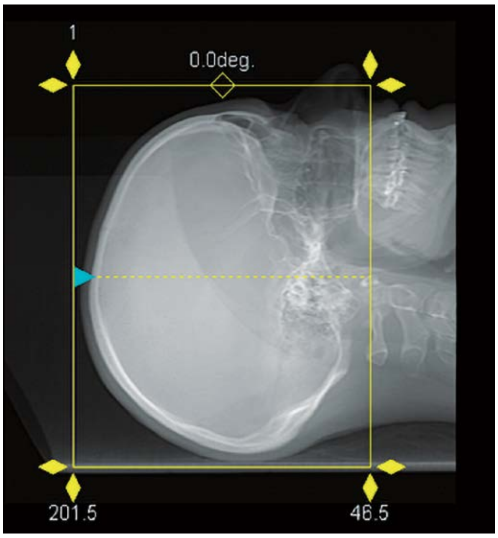
Guidelines for Neuro ONE Scanning

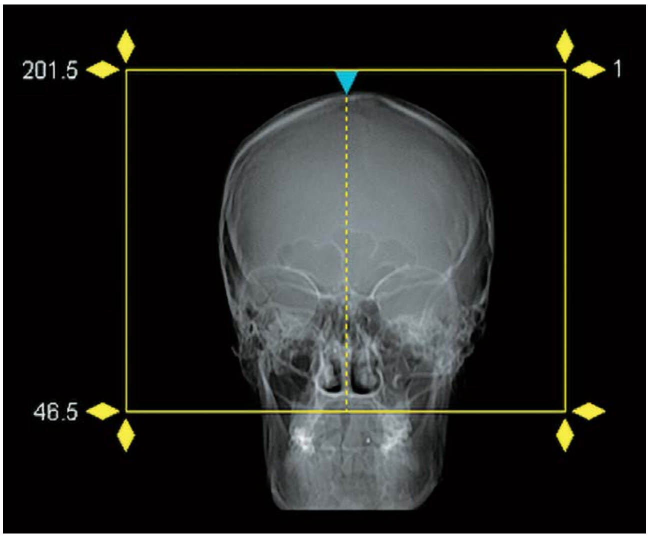
Select and perform the Neuro ONE brain perfusion protocol.

1. Acquire lateral and AP scanograms of the patient's head.

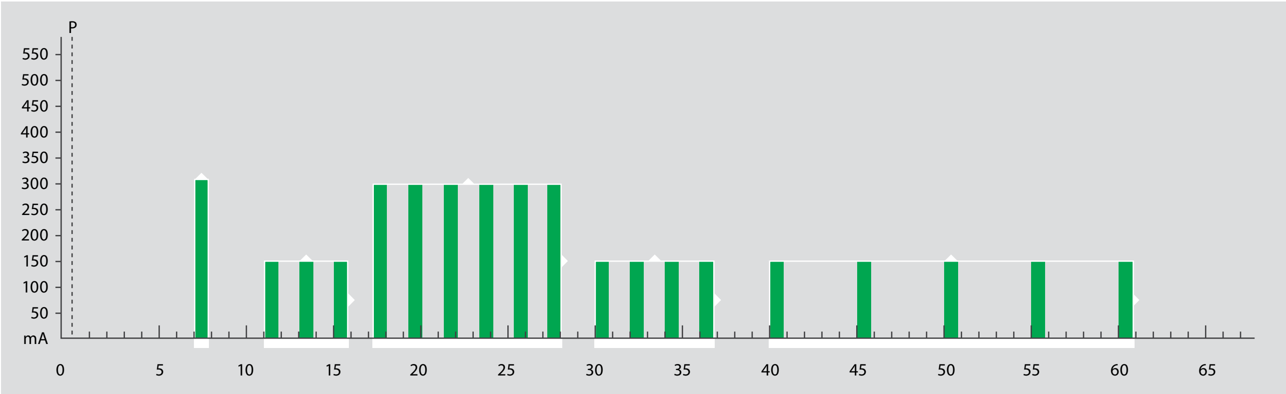
2. Position the dynamic volume sequence to cover the entire brain.

Scan Plan Example





Time Sequence Display



3. Set the power injector protocol and connect the injector to the patient.
   – The following injection protocol is recommended with a contrast medium iodine concentration of at least 350 mgI/mL.

Single-Phase Contrast Medium with Saline Flush	
Phase 1 (Contrast medium)	50 mL @ 4-6 mL/s
Phase 2 (Saline)	50 mL @ 4-6 mL/s

4. Start the injection and scan together.
   – This will ensure correct timing of the scan sequence.

Nineteen volumes will be automatically reconstructed from this protocol.

Examination Guidelines

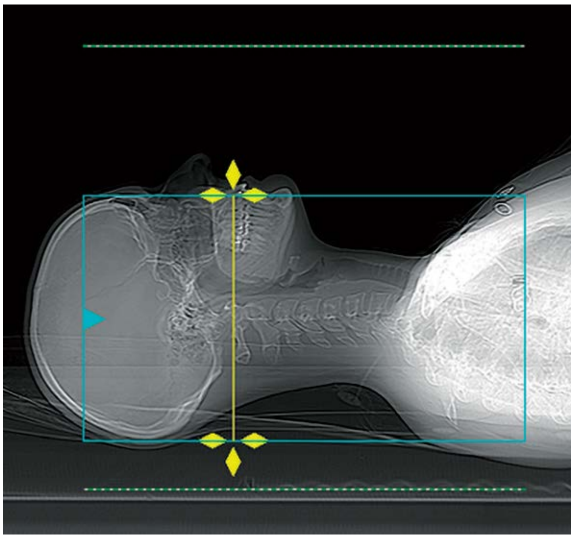
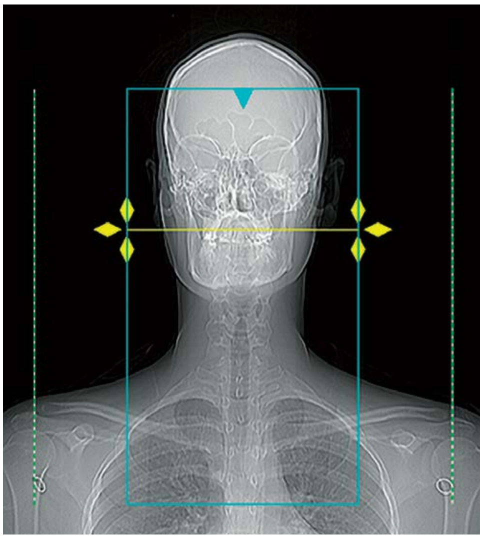
Guidelines for Carotid CTA Scanning (Site Option)

Following the Neuro ONE scan, a CTA of the carotid arteries can be performed to provide a complete diagnostic picture of the blood supply to the brain. The necessity of this scan will depend on your site's stroke workup protocol.

Select and perform the carotid CTA protocol.
- Scanograms to include the entire neck can be programmed into the Neuro ONE protocol, so reacquisition is unnecessary.

1. Position the carotid CTA scan to include the range from above the base of the skull to the aortic arch (top-down technique).

2. Position the SURE Start test slice below the base of the skull. Visual triggering will be used at the time the contrast medium reaches the internal carotid arteries.

A second injection of contrast medium is necessary for this scan.

3. Set the power injector protocol and connect the injector to the patient.
   - The following injection protocol is recommended with a contrast medium iodine concentration of at least 350 mgI/mL.
   - Use higher injection rates for large patients.
   - The contrast medium amount should be tailored to the scan time and injection rate used. This will ensure good washout of contrast medium arriving via the subclavian vein.

Single-Phase Contrast Medium with Saline Flush	
Phase 1 (Contrast medium)	XX mL @ 4-5 mL/s
Phase 2 (Saline)	50 mL @ 4-5 mL/s

XX = (Scan time + 10) × injection rate

4. Acquire the SURE Start image.
   – The scan is triggered manually as soon as contrast medium is seen.
   – Select Manual triggering.

5. Start the scan and injection together.

6. During SURE Start, click the "Next Scan" button as soon as contrast medium is seen.
   – Helical scanning will commence after the breathing instruction.

A Helical Volume will be reconstructed and automatically transferred to the Vitrea workstation for further evaluation of the carotid circulation.

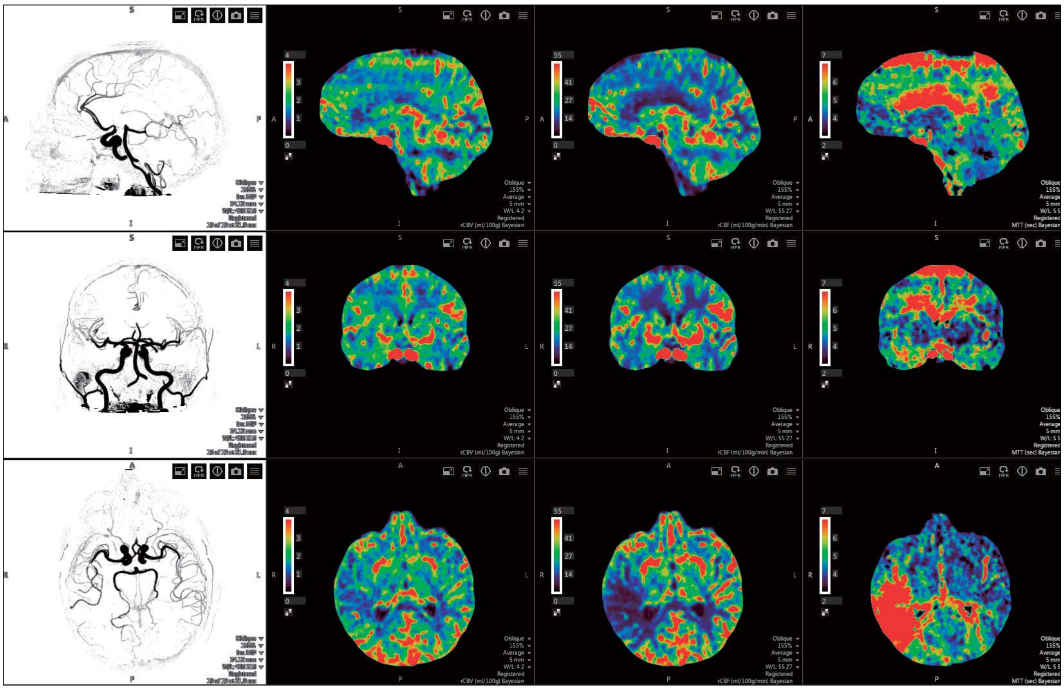
Note: As part of your site's stroke workup protocol, a diagnostic post-contrast brain scan may also be necessary. This is best performed after the carotid scan.

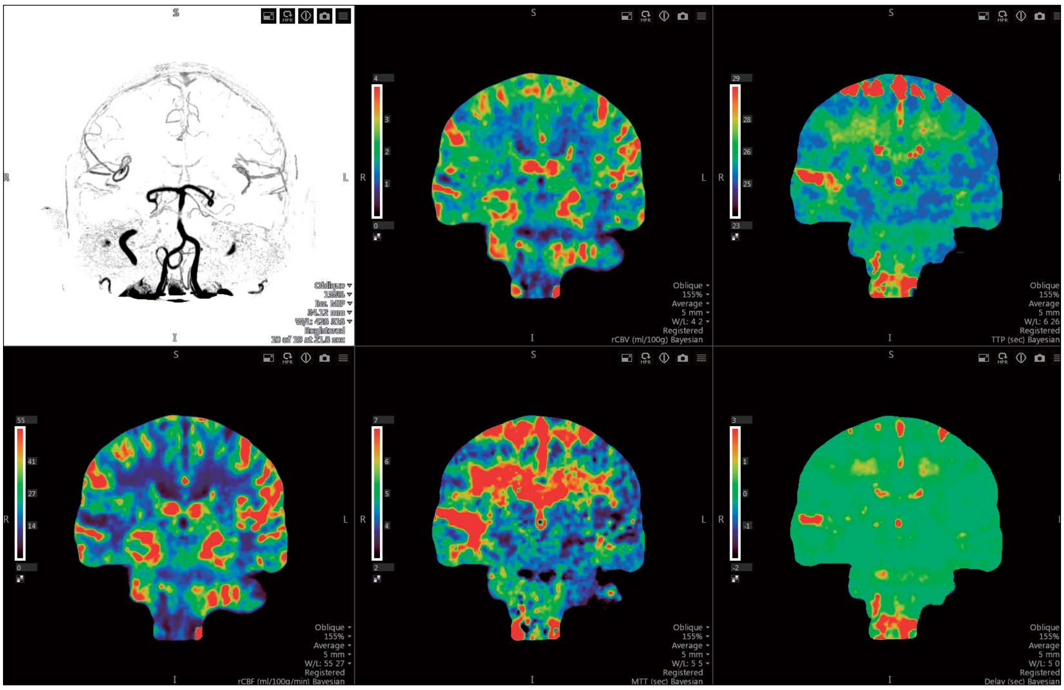
Neuro ONE for Stroke Post Processing: Vitrea

Following completion of the scan, the reconstructed volumes are automatically sent to the Vitrea for comprehensive analysis on the workstation. This software automatically generates volumetric multiplanar perfusion maps and subtracted 4D DSA images.

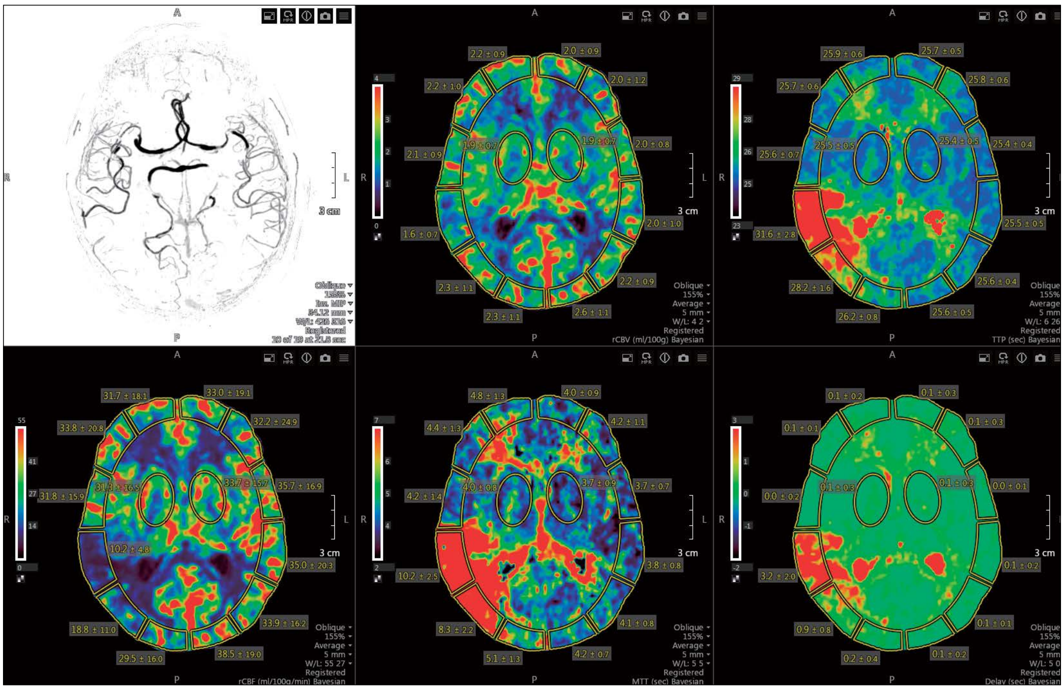
1. Load the datasets into the 4D brain perfusion protocol. Artery and vein selection is automatic.

2. Once the perfusion maps have been generated, multiple layouts are available for easy review.





3. Quantitative ROI measurements can be performed. Click on the desired template.



4D CT Digital Subtraction Angiography (DSA)

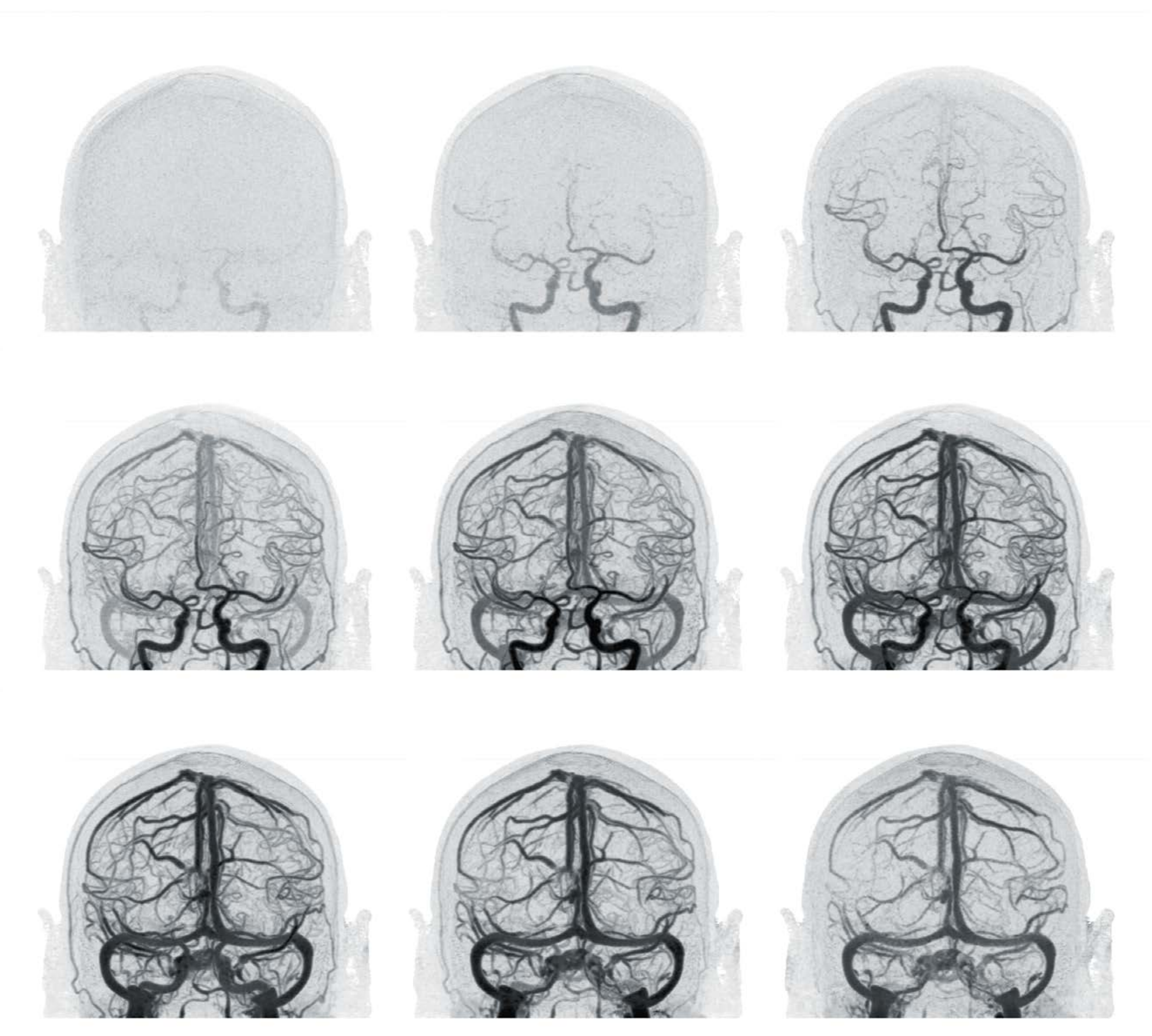
Introduction

This protocol provides dynamic subtracted images of the entire cerebrovascular circulation. Due to the low-exposure dose acquisition techniques made possible by dynamic volume imaging, this protocol is set to replace the standard Brain CTA scan performed routinely on multislice scanners today.

The “gold standard” in cerebrovascular system imaging is catheter angiography, which employs DSA to provide comprehensive review of the vascular circulation. 4D CT DSA provides the same dynamic information, with the additional benefit of producing subtracted volumetric data which can be rotated in any plane while reviewing the dynamic flow.

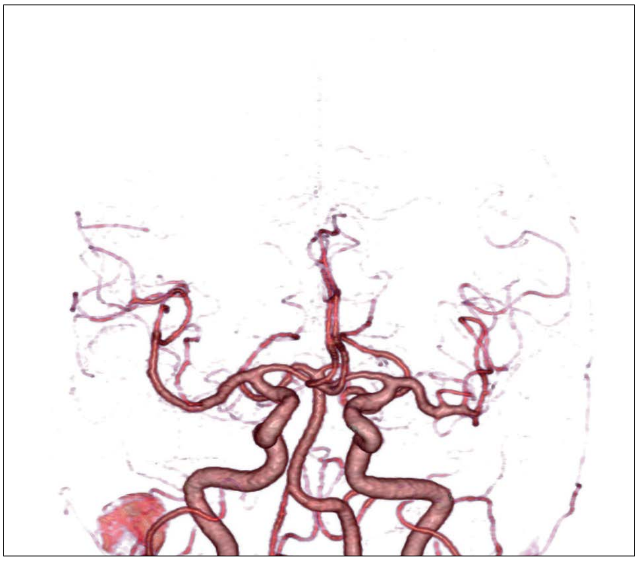
A test bolus scan is suggested to tailor the acquisition time for each patient to further reduce exposure dose.

4D CT DSA images

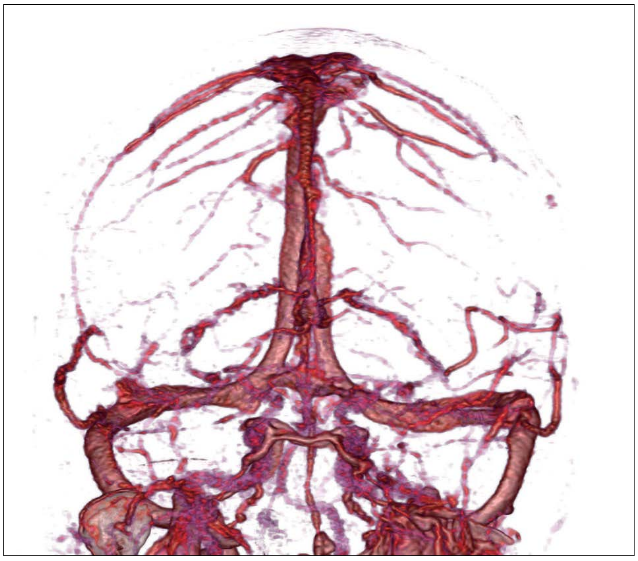


Moving Beyond Static Imaging

While fast multidetector systems armed with robust bolus tracking software produce excellent static images of the intracranial circulation, a pure arterial phase cannot be guaranteed for each patient's variable flow. Below is an example of the benefit of dynamic imaging where completely pure arterial and venous images can be generated, without overlying vessels that may obscure pathology. Additionally flow dynamics and aneurysm wall pulsation can be appreciated in 4D viewing.



Pure Arterial



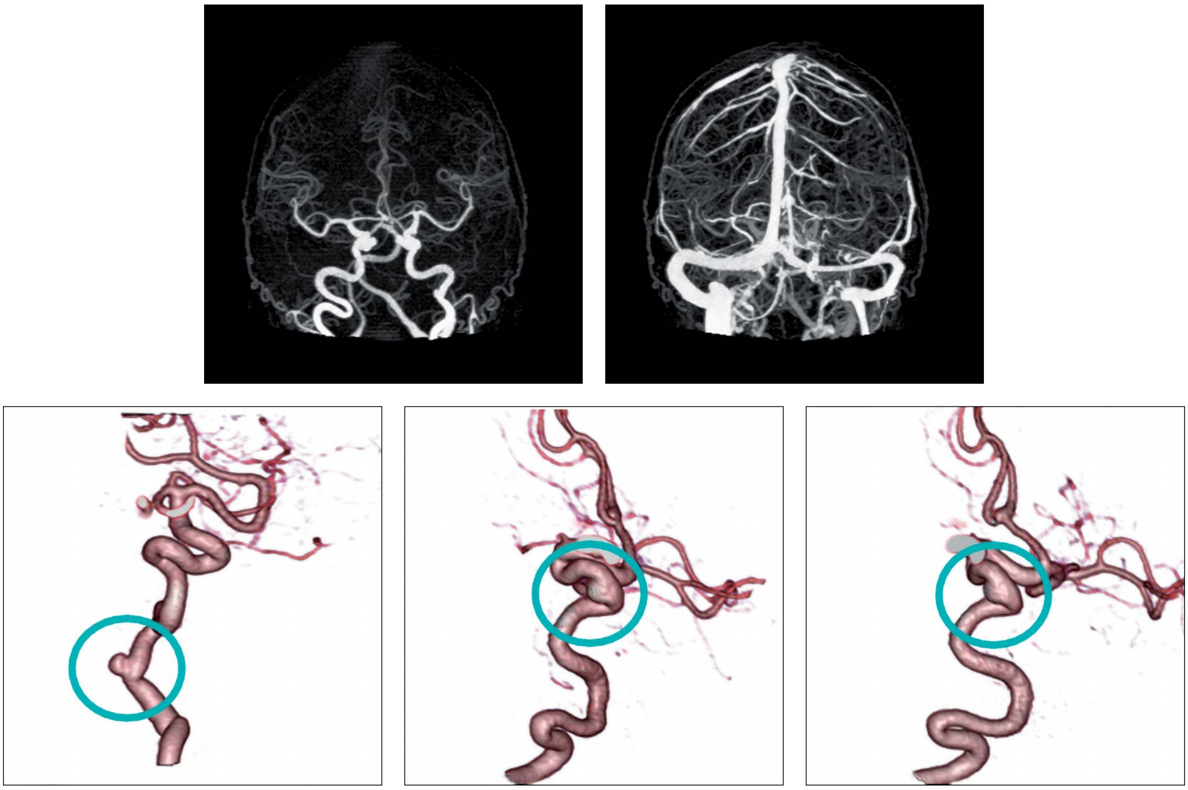
Pure Venous

4D CT Digital Subtraction Angiography (DSA)

Clinical Examples

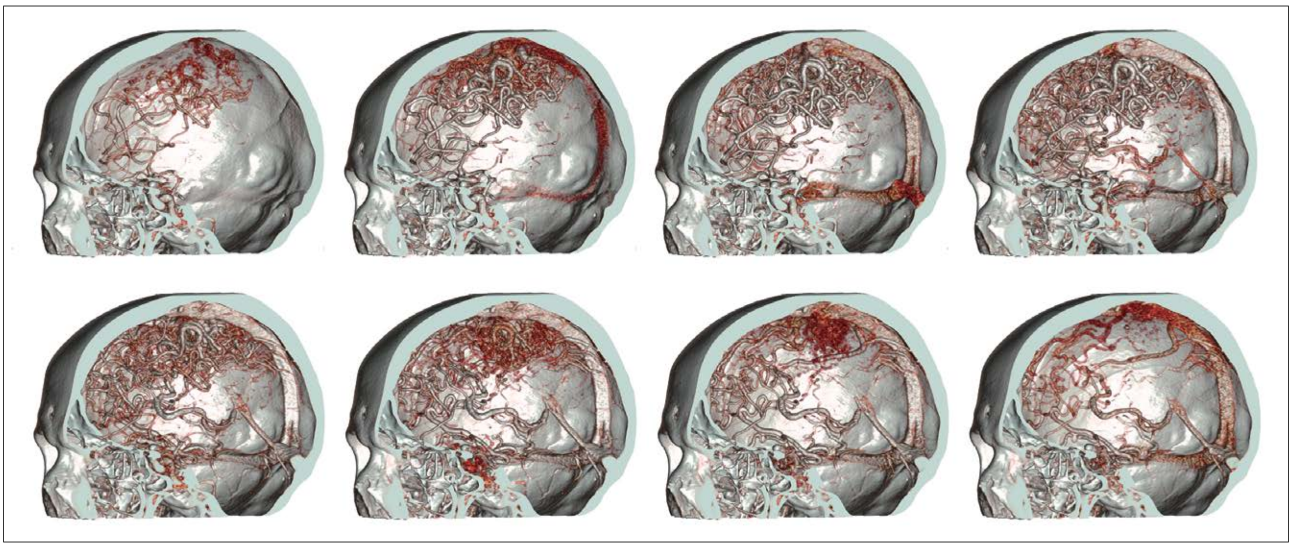
Aneurysm:

SURESubtraction software automatically subtracts the bone from every volume, providing outstanding images of the carotid arteries through the base of the skull. The two left internal carotid artery aneurysms would be very difficult to visualize without artifact-free subtraction.

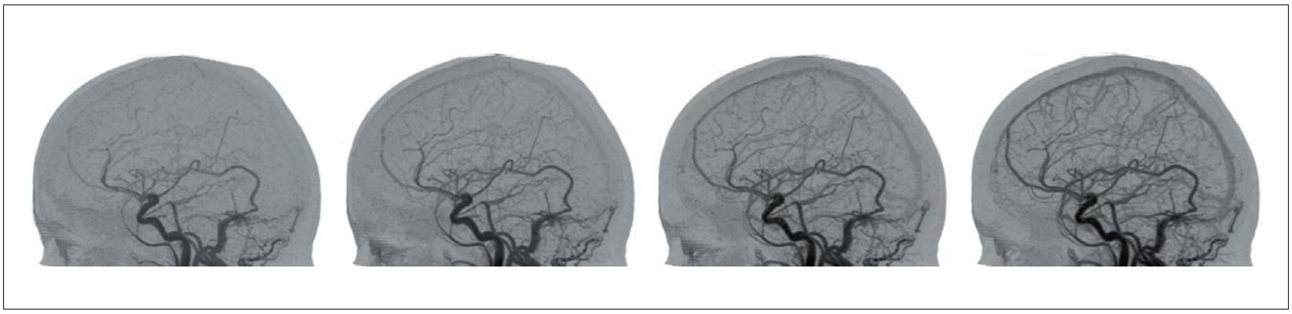


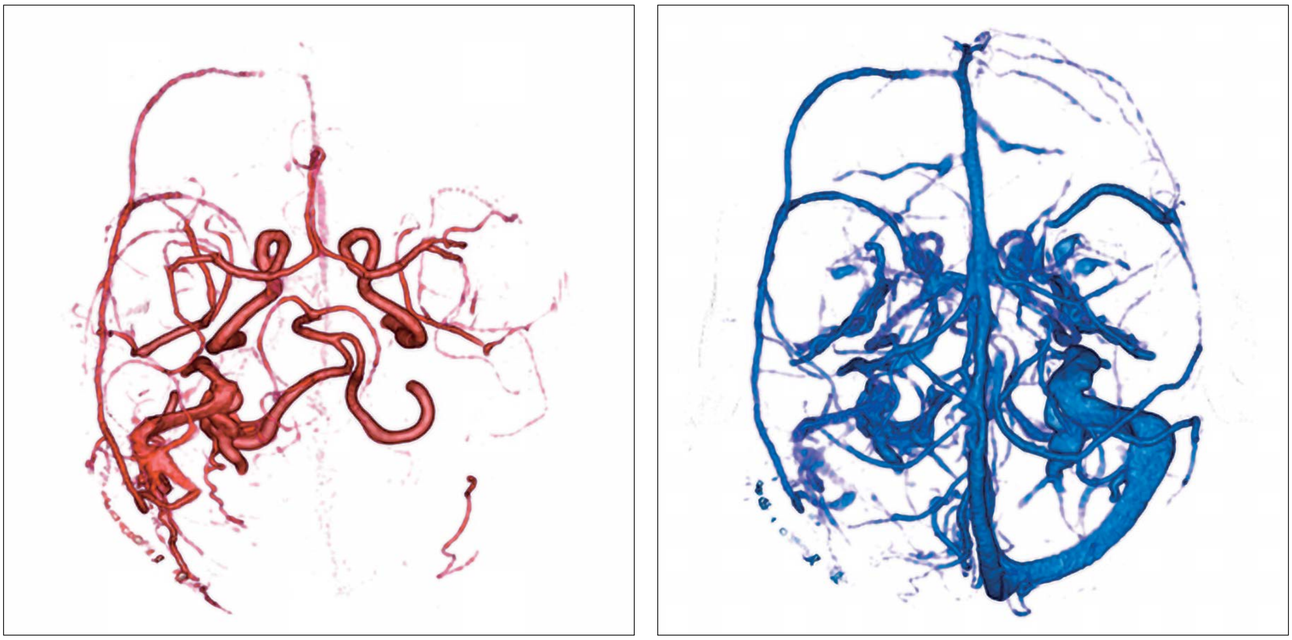
AVM:

The arterial vessels feeding this AVM are well demonstrated in this series of DSA images.



Fistula:
An aberrant vessel can be seen in the left posterior fossa. This vessel is supplied by small arteries arising from the occipital artery. The dynamic visualization of the flow of contrast medium greatly assists the physician in planning an interventional treatment approach for this patient.





The early venous filling on the left side can be appreciated in these true arterial and true venous phase images.

Examination Guidelines

Patient Preparation and Positioning

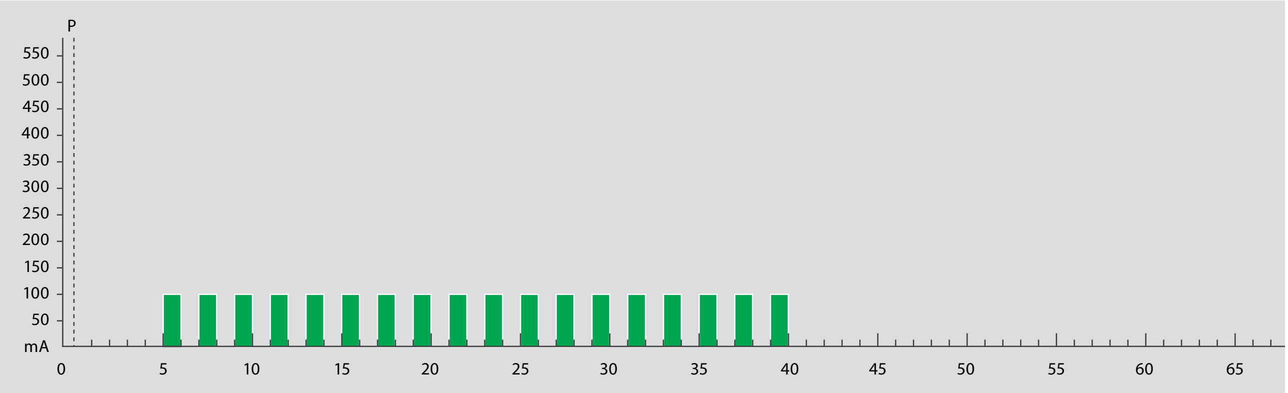
- Give the patient a full explanation of the procedure (if possible).
- An 18- or 20-gauge cannula should be placed in the right arm.
- Position the patient for a lateral scanogram.
- Position the head as symmetrically as possible.
- Position the head so that the OM baseline (mid orbit to EAM) is perpendicular to the floor (or as close as possible).
- Immobilize the patient with the head strap and pads to ensure that the patient remains still during the examination.

Guidelines for 4D DSA Scanning

A. Test Bolus
– **Select and perform the test bolus protocol.**

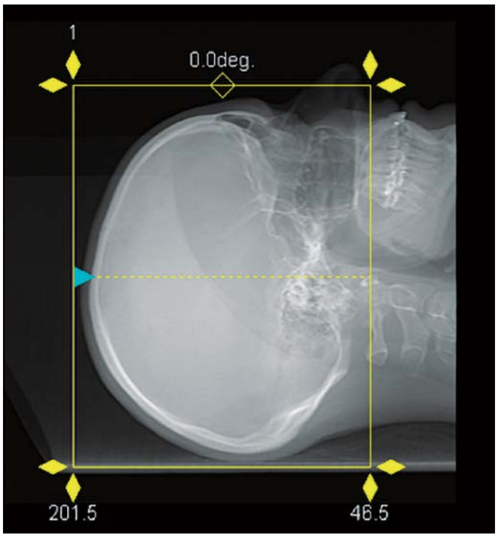
1. Acquire lateral and AP scanograms of the patient's head.

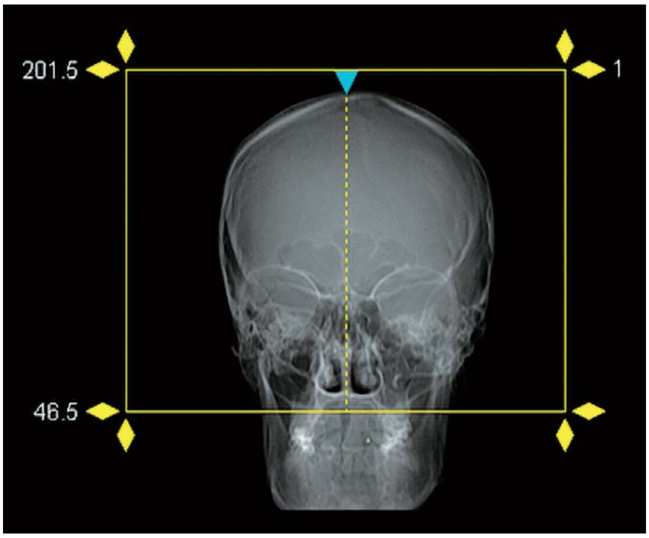
2. Position the Test Bolus slice just below the base of the skull.
   – Starting at 5 seconds and ending at 40 seconds, the test bolus protocol performs a series of low-dose scans at scan intervals of 2 seconds.



3. Start the test bolus scan and the contrast medium injection together.
   – The following injection protocol is recommended with a contrast medium iodine concentration of at least 350 mgI/mL
   – Use the same injection rate for the 4D DSA scan.

Single Phase Contrast Medium with Saline Flush	
Phase 1 (Contrast medium)	20 mL @ 4-6 mL/s
Phase 2 (Saline)	50 mL @ 4-6 mL/s

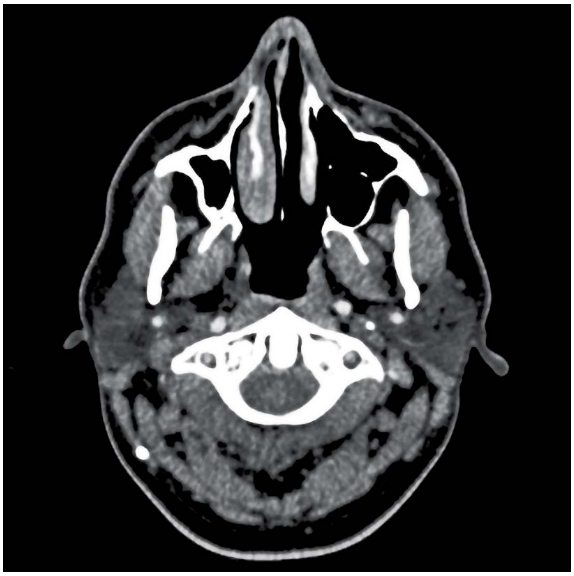




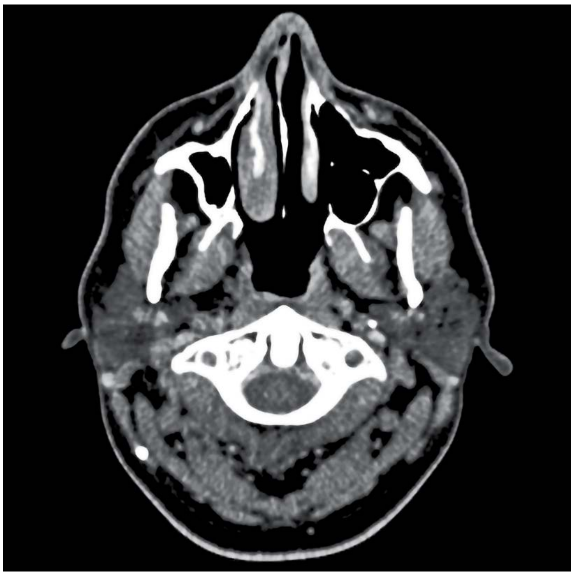
Examination Guidelines

4 Review the test bolus images and determine the contrast medium arrival time and venous washout time.
– This can be easily determined by the delay time shown on each image.

Arrival Time



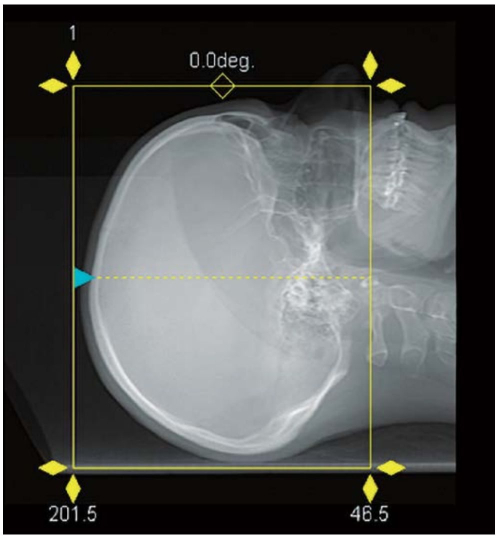
Washout Time

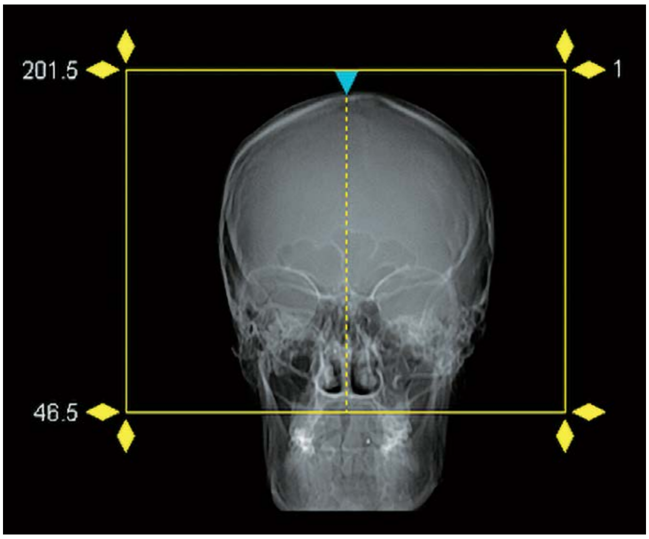


B. CT DSA Scan Protocol
– Select the 4D CT DSA protocol.

1. Position the volume to cover the entire brain.

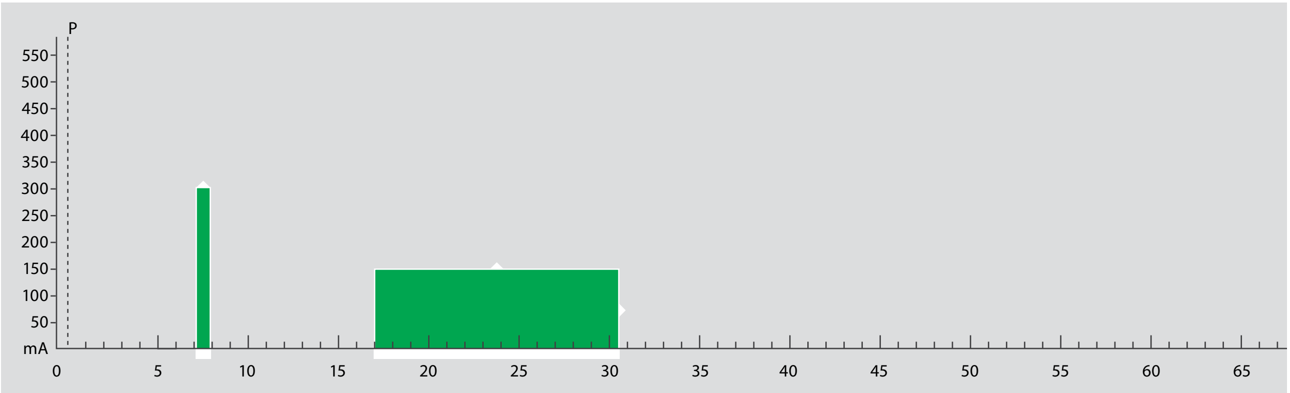
Note: The scan range can be reduced if clinically indicated.





2. Adjust the length of the continuous dynamic scan element as determined from the test bolus timing. This can be adjusted easily from the time sequence display screen.
   – The contrast medium arrival time determines the start of the continuous scan.
   – The venous washout time determines the end of the continuous scan.
   – The first scan is a noncontrast scan which is used as the mask for dynamic subtraction.

Scan	kV	mA	Rotation Time	Sample Time
1	80	310	0.75 s	7 s
2	80	150	0.75 s	17-30 s



3. Set the power injector protocol and connect to the patient.
   – The following injection protocol with a contrast medium iodine concentration of at least 350 mgI/mL is recommended.

	Amount
Phase 1 (Contrast medium)	50 mL @ 4-6 mL/s
Phase 2 (Saline)	50 mL @ 4-6 mL/s

   Faster injection rates will provide a higher contrast-to-noise ratio and allow superior pure arterial phase and venous phase viewing.

4. Start the injector and scan together.
   – This will ensure correct timing of the scan sequence.

Examination Guidelines

Temporal Resolution and 4D DSA

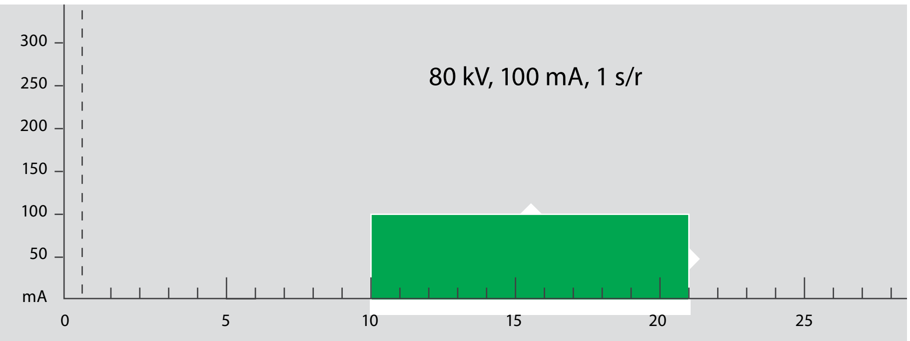
There are two types of temporal resolution in this scan.

Image temporal resolution
- How well patient motion is frozen
- Determined by the gantry rotation speed and reconstruction method (full vs. half)

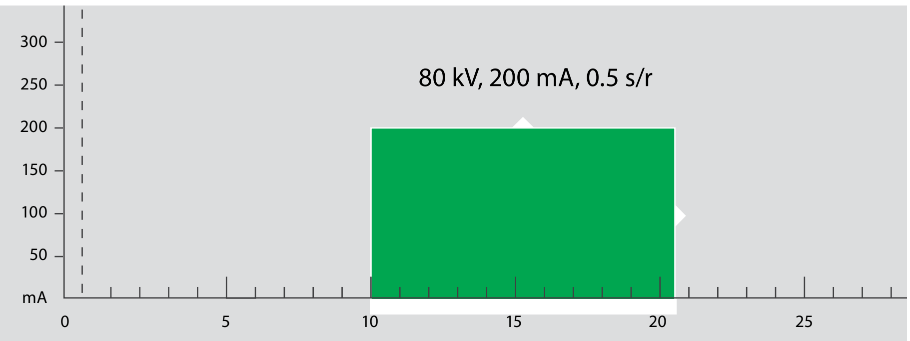
Physiological temporal resolution
- How often physiological motion is sampled
- Determined by the reconstruction time interval for a continuous dynamic volume scan

Exposure Dose

The exposure dose for the 4D CT DSA protocol depends specifically on the parameters for the continuous dynamic volume scan. The total scan time, as well as the rotation time, directly affects the total exposure dose. If the rotation time is halved, the mA must be doubled to maintain an appropriate signal-to-noise ratio. Although this will provide images with superior image temporal resolution, it will also result in a higher exposure dose.



Total mAs = 100 mA × 11 s



Total mAs = 200 mA × 10.5 s

Decreasing the rotation time requires an increase in mA to maintain image quality. However, the exposure dose will be increased.

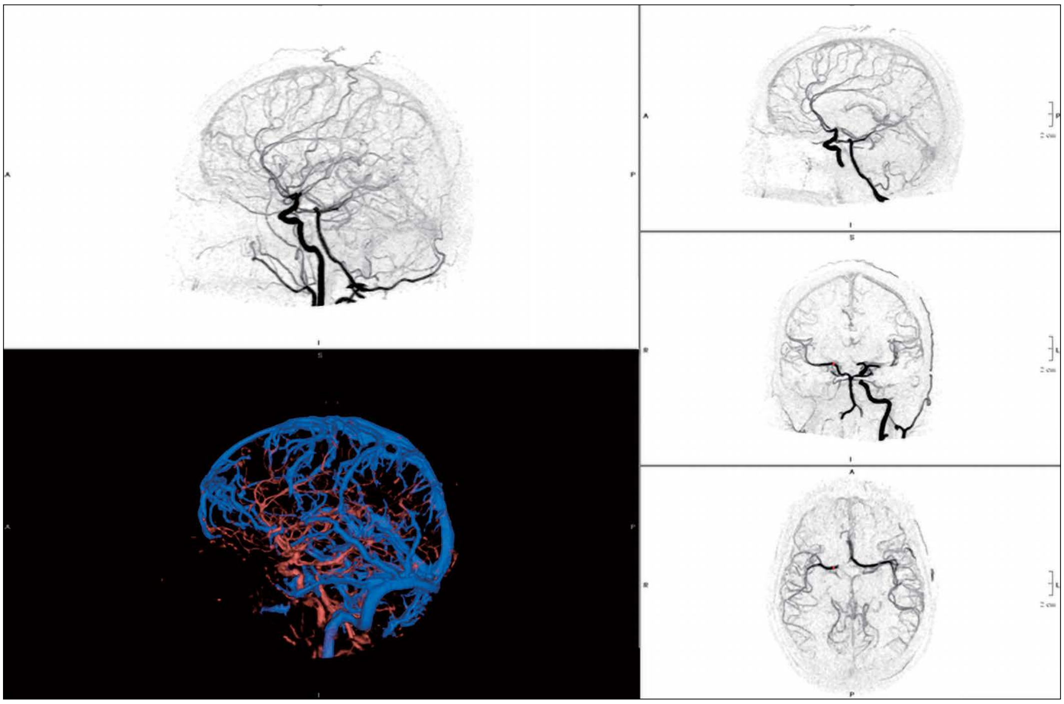
Modifying the total exposure time based on the test bolus scan for each patient's clinical presentation is the most effective way to reduce exposure dose.

4D DSA Post Processing: Vitrea

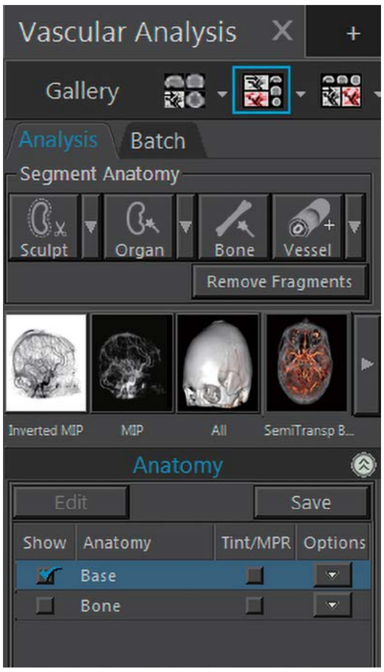
Following completion of the scan, the reconstructed volumes are automatically sent to the Vitrea for comprehensive analysis on the workstation. This software automatically generates subtracted 4D DSA images.

1. Load the datasets into the 4D DSA protocol.

2. The fully automatic subtraction will be complete within 90 seconds and will then be immediately ready for review.



3. The color of the CTA/CTV fusion image can be changed using the region management tools.



Calculating Perfusion

Introduction

Only eight years after Sir Geoffrey Hounsfield performed the first head CT scan on a human patient (to examine a cranial cyst), Dr. Leon Axel proposed that dynamic CT could be used to measure tissue perfusion.

The perfusion of oxygenated blood is not directly observable. It is approximated by measurements of enhancement following the introduction of a radio-opaque contrast agent such as intravenous iodine.

There are several mathematical models that have been developed to approximate perfusion.

Basic Principles

Quantitative perfusion is calculated from a dynamic CT acquisition during the intravenous injection of contrast media. The perfusion software requires three input readings:

1. Arterial Enhancement Time Density Curve (TDC).
2. Venous Enhancement Time Density Curve (TDC).
3. Tissue Enhancement Time Density Curve (TDC).

As the target arteries in the brain can be affected by partial volume averaging, the venous TDC is used to correct the height of the arterial TDC.

Brain tissue perfusion can be calculated by looking at the difference between the arterial TDC and the tissue TDC's. (Perfusion is calculated for each tissue voxel).

Arterial TDC

Tissue TDC

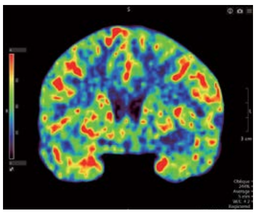
Perfusion Algorithms

SVD+

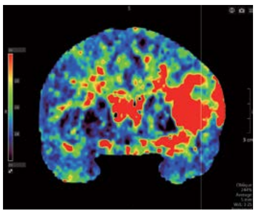
There are several types of deconvolution that can be used for perfusion analyses. Singular Value Decomposition (SVD+) is a delay insensitive SVD algorithm that uses an innovative technique to account for delayed blood flow and perform calculations with fast computation times. SVD algorithms are often viewed as the most accurate method because they rely on less assumptions than other methods, however these algorithms are sensitive to noise and in some occasions, can result in underestimation of high MTT and CBF values and overestimation of low CBF values in certain conditions. SVD+ has been superseded by the Bayesian algorithm but is used for follow up studies where the same algorithm should be used.

Bayesian

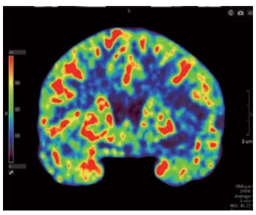
Canon Medical Systems has now introduced the Bayesian post processing algorithm to the CT perfusion application. The Bayesian method is a probabilistic algorithm, which is based on the Bayes theorem[2]. The Bayesian algorithm aids clinicians to evaluate CT perfusion images with accurate perfusion mapping which enables a more confident diagnosis. Bayes theory of probability was first published in the 18th century. The theory allows the combination of experimental data and priori information about the parameters of a model (such as CBF and MTT values), to generate a robust probability distribution for these parameters[3]. Thanks to this probabilistic approach, the parameter estimations are more robust[2]. The Bayesian method uses a probabilistic approach to CT perfusion, which is delay insensitive. The algorithm calculates a delay in CT perfusion independent of MTT values, giving highly accurate estimates of delay values. This has been validated in a number of studies[4-9]. Sometimes when performing CT perfusion high levels of noise often prevent the accurate estimation of penumbra volumes when using deconvolution based methods. In comparison, the Bayesian method is more robust against noise[9]. In CT perfusion studies, Bayesian has been reported to outperform SVD based algorithms, in particular for CBF and MTT computation[6].



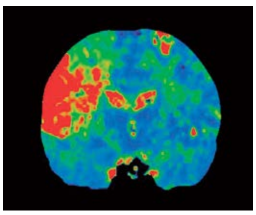
Cerebral Blood Volume (CBV)
- Volume of blood per unit brain tissue
- In units of mL per 100 grams of brain tissue
- CBV permits evaluation of autoregulation



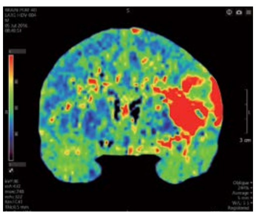
Time To Peak (TTP)
- Length of time for brain tissue to reach peak density enhancement
- In units of seconds
- TTP is an indicator of delayed flow due to stenosis or occlusion
- TTP is also helpful in identifying collateralization



Cerebral Blood Flow (CBF)
- Amount of blood flowing through capillaries per unit time per unit tissue
- In units of mL per minute per 100 grams of brain tissue
- CBF identifies areas of low blood flow



Tmax
- Measured in seconds
- An indicator of delayed or dispersion of flow
- Tmax is theoretically the arrival delay between the AIF and contrast



Mean Transit Time (MTT)
- Average time for blood to move through capillary vessels
- In units of seconds
- An increase in MTT can indicate a vasodilatory response to reduced flow

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