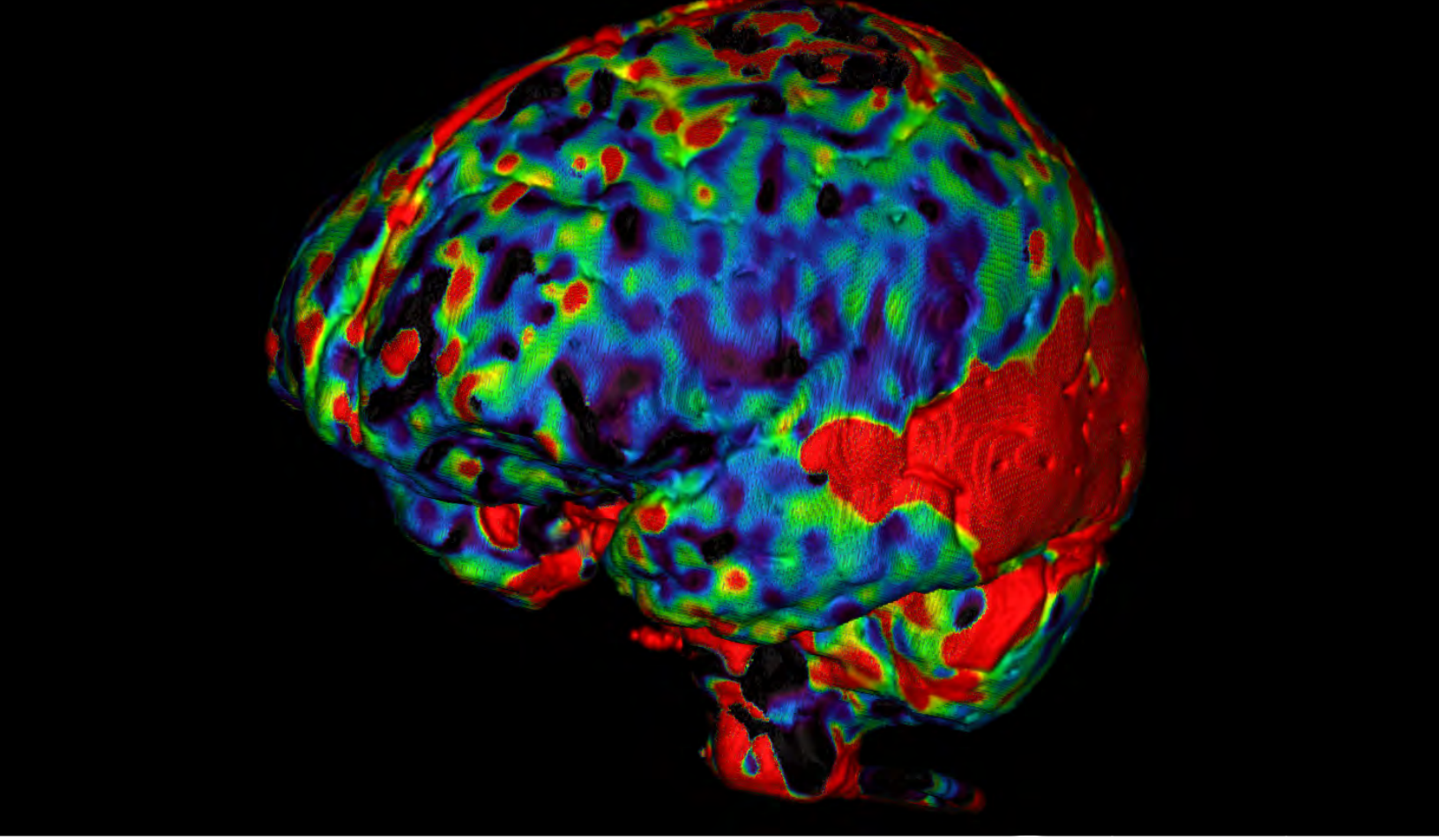
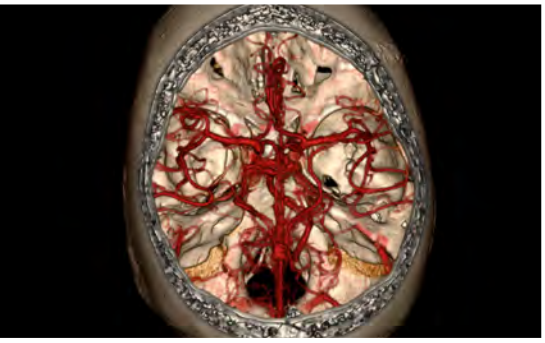
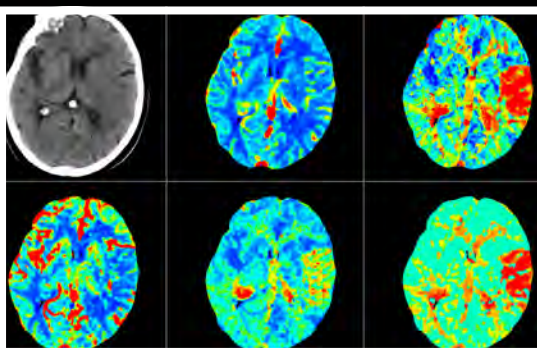






Vitrea Advanced®
Vitrea Workstation®

Education and Reference Guide

Neuro

VITAL U®

Copyright © 1997 - 2014 Vital Images, Inc. All rights reserved. Date of Publication September, 2014
VitreaWorkstation™ protected by U.S. Patents 5,986,662; 6,130,671; 6,219,059; 7,031,504; 7,136,064; 7,362,329; 7,574,029; 7,590,272; 7,660,481;7,929,748;7,991,210; 8,214756; 8,249,687 Other Patents Pending in the U.S. and other countries.
VitreaAdvanced® protected by U.S. Patents 5,986,662; 6,130,671; 6,219,059; 7,031,504; 7,136,064; 7,362,329; 7,574,029; 7,590,272; 7,660,481;7,929,748;7,991,210; 8,214756; 8,249,687 Other Patents Pending in the U.S. and other countries.
VitreaCore™ protected by U.S. Patents 5,986,662; 6,130,671; 6,219,059; 7,039,723; 7,136,064; 7,362,329; RE42,952; Other Patents Pending in the U.S. and other countries.

REF VPMC-13505 A VitreaAdvanced - VitreaWorkstation Neuro Education and Reference Guide

This publication is valid for VitreaAdvanced 6.7, Vitrea fX 6.7, and Vitrea Enterprise Suite (VES) 6.7 and later software versions.
No part of this work may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic or mechanical, including photocopying and recording, or by any information storage or retrieval system without permission in writing from Vital Images.

Trademarks

"Vitrea", "Vital Images", "VitreaAdvanced", "Vital", "Vital U", and "VitreaView" are registered trademarks of Vital Images, Inc.
All other marks are property of their respective owners.

Restricted Rights Legend

If this software or documentation is delivered to the Department of Defense (DOD) of the U.S. Government, it is delivered with Restricted Rights as follows:
Use, duplication or disclosure of the software by the U.S. Government is subject to restrictions as set forth in subparagraph (c)(l)(ii) of the Rights in Technical Data and Computer Software clause at DFARS 252.227-7013.
If this software or documentation is delivered to any unit or agency of the U.S. Government other than DOD, it is delivered with Restricted Rights and use, duplication or disclosure by the U.S. Government is subject to the restrictions as set forth in FAR 52.227-19 (b)(3). If the software or documentation is delivered to NASA, it is delivered with Restricted Rights subject to the restrictions set forth in 18-52.227-86(d) of the NASA FAR Supplement.

Limits of Liability and Disclaimer of Warranty

VITAL IMAGES SHALL HAVE NO LIABILITY OF ANY KIND FOR ANY DIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES BASED ON ANY DEFECT, FAILURE OR MALFUNCTION OF THE SOFTWARE,OR USE OF ANY VITAL IMAGES DOCUMENTATION, WHETHER THE CLAIM IS BASED UPON WARRANTY, CONTRACT, TORT OR OTHERWISE. VITAL IMAGES MAKES NO WARRANTY, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO, ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE WHETHER ARISING FROM STATUTE, COMMON LAW, CUSTOM OR OTHERWISE.

Notice of Confidentiality

This software and the information in this software including, but not limited to, the ideas, concepts and know-how are proprietary, confidential and trade secret to Vital Images, and the information contained therein shall be maintained as proprietary, confidential and trade secret to Vital Images and shall not be copied or reproduced in any form whatsoever. This software and any information contained therein shall not be disclosed to anyone other than authorized representatives of the user's employer, who is contractually obligated not to disclose same without the express written consent of Vital Images. The user of this software and any information contained therein shall not attempt to discern Vital Images' confidential and trade secret information and shall not reverse compile, disassemble, or otherwise reverse engineer this software or any information contained therein.

Software License Notice

This software is a licensed product of and is distributed by Vital Images, and may only be used according to the terms of that license on the system identified in the License Agreement. In the event of any conflict between these terms and the terms of any written agreement or agreement assented to through electronic means with Vital Images, the terms of such written or assented agreement shall control.

CE 0086

EC REP

MDSS GmbH
Schiffgraben 41
30175 Hannover, Germany

Australian Sponsor:
CELEO Pty Ltd
15 Alvarado Court
Broadbeach Waters, QLD 4218
Australia

Australian Sponsor:
Toshiba Australia Pty Ltd
PO Box 350
North Ryde, NSW 1670
Australia

CELEO Pty Ltd. and Toshiba Australia Pty Ltd are authorized sponsors in Australia and act on behalf of Vital Images, Inc. in the communication of safety-related incidents and regulatory matters with Therapeutic Goods Administration in Australia. Distributors are still the first line of communication with their customers regarding service and complaints.

Manufactured by: Vital Images, Inc.; 5850 Opus Parkway, Suite 300; Minnetonka, MN, US; 55343; Phone 866.433.4624

Safety and Regulatory Considerations

PLEASE REFER TO THE **ABOUT VITAL IMAGES MEDICAL IMAGING SOFTWARE** DOCUMENT BEFORE USING THIS PRODUCT. This document includes important information regarding general Vitrea Safety and Regulatory considerations.

CAUTION: Federal law restricts this device to sale by or on the order of a physician, as directed by 21 CFR 801.109(b)(1).

Contact Us

- For general, non-technical support questions, contact us through our Web site: www.vitalimages.com.
- For customer technical support, contact us:
  - In the U.S., call the Customer Support line at 1.800.208.3005.
  - Outside the U.S., contact your Vital distributor.
  - Send an email to support@vitalimages.com.
- For a printed version of the Release Notes, Education and Reference Guide, or Installation Guides, contact Customer Support at 1.800.208.3005.

Release Notes

Vitrea Release Notes contain late-breaking information not available at the time the Education and Reference Guide was released. This document is available from your System Administrator or from Vital Images.

Table of Contents

Safety and Regulatory Considerations iv
Contact Us iv
Release Notes iv

CT Carotid 7

Contents 7
CT Carotid Artery Overview 8
CT Carotid Artery Lesson 8
Additional Procedures. 22

CT Circle of Willis Analysis 33

Contents 33
CT Circle of Willis Analysis Overview 34
CT Circle of Willis Analysis Lesson 34
Additional Procedures. 37

CT Brain Perfusion 2D 47

Contents 47
CT Brain Perfusion 2D Overview 49
CT Brain Perfusion 2D Lesson 52
Additional Procedures. 61
Appendix 72

- Input Artery and Output Vein Positions 72
- CT Brain Perfusion Measurements 74
- Calculations 75
- Perfusion Image Map Calculations 78
- Summary Map 80

CT Brain Shuttle Perfusion. 83

Contents 83
Brain Shuttle Perfusion Overview 85
Brain Shuttle Perfusion Lesson 88
Additional Procedures. 97

Troubleshooting 109
Appendix 112
Calculations 112
Perfusion Image Map Calculations 114
Summary Map 116

CT Brain Perfusion 4D for Vitrea fX. 119

Contents 119
CT Brain Perfusion 4D Overview 121
CT Brain Perfusion 4D Lesson 124
Additional Procedures. 137
Troubleshooting 151
Appendix 154
Calculations 154
Perfusion Results 156
Summary Map 158

MR Tumor Volume. 161

Contents 161
MR Tumor Volume Overview 161
MR Tumor Volume Lesson 163
Additional Procedures. 167

Index. 169

CT Carotid

Contents

CT Carotid Artery Overview

CT Carotid Artery Lesson

- **I** Select Study
- **II** Choose Protocol and Preset
  - Data Manager
  - Gallery Window
- **III** Perform Analysis
  - Automatically Remove Bone
  - Segment Vessels
  - Probe the Carotids
  - Extend a Probed Vessel
  - Define a Lesion
  - Define a Lesion
  - Lesion Measurements
  - Vessel Probe Curved Inset View
  - Measure Centerline Length
  - Create Centerline Angles
  - Take Snapshots
- **IV** Distribute Findings

Additional Procedures

- Point-of-Interest View Mode
- Switching Active Volumes

- Manual Stenosis Measurement
- Rotate CPR Views
- Trim CPR Views
- Measure Density in CPR Views
- Create an Automatic MIP
- Automatic Curved Reformats
- Head and Neck Bone Subtraction

CT Carotid Artery Overview

The CT Carotid workflow the ability to visualize vessel structures.

The evaluation of contrast filled carotid arteries can be performed with one-click segmentation using Vitrea. The one-click segmentation permits you to easily calculate arterial stenosis and plaque burden.

NOTE: Because of the high HU value of contrast media in 100kV scans, the reliability of calcium detection within the vessel lumen is expected to be lower than that of regular kV scans.

CT Carotid Artery Lesson

I. Select Study

Load a Carotid study.

See the instructions for your Vitrea type (VitreaAdvanced Through the Data Manager or VitreaWorkstation) in the **Select Study** chapter of the

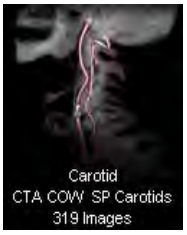
VitreaAdvanced-VitreaWorkstation General Education and Reference Guide.

II. Choose Protocol and Preset

Use one of these procedures:

Data Manager

- Double-click the **Carotid** application thumbnail.



Gallery Window

1. On the Gallery window, select the **Vascular: Carotid CT** protocol.

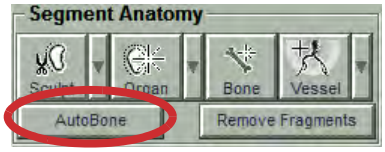
   The Gallery choices update automatically.

2. Click Pick next to the **3D Analysis** preset.

III. Perform Analysis

Automatically Remove Bone

1. In the Segment Anatomy Area, click **AutoBone.**



2. Review the segmentation and use the Manually Segment Bone technique to segment any additional bone regions.

Segment Vessels

You can segment additional vessels that the automatic vessel segmentation missed.

NOTE: The default window/level value is the optimal setting for vessel segmentation using dynamic grow in COW studies.

3. In the Segment Anatomy area, select the dropdown arrow next to Vessel and click

.

4. Click and hold on a vessel.

TIP: Watch the blue selection area “grow”. Keep holding until entire vessel is selected.

5. Repeat from step 3 for other vessels.

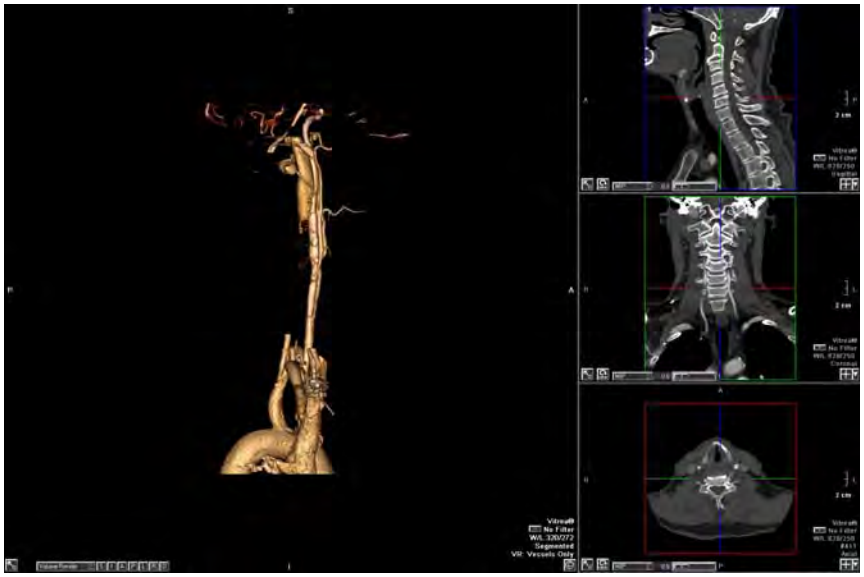
6. Click

.

7. Apply Visualization settings to the Vessels region.

Probe the Carotids

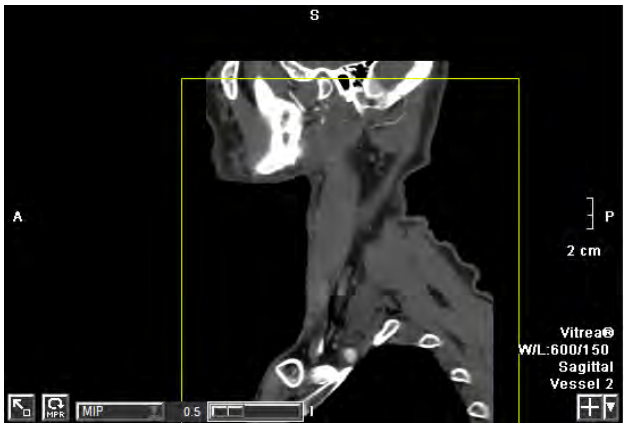
8. Press **F7** to display the Right Lateral view or press **F6** to display the Left Lateral view.



9. To remove a portion of the jaw to view the distal portions of the carotid:

   a. Press T to activate the **Trim** tool.

   b. On the Sagittal MPR view, click and drag the yellow line to the desired location.



c. To undo the trim, click the Reset Trim Limits icon.

10. On the Analysis tab, click

.

11. Probe the internal carotid followed by the external carotid artery bilaterally in 3D or any MPR view:

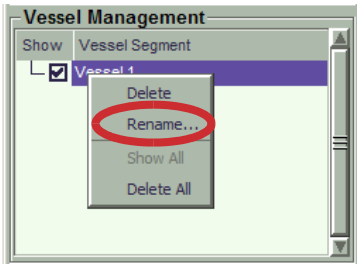
TIP: You may need to rotate the image to get the best view of the vessel in the 3D view.

a. Click the vessel.

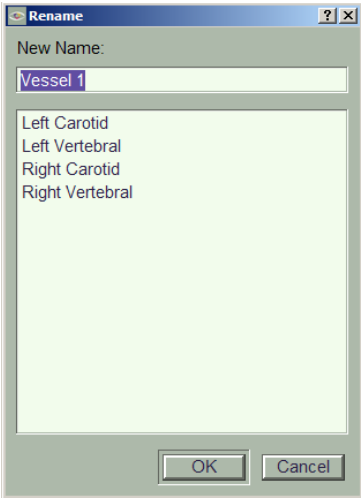
The Vessel Management box displays named vessels and unnamed vessels to show progression of work.

b. Select the vessel in the Vessel management box. Right-click and select **Rename**, or double-click on the vessel name.

The Rename dialog box displays.



c. In the New name field, select a name from the list or type the name of the vessel.



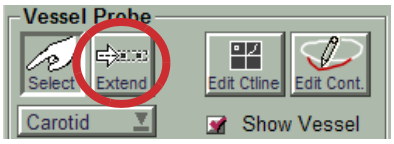
d. Click **OK**.

Extend a Probed Vessel

12. If the vessel you want to extend is not the currently selected vessel in the Vessel Management list, click the vessel name to select it.

13. Rotate the image to display the desired area of the vessel.

14. Click **Extend**.



The cursor changes to a pointed finger .

15. Click a point farther along the already selected vessel.

TIP: If the vessel probe can extend the vessel, it adds to the current vessel indicator line. If the vessel probe cannot extend the vessel, the status line displays the message Failed to find vessel.

16. To refine the vessel indicator line, drag the cursor along the vessel indicator line to a desired end point and click.

TIP: As you drag the cursor, the vessel indicator line disappears. It will not be removed until you click.

Define a Lesion

The Lesion tool defines a lesion in the vessel in either of the CPR views.

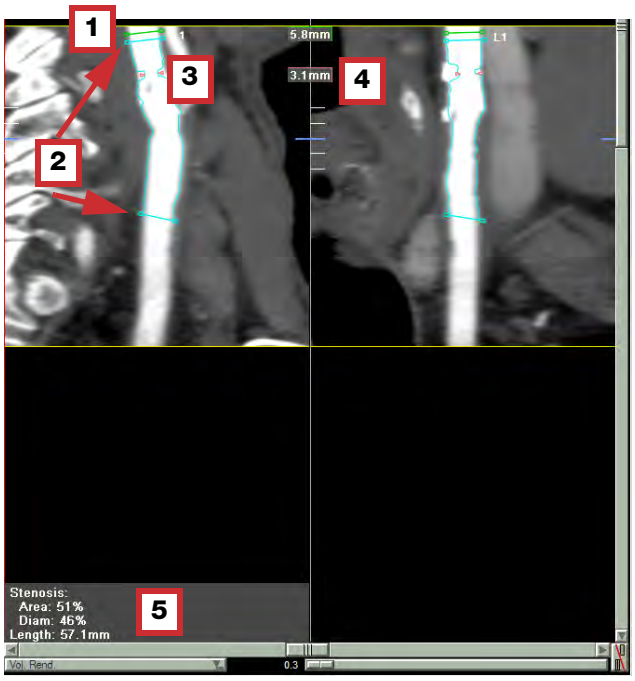
17. From the Analysis tab, verify **Show Vessel** is selected.

18. In the Vessel Tools area, click the dropdown for the second button.

The dropdown contains the following tools:

Single - When you draw a lesion using the Single method, Vitrea identifies a point as the reference point. Vitrea displays the area and minimum diameter at the narrowest point and at the reference point, and uses these measurements to calculate the area and diameter stenosis.

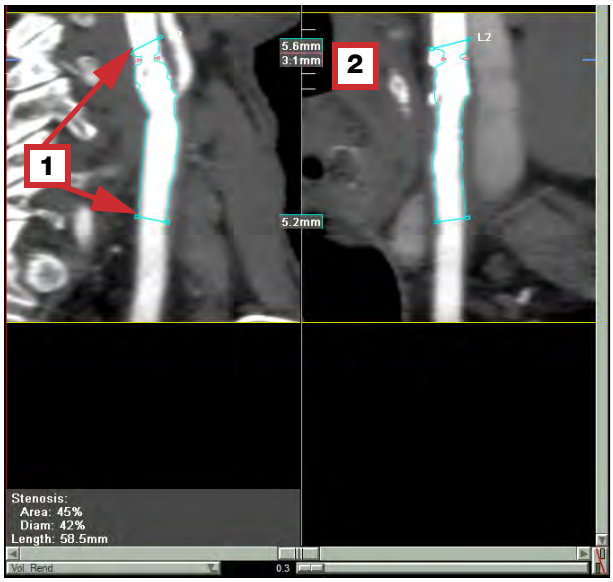
TIP: The reference point may need to be moved manually.



Callout	Description
1	Green line indicates reference point

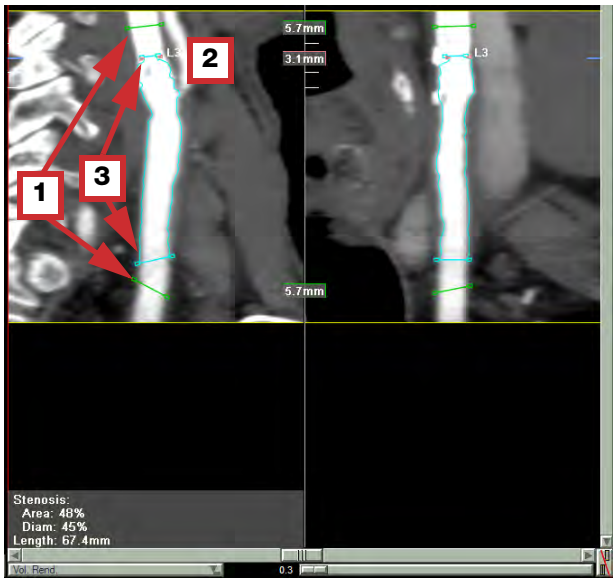
2	Cyan lines indicate start and end points of lesion
3	Red arrows indicate stenosis point
4	Minimum lumen diameter at the stenosis point
5	Stenosis measurements

Average - When you draw a lesion using the Averaged method, Vitrea calculates the average of the area and minimum diameter for the start and end points. It compares these measurements to the area and minimum diameter at the narrowest point to create stenosis measurements.



Callout	Description
1	Averages diameter/area (top and bottom line) as the reference measurement
2	Minimum lumen diameter at the stenosis point

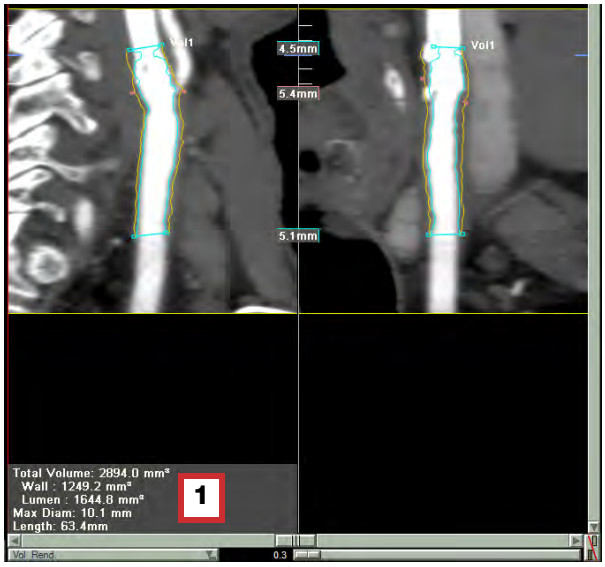
Dual -When you draw a lesion using the Dual Reference method, Vitrea calculates the average of the area and minimum diameter for the reference points marked with green lines. It compares these measurements to the area and minimum diameter at the narrowest point to create stenosis measurements.



Callout	Description
1	Top and bottom green cross sections as reference
2	Red cross section is the minimum diameter
3	Blue line represents length measurement

Volume - When you draw a region using the Volume method, Vitrea displays the volume of the lumen and outer wall. It also identifies the maximum outer wall diameter. Use this option for thrombosed regions.

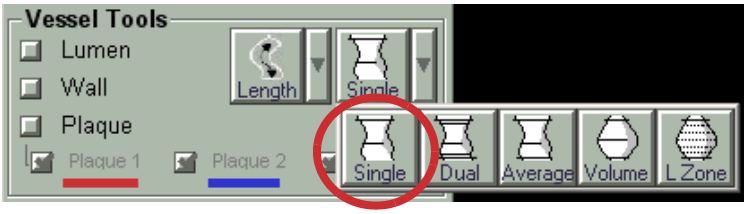
FIGURE 1. **Lesions — Volume Method**



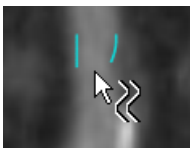
Callout	Description
1	Displays the volume of the lumen and outer wall, and identifies the maximum outer wall diameter.

Landing Zone - Use the Landing Zone option to define specific regions for in-depth analysis.

19. Click the dropdown arrow next to the Single tool and select Single. The cursor changes to the selected Lesion Measurement shape.



20. Click in the CPR view just above the start of the lesion and drag to just below the end.



TIP: Vitrea adds an entry in the Vessel Management area.

TIP: Vitrea identifies:

Feature	Identified by
Identified lesion	Cyan lines
Point of maximum narrowing (stenosis)	Red arrows
Lumen diameter at the stenosis point	Number in the curved view with red border, corresponding to the red arrows (displays in the two-up curved view)
Reference point(s) for single or dual-reference lesions	Green line(s) **TIP:** Be sure the location of the reference point is accurate for the identified lesion. If necessary, drag the green line to move it.
Lumen diameter at the reference point	Number(s) in the curved view with green border, corresponding to the green line(s) (displays in the two-up curved view)
Stenosis measurements	Table at the bottom of the CPR view Stenosis: Area: 96% Diam: 90% Length: 22.8mm

21. Repeat the step above as many times as necessary.

Lesion Measurements

Each lesion object displays the following measurements:

- Minimum lumen diameter at each of the above points
- Length of the lesion in mm
- Percentage Area Stenosis

The percentage area stenosis is calculated using the formula:

% area stenosis = (1 - Stenosed lumen area **/** Reference lumen area**) × 100%**

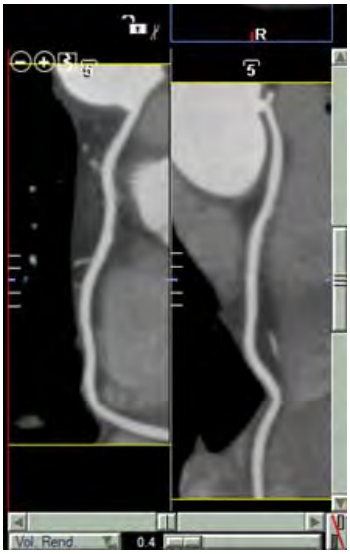
- Percentage Diameter Stenosis

  The percentage diameter stenosis is calculated using the formula:

% diameter stenosis = (1 - Stenosed min lumen diameter **/** Reference min lumen diameter**) × 100%**

Vessel Probe Curved Inset View

The curved inset view is similar to the view you create by changing the MPR to curved reference. The length is preserved when you rotate the CPR.



Fit the image in view

Fit the image on the side that currently has the larger longitudinal length. After the image is fit in the view, zoom the image in and out to cover most of the viewer area.

NOTE: When you fit the image to the viewer in curved mode and switch to the straightened mode, re-fit the image to view it in the viewer.

Measurement in the Left and Right CPR on Y direction

The ruler references that refer to the same ruler have different Y coordinates in the left and right CPR.

- For **ruler** references, the annotation is drawn in different Y coordinates in the left and right CPR view.
- For **lesion** references, the annotation is drawn in the middle of the left and right viewer and uses the Y coordinate from the ruler drawn on the right CPR.

Measure Centerline Length

The Length tool measures length along the centerline or between two points on the vessel centerline.

22. Click to change the volume view to a 1-up image and display a vessel probe view.

23. Select

located under Lesion Analysis.

24. Click and drag either end to edit the length.

The value of the length displays at the proximal end of the length measurement. It represents the length along the centerline between the two specified points.

Create Centerline Angles

The Angle tool creates an angle along the centerline.

25. Click to change the volume view to a 1-up image and display a vessel probe view.

26. Select

located under Lesion Analysis.

27. Select

NOTE: Once you select Angle, the Length dropdown changes to Angle. Toggle the Length and Angle buttons.

28. In Curved CPR view, click and release at the start of the angle.

29. Move the cursor to the vertex location on the centerline and click and release.

30. Move the cursor to the end point of the angle and click and release to complete the angle.

Apply a Visibility Preset Setting

Change the appearance of the 3D view by applying an anatomy setting.

31. Select a Visibility Preset setting.

NOTE: Select the dropdown arrow for more preset selector options.

TIP: Drag the Transparency slider

to adjust the transparency of a region.

Take Snapshots

32. Right-click and select (or press S) to activate the camera.

33. Move the cursor to the image and click.

Snapshots, measurements, rulers, W/L, or segmentation option can be restored from the Report page or the Study Directory.

IV. Distribute Findings

The snapshots you save in the Viewer window are saved to the Report window.

1. Click

at the bottom of the window.

2. Export your findings or create a report.

See the **Distribute Findings** chapter of the **VitreaAdvanced-VitreaWorkstation General Education and Reference Guide** for instructions on exporting findings, restoring workflow, and creating reports.

Additional Procedures

Point-of-Interest View Mode

The Point-of-Interest View mode shows the volume immediately surrounding the current crosshair position. This mode removes all surrounding tissue, bone, and so on, to reveal the point of interest.

5:1 format

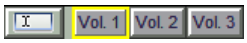
Point of Interest Box

To activate the Point-of-Interest box:

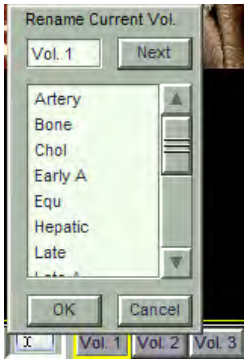
1. Click the crosshair on the anatomy of interest in 2D.
2. In the POI box, right-click and drag the mouse away from you to decrease the size of the POI cube; move the mouse toward you to increase.

Switching Active Volumes

1. With multiple volumes loaded, switch the selected volume by using the Volume Navigation buttons at the bottom of the Viewer window.



2. To change the label on the button for the currently selected button, click and select a name or type a new one.



Manual Stenosis Measurement

To measure vessel diameter and calculate stenosis ratio percentage:

1. Click Ruler .

2. Click and drag across the width of the displayed lumen of the axial cross-sectional view.

3. Scroll to a narrowed area and measure the lumen.
   - The system displays the current maximum and minimum diameter measurements in green (max) and red, (min) respectively, in the CPR views. Any other measurements display in blue.
   - When you have drawn at least 2 rulers, the system calculates the percentage of stenosis by comparing the maximum (normal) and minimum (stenosed) measurements. The percentage and the formula to calculate it display in the lower corner of the CPR views.

TIP: Place two rulers per cross-section, but you may redraw the rulers as many times as needed.

Rotate CPR Views

To rotate the CPR views:

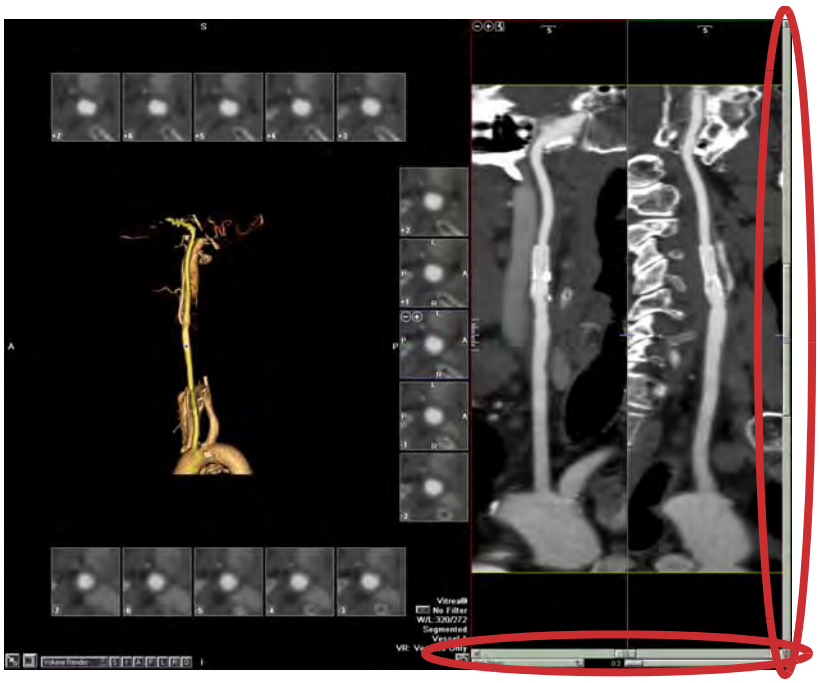
- Click and drag the slider bar to the right of the CPR views to move along the vessels.

TIP: Roll the mouse wheel to move the CPR views.

- Click and drag the slider bar under the CPR views to rotate them.

  TIP: In the CPR view, you also have the option to click and drag to rotate.

  TIP: The blue line in the CPR view corresponds to the location of the blue dot in the green shaded vessel and the cross-sectional view with the blue border.

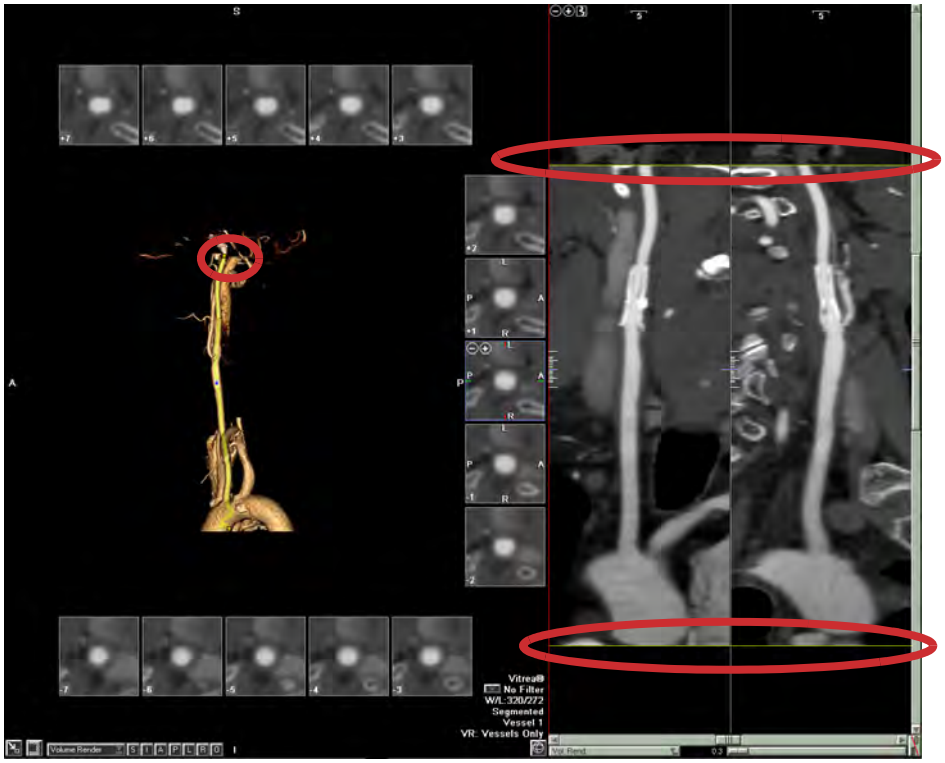


Trim CPR Views

To trim the CPR views, locate the yellow trim line on the top or bottom of the CPR view. Click and drag the yellow trim line.

TIP: A yellow dot displays in the 3D view to identify the trim location.

NOTE: Press **F11** to Undo.



Measure Density in CPR Views

Draw contours to measure HU intensity of a region of interest.

1. From the Analysis tab, click **ROI**

.

2. Click to maximize the curved view.

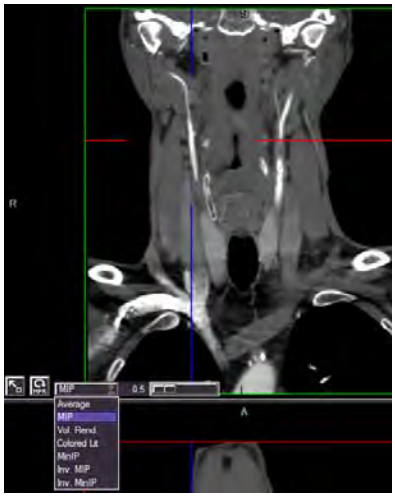
3. In the CPR view, draw a contour around an area of interest.

TIP: A reference number displays next to the contour and the average HU for the region (with the standard deviation) displays at the bottom of the CPR view.

TIP: To erase the contours, move the CPR views.

Create an Automatic MIP

MIP is a shading setting that displays data using the highest data values for each voxel of the image. MIP is a good setting to use when competing features composed of voxels with similar or higher values might be obscuring the feature of interest.



Use MIP to:

1. Differentiate between contrast and calcium in vessels.
2. View thick slab MPRs with many tiny, loose body bone fragments.
3. View the carotids.
4. View a thick slab MPR.

Automatic Curved Reformats

In Curved MPR mode, use one of the MPR views to define a curve to measure curved vessels in another MPR view. This is useful for pre-surgical carotid artery measurements.

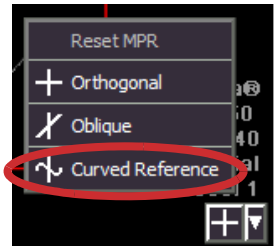
1. Click to switch to a 4-up view.

2. Select the vessel listing in the Vessel Management area.

TIP: Do not select a lesion listing.

3. In the lower-right corner of the axial view, click the dropdown arrow.

4. Click **Curved Reference**.



TIP: The curved centerline displays in the Curved view, and the measurement of the entire centerline displays in yellow.

TIP: To zoom in on the view, left + middle click and drag down in the view.

5. In the Curved view, drag the smaller, lighter blue line (Measuring line) to a point along the centerline you want to measure.

6. Drag the longer, darker blue line (Transverse line) to the other point along the centerline you want to measure.

TIP: The measurement between the two blue lines displays in blue and the measurement of the entire centerline displays in yellow.

7. Right-click in the image, then click .

TIP: If the centerline and measuring lines disappear when you click the camera button, right-click in the view again and select Hide Crosshair in Export, then click the view to take the snapshot.

Head and Neck Bone Subtraction

Use the head and neck bone subtraction feature to display a volume of the vessels with the bone removed.

1. Load two coincident CT volumes of the head and neck: a pre-contrast series and a post-contrast series.

   NOTE: Loading thick-slice datasets may result in sub-optimal performance.

2. Select a preset:

   - From the Data Manager, double-click the Head/Neck Subtraction Application icon.

   OR

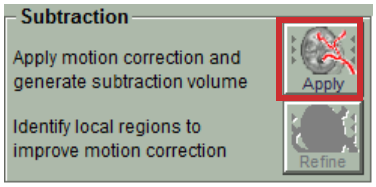
   - From the Gallery, click Pick for the 3D Analysis preset.

   Vitrea attempts to register the two volumes to correct for patient motion, then creates a “subtraction” volume that attempts to retain all contrast-enhanced structures, such as vessels, and to eliminate all high-density structures, such as bone or calcium.

NOTE: Vitrea uses the contrast/bolus agent DICOM tags to classify each volume as “Pre” and “Post.” If Vitrea is unable to classify the volumes, or if Vitrea misidentified the volumes, you must rename the volumes before applying the registration.

- Click the Volume Rename button and rename each volume “Pre” and “Post” appropriately.

3. If Vitrea did not apply the motion correction registration automatically, or if you wish to re-apply the motion correction registration, click **Apply**.



TIP: To cancel the registration during processing, click

.

Vitrea creates a new “Sub” volume, which displays on the left side of the viewer. The views are locked with regard to crosshair position, pan, and zoom.

TIP: Click to display all three volumes in one view.

4. To refine the motion correction in local regions with misregistration, do the following steps:

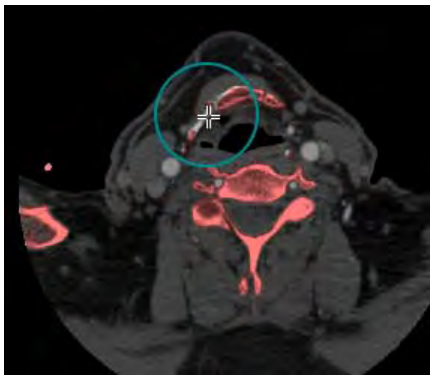
   a. Click

.

   A red overlay displays on the “Post” volume.

   b. Scroll through the MPR view of the “Post” volume looking for bone, artifact, or calcium that did not get subtracted.

c. Click in the MPR view to start the local motion correction registration.



d. Repeat from step b as necessary.

NOTE: The Refine tool is not available for volumes with gantry tilt. With the Refine tool, you can undo/redo one step back, but no more than one. When you undo/redo, verify refinement.

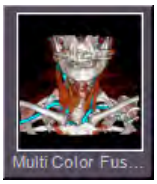
5. Perform segmentation, sculpting, measuring, Vessel Probe, Lesion Analysis, and other tasks on the “Sub” volume to complete your workflow.

NOTE: The software may adjust the HU values in the “Sub” volume during subtraction, especially for high-density regions.

NOTE: Wall contours and SUREPlaque measurements are not supported in the “Sub” volume.

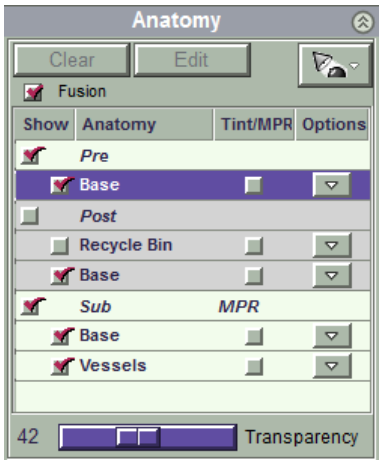
NOTE: Denoising is not available with the subtraction feature.

6. To create a fused volume of the “Pre” and “Sub” volumes to visualize bony landmarks or calcium, select the Multi-color Fusion preset selector.



7. Adjust the transparency as desired.

8. Take snapshots.



CT Circle of Willis Analysis

Contents

CT Circle of Willis Analysis Overview

CT Circle of Willis Analysis Lesson

- **I** Select Study
  - Data Manager
  - Gallery Window
- **II** Choose Protocol and Preset
- **III** Perform Analysis
  - Automatically Remove Bone
  - Segment Vessels
  - Inspect the ROI View
  - Take Snapshots
- **IV** Distribute Findings

Additional Procedures

- Switching Active Volumes
- Probe Vessels
- Sculpt From One MPR
- Add Additional Anatomy
- Point-of-Interest View Mode
- Remove Fragments
- Preset Selector
- Sculpt Multiple MPRs
- Perform Volume Measurements

- Create MPR Image Batches
- Head Bone Subtraction

CT Circle of Willis Analysis Overview

The CT Circle of Willis workflow views the vascular anatomy in the Circle of Willis.

The Circle of Willis CTA data in Vitrea removes the bone and displays the Circle of Willis (COW). Perform these functions in either the MPR views or the 3D view.

NOTE: Because of the high HU value of contrast media in 100kV scans, the reliability of calcium detection within the vessel lumen is expected to be lower than that of regular kV scans.

CT Circle of Willis Analysis Lesson

I. Select Study

Load a Circle of Willis study.

See the instructions for your Vitrea type (VitreaAdvanced Through the Data Manager or VitreaWorkstation) in the **Select Study** chapter of the **VitreaAdvanced-VitreaWorkstation General Education and Reference Guide**.

II. Choose Protocol and Preset

Use one of these procedures:

Data Manager

- Double-click the **Circle of Willis** application thumbnail.

Gallery Window

1. On the Gallery window, select the **Vascular: CoW CT** protocol.

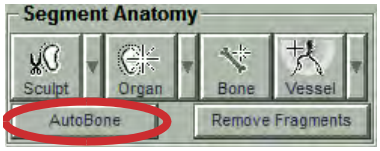
   The Gallery choices update automatically.

2. Click Pick next to the **3D Analysis** preset.

III. Perform Analysis

Automatically Remove Bone

1. In the Segment Anatomy Area, click **AutoBone.**



2. Review the segmentation and use the Manually Segment Bone technique to segment any additional bone regions.

Segment Vessels

You can segment additional vessels that the automatic vessel segmentation missed.

NOTE: The default window/level value is the optimal setting for vessel segmentation using dynamic grow in COW studies.

3. In the Segment Anatomy area, click .

4. Click and hold on a vessel.

   TIP: Watch the blue selection area "grow". Keep holding until entire vessel is selected.

5. Repeat from step 3 for other vessels.

6. Click .

7. Apply Visualization settings to the Vessels region.

Inspect the ROI View

8. Click .

9. In the lower 3D view, click an area of interest.

   TIP: The POI view, in the upper right, "jumps" to that crosshair location.

10. In the POI view, roll the mouse wheel to trim or expand the point of interest.

11. Click and drag in the POI view to rotate.

12. Add rulers and markers as desired.

Take Snapshots

13. Right-click and select (or press S) to activate the camera.

14. Move the cursor to the image and click.

    Snapshots, measurements, rulers, W/L, or segmentation option can be restored from the Report page or the Study Directory.

    See the Additional Procedures section for information on Creating 3D Image Batches.

IV. Distribute Findings

The snapshots you save in the Viewer window are saved to the Report window.

1. Click

at the bottom of the window.

2. Export your findings or create a report.

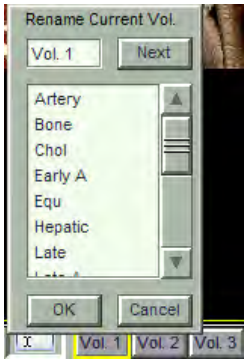
    See the **Distribute Findings** chapter of the **VitreaAdvanced-VitreaWorkstation General Education and Reference Guide** for instructions on exporting findings, restoring workflow, and creating reports.

Additional Procedures

Switching Active Volumes

1. With multiple volumes loaded, switch the selected volume by using the Volume Navigation buttons at the bottom of the Viewer window.

2. To change the label on the button for the currently selected button, click and select a name or type a new one.



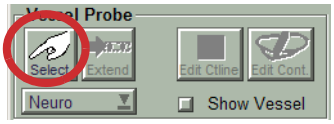
Probe Vessels

Use the Vessel Probe feature to view: the highlighted vessel in 3D, a curved reformat view of the vessel, and cross-sectional reformat views.

1. Click in the lower-left of the 3D view.

   TIP: If necessary, click and drag in the 3D view to rotate it for a better view of the vessel.

2. In the Vessel Probe area click Select.



3. Click the vessel.

Sculpt From One MPR

1. Click in the bottom left corner of the axial image to magnify the image.

2. Scroll through the image and locate the superior aspect of Circle of Willis or any information you want to include in your image.

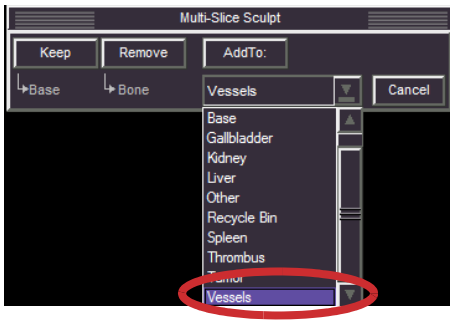
3. Right-click and select to draw contours.

4. In the axial image, draw contours large enough to encompass COW anatomy while scrolling through to inferior circulation.

TIP: Draw a new contour line where regions change size, shape, or location.

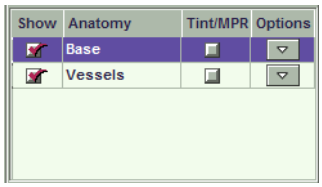
TIP: Make sure you draw all contour lines before you segment the image.

5. Select vessels from the dropdown and click **Add To:**.



6. Click to return to the 5 on 1 display.

7. In the Anatomy list, clear the **Base** check box.



8. With Vessels selected, right-click and select to window level the 3D image to better visualize structures.

Add Additional Anatomy

Perform sculpt to add additional anatomy.

1. Right-click and select .

2. Select the **Tint/MPR** check box to show results of any segmentation done in the MPR images.

3. Click in the lower left corner of the axial view to magnify.

4. Scroll to one end of the anatomy you are adding back in and circle it. Continue adding contours to the entire anatomy.

TIP: Contours should be added whenever the anatomy changes size, shape, or location.

5. When you are finished drawing the contours, click the dropdown menu and choose a region.

6. Click in the lower left corner of the Viewer window to return to the previous window.

TIP: Click Win/Lev and click in 3D. Click and hold the mouse and drag towards you to add additional anatomy.

Point-of-Interest View Mode

The Point-of-Interest View mode shows the volume immediately surrounding the current crosshair position. Use this mode to remove all surrounding tissue, bone, and so on, to reveal the point of interest.

5:1 format **Point of Interest Box**

To activate the Point-of-Interest box:

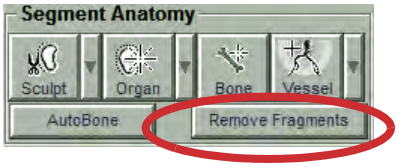
1. Click the crosshair on the anatomy of interest in 2D.

TIP: Typical areas to investigate include: anterior communicating artery, right middle cerebral artery, left middle cerebral artery, and posterior communicating artery.

2. In the POI box, right-click and drag the mouse away from you to decrease the size of the POI cube; move the mouse toward you to increase.

Remove Fragments

1. Click **Remove Fragments**.



2. Right-click and select to window level.

3. In the Remove Fragment In-viewer window, click Smaller or Larger.

TIP: Remove fragments removes all visibly distinct regions that are smaller than the number of cubic centimeters listed in the Segment Anatomy area.

4. Verify the selected region is Recycle Bin.

5. Click **Add To:**.

Preset Selector

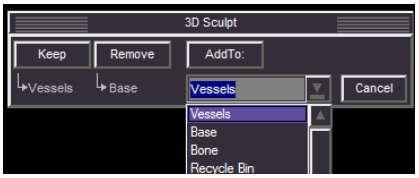
Preset Selector options on the Analysis tab control how images display in the region default depending on the protocol you use.

Sculpt Multiple MPRs

1. Right-click and select to draw contours.

2. Draw a single contour line on two or more MPR planes containing the anatomy of interest.

3. In one of the views, click the dropdown list and select a region.



Perform Volume Measurements

1. Right-click and select to draw contours.

TIP: Click to magnify the image.

2. Accurately trace the region you want to measure from an MPR view.

3. Click to return to the 5 up view.

4. The surface displays in the 3D view. If the contours do not define the region you want them to, edit them.

5. In the Multi-slice Sculpt in-viewer, click the dropdown and select the region or type a name in the field.

NOTE: The accuracy of the volume measurement is as accurate as the contour lines you draw.

6. Click **Add To:**.

7. Right-click the region name in the Anatomy Management list and select **Show Volume**.

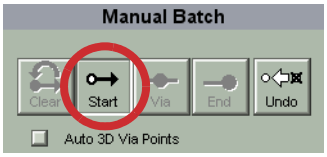
Create MPR Image Batches

Create a manual batch by selecting the desired starting, intermediate, and ending images.

1. From the Visual tab, select desired settings or display options.

2. Select the **Batch** tab.

   The **Start** button is automatically selected.



3. To capture intermediate images manually:

   a. Click the image.

   A check mark displays on the image. The Start button is unavailable and the Via button is available to collect intermediate images for the batch. The Via button stays available until you click the End button.

   b. Change the volume image position.

   c. Click to capture an intermediate image.

   A check mark displays on the image.

   d. Repeat steps b and c until you capture all desired intermediate images.

   e. Change the volume position for ending image.

4. Click .

5. Click **Batch** or **Movie**.

Head Bone Subtraction

Use the head bone subtraction feature to display a volume of the vessels with the bone removed.

1. Load two coincident CT volumes of the head: a pre-contrast series and a post-contrast series.

   NOTE: Loading thick-slice datasets may result in sub-optimal performance.

2. Select a preset:

   - From the Data Manager, double-click the Head Subtraction Application icon.

   OR

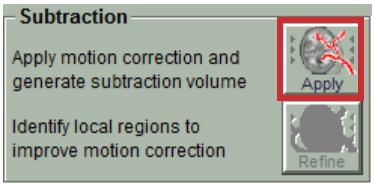
   - From the Gallery, click Pick for the 3D Analysis preset.

   Vitrea attempts to register the two volumes to correct for patient motion, then creates a “subtraction” volume that attempts to retain all contrast-enhanced structures, such as vessels, and to eliminate all high-density structures, such as bone or calcium.

NOTE: Vitrea uses the contrast/bolus agent DICOM tags to classify each volume as “Pre” and “Post.” If Vitrea is unable to classify the volumes, or if Vitrea misidentified the volumes, you must rename the volumes before applying the registration.

- Click the Volume Rename button and rename each volume “Pre” and “Post” appropriately.

3. If Vitrea did not apply the motion correction registration automatically, or if you wish to re-apply the motion correction registration, click **Apply**.



TIP: To cancel the registration during processing, click

.

Vitrea creates a new “Sub” volume, which displays on the left side of the viewer. The views are locked with regard to crosshair position, pan, and zoom.

TIP: Click to display all three volumes in one view.

4. To refine the motion correction in local regions with misregistration, do the following steps:

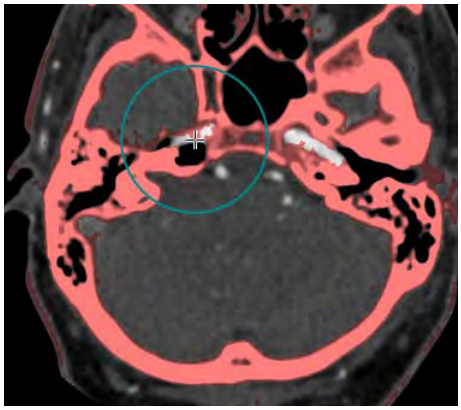
   a. Click

.

   A red overlay displays on the “Post” volume.

   b. Scroll through the MPR view of the “Post” volume looking for bone, artifact, or calcium that did not get subtracted.

c. Click in the MPR view to start the local motion correction registration.



d. Repeat from step b as necessary.

NOTE: The Refine tool is not available for volumes with gantry tilt. With the Refine tool, you can undo/redo one step back, but no more than one. When you undo/redo, verify refinement.

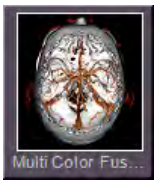
5. Perform segmentation, sculpting, measuring, Vessel Probe, Lesion Analysis, and other tasks on the “Sub” volume to complete your workflow.

NOTE: The software may adjust the HU values in the “Sub” volume during subtraction, especially for high-density regions.

NOTE: Wall contours and SUREPlaque measurements are not supported in the “Sub” volume.

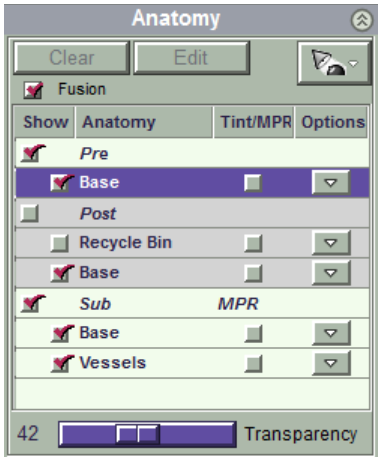
NOTE: Denoising is not available with the subtraction feature.

6. To create a fused volume of the “Pre” and “Sub” volumes to visualize bony landmarks or calcium, select the Multi-color Fusion preset selector.



7. Adjust the transparency as desired.

8. Take snapshots.



CT Brain Perfusion 2D

Contents

CT Brain Perfusion 2D Overview

- Perfusion Maps
- Basic Scanning Techniques
- “Time Series” Study
- Caution Statements

CT Brain Perfusion 2D Lesson

I Select Study

II Choose Protocol and Preset

- Data Manager
- Gallery Window

III Perform Analysis

- Select Slice Levels (multi-detector scanners only)
- Scroll the Series to Look for Motion
- Correct for Motion if Necessary
- Review the Time-Density Graph
- Review Artery and Vein Positions
- Compute the Results
- Display the Perfusion Maps
- Edit the Midline
- Apply ROI Templates
- Take Snapshots
- Create an Orthogonal Batch or Movie
- Create a Collage Batch

IV Distribute Findings

Additional Procedures

- Display the Summary Map
- Apply Preset Window Level Setting for the MPR View
- Set the Window/Level Settings in the Perfusion Maps
- Correct the Artery Location
- Correct the Vein Location
- Adjust Measurement Colors
- Select a Deconvolution Method
- Display Measurements for Crosshair Positions
- Place User-defined ROI Contours
- Customize the ROI Templates

Appendix

- Input Artery and Output Vein Positions
- CT Brain Perfusion Measurements
- Calculations
  - Automatic Artery/Vein Selection
  - Manual Artery/Vein Selection Effect on Reproducibility
  - Time-Density Graph Calculations
- Perfusion Image Map Calculations
- Summary Map
  - Categories by Relative Value
  - Tissue Classifications

CT Brain Perfusion 2D Overview

Perfusion Maps

Vitrea uses the input artery with the earliest transit time and the output vein with the maximum total density to calculate brain perfusion.

After the artery and vein are identified, Vitrea computes five color-coded image maps with quantitative results related to:

- cerebral blood volume (CBV)
- mean transit time (MTT)
- cerebral blood flow (CBF)
- time to peak of tissue (TTP)
- delay of tissue response (Delay)

Basic Scanning Techniques

- 2-5 second delay
- 4 to 5cc injection rate
- 5 to 10mm slice thickness
- Scanning the same location rapidly before and during the contrast injection
- Minimum of 9 time points
- Must have “brain”, “head”, or “perfusion” in study description
- Multi-slice offers an advantage to scan several slice planes, with increased coverage

NOTES:

- Vitrea Brain Perfusion 2D supports standard axial scans and multi-time series scans with no table motion for supported scanners and scanner protocols from Toshiba, GE, Siemens, and Philips.
- Vitrea Brain Perfusion 2D supports helical shuttle scans from both GE and Siemens scanners, except for scans that have slice levels greater than 50 or scans that are sent as more than one series.

Helical shuttle has not been validated for any other scanner manufacturer.

- Vitrea Brain Perfusion 2D supports jog shuttle scans for GE and Philips scanners, except for scans that have slice levels greater than 30 or scans that are sent as more than one series. Jog shuttle has not been validated for any other scanner manufacturer.
- If unsupported wide-coverage data is loaded in Vitrea Brain Perfusion 2D, the perfusion maps may not be accurate. Known behaviors include a potential for perfusion differences between the top half of the scan and the bottom half of the scan. Vitrea attempts to block the loading of most unsupported wide-coverage data.

NOTE: For shuttle acquisition techniques, VitreaAdvanced uses time-based interpolation to build some of the study. This interpolation may cause slight motion artifacts. When time-based normalization and slice interpolation is performed to account for each half of the brain acquisition at different times, there are roughly twice as many slices as the original acquisition. Interpolated slices are labeled.

“Time Series” Study

A CT series scanned for brain perfusion measurement in VitreaAdvanced consists of a series of slices produced by repeatedly scanning the same region, at the same table position.

VitreaAdvanced interprets a set of images as a “time series” if it detects at least 9 images in the same Z position (differing only in time). Series that meet these criteria are constructed into a single “time series” volume.

Multi-detector series, which contain multiple levels (different Z positions), shows the total number of images in the series on the Study Directory window. A multilevel (multi-detector) series appears as a single series on the Study Directory window.

CAUTION: If the volume loaded is not a valid perfusion dataset, you will not be able to select a Brain Perfusion preset.

Caution Statements

CAUTIONS:

- **For measuring brain perfusion in Vitrea, you must load only a series of the brain scanned at Brain Perfusion CT protocol settings. This measuring tool is not intended for measuring perfusion in other anatomical regions.**
- **Verify the absence of a compromised blood-brain barrier (such as a hemorrhage) and motion. If either of these conditions exist in the study, you should not rely on the resulting brain perfusion measurements. The computations assume an intact blood-brain barrier and no motion. The accuracy of measurements of images that do not meet these criteria will be compromised.**
- **Verify that Vitrea has marked the artery and vein locations correctly. If the relationship between the artery and vein curves does not look appropriate, re-evaluate the artery and vein selections and, if needed, find new vessel positions. Measurements will most closely characterize the actual series when you select the optimal location and contrast density for each vessel position.**

CAUTION: Factors that can impact the accuracy of the results are:

- **Not fully capturing the contrast bolus (including at least 2 seconds of pre-enhancement images and post-enhancement).**
- **Patient head motion (even the slightest motion can cause numerical errors in the calculations).**
- **Selecting a delayed artery as a reference.**

DICOM Export Limits:

Export a CT Brain Perfusion report to DICOM servers or PACS devices. Keep these limitations in mind when using exported reports:

CAUTIONS:

- **You should not rely on VitreaAdvanced CT Brain Perfusion color maps viewed in grayscale on PACS workstations in making a diagnosis, as the conversion from color may be inaccurate.**
- **VitreaAdvanced exports each image in a report as a DICOM Secondary Capture image. Therefore, taking measurements (Hounsfield unit readings or dimensional rulers) and performing**

other similar operations on PACS or other devices on these Secondary Capture images will not yield accurate results.

- **If you export images to a DICOM image server, the exported images may not have the same detail as the original scanned images.**

CT Brain Perfusion 2D Lesson

I. Select Study

Load a Brain Perfusion 2D study.

See the instructions for your Vitrea type (VitreaAdvanced Through the Data Manager or VitreaWorkstation) in the **Select Study** chapter of the **VitreaAdvanced-VitreaWorkstation General Education and Reference Guide**.

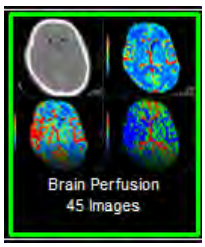
For multiple-time-series studies, select all the volumes.

II. Choose Protocol and Preset

Use one of these procedures:

Data Manager

- Double-click the **Brain Perfusion** application thumbnail.



Gallery Window

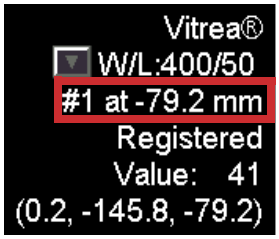
5. Select **Brain Perfusion CT** protocol.

6. Click Pick next to the **2D Perfusion** preset.

III. Perform Analysis

Select Slice Levels (multi-detector scanners only)

For series produced using multi-detector scanners, select the Slice Level. Change in slice level is indicated by number and couch position.



1. Roll the mouse wheel.

   OR

   Right-click and drag up and down in the view.

Scroll the Series to Look for Motion

Review the series to verify the absence of motion.

2. Right-click and drag left and right in the 2D image to scroll through time in the series.

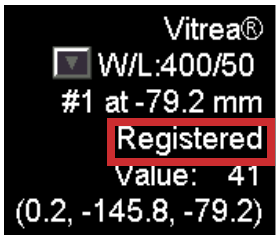
   TIP: Images that appear to shift as you scroll may indicate motion.

Correct for Motion if Necessary

If there is evidence of motion, correct for motion.

3. Click to apply motion correction.

   TIP: After motion correction is complete, `Registered` displays in the lower-right corner of the view.



4. Review the series again to verify motion has been corrected.

   TIP: If necessary, click to undo motion correction.

Review the Time-Density Graph

The Time-Density graph displays the density over time curve and the transit time for the artery in red, and it displays the image density over time curve and the area under the curve for the vein in blue.

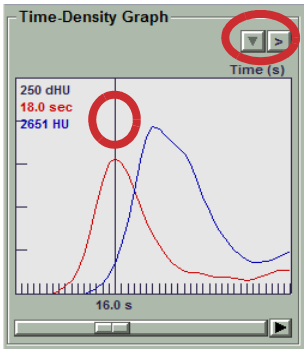
For more information regarding the elements on the Time-Density graph, see the Appendix of this chapter.

5. To display a time along the curves, move the black time line to the desired location (for example, the peak of the artery curve).

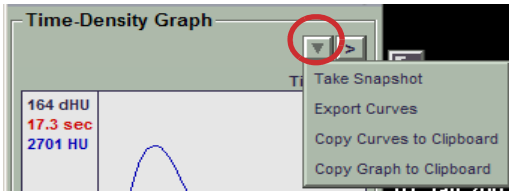
   OR

   Drag the **Time Slice** slider.

   TIP: To expand the Time-Density Graph into a separate, larger viewer, click .



6. To distribute a snapshot of the graph, click the drop down arrow and select from the menu.

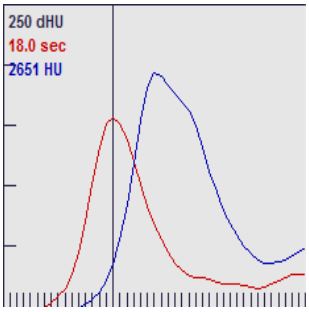
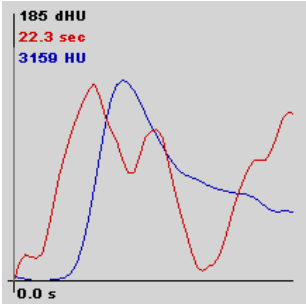


Review Artery and Vein Positions

In most cases, Vitrea selects the correct locations for the artery and vein. Verify that Vitrea marked the vein and artery locations correctly.

7. Review the Time-Density Graph to look for two single-peaked bell-curve lines:

- The red line indicates the Artery
- The blue line indicates the Vein

Good Bell Curves (indicate correct locations)	Multi-Peak Curves (indicate incorrect locations or motion in the study)
	

If either the red or blue curve has multiple peaks, apply motion correction. If there are still multiple peaks, override the artery or vein location. Incorrect vessel locations result in invalid perfusion maps.

See the Additional Procedures section of this Module for information on correcting artery and vein locations.

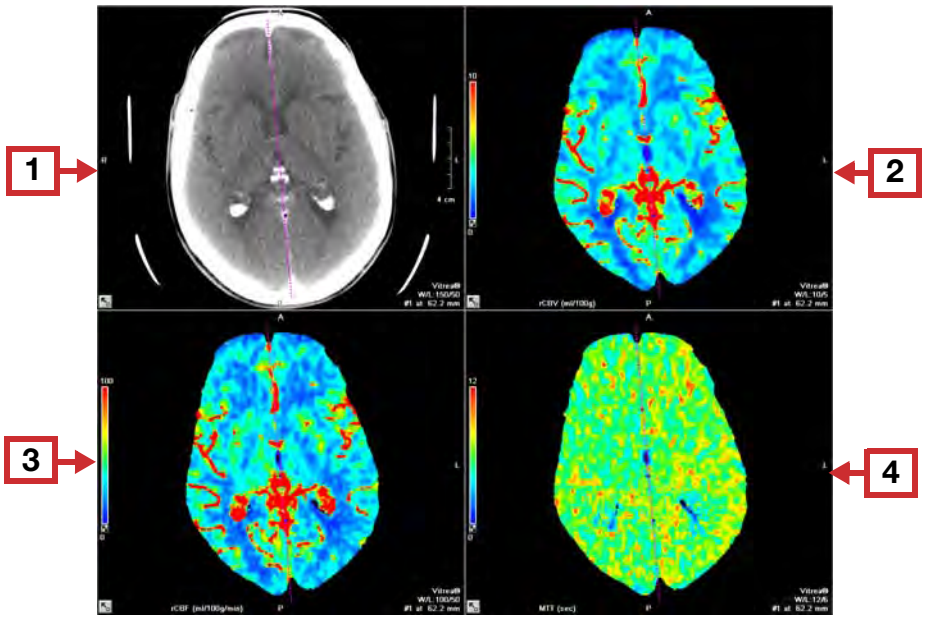
Compute the Results

When you are satisfied with the artery and vein locations, compute the results.

8. Click .

Display the Perfusion Maps

The 4-up view displays:

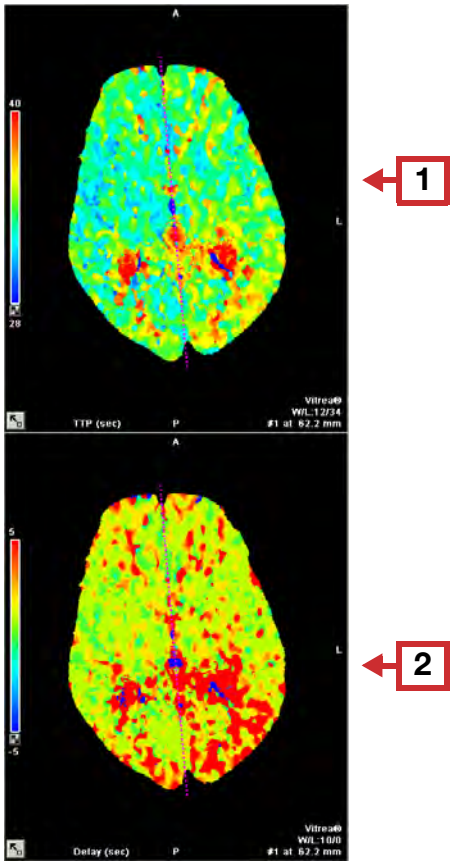


Callout	Description	Unit of Measure
1	2D grayscale view	
2	Cerebral Blood Volume (CBV) view	ml/100g
3	Cerebral Blood Flow (CBF) view	ml/100g/min
4	Mean Transit Time (MTT) view	seconds

Each of the views includes an editable midline.

9. Click to switch to a 6-up view, which also displays:

The 6-up Viewer window format displays the TTP and Delay views.

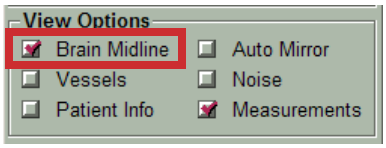


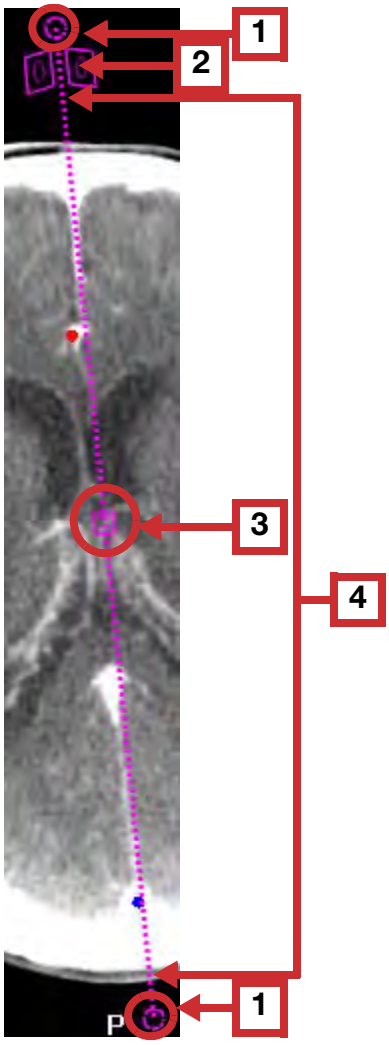
Callout	Description	Unit of Measure
1	Time to peak of tissue response curve (TTP)	Seconds
2	Delay of tissue response curve	Seconds

Edit the Midline

Each of the views contains an editable midline. Vitrea uses the midline to determine the mirror ROI contour placement, so it is important to place the midline in the correct location.

10. Select the **Brain Midline** check box in the View Options area.



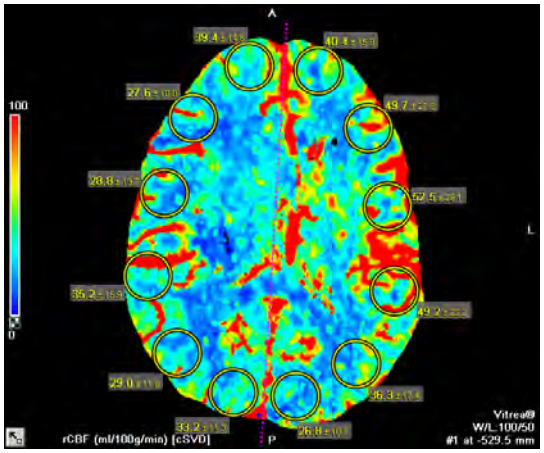


Callout	Description
1	To move an end of the midline, pivoting on the opposite end, or to extend the length of the midline: • Click and drag a **Midline End** icon.
2	To mirror the ROIs on the other side of the midline: • Click the **Mirror** icon on the side that has the ROI.
3	To slide the entire midline: • Click and drag the **Midline Center** icon.
4	To pivot the midline on its center: • Click and drag anywhere along the midline (other than the Midline End, Midline Center, or Mirror icons).

Apply ROI Templates

Use a template to display perfusion measurements in mirrored ROIs.

11. Click to display orbital ROIs.



See the Additional Procedures section of this Module for more information on customizing the ROI Templates.

Take Snapshots

Take snapshots to save your work and to put into a report.

12. Click , and click in the view.

OR

Hold ALT to keep taking snapshots without having to activate the snapshot tool each time.

OR

Hold CTRL to take one snapshot that includes all views.

NOTE: If the resulting image is viewed on a PACS, the measurements on the image may be difficult to read.

Create an Orthogonal Batch or Movie

Make orthogonal slice batches or movies of the perfusion maps.

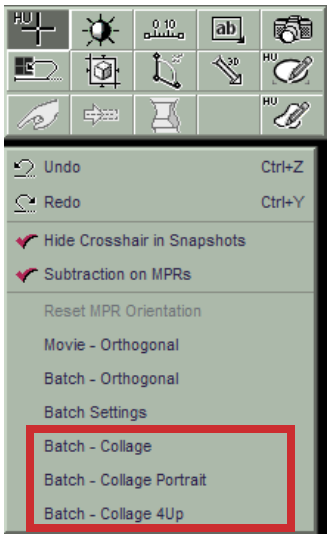
13. Right-click in a perfusion map view and select **Movie - Orthogonal** or **Batch - Orthogonal**.

Create a Collage Batch

Create a single batch that includes the MPR and perfusion map views in one screen. Choose between a 4-up or 6-up format. The Collage Portrait format produces images in a portrait orientation, suitable for PACS monitors.

NOTE: The Collage Portrait option is only available in the 6-up view.

14. Right-click in a perfusion map view and select **Batch - Collage, Batch - Collage Portrait** or **Batch - Collage 4-up**.



IV. Distribute Findings

The snapshots you save in the Viewer window are saved to the Report window.

1. Click Report at the bottom of the window.

2. Export your findings or create a report.

See the **Distribute Findings** chapter of the **VitreaAdvanced-VitreaWorkstation General Education and Reference Guide** for instructions on exporting findings, restoring workflow, and creating reports.

Additional Procedures

This section addresses some less common procedures you may need to do to complete your workflow.

Display the Summary Map

The Brain Perfusion Summary Map displays color-coded regions, based on a derivative of the hemispherical comparisons of all the other maps, where perfusion values appear to be increased or decreased based on the contralateral hemisphere.

The Summary Map image can be used to communicate the results of a CT Perfusion exam and to provide tissue classification.

For areas marked as Yellow, VitreaAdvanced uses a relative value where TTP is increased, in seconds, compared to the reference hemisphere.

For areas marked as Red, VitreaAdvanced uses a relative value where CBV is decreased, in percent, compared to the reference hemisphere.

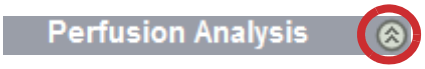
See the Appendix for exact rules for Yellow and Red.

CAUTION: Use the Summary Map in conjunction with the other perfusion maps. Do not use the Summary Map by itself to make diagnostic decisions.

1. Complete the workflow and display the perfusion maps as outlined in the Perform Analysis section.

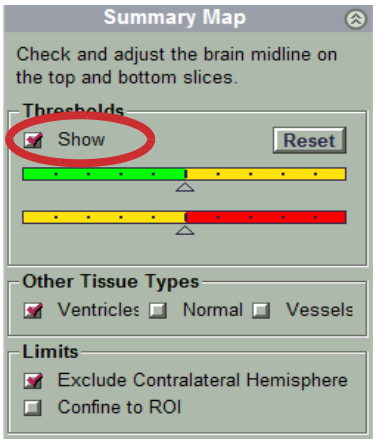
2. Display and edit the brain midline as described in the Perform Analysis section.

TIP: In order to see the full Summary Map tool panel, you may have to collapse one of the other tool panels.

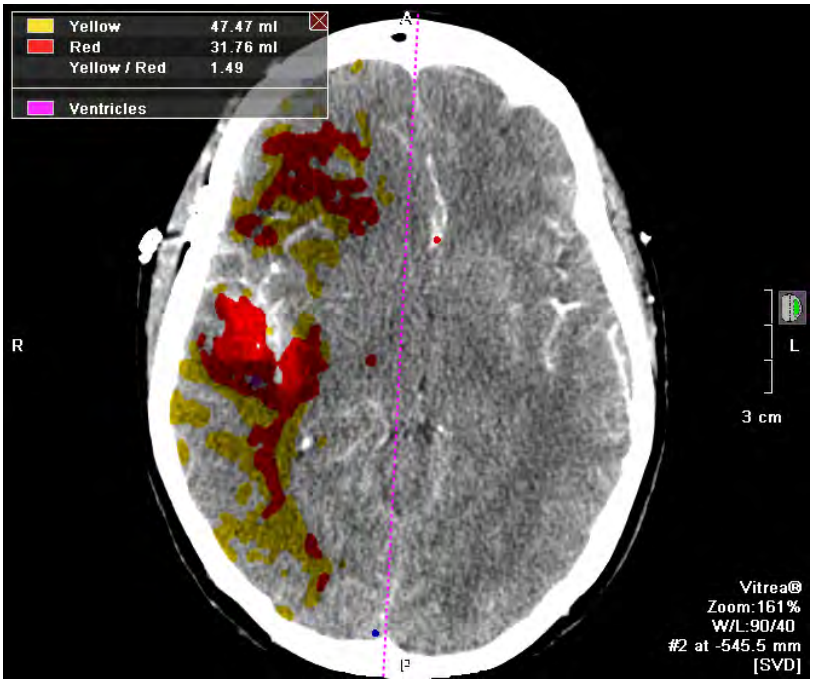


3. Select the **Show** check box.

   The Summary Map displays in the 2D view.



   - Yellow indicates areas where TTP is above the threshold
   - Red indicates areas where CBV is below the threshold
   - Magenta indicates ventricles
   - Green indicates normal areas (when **Normal** check box is selected)



   NOTE: The Volume, in ml, is the total volume of Yellow or Red areas for all slices. The Yellow/Red ratio is also displayed.

- To hide the magenta areas that indicate ventricles, clear the **Ventricles** check box. Hiding the magenta area will still show any tissue classification (yellow or red) for that same area.

  NOTE: Hiding the ventricles may increase the volume values given for Yellow and Red since that same area was not included in the volumes when the tissue was classified as “Ventricles.”

- To show unaffected areas shaded in green, select the **Normal** check box.

- To show vessels shaded in light pink, select the **Vessels** check box.
- To show the data that displays on the contralateral hemisphere, clear the **Exclude Contralateral Hemisphere** check box.
- To show only data within a defined region of interest, draw ellipse(s) or ROI(s) on the view or place an ROI template, then select **Confine to ROI**.

NOTE: Use of the Exclude Contralateral Hemisphere or Confine to ROI check boxes will affect the volumes displayed in the Yellow or Red.

Set Reference Hemisphere

When Vitrea displays the Summary Map, it uses the TTP value to attempt to determine the unaffected hemisphere as a reference for perfusion normalization. An indicator or displays on the appropriate side of the viewer to correlate with the unaffected side.

NOTE: It is important that you verify that Vitrea has correctly identified the unaffected side to be the reference hemisphere.

Re-set the Reference Hemisphere if necessary.

1. Click the Hemisphere Indicator or .
2. Choose **Force Left** or **Force Right** from the dropdown.

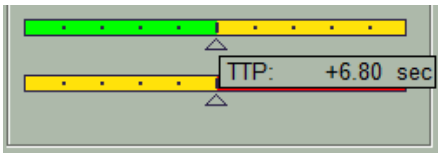
Edit the Summary Map Thresholds

Use the Thresholds slider bars to edit the rules for determining areas of Yellow and Red.

NOTE: It is your responsibility to adjust the sliders to the proper thresholds and to use the proper definitions of “Normal,” “Yellow,” and “Red.” Review the other perfusion maps as a guide.

See the Appendix for details on tissue classification.

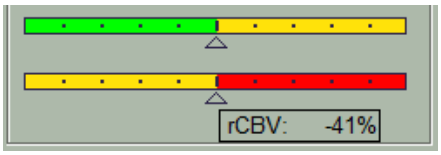
3. Adjust the top slider bar to define the threshold between Normal and Yellow. Use the values in the tool tip as a guide.



- Move the slider left for more aggressive rules for Yellow.
- Move the slider right for less aggressive rules for Yellow.

See the Appendix for definitions of Normal and Yellow.

4. Adjust the bottom slider bar to define the threshold between Yellow and Red. Use the values in the tool tip as a guide.



- Move the slider left for more aggressive rules for Red.
- Move the slider right for less aggressive rules for Red.

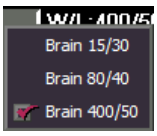
See the Appendix for definitions of Red.

Apply Preset Window Level Setting for the MPR View

View the MPR views in different preset window/level settings.

1. Click the dropdown arrow in the MPR view.

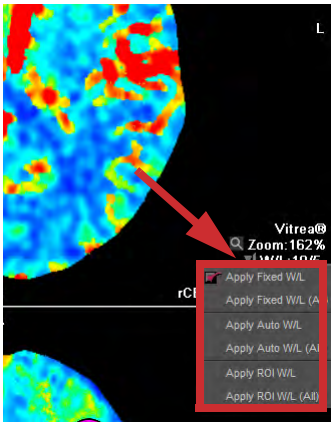
2. Select a preset window/level setting.



3. Press INSERT to toggle between the preset window/level settings.

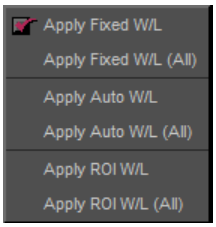
Set the Window/Level Settings in the Perfusion Maps

Set the window/level settings in the perfusion maps based on fixed, automatic, or user-defined ROI settings.



4. Click the Window/Level dropdown in a perfusion map. W/L:10/5

5. Select a setting.



- **Apply Fixed W/L** - a fixed setting for the map
- **Apply Fixed W/L (All) -** applies the fixed setting to all the maps
- **Apply Auto W/L** - Vitrea assesses and computes an optimal setting based on a histogram analysis of the perfusion values
- **Apply Auto W/L (All) -** applies the auto setting to all the maps
- **Apply ROI W/L** - Vitrea assess the ROI and normalizes the map to the region

  NOTE: If you draw an ROI in an incorrect location, Vitrea will not apply the normalization correctly.
- **Apply ROI W/L (All)** - applies the ROI setting to all the maps

6. To make any of these settings the default, press CTRL-P to create a modified preset.

CAUTION: Manually window/level the maps if the automatic window/level does not apply or applies incorrectly.

Correct the Artery Location

If Vitrea selects an incorrect artery location, manually specify a new location.

1. Right-click and drag left and right to scroll temporally, and drag forward and back to scroll spatially, to locate the earliest enhancing artery.

2. Click

.

3. Click and drag in the view to draw a generous contour around the artery location.

4. Click

.

5. Click

.

Correct the Vein Location

If Vitrea selects an incorrect vein location, manually specify a new location.

1. Right-click and drag left and right to scroll temporally, and drag forward and back to scroll spatially, to locate the densest enhancing vein.

2. Click and drag in the view to draw a generous contour around the vein location, typically the superior sagittal sinus vein.

3. Click

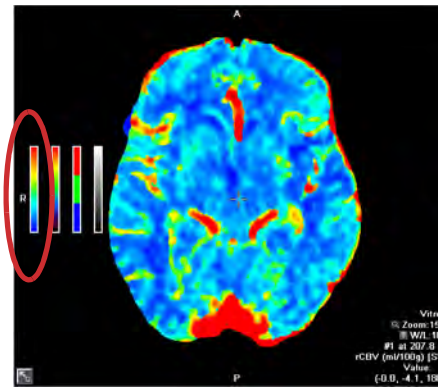
.

4. Click

.

Adjust Measurement Colors

Change the color on any of the perfusion map images to highlight areas of the brain in different color schemes.



1. Click the color scale bar in any view.
2. Hover the cursor on each color scale to see the name and a preview of each one.
3. Click the desired color scale.

   OR

   Press CTRL then click the color scale to apply to all maps.
4. To invert the color scale, click under the color scale bar.

Select a Deconvolution Method

1. Click the dropdown arrow next to the **Compute** button. Note the two deconvolution methods:
   - SVD – Conventional singular value decomposition or cSVD — a deconvolution method that uses the central volume principle.
   - SVD+ – Delay-insensitive singular value decomposition or dSVDs – an algorithm that accounts for delay of contrast arrival (delayed flow) in the calculation of the MTT.

TIP: The currently selected method displays near the Compute button and at the bottom of each of the views.

NOTE: Changing the deconvolution method causes a change in the appearance in the perfusion maps and the computed values.

NOTE: The default layout for the SVD+ method is the 6-up perfusion display.

TIP: ROI contours will be preserved as you switch between methods.

Display Measurements for Crosshair Positions

Crosshairs display perfusion measurements for a particular location in the view.

1. Click

.

2. Click and drag in any of the images.

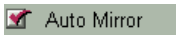
   Vitrea displays the perfusion measurements and coordinates for that location in each view.

   The Time-Density Graph displays:

   - “density over time” curve, the area under the curve, and the transit time for this crosshair location in green, and
   - the gamma approximation curve (how the algorithm approximates the first pass of contrast) for this crosshair location in gray

Place User-defined ROI Contours

If you prefer to place ROIs yourself, draw your own contours. Mirror ROI contours display in the contralateral hemisphere. Edit any ROI, including mirrored ROIs, or ROIs that are part of a template.

1. Select the Auto Mirror check box 

in the View Options area.

2. Click

.

3. Click and drag in any image to draw a contour.

   Vitrea places matching ROI contours in the other views.

4. Manage the contours:

To	Then
Edit the size or shape of a contour	**1.** Hover the cursor over the edge of a contour. **TIP:** The cursor changes to a pencil. **2.** Click the edge of the contour and drag.
Move a contour	**1.** Hover the cursor near the center of the contour. **TIP:** A small circle displays inside the contour. **2.** Click and drag the small circle.
Copy and paste a contour	**1.** Click the contour to select it. **TIP:** The contour turns pink. **2.** Press CTRL-C. **3.** Press CTRL-V. **4.** Move the new contour into place.
Delete a contour	**1.** Click the contour to select it. **TIP:** The contour turns pink. **2.** Press DELETE.
Delete all contours	**1.** Press CTRL-A to select all the contours. **2.** Press DELETE.

Customize the ROI Templates

Customize the ROI templates by type, size and number, and whether to fit the ROIs within the skull. The types of ROIs are:

- Orbital
- Conical
- Conical with deep gray nuclei
- Vascular territories

- Customize the template:

To	Then
Change the type of template	**1.** Click next to the template button. **2.** Click the button for the template type.
Change the size of ROIs	**1.** Click in the Diameter field . **TIP:** This field is labeled Thickness if you are using a Conical type. **2.** Enter a new number.
Change the number of ROIs	**1.** Click in the Count field . **2.** Enter a new number.
Display the ROIs as true mirror images	• Clear the Tight Fit check box .
Fit the ROIs within the skull	• Select the Tight Fit check box .

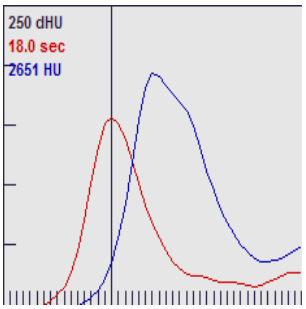
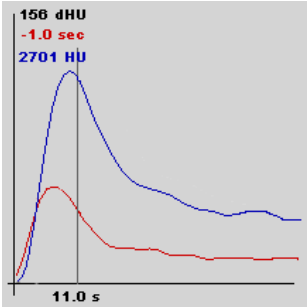
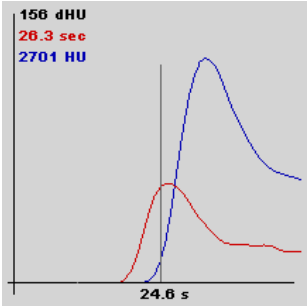
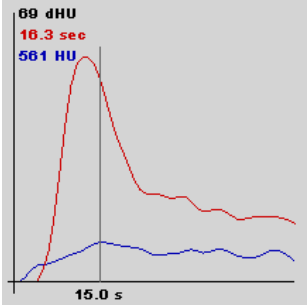
Appendix

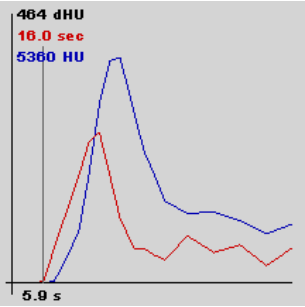
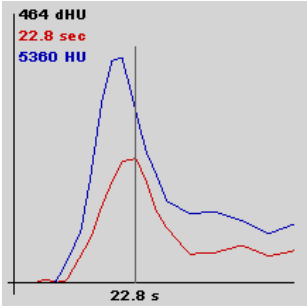
Input Artery and Output Vein Positions

VitreaAdvanced uses an early-peaking, dense input artery as a reference input in the perfusion computations. The artery selection affects the CBF and MTT maps. A late-peaking, dense vein reference is used as an internal reference in the brain to normalize the blood volume results. The vein selection affects the CBV map.

The Time-Density Graph displays the “image density over time” curve and the transit time for the artery in red. The Time-Density Graph displays the “image density over time” curve and the total density for the vein in blue. For more information regarding the Time-Density Graph, see Time-Density Graph Calculations.

Be sure you verify that VitreaAdvanced has marked the artery and vein locations correctly.

Graph	Description
	Good Choice • The artery and vein curves start after time 0. • The artery and vein curves show some time after wash-out. • The artery curve peaks first and the vein curve peaks later. • Both curves are smooth, bell-type curves.
	Bolus Timing - Scan Starts Too Late • The curves start increasing before time 0. • This may cause inaccurate results.
	Bolus Timing - Scan Stops Too Early • The curves end before wash-out. • This may cause inaccurate results.
	Artery and Vein Curves - Vein Not Dense • Vein peak is small. • This may cause inaccurate results. • Edit the vein selection.

Graph	Description
	Artery and Vein Curves - Artery Not Dense, Has Artifacts • Artery peak is small. • This may cause inaccurate results. • Edit the artery selection.
	Artery and Vein Curves - Artery Too Late (Affected Side Selected) • May occur if artery in affected side is selected. • Artery peak is small. • Artery is not dense. • Artery curve peaks after the vein curve. • This may cause inaccurate results. • Edit the artery selection.

If necessary, edit the automatically-selected artery or vein locations. To override the automatic selections, locate the input artery with an early transit time (such as the middle cerebral arteries, the anterior cerebral arteries, the posterior communicating arteries, or the anterior communicating arteries) and the output vein with the maximum total density (such as the sagittal sinus vein). There are two methods for identifying these positions:

- Drawing contours in the areas and allowing Vitrea to locate the positions within the contours
- Placing the crosshairs in the positions you choose (not recommended)

CT Brain Perfusion Measurements

VitreaAdvanced uses the artery and vein positions to calculate the CT brain perfusion measurements, which consist of:

Identification	Description	Unit of Measure
CBV (Cerebral Blood Volume)	The distribution of blood per unit brain tissue. It provides evaluation of autoregulation (collateralization).	ml/100g
CBF (Cerebral Blood Flow)	The blood volume running throughout the capillary blood vessels per unit time per unit brain tissue. CBF identifies areas of low blood flow.	ml/100g/min
MTT (Mean Transit Time)	The average amount of time that blood takes to transit through the capillary vessels. Increases in MTT indicate vasodilatory response to reduced flow.	seconds
TTP (Time to Peak of tissue response curve)	Demonstrates the relative time of peak enhancement for brain tissue voxels. It provides an indication of delayed flow due to stenosis or occlusion and is useful for identifying collateralization.	seconds
Delay (Delay time of tissue response curve)	Demonstrates the relative arrival time of contrast medium for tissue voxels. The information the delay map provides is similar to TTP although the calculation method differs. (The delay time is used to correct the MTT values.) **NOTE:** In the case of arterial occlusion, brain tissue survives if sufficient collateral flow is present. In essence, it does not matter when the oxygenated blood arrives in the brain, as long as it arrives in the appropriate concentration. A delay in blood flow can therefore be ignored for perfusion.	seconds

NOTE: The TTP and Delay measurements display on the 6-up Viewer window format only.

For information on how VitreaAdvanced calculates these measurements, see Perfusion Image Map Calculations.

Calculations

The following guidelines help you interpret the brain perfusion measurements and the Time-Density Graph calculations.

Automatic Artery/Vein Selection

The software selects artery and vein locations from over the whole brain or from within specified regions of interest. To correct the auto-selected locations, use the ROI method to specify new locations.

Automatic artery/vein selection identifies vessels using the following rules:

- Early artery rule: The time-to-peak of the artery curve is smaller than the average time-to-peak of vessels in the ROI.
- Late vein rule: The time-to-peak of the vein curve is larger than the average time-to-peak of vessels in the ROI.
- Dense vessels rule: The area under the artery and vein curves is larger than the average area under the curve of the respective vessel types in the ROI.
- Dense vessels rule: The artery and vein curves with the highest peak enhancement, subject to the previous rules, are the ones selected.

Automatic selection ensures that:

- The artery curve enhances earlier than the average enhancement time of the vessels in the ROI.
- The vein curve enhances later than the average vessel curve.
- The area under both the artery and vein curves is above average.
- The artery and vein curves with highest peak enhancement, subject to the previous rules, are the ones selected.

Manual Artery/Vein Selection Effect on Reproducibility

When you select an artery or vein using the Crosshair tool, the software uses the concentration curves from the exact locations you specified and does not ensure their suitability for obtaining correct perfusion measurements.

Effects of vein location choice include:

- Area under the first pass of the vein curve directly scales CBV and CBF values (this does not introduce relative differences in either CBV or CBF, but affects scale).

- The time span for all calculations is restricted to the first pass of contrast estimated from the vein curve (this can introduce variability in the MTT and CBF maps since it controls what portion of the artery curve is used in computations).

Effects of artery location choice include:

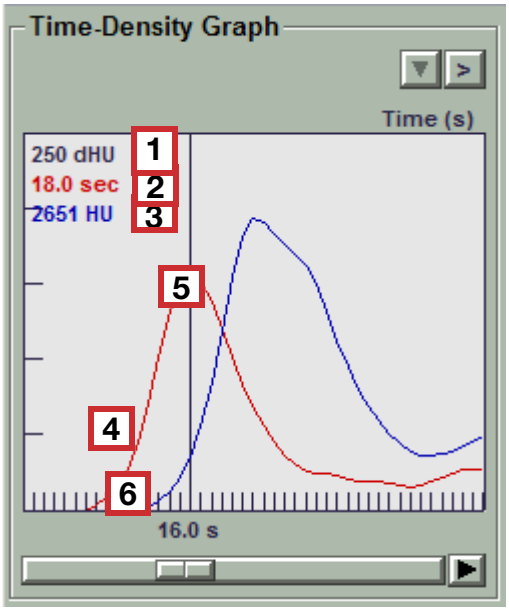
- The MTT and CBF computation is affected by the shape (not scale) and time of peak enhancement of the artery curve.
- If the artery enhances after tissue does, CBF can be drastically overestimated with the SVD method (but not the SVD+ method).

Time-Density Graph Calculations

The Time-Density Graph plots the contrast density over time.

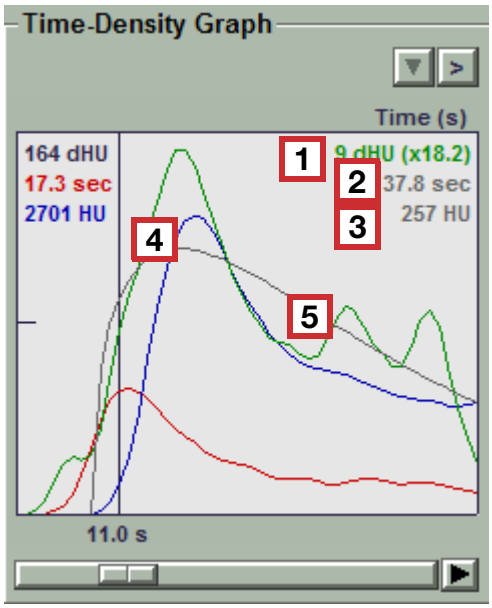
The vertical line indicates the time of the currently displayed image, and the corresponding time value is displayed along the horizontal axis.

The Time-Density Graph displays the image density over time for both the identified input artery and output vein.



No	Description	Details
1	Range of image density	The difference between the peak and baseline of either the artery or the vein, whichever difference is greater
2	Transit time for the artery location	Mean time for the first pass of contrast to reach the artery location
3	Total density for the vein location	Area under the vein curve
4	Artery (red) curve	Image density over time for the artery location
5	Vein (blue) curve	Image density over time for the vein location
6	Cross-reference line	Includes corresponding time value

When the crosshair is active, the graph adds a green curve corresponding to the smoothed data and a gamma approximation curve.



No	Description	Details
1	Range of image density	The difference between the peak and baseline of the crosshair location (the number in parentheses is the factor used to scale the curve to fit the graph)
2	Transit time for the crosshair location	Mean time for the first pass of contrast to reach the crosshair location
3	Total density for the crosshair location	Area under the gamma curve
4	Crosshair (green) curve	Image density over time for the crosshair location
5	Gamma (gray) curve	Gamma approximation of the crosshair curve

Perfusion Image Map Calculations

VitreaAdvanced uses the earliest input artery and densest output vein positions to calculate the CT brain perfusion measurements. Once VitreaAdvanced calculates the results, a 4-up view that includes the computed color maps displays.

Value	Unit of Measure	Description	Valid Range
Cerebral Blood Volume (CBV)	ml/100g of tissue	The ratio of the area under the tissue curve and the area under the curve of the vein curve, computed over the first pass of the bolus. A correction factor accounting for the difference in large-vessel and small-vessel hematocrit is used (0.85), and the conversion into units of ml/100g tissue assumes average brain tissue density of (1.1 g/ml).	0 — 20 ml/100g
Time to Peak (TTP)	seconds	The time at which the density reaches a maximum value.	0 — 100 seconds
Mean Transit Time (MTT)	seconds	The area under the normalized (impulse) residue function. The residue function is computed by non-parametric deconvolution using a delay-insensitive method.	0 — 20 seconds
Cerebral Blood Flow (CBF)	ml/100g/ minute	The ratio of rCBV and MTT, converted into the appropriate units.	0 — 150 ml/100g/ min
Delay	seconds	The time when the computed residue function reaches the maximum, relative to the time of contrast arrival in the artery.	-50 — 50 seconds
Region of Interest (ROI) measurement	cm^2 and HU in the 2D view, applicable UOM in other views	Average value in the region ± standard deviation (as indicated). Pixels that have been identified as vessels are ignored during the perfusion calculations. Average/Std values in ROIs exclude any detected vessel pixels.	

CAUTION: Some vessels may not be detected by the segmentation algorithm— a circumstance that will skew the results.

Summary Map

The Summary Map is a simplified derivative of the other perfusion maps. The software compares the two hemispheres to make distinctions of “maintained,” “reduced,” and “increased.”

Categories by Relative Value

The numbers that display in the tool tip when you adjust the slider bars are based on the software-generated distinctions.

If the top slider shows a TTP value of +5 seconds, that means that TTP values that are more than 5 seconds greater than the average TTP within the contralateral MCA territory are considered “increased.”

Similarly, if the bottom slider shows a CBV value of -20%, that means that CBV values that are more than 20% below the average CBV within the contralateral MCA territory are considered “reduced.”

Tissue Classifications

The software assesses which tissue is Normal, Yellow, or Red by applying the following logical rules to the categorized perfusion map data.

Tissue Classification	Rule
Red	(**rel. CBV** ↓ **AND** (**TTP** ↑ or **Delay** ↑)) **OR** **abs. CBV** ↓↓ **OR** **MTT** ↓↓ Relative CBV is reduced and either TTP or Delay is increased, or absolute CBV is extremely reduced, or MTT is extremely reduced. **NOTE:** CBV is reduced compared with the reference hemisphere, but, because it is possible to have a locally reduced CBV in healthy white matter, the software also looks for an increase in TTP or Delay. For computational reasons, extremely reduced CBV (in absolute terms) or extremely reduced MTT (in relative terms) are also marked Red.

Tissue Classification	Rule
Yellow	(**TTP** ↑ or **Delay** ↑ or **CBF** ↓) **AND CBV** → TTP is increased, or Delay is increased, or CBF is decreased, and CBV is maintained. **NOTE:** TTP or Delay is increased or CBF is decreased. In order to differentiate Yellow from Red, this rule states that CBV must not be reduced.
Normal (Green)	**TTP** → **AND Delay** → **AND CBV** → TTP, Delay, and CBV are all maintained. **NOTE:** All indicators are normal.

CT Brain Shuttle Perfusion

Contents

Brain Shuttle Perfusion Overview

- Perfusion Study
- Shuttle Data
- Perfusion Maps
- DICOM Export Limits
- Bolus Injection

Brain Shuttle Perfusion Lesson

I Select Study

II Choose Protocol and Preset

- Data Manager
- Gallery Window

III Perform Analysis

- Review the Time-Density Graph
- Review the Artery and Vein Positions
- Display the Perfusion Maps
- Set the Window/Level Settings in the Perfusion Maps
- Edit the Midline
- Use the ROI Templates
- Take Snapshots
- Create an Orthogonal Batch or Movie
- Create a Collage Batch

IV Distribute Findings

Additional Procedures

- Display the Summary Map

- Change the Artery Location
- Change the Vein Location
- Re-compute the Results
- Sculpting
- Oblique MPR Mode
- Change the Appearance of the Views
- Set Measurement Colors
- Display Measurements for Crosshair Positions
- Place User-defined ROI Contours
- Normalize the Map Window/Level Values Based On a ROI
- Customize the ROI Templates
- Review the CT/Perfusion Map Fusion View

Troubleshooting

Appendix

- Calculations
  - Automatic Artery/Vein Selection
  - Manual Artery/Vein Selection Effect on Reproducibility
  - Time-Density Graph (Artery and Vein Locations)
  - Time-Density Graph (Crosshair Location)
- Perfusion Image Map Calculations
- Summary Map
  - Categories by Relative Value
  - Tissue Classifications

Brain Shuttle Perfusion Overview

The CT Brain Shuttle Perfusion workflow is for assessing perfusion disturbances within the brain using Toshiba thin-slice, wide-volume data.

When you choose a perfusion preset, Vitrea identifies the artery and vein, then computes five color-coded image maps with quantitative results related to the patient's regional cerebral blood volume (rCBV), mean transit time (MTT), regional cerebral blood flow (rCBF), time to peak of tissue (TTP), and delay of tissue response (Delay). The concurrent display of the five color image maps aid in the assessment of the type and extent of cerebral perfusion disturbances.

Perfusion Study

A CT series scanned for brain perfusion measurement in Vitrea consists of a series of slices produced by repeatedly scanning the same region, at the same table position.

NOTE: If the volume loaded is not a valid perfusion dataset, you will not be able to load the volume into the Brain Perfusion protocol.

CAUTIONS:

- **For measuring brain perfusion in Vitrea, you must load only a series of the brain scanned at Brain Shuttle Perfusion CT protocol settings. This measuring tool is not intended for measuring perfusion in other anatomical regions.**
- **Verify the absence of a compromised blood-brain barrier (such as a hemorrhage) and motion. If either of these conditions exist in the study, you should not rely on the resulting brain perfusion measurements. The computations assume an intact blood-brain barrier and no motion. The accuracy of measurements of images that do not meet these criteria will be compromised.**
- **Verify that Vitrea has marked the artery and vein locations correctly. If the relationship between the artery and vein curves does not look appropriate, re-evaluate the artery and vein selections and, if needed, find new vessel positions. Measurements will most closely characterize the actual series when you select the optimal location and contrast density for each vessel position.**

CAUTION: Factors that can affect the accuracy of the results are:

- **Not fully capturing the contrast bolus (including at least 2 seconds of pre-enhancement images and post-enhancement).**
- **Extreme patient head motion (Vitrea corrects for slight head motion, however extreme motion may cause numerical errors in the calculations).**
- **Selecting a delayed artery as a reference.**

CAUTION: Clear the Brain Midline check box to hide the brain midline before applying oblique orientation. When the view is in oblique orientation, the displayed midline is not accurate.

Shuttle Data

Perfusion studies with shuttle are scanned in a variety of subsets with wide-coverage acquisition protocols. Vitrea builds volumes from data from supported thin-slice scanners and scanning protocols including jog and helical acquisition.

Vitrea interpolates between time points so that the full range is viewable within the volume. Volumes will have “interpolated” labeled in view.

CAUTION: Due to the nature of shuttle studies, you may notice some slices with missing data where the top and bottom scans were pieced together. Do not use these slices for any assessment.

Perfusion Maps

Vitrea uses the input artery with the earliest transit time and the output vein with the maximum total density to calculate brain perfusion.

After the artery and vein are identified, Vitrea computes five color-coded image maps with quantitative results:

Identification	Description
rCBV (regional Cerebral Blood Volume)	The distribution of blood per unit brain tissue. It provides evaluation of autoregulation (collateralization).
rCBF (regional Cerebral Blood Flow)	The blood volume running throughout the capillary blood vessels per unit time per unit brain tissue. CBF identifies areas of low blood flow.
MTT (Mean Transit Time)	The average amount of time that blood takes to transit through the capillary vessels. Increases in MTT indicate vasodilatory response to reduced flow.
TTP (Time to Peak of tissue response curve)	Demonstrates the relative time of peak enhancement for brain tissue voxels. It provides an indication of delayed flow due to stenosis or occlusion and is useful for identifying collateralization.
Delay (Delay time of tissue response curve)	Demonstrates the relative arrival time of contrast medium for tissue voxels. The information the delay map provides is similar to TTP although the calculation method differs. (The delay time is used to correct the MTT values.) **NOTE:** In the case of arterial occlusion, brain tissue survives if sufficient collateral flow is present. In essence, it does not matter when the oxygenated blood arrives in the brain, as long as it arrives in the appropriate concentration. A delay in blood flow can therefore be ignored for perfusion.

DICOM Export Limits

Export a CT Brain Shuttle Perfusion report to DICOM servers or PACS devices. Keep these limitations in mind when using exported reports:

CAUTIONS:

- **You should not rely on Vitrea brain perfusion color maps viewed in grayscale on PACS workstations in making a diagnosis, as the conversion from color may be inaccurate.**

- **Vitrea exports each image in a report as a DICOM Secondary Capture image. Therefore, taking measurements (Hounsfield unit readings or dimensional rulers) and performing other similar operations on PACS or other devices on these Secondary Capture images will not yield accurate results.**
- **If you export images to a DICOM image server, the exported images may not have the same detail as the original scanned images.**

Bolus Injection

The operator should take care to capture the entire time of bolus transit, from just before wash-in to wash-out.

Brain Shuttle Perfusion Lesson

I. Select Study

Load a Brain Shuttle Perfusion study.

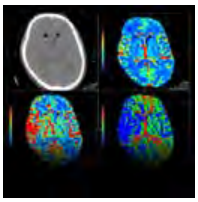
See the instructions for your Vitrea type (VitreaAdvanced Through the Data Manager or VitreaWorkstation) in the **Select Study** chapter of the **VitreaAdvanced-VitreaWorkstation General Education and Reference Guide**.

II. Choose Protocol and Preset

Use one of these procedures:

Data Manager

- Double-click the **Brain Shuttle Perfusion** application thumbnail.



Gallery Window

1. On the Gallery window, select the **Brain Perfusion CT** protocol.

2. Click Pick next to the **Shuttle Perfusion**.

III. Perform Analysis

Review the Time-Density Graph

The Time-Density graph displays the density over time curve and the transit time for the artery in red, and it displays the density over time curve, area under the curve, and transit time for the vein in blue.

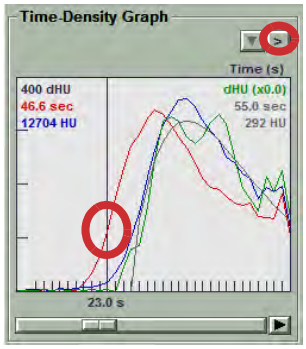
For more information regarding the elements on the Time-Density graph, see the Appendix of this chapter.

3. To display a time along the curves, move the black time line to the desired location (for example, the peak of the artery curve).

   OR

   Drag the **Time Slice** slider.

   TIP: To expand the Time-Density Graph into a separate, larger viewer, click .



4. To distribute a snapshot of the graph, click the drop down and select from the menu.

Review the Artery and Vein Positions

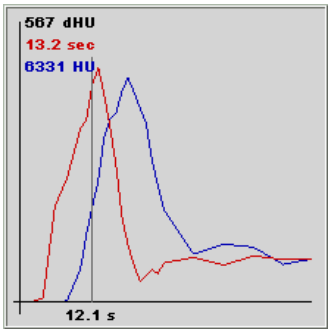
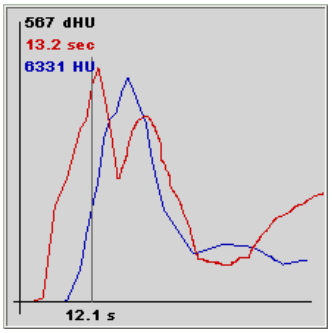
In most cases, Vitrea selects the correct locations for the artery and vein. It is important to verify that Vitrea marked the vein and artery locations correctly.

5. Scroll through MPRs to review the locations of the artery selection (red dot) and vein selection (blue dot).

TIP: Click the red or blue curve in the graph to navigate the MPR view to the artery or vein position.

6. Review the Time-Density graph and be sure that:

- The rise in the curves start after time 0
- The curves do not have multiple peaks
- The artery curve peaks before the vein curve
- Some time of washout is present.

Good Bell Curves (indicate correct locations)	Multi-Peak Curves (indicate incorrect locations)
	

- The red line indicates the Artery
- The blue line indicates the Vein

See the Troubleshooting section of this Module for examples of Time-Density graphs.

TIP: To enlarge the graph in a separate viewer, click .

If either the red or blue curve looks inappropriate, override the artery or vein location. Incorrect vessel locations result in invalid perfusion maps.

See the Additional Procedures section of this Module for information on correcting artery and vein locations.

Display the Perfusion Maps

7. Click to switch to a six-up view, which displays:

- MPR view
- regional cerebral blood volume (rCBV)
- regional cerebral blood flow (rCBF)
- mean transit time (MTT)
- time to peak of tissue (TTP)
- delay of tissue response (Delay)

NOTE: Vitrea uses the SVD+ deconvolution algorithm to generate the quantitative maps. SVD+ is based on the standard SVD (singular value decomposition) deconvolution algorithm. However, SVD+ is designed to be delay insensitive.

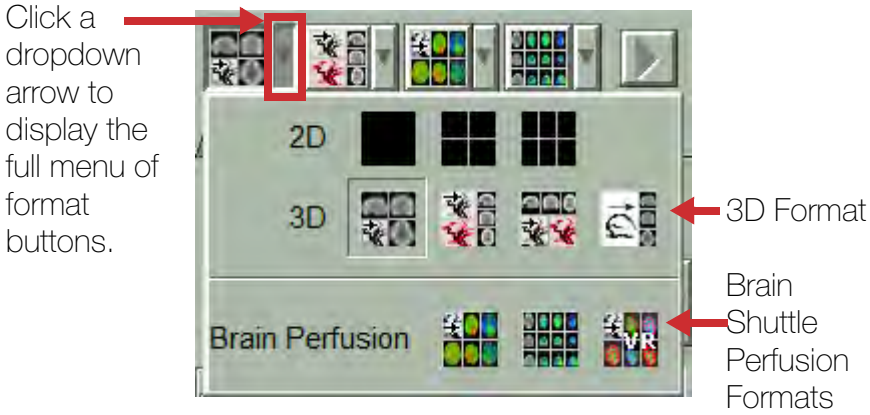
Analysis using the SVD+ algorithm does not include any delay of contrast arrival (delayed flow) in the calculation of the MTT, and therefore provides an accurate MTT measurement according to the definition.

As perfusion is calculated from CBV/MTT, be aware that, unlike other algorithms, delayed flow will not be shown as low flow.
Vital prefers a delay insensitive deconvolution method for whole brain perfusion imaging. Without delay insensitivity, where a single arterial input function is used, the computed blood flow would appear to

gradually decrease on cranially scanned slices due to natural blood flow dynamics.

TIP: To change the MPR plane of the perfusion maps view, click .

TIP: To display the MPR, rCBV, MTT, rCBF views in the axial, coronal, and sagittal planes, click .

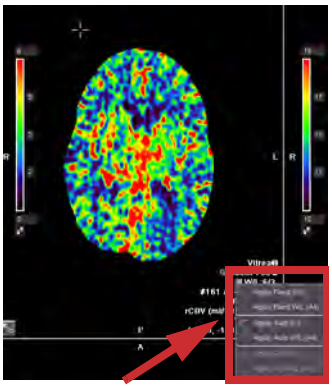


Format Button	Description
2D Formats	One-up 2D — 2D axial view. Four-up 2D — 2D axial, rCBV, rCBF, and MTT views. Six-up 2D — 2D axial, rCBV, TTP, rCBF, MTT, and Delay views.
3D Formats	Four-up 3D — Sagittal, coronal, axial, and 3D views.
Brain Shuttle Perfusion Formats	Six-up 3D — MPR view, plus the rCBV, TTP, rCBF, MTT, and Delay views in the same plane. **NOTE:** To change the order in which the MPR planes display, click Rotate MPRs. Twelve-up 3D — MPR, rCBV, rCBF, MTT views in the axial, coronal, and sagittal planes. Six-up Alt — 3D view, plus the rCBV, rCBF, MTT, TTP and Delay views in 3D.

8. Right-click and drag up and down in the views to scroll through crosshair locations.

Set the Window/Level Settings in the Perfusion Maps

Set the window/level settings in the perfusion maps based on fixed, automatic, or user-defined ROI settings.



9. Click the Window/Level dropdown in a perfusion map. W/L:4/2

10. Select a setting.

- **Apply Fixed W/L** - a fixed setting for the map
- **Apply Fixed W/L (All) -** applies the fixed setting to all the maps
- **Apply Auto W/L** (default setting) - Vitrea assesses the map and computes a setting based on scan-specific factors using ASIST guidelines
- **Apply Auto W/L (All) -** applies the auto setting to all the maps
- **Apply ROI W/L** - Vitrea assesses the ROI and normalizes the map to the region

  NOTE: If you draw an ROI in an incorrect location, Vitrea will not apply the normalization correctly.
- **Apply ROI W/L (All)** - applies the ROI setting to all the maps

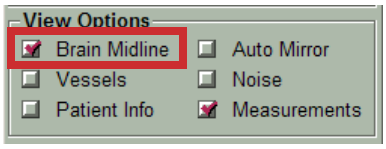
TIP: To make any of these settings the default, press CTRL-P to create a modified preset.

CAUTION: Manually window/level the maps if the automatic window/level does not apply or applies incorrectly.

Edit the Midline

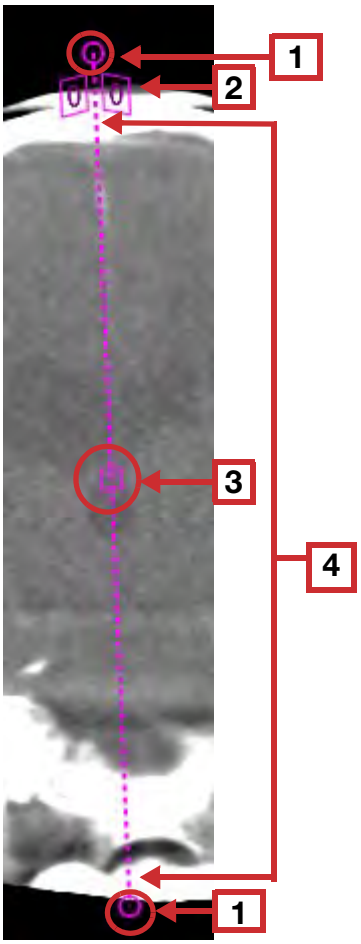
Each of the views contains an editable midline. Vitrea uses the midline to determine the mirror ROI contour placement, so it is important to place the midline in the correct location.

1. Select the Brain Midline check box in the View Options area.



2. Edit the brain midline.

   TIP: Edit in the coronal view first, then in the axial view.



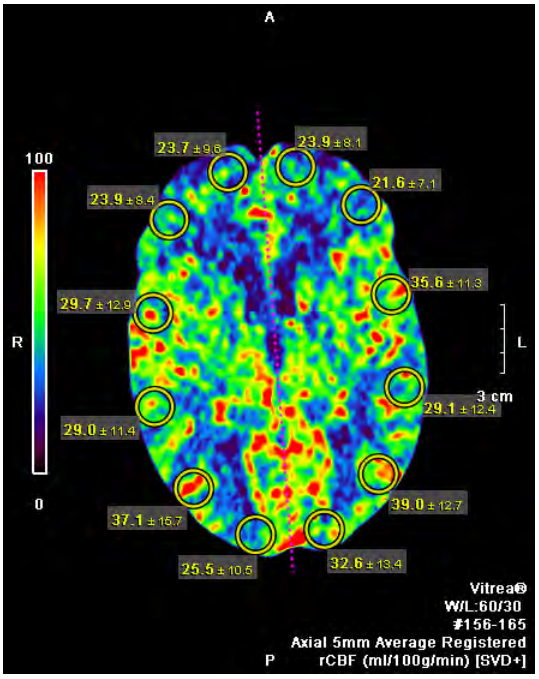
Callout	Description
1	To move an end of the midplane line, pivoting on the opposite end, or to extend the length of the midline: • Click and drag a **Midplane Line End** icon.
2	To mirror the ROIs on the other side of the midline: Click the **Mirror** icon on the side that has the ROI.
3	To slide the entire midplane line: • Click and drag the **Midplane Line Center** icon.
4	To pivot the midplane line on its center: • Click and drag anywhere along the midplane line (other than the Midline End, Midline Center, or Mirror icons).

Use the ROI Templates

Use a template to display perfusion measurements in mirrored ROIs.

3. Click MPR to change the MPR plane to axial.

4. Click to display orbital ROIs in the axial view.



See the Additional Procedures section of this Module for more information on customizing the ROI Templates.

Take Snapshots

Take snapshots to save your work and to put into a report.

5. Right-click and select , then click in each view.

OR

Hold ALT to keep taking snapshots without having to activate the snapshot tool each time.

OR

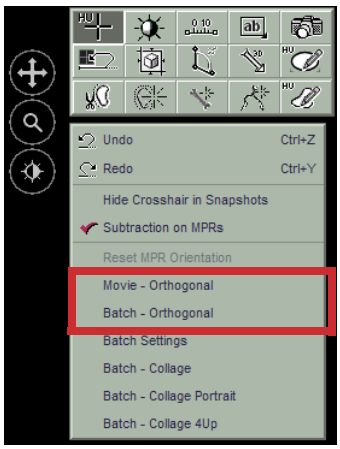
Hold CTRL to take one snapshot that includes all views.

NOTE: If the resulting image will be viewed on a PACS, the measurements on the image may be difficult to read.

Create an Orthogonal Batch or Movie

Make orthogonal slice batches or movies of the perfusion maps.

6. Right-click in a perfusion map view and select **Movie - Orthogonal** or **Batch - Orthogonal**.

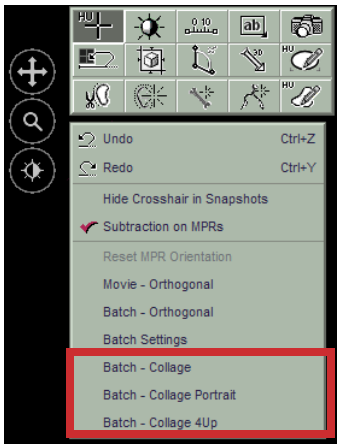


Create a Collage Batch

Create a single batch that includes the MPR and perfusion map views in one screen. Choose between a 4-up or 6-up format. The Collage Portrait format produces images in a portrait orientation, suitable for PACS monitors.

NOTE: The Collage Portrait option is only available in the 6-up view.

7. Right-click in a perfusion map view and select **Batch - Collage, Batch - Collage Portrait** or **Batch - Collage 4-up**.



IV. Distribute Findings

The snapshots you save in the Viewer window are saved to the Report window.

1. Click Report at the bottom of the window.

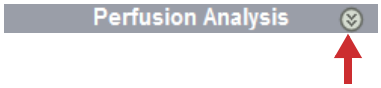
2. Export your findings or create a report.

   See the **Distribute Findings** chapter of the **VitreaAdvanced-VitreaWorkstation General Education and Reference Guide** for instructions on exporting findings, restoring workflow, and creating reports.

Additional Procedures

This section addresses some less common procedures to complete your workflow.

TIP: You may need to click next to **Perfusion Analysis** in order to display the tools mentioned in this section.



Display the Summary Map

The Brain Perfusion Summary Map displays color-coded regions, based on a derivative of the hemispherical comparisons of all the other maps, where perfusion values appear to be increased or decreased based on the contralateral hemisphere.

The Summary Map image can be used to communicate the results of a CT Perfusion exam and to provide tissue classification.

For areas marked as Yellow, VitreaAdvanced uses a relative value where TTP is increased, in seconds, compared to the reference hemisphere.

For areas marked as Red, VitreaAdvanced uses a relative value where CBV is decreased, in percent, compared to the reference hemisphere.

See the Appendix for exact rules for Yellow and Red.

CAUTION: Use the Summary Map in conjunction with the other perfusion maps. Do not use the Summary Map by itself to make diagnostic decisions.

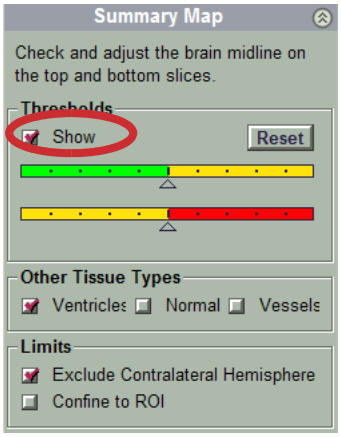
1. Complete the workflow and display the perfusion maps as outlined in the Perform Analysis section.

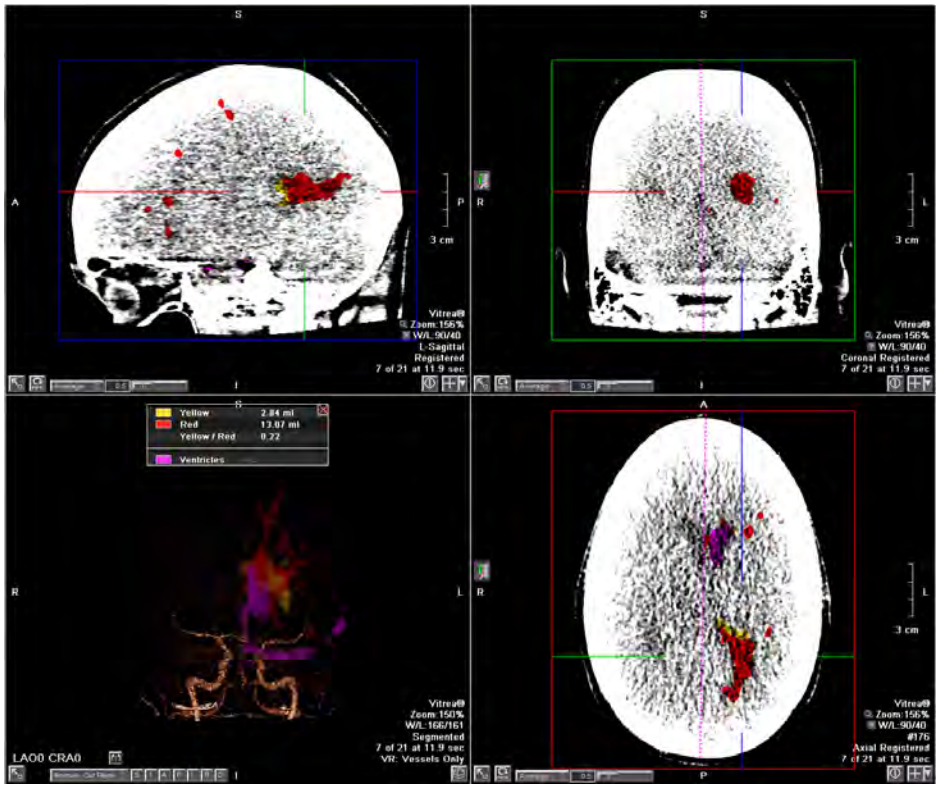
2. Display and edit the brain midline as described in the Perform Analysis section.

3. Select the **Show** check box.

   The Summary Map displays in the MPR and 3D views.

   - Yellow indicates areas where TTP is above the threshold
   - Red indicates areas where CBV is below the threshold
   - Magenta indicates ventricles
   - Green indicates normal areas (when **Normal** check box is selected)





NOTE: The Volume, in ml, is the total volume of Yellow or Red areas for all slices. The Yellow/Red ratio is also displayed.

- To hide the magenta areas that indicate ventricles, clear the **Ventricles** check box. Hiding the magenta area will still show any tissue classification (yellow or red) for that same area.

  NOTE: Hiding the ventricles may increase the volume values given for Yellow and Red since that same area was not included in the volumes when the tissue was classified as “Ventricles.”

- To show unaffected areas shaded in green, select the **Normal** check box.
- To show vessels shaded in light pink, select the **Vessels** check box.
- To show the data that displays on the contralateral hemisphere, clear the **Exclude Contralateral Hemisphere** check box.
- To show the data that displays in the cerebellum, clear the **Exclude Cerebellum** check box.
- To show only data within a defined region of interest, draw an ellipse or ROI on the view, then select **Confine to ROI**.

NOTE: Use of the Exclude Contralateral Hemisphere or Confine to ROI check boxes will affect the volumes displayed in the Yellow or Red.

Set Reference Hemisphere

When Vitrea displays the Summary Map, it uses the TTP value to attempt to determine the unaffected hemisphere as a reference for perfusion normalization. An indicator or displays on the appropriate side of the viewer to correlate with the unaffected side.

NOTE: It is important that you verify that Vitrea has correctly identified the unaffected side to be the reference hemisphere.

Re-set the Reference Hemisphere if necessary.

1. Click the Hemisphere Indicator or .
2. Choose **Force Left** or **Force Right** from the dropdown.

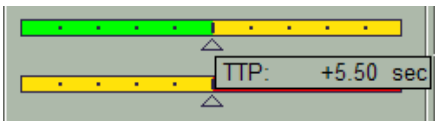
Edit the Summary Map Thresholds

Use the Thresholds slider bars to edit the rules for determining areas of Yellow and Red.

NOTE: It is your responsibility to adjust the sliders to the proper thresholds and to use the proper definitions of “Normal,” “Yellow,” and “Red.” Review the other perfusion maps as a guide.

See the Appendix for details on tissue classification.

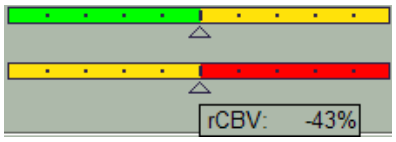
3. Adjust the top slider bar to define the threshold between Normal and Yellow. Use the values in the tool tip as a guide.



- Move the slider left for more aggressive rules for Yellow.
- Move the slider right for less aggressive rules for Yellow.

See the Appendix for definitions of Normal and Yellow.

4. Adjust the bottom slider bar to define the threshold between Yellow and Red. Use the values in the tool tip as a guide.



- Move the slider left for more aggressive rules for Red.
- Move the slider right for less aggressive rules for Red.

See the Appendix for definitions of Red.

Change the Artery Location

To change the artery location, draw ROIs to specify a new location.

1. Right-click and drag left and right to scroll temporally, and drag forward and back to scroll spatially, to locate the earliest enhancing artery, typically the internal carotid or a cerebral artery.

2. Right-click and select .

3. Click and drag in the view to draw a generous contour around the artery location.

   TIP: Be sure to avoid any clip or coil.

   TIP: Avoid selecting an artery on the affected side.

4. Click

.

   TIP: Vital recommends you use an ROI to specify the earliest artery location. Using the Crosshair tool to select an artery is possible but not advised because the software calculates the findings for that exact location, and the suitability of that location cannot be ensured.

Change the Vein Location

To change the vein location, manually specify a new location.

1. Right-click and drag left and right to scroll temporally, and drag forward and back to scroll spatially, to locate the densest enhancing vein.

2. Click and drag in the view to draw a generous contour around the vein location, typically the superior sagittal sinus or transverse sinus vein.

3. Click

.

   TIP: Vital recommends you use an ROI to specify the densest enhancing vein location. Using the Crosshair tool to select an artery is possible but not advised because the software calculates the findings for that exact location, and the suitability of that location cannot be ensured.

Re-compute the Results

Once you change the artery or vein location (or both locations), you need to re-compute the perfusion results.

- Click

.

Sculpting

Sculpt in the 3D or MPR views just like any other study in Vitrea.

Oblique MPR Mode

Rotate the crosshairs in the MPR views to adjust the orientation of the views just like any other study in Vitrea.

1. Click in the lower right corner of the view to switch to oblique mode.

2. In one of the MPR views, position the cursor over one of the crosshairs .

TIP: This view remains in Orthogonal mode, and the other two views display images at oblique angles.

3. Drag the crosshair in the view while watching the other views.

TIP: As you drag, the crosshairs rotate around their intersection point, staying perpendicular to each other.

TIP: Rotate crosshairs in more than one view.

TIP: Rotating the crosshairs in the MPR views also rotates the crosshairs in the perfusion map views.

4. To “walk” a vessel, press and hold CTRL , and drag in the view.

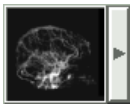
TIP: The center of the crosshairs act as a fulcrum point.

Change the Appearance of the Views

When Vitrea processes a Brain Analysis study, it segments the bone and tissue. You can change the appearance of those regions.

TIP: Click in the view to activate it before you apply the changes.

Select a Preset:

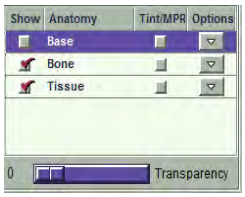
1. Click a **Preset** button  .

TIP: The graphic on the **Preset** button changes depending on the view you select.

2. Click a preset from the Preset Selector.

Change the Window/Level by region:

1. Select a region in the Region Management area.



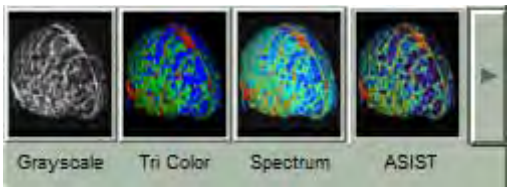
2. Right-click and select .

3. Click and drag in the view.

Set Measurement Colors

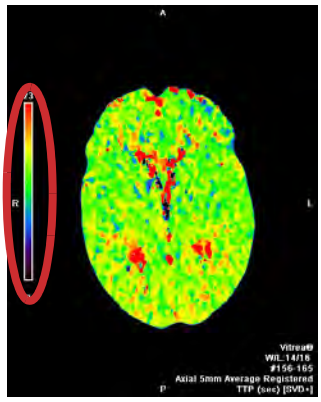
Change the color on any of the perfusion map images to highlight areas of the brain in different color schemes.

1. Select a color scale visualization preset button.



OR

2. Use the color scale bar:



   a. Click the color scale bar in any view.
   b. Hover the cursor on each color scale to see the name and a preview of each one.
   c. Click the desired color scale.

      OR

      Press CTRL then click the color scale to apply to all maps.

   d. To invert the color scale, click under the color scale bar.

Display Measurements for Crosshair Positions

Use the crosshairs to display perfusion measurements for a particular location in the view.

1. Right-click and select .

2. Click and drag in any of the images.

   TIP: Vitrea displays the perfusion measurements for that location in each view.

   The Time-Density Graph displays:

   - "density over time" curve, the area under the curve, and the transit time for this crosshair location in green, and

- the gamma approximation curve (of the crosshair curve) for this crosshair location in gray

Place User-defined ROI Contours

To place ROIs, draw your own contours. Mirror ROI contours display in the contralateral hemisphere on the axial view. Edit any ROI, including mirrored ROIs, or ROIs that are part of a template.

NOTE: User-defined ROI contours are only available in orthogonal orientation. They are not supported in oblique MPRs.

1. Check the Auto Mirror check box Auto Mirror in the View Options area.

2. Right-click and select .

3. Click and drag in any image to draw a contour.

   TIP: Vitrea places matching ROI contours in the axial view.

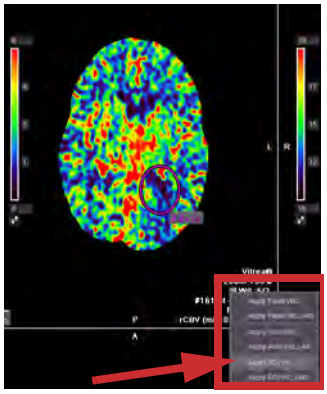
4. Manage the contours:

To	Then
Edit the size or shape of a contour	**1.** Hover the cursor over the edge of a contour. **TIP:** The cursor changes to a pencil. **2.** Click the edge of the contour and drag.
Move a contour	**1.** Hover the cursor near the center of the contour. **TIP:** A small circle displays inside the contour. **2.** Click and drag the small circle.

To	Then
Delete a contour	**1.** Click the contour to select it. **TIP:** The contour turns pink. **2.** Press DELETE.
Delete all contours	**1.** Press CTRL-A to select all the contours. **2.** Press DELETE.

Normalize the Map Window/Level Values Based On a ROI

Set the window/level values for a map based on an ROI of the affected area for better visual contrast of the hemispheres.



1. Click

or

.

2. Draw a contour on the map.

TIP: If there is more than one contour on the image, select one.

3. Click the Window/Level dropdown in a perfusion map.

4. Select **Apply ROI W/L**.

Customize the ROI Templates

Customize the ROI templates by type, size and number, and whether to fit the ROIs within the skull. The types of ROIs are:

- Orbital
- Conical
- Conical with deep gray nuclei
- Vascular territories

- Customize the template:

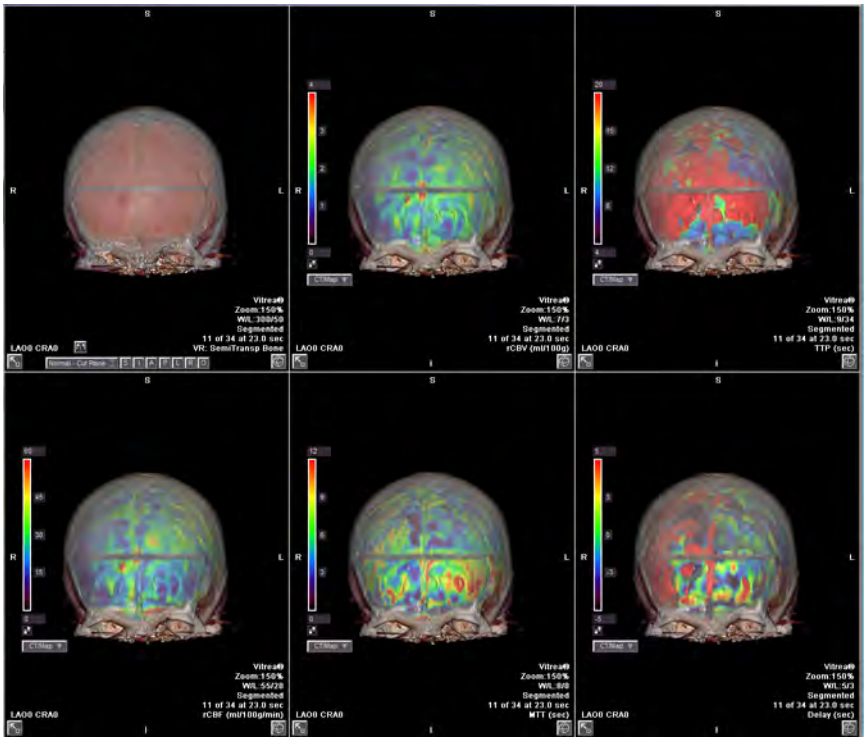
To	Then
Change the type of template	**1.** Click next to the template button. **2.** Click the button for the template type.
Change the size of ROIs	**1.** Click in the Diameter field Diameter 20 mm. **TIP:** This field is labeled Thickness if you are using a Conical type. **2.** Enter a new number.
Change the number of ROIs	**1.** Click in the Count field Count 10. **2.** Enter a new number.
Display the ROIs as true mirror images	• Clear the Tight Fit check box Tight Fit.
Fit the ROIs within the skull	• Check the Tight Fit check box Tight Fit.

Review the CT/Perfusion Map Fusion View

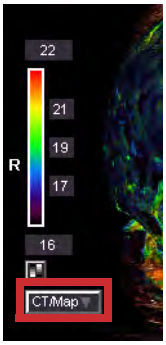
Display a CT view overlaid with a perfusion map view.

1. Click Viewer window layout.

TIP: You may need to click one of the Viewer window layout dropdown buttons to display the Six-up Alt button.



TIP: To switch to the Perfusion Map only view, click the **CT Map** dropdown and select **Map**.



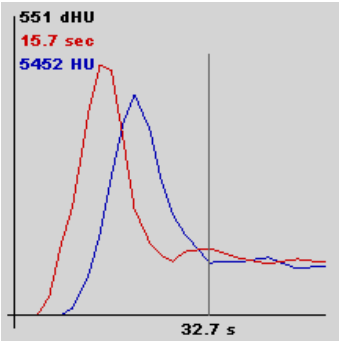
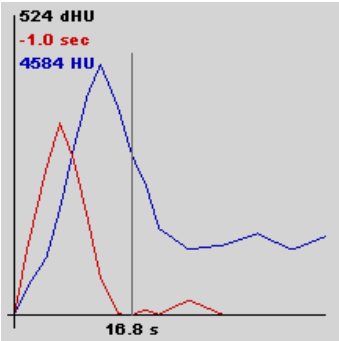
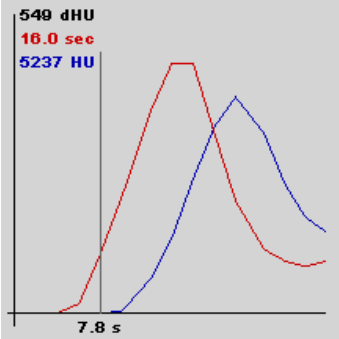
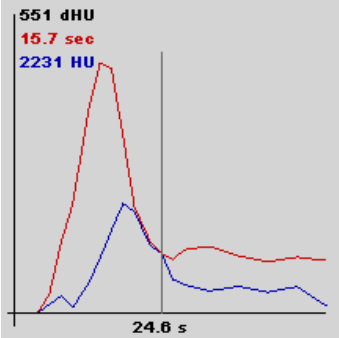
TIP: To change the rendering of the CT portion of the overlay view, click the rendering dropdown in the CT view.

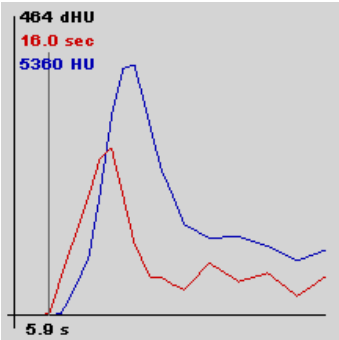
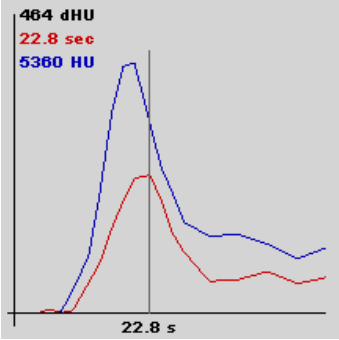
Troubleshooting

Vitrea uses an early-peaking, dense input artery as a reference input in the perfusion computations. The artery selection affects the CBF and MTT maps. A late-peaking, dense vein reference is used as an internal reference in the brain to normalize the blood volume results. The vein selection affects the CBV map.

The Time-Density Graph displays the “density over time” curve and the transit time for the artery in red. The Time-Density Graph displays the “density over time” curve, the area under the curve, and the total density for the vein in blue.

CAUTION: Review the slices and Time-Density graph to verify that Vitrea has marked the artery and vein locations correctly. Verify that the artery and vein peak times are well separated and that the artery and vein curve shapes are similar, with the vein curve more dispersed. If the relationship between the artery and vein curves does not look appropriate, re-evaluate the artery and vein selections and, if needed, find new vessel positions. See the table below for examples of Time-Density graphs.

Graph	Description
	Good Choice • The artery and vein curves start after time 0. • The artery and vein curves show some time after wash-out. • The artery curve peaks first and the vein curve peaks later. • Both curves are smooth, bell-type curves.
	Bolus Timing - Scan Starts Too Late • The curves start increasing before time 0. • This may cause inaccurate results.
	Bolus Timing - Scan Stops Too Early • The curves end before wash-out. • This may cause inaccurate results.
	Artery and Vein Curves - Vein Not Dense • Vein peak is small. • This may cause inaccurate results. • Edit the vein selection.

Graph	Description
	Artery and Vein Curves - Artery Not Dense, Has Artifacts • Artery peak is small. • This may cause inaccurate results. • Edit the artery selection.
	Artery and Vein Curves - Artery Too Late (Affected Side Selected) • May occur if artery in affected side is selected. • Artery peak is small. • Artery curve peaks after the vein curve. • This may cause inaccurate results. • Edit the artery selection.

Appendix

Calculations

The following guidelines help you interpret the brain perfusion measurements and the Time-Density Graph calculations.

Automatic Artery/Vein Selection

The software selects artery and vein locations from over the whole brain or from within specified regions of interest. To correct the auto-selected locations, use the ROI method to specify new locations.

Automatic artery/vein selection identifies vessels using the following rules:

- Early artery rule: The time-to-peak of the artery curve is smaller than the average time-to-peak of vessels in the ROI.
- Late vein rule: The time-to-peak of the vein curve is larger than the average time-to-peak of vessels in the ROI.
- Dense vessels rule: The area under the artery and vein curves is larger than the average area under the curve of the respective vessel types in the ROI.
- Dense vessels rule: The artery and vein curves with the highest peak enhancement, subject to the previous rules, are the ones selected.

Manual Artery/Vein Selection Effect on Reproducibility

When you select an artery or vein using the Crosshair tool, the software uses the concentration curves from the exact locations you specified and does not ensure their suitability for obtaining correct perfusion measurements.

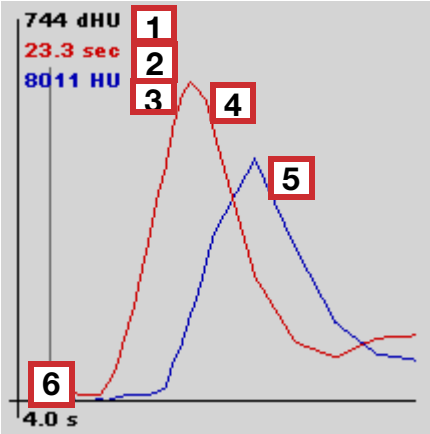
Effects of vein location selection include:

- Area under the first pass of the vein curve directly scales CBV and CBF values (this does not introduce relative differences in either CBV or CBF, but affects scale).

- The time span for all calculations is restricted to the first pass of contrast estimated from the vein curve (this can introduce variability in the MTT and CBF maps since it controls what portion of the artery curve is used in computations).

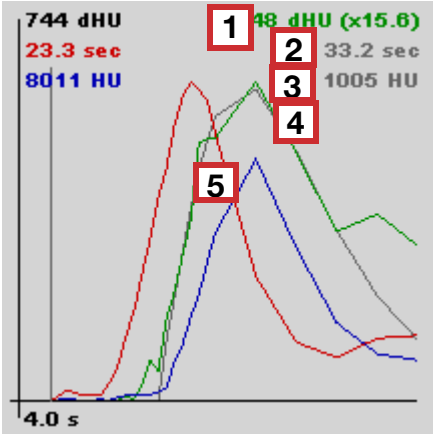
Effect of artery location selections includes the MTT and CBF computation which is affected by the shape (not scale) and time of peak enhancement of the artery curve.

Time-Density Graph (Artery and Vein Locations)



No.	Description	Details
1	Range of density	The difference between the peak and baseline of either the artery or the vein, whichever difference is greater
2	Transit time for the artery location	Mean time for the first pass of contrast to reach the artery location
3	Total density for the vein location	Area under the vein curve
4	Artery (red) curve	Density over time for the artery location
5	Vein (blue) curve	Density over time for the vein location
6	Cross-reference line	Includes corresponding time value

Time-Density Graph (Crosshair Location)



No.	Description	Details
1	Range of density	The difference between the peak and baseline of the crosshair location (the number in parentheses is the factor used to scale the curve to fit the graph)
2	Transit time for the crosshair location	Mean time for the first pass of contrast to reach the crosshair location
3	Total density for the crosshair location	Area under the gamma curve
4	Crosshair (green) curve	Density over time for the crosshair location
5	Gamma (gray) curve	Gamma approximation of the crosshair curve

Perfusion Image Map Calculations

Vitrea uses the earliest input artery and densest output vein positions to calculate the brain perfusion measurements. Once Vitrea calculates the results, you select a layout that contains the computed color maps displays.

Vitrea uses the SVD+ algorithm during post-processing.

Value	Unit of Measure	Description	Extreme Ranges
Regional Cerebral Blood Volume (rCBV)	ml/100g of tissue	The ratio of the area under the tissue curve and the area under the curve of the vein curve, computed over the first pass of the bolus. A correction factor accounting for the difference in large-vessel and small-vessel hematocrit is used (0.85), and the conversion into units of ml/100g tissue assumes average brain tissue density of (1.1 g/ml).	0 - 20 ml/100g
Time to Peak (TTP)	seconds	The time at which the density reaches a maximum value.	0 - 100 seconds
Mean Transit Time (MTT)	seconds	The area under the normalized (impulse) residue function. The residue function is computed by non-parametric deconvolution using a delay-insensitive method.	0 - 20 seconds
Regional Cerebral Blood Flow (rCBF)	ml/100g/ minute	The ratio of rCBV and MTT, converted into the appropriate units.	0 - 150 ml/100g/ min
Delay	seconds	The time when the computed residue function reaches the maximum, relative to the time of contrast arrival in the artery.	-50 - 50 seconds
Region of Interest (ROI) measurement	cm^2 in the 2D view, applicable UOM in other views	Average value in the region ± standard deviation (as indicated). Pixels that have been identified as vessels are ignored during the perfusion calculations. Average/Std values in ROIs exclude any detected vessel pixels.	

CAUTION: Some vessels may not be detected by the segmentation algorithm— a circumstance that will skew the results.

NOTE: Use only relative comparisons between affected and unaffected hemispheres for stroke diagnosis (absolute values would be required to calculate clinical values).

Summary Map

The Summary Map is a simplified derivative of the other perfusion maps. The software compares the two hemispheres to make distinctions of “maintained,” “reduced,” and “increased.”

Categories by Relative Value

The numbers that display in the tool tip when you adjust the slider bars are based on the software-generated distinctions.

If the top slider shows a TTP value of +5 seconds, that means that TTP values that are more than 5 seconds greater than the average TTP within the contralateral MCA territory are considered “increased.”

Similarly, if the bottom slider shows a CBV value of -20%, that means that CBV values that are more than 20% below the average CBV within the contralateral MCA territory are considered “reduced.”

Tissue Classifications

The software assesses which tissue is Normal, Yellow, or Red by applying the following logical rules to the categorized perfusion map data.

Tissue Classification	Rule
Red	(**rel. CBV** ↓ **AND** (**TTP** ↑ or **Delay** ↑)) **OR** **abs. CBV** ↓↓ **OR** **MTT** ↓↓ Relative CBV is reduced and either TTP or Delay is increased, or absolute CBV is extremely reduced, or MTT is extremely reduced. **NOTE:** CBV is reduced compared with the reference hemisphere, but, because it is possible to have a locally reduced CBV in healthy white matter, the software also looks for an increase in TTP or Delay. For computational reasons, extremely reduced CBV (in absolute terms) or extremely reduced MTT (in relative terms) are also marked Red.

Tissue Classification	Rule
Yellow	(**TTP** ↑ or **Delay** ↑ or **CBF** ↓) **AND CBV** → TTP is increased, or Delay is increased, or CBF is decreased, and CBV is maintained. **NOTE:** TTP or Delay is increased or CBF is decreased. In order to differentiate Yellow from Red, this rule states that CBV must not be reduced.
Normal (Green)	**TTP** → **AND Delay** → **AND CBV** → TTP, Delay, and CBV are all maintained. **NOTE:** All indicators are normal.

CT Brain Perfusion 4D for Vitrea fX

Contents

CT Brain Perfusion 4D Overview

- Perfusion Study
- DSA View
- Perfusion Maps
- DICOM Export Limits:
- Bolus Injection

CT Brain Perfusion 4D Lesson

I Select Study

II Choose Protocol and Preset

- DSA View
- Perfusion Maps

III Perform Analysis

Vascular 4D Analysis

- Examine the MPR Views
- Cine Through the DSA View
- Apply Preset Window/Level Settings
- Trim the DSA View on an Orthogonal Plane
- Point-of-Interest View Mode

Perfusion Analysis

- Review the Time-Density Graph
- Review the Artery and Vein Positions

- Display the Perfusion Maps
- Set the Window/Level Settings in the Perfusion Maps
- Edit the Midline
- Use the ROI Templates
- Take Snapshots
- Create a Time-Series Batch or Movie of the DSA View
- Create an Orthogonal Batch or Movie
- Create a Collage Batch

IV Distribute Findings

Additional Procedures

- Display the Summary Map
- Change the Artery Location
- Change the Vein Location
- Re-compute the Results
- Examine the CTA-V View
- Trim the DSA or CTA-V View on an Oblique Plane
- Sculpting
- Oblique MPR Mode
- Apply Digital Subtraction to the MPR Views
- Change the Appearance of the Views
- Set Measurement Colors
- Display Measurements for Crosshair Positions
- Place User-defined ROI Contours
- Normalize the Map Window/Level Values Based On a ROI
- Customize the ROI Templates
- Review the CT/Perfusion Map Fusion View

Troubleshooting

Appendix

- Calculations
  - Automatic Artery/Vein Selection

    - Manual Artery/Vein Selection Effect on Reproducibility
    - Time-Density Graph (Artery and Vein Locations)
    - Time-Density Graph (Crosshair Location)
  - Perfusion Results
  - Summary Map
    - Categories by Relative Value
    - Tissue Classifications

CT Brain Perfusion 4D Overview

The CT Brain Perfusion 4D application is for post-processing of dynamic CT images continuously acquired during the injection of contrast on a wide-detector, Toshiba thin slice (256-slice or higher), scanner. It is used for the visualization of apparent blood flow in brain tissue and pictorial illustration of perfusion-related parameters to aid in the assessment of the type and extent of cerebral perfusion disturbances in stroke patients.

When you choose a perfusion preset, Vitrea identifies the artery and vein, then computes five color-coded image maps with quantitative results related to the patient's regional cerebral blood volume (rCBV), mean transit time (MTT), regional cerebral blood flow (rCBF), time to peak of tissue (TTP), and delay of tissue response (Delay). The concurrent display of the five color image maps aid in the assessment of the type and extent of cerebral perfusion disturbances.

Perfusion Study

A CT series scanned for brain perfusion measurement in Vitrea consists of a series of slices produced by repeatedly scanning the same region, at the same table position.

NOTE: If the volume loaded is not a valid perfusion dataset, you will not be able to load the volume into the Brain Perfusion CT protocol.

CAUTIONS:

- **For measuring brain perfusion in Vitrea, you must load only a series of the brain scanned at CT Brain Perfusion protocol settings. This measuring tool is not intended for measuring perfusion in other anatomical regions.**
- **Verify the absence of a compromised blood-brain barrier (such as a hemorrhage) and motion. If either of these conditions exist in the study, you should not rely on the resulting brain perfusion measurements. The computations assume an intact blood-brain barrier and no motion. The accuracy of measurements of images that do not meet these criteria will be compromised.**
- **Verify that Vitrea has marked the artery and vein locations correctly. If the relationship between the artery and vein curves does not look appropriate, re-evaluate the artery and vein selections and, if needed, find new vessel positions. Measurements will most closely characterize the actual series when you select the optimal location and contrast density for each vessel position.**

CAUTION: Factors that can affect the accuracy of the results are:

- **Not fully capturing the contrast bolus (including at least 2 seconds of pre-enhancement images and post-enhancement).**
- **Extreme patient head motion (Vitrea corrects for slight head motion, however extreme motion may cause numerical errors in the calculations).**
- **Selecting a delayed artery as a reference.**

CAUTION: Clear the Brain Midline check box to hide the brain midline before applying oblique orientation. When the view is in oblique orientation, the displayed midline is not accurate.

DSA View

Vitrea extracts vessels for viewing in the DSA (Digital Subtraction Angiography) views. The DSA view displays the flow of contrast over time. This views may be useful for examining Arterial-Venous Malformation (AVM) cases in addition to perfusion cases.

Perfusion Maps

Vitrea uses the input artery with the earliest transit time and the output vein with the maximum total density to calculate brain perfusion.

After the artery and vein are identified, Vitrea computes five color-coded image maps with quantitative results:

Identification	Description
rCBV (regional Cerebral Blood Volume)	The distribution of blood per unit brain tissue. It provides evaluation of autoregulation (collateralization).
rCBF (regional Cerebral Blood Flow)	The blood volume running throughout the capillary blood vessels per unit time per unit brain tissue. CBF identifies areas of low blood flow.
MTT (Mean Transit Time)	The average amount of time that blood takes to transit through the capillary vessels. Increases in MTT indicate vasodilatory response to reduced flow.
TTP (Time to Peak of tissue response curve)	Demonstrates the relative time of peak enhancement for brain tissue voxels. It provides an indication of delayed flow due to stenosis or occlusion and is useful for identifying collateralization.
Delay (Delay time of tissue response curve)	Demonstrates the relative arrival time of contrast medium for tissue voxels. The information the delay map provides is similar to TTP although the calculation method differs. (The delay time is used to correct the MTT values.) **NOTE:** In the case of arterial occlusion, brain tissue survives if sufficient collateral flow is present. In essence, it does not matter when the oxygenated blood arrives in the brain, as long as it arrives in the appropriate concentration. A delay in blood flow can therefore be ignored for perfusion.

DICOM Export Limits:

Export a CT Brain Perfusion 4D report to DICOM servers or PACS devices. Keep these limitations in mind when using exported reports:

CAUTIONS:

- **You should not rely on Vitrea brain perfusion color maps viewed in grayscale on PACS workstations in making a diagnosis, as the conversion from color may be inaccurate.**
- **Vitrea exports each image in a report as a DICOM Secondary Capture image. Therefore, taking measurements (Hounsfield unit readings or dimensional rulers) and performing other similar operations on PACS or other devices on these Secondary Capture images will not yield accurate results.**
- **If you export images to a DICOM image server, the exported images may not have the same detail as the original scanned images.**

Bolus Injection

The operator should take care to capture the entire time of bolus transit, from just before wash-in to wash-out.

CT Brain Perfusion 4D Lesson

I. Select Study

Load a Brain Perfusion 4D study.

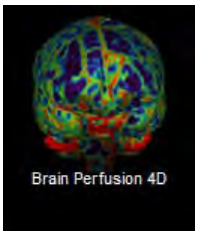
See the instructions for your Vitrea type (VitreaAdvanced Through the Data Manager or VitreaWorkstation) in the **Select Study** chapter of the **VitreaAdvanced-VitreaWorkstation General Education and Reference Guide**.

II. Choose Protocol and Preset

Use one of these procedures:

Data Manager

- Double-click the **Brain Perfusion 4D** application thumbnail.



Gallery Window

1. On the Gallery window, select the **Brain Perfusion CT** protocol.

2. Click Pick next to the **4D Perfusion (smooth)** or **4D Perfusion** preset.

   NOTE: The **4D Perfusion (smooth)** preset applies additional smoothing during processing to make the maps appear less noisy.

   TIP: The 4D Perfusion preset may take several minutes for Vitrea to complete processing. However, once the status bar indicates that a certain portion of processing is complete, you may continue with that portion of the workflow while Vitrea performs other processing.

   TIP: To complete only the vascular portion of the workflow, without the perfusion maps, select the **4D Vascular** preset. This would be appropriate for examining AVM studies and saves processing time.

   NOTE: Load as few as two volumes to perform the vascular workflow. Be aware that the CTA-V view may have sub-optimal results with fewer than ten volumes loaded.

NOTE: If you load a standard 2D perfusion study, 2D Perfusion is the only available preset. This preset allows you to view the perfusion maps and apply ROIs, but it does not display the CTA-V or DSA views.

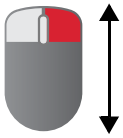
III. Perform Analysis

Vascular 4D Analysis

Examine the MPR Views

To examine the axial, sagittal, or coronal views, scroll through the views. During processing, Vitrea corrects for motion. While Vitrea is completing its processing, do the following steps:

1. To scroll through the crosshair locations in the MPR views, right-click and drag up or down in the view.

   OR

   Roll the mouse wheel in the view.

   The Z positions and slice level display in the status bar.

2. To cine through time in the MPR views, right-click and drag left or right in the view.

Cine Through the DSA View

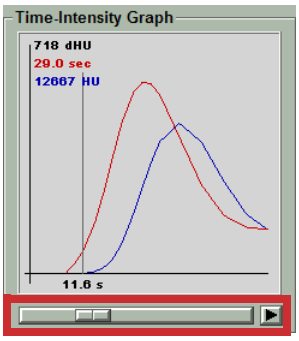
Cine through the DSA view to examine the flow of contrast.

3. Drag the **Time Slice** slider.

   OR

   Click .

   NOTE: The first playback may be slow, but on subsequent loops, the images are cached and the playback is faster.



TIP: Drag the small slider to change the cine speed.

4. Click and drag in the view to rotate.

Apply Preset Window/Level Settings

View the MPR views in different preset window/level settings.

5. Click the dropdown arrow in the MPR view.

6. Select a preset window/level setting.

   TIP: Press INSERT to toggle between the preset window/level settings.

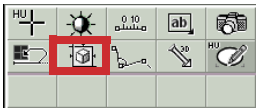
Trim the DSA View on an Orthogonal Plane

Use the trim box to isolate a portion of the view.

7. Right-click in any view and select .

   OR

   Press T to activate the trim tool.



8. In the MPR views, drag the yellow lines.

   TIP: To undo trimming, right-click and select .

Point-of-Interest View Mode

The Point-of-Interest View mode shows the volume immediately surrounding the current crosshair position. Use this mode to remove all surrounding tissue, bone, and so on, to reveal the point of interest.

To activate the Point-of-Interest mode:

9. Click the crosshair

on the anatomy of interest in 2D.

10. Click the button in the lower-right corner of the view until it changes to the POI box .

11. Right-click and drag the mouse away from you to decrease the size of the POI cube; move the mouse toward you to increase.

Perfusion Analysis

Review the Time-Density Graph

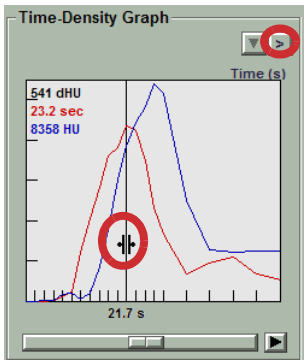
The Time-Density graph displays the density over time curve and the transit time for the artery in red, and it displays the density over time curve, area under the curve, and transit time for the vein in blue.

For more information regarding the elements on the Time-Density graph, see the Appendix of this chapter.

12. To display a time along the curves, move the black time line to the desired location (for example, the peak of the artery curve).

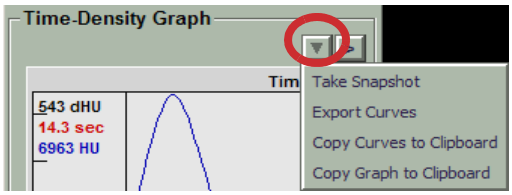
OR

Drag the **Time Slice** slider.



TIP: To expand the Time-Density Graph into a separate, larger viewer, click .

13. To distribute a snapshot of the graph, click the drop down and select from the menu.



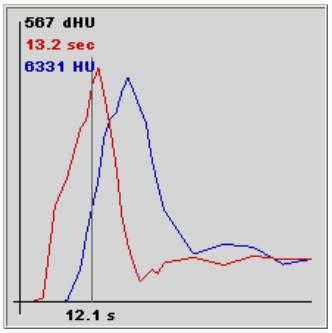
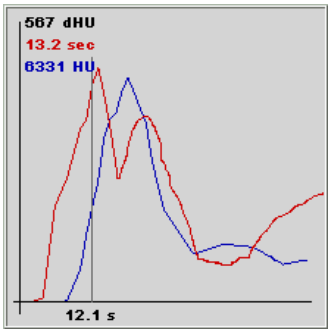
Review the Artery and Vein Positions

In most cases, Vitrea selects the correct locations for the artery and vein. It is important to verify that Vitrea marked the vein and artery locations correctly.

14. Scroll through MPRs to review the locations of the artery selection (red dot) and vein selection (blue dot).

15. Review the Time-Density graph and be sure that:

- The rise in the curves start after time 0
- The curves do not have multiple peaks
- The artery curve peaks before the vein curve
- Some time of washout is present.

Good Bell Curves (indicate correct locations)	Multi-Peak Curves (indicate incorrect locations)
	

- The red line indicates the Artery
- The blue line indicates the Vein

See the Troubleshooting section of this Module for examples of Time-Density graphs.

TIP: To enlarge the graph in a separate viewer,

If either the red or blue curve looks inappropriate, override the artery or vein location. Incorrect vessel locations results in invalid perfusion maps.

See the Additional Procedures section of this Module for information on correcting artery and vein locations.

Display the Perfusion Maps

16. Click to switch to a six-up view, which displays:

- MPR view
- regional cerebral blood volume (rCBV)
- regional cerebral blood flow (rCBF)
- mean transit time (MTT)
- time to peak of tissue (TTP)
- delay of tissue response (Delay)

NOTE: Vitrea uses the SVD+ deconvolution algorithm to generate the quantitative maps. SVD+ is based on the standard SVD (singular value decomposition) deconvolution algorithm. However, SVD+ is designed to be delay insensitive.

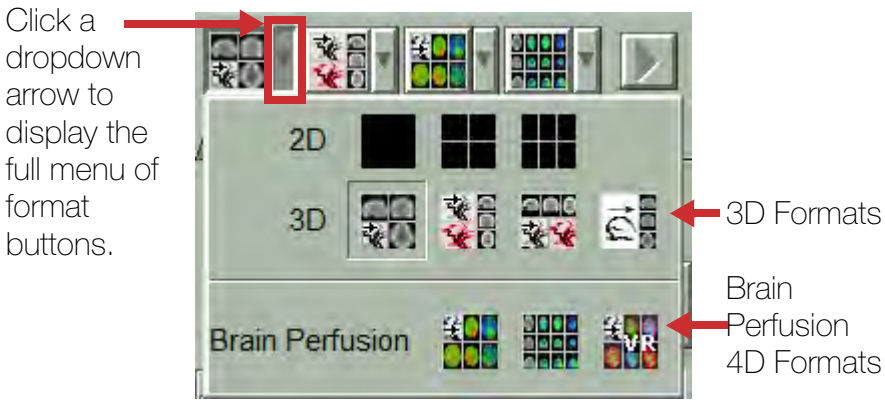
Analysis using the SVD+ algorithm does not include any delay of contrast arrival (delayed flow) in the calculation of the MTT, and therefore provides an accurate MTT measurement according to the definition.

As perfusion is calculated from CBV/MTT, be aware that, unlike other algorithms, delayed flow will not be shown as low flow.
Vital prefers a delay insensitive deconvolution method for whole brain perfusion imaging. Without delay insensitivity, where a single arterial input function is used, the computed blood flow would appear to gradually decrease on cranially scanned slices due to natural blood flow dynamics.

TIP: To change the MPR plane of the perfusion maps view,

click .

TIP: To display the MPR, rCBV, MTT, rCBF views in the axial, coronal, and sagittal planes, click .

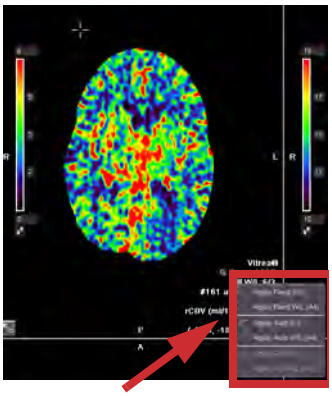


Format Button	Description
2D Formats	One-up 2D — 2D axial view. Four-up 2D — 2D axial, rCBV, rCBF, and MTT views. Six-up 2D — 2D axial, rCBV, TTP, rCBF, MTT, and Delay views.
3D Formats	Four-up 3D — Sagittal, coronal, axial, and DSA views. Five-up 3D — DSA and Generated CTA-V views plus the sagittal, coronal, and axial views. Five-up 3D Alt — Axial (in a larger view), sagittal, coronal, DSA, and Generated CTA-V views. Four-up 3D Runoff — One large DSA view plus the sagittal, coronal, and axial views.
Brain Perfusion 4D Formats	Six-up 3D — MPR view, plus the rCBV, TTP, rCBF, MTT, and Delay views in the same plane. **NOTE:** To change the order in which the MPR planes display, click Rotate MPRs. Twelve-up 3D — MPR, rCBV, MTT, rCBF views in the axial, coronal, and sagittal planes. Six-up Alt — DSA, plus the rCBV, rCBF, MTT views in 3D.

17. Right-click and drag up and down in the views to scroll through crosshair locations.

Set the Window/Level Settings in the Perfusion Maps

Set the window/level settings in the perfusion maps based on fixed, automatic, or user-defined ROI settings.



18. Click the Window/Level dropdown in a perfusion map. W/L:4/2

19. Select a setting.

- **Apply Fixed W/L** - a fixed setting for the map
- **Apply Fixed W/L (All) -** applies the fixed setting to all the maps
- **Apply Auto W/L** (default setting) - Vitrea assesses the map and computes a setting based on scan-specific factors using ASIST guidelines
- **Apply Auto W/L (All) -** applies the auto setting to all the maps
- **Apply ROI W/L** - Vitrea assess the ROI and normalizes the map to the region

  NOTE: If you draw an ROI in an incorrect location, Vitrea will not apply the normalization correctly.
- **Apply ROI W/L (All)** - applies the ROI setting to all the maps

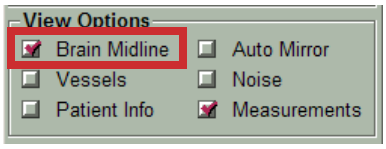
TIP: To make any of these settings the default, press CTRL-P to create a modified preset.

CAUTION: Manually window/level the maps if the automatic window/level does not apply or applies incorrectly.

Edit the Midline

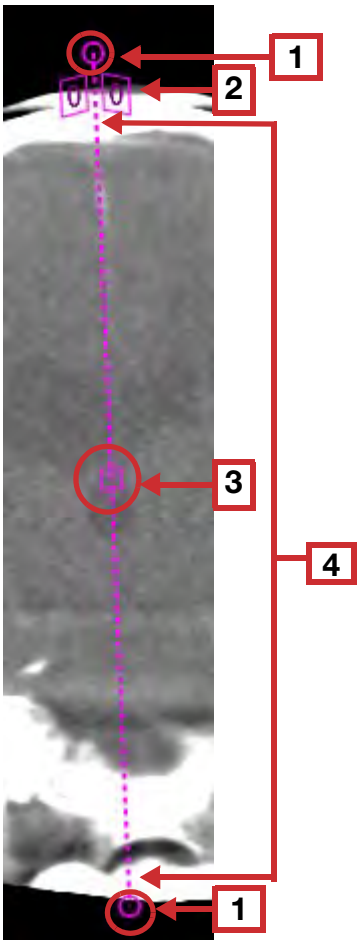
Each of the views contains an editable midline. Vitrea uses the midline to determine the mirror ROI contour placement, so it is important to place the midline in the correct location.

1. Select the Brain Midline check box in the View Options area.



2. Edit the brain midline.

   TIP: Edit in the coronal view first, then in the axial view.



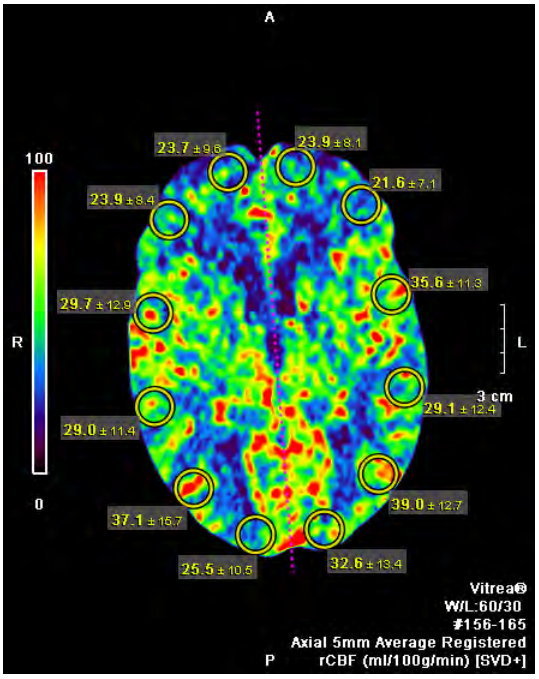
Callout	Description
1	To move an end of the midplane line, pivoting on the opposite end, or to extend the length of the midline: • Click and drag a **Midplane Line End** icon.
2	To mirror the ROIs on the other side of the midline: Click the **Mirror** icon on the side that has the ROI.
3	To slide the entire midplane line: • Click and drag the **Midplane Line Center** icon.
4	To pivot the midplane line on its center: • Click and drag anywhere along the midplane line (other than the Midline End, Midline Center, or Mirror icons).

Use the ROI Templates

Use a template to display perfusion measurements in mirrored ROIs.

3. Click MPR to change the MPR plane to axial.

4. Click to display orbital ROIs in the axial view.



See the Additional Procedures section of this Module for more information on customizing the ROI Templates.

Take Snapshots

Take snapshots to save your work and to put into a report.

5. Right-click and select , then click in each view.

OR

Hold ALT to keep taking snapshots without having to activate the snapshot tool each time.

OR

Hold CTRL to take one snapshot that includes all views.

NOTE: If the resulting image will be viewed on a PACS, the measurements on the image may be difficult to read.

Create a Time-Series Batch or Movie of the DSA View

Create an image batch or a movie of a 3D time-series (4D) study.

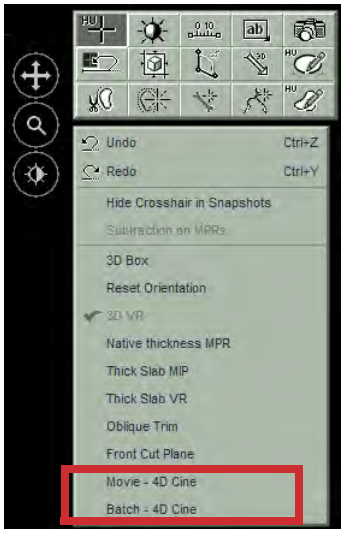
6. Click to display the DSA view.

   TIP: Click in the lower left corner of the DSA view to maximize it.

7. Drag the **Time Slice** slider all the way to the left, until the graph indicates 0.0 seconds.

8. Right-click in the DSA view.

9. Select **Movie - 4D Cine** to save it as a movie, or select **Batch - 4D Cine** to save it as a batch.

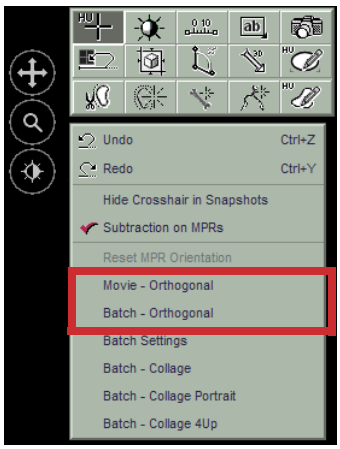


TIP: Make a standard MPR-scroll or 3D-rotation batch the same way you would for any other Vitrea study. See the Introduction to Vitrea module for more information.

Create an Orthogonal Batch or Movie

Make orthogonal slice batches or movies of the perfusion maps.

10. Right-click in a perfusion map view and select **Movie - Orthogonal** or **Batch - Orthogonal**.

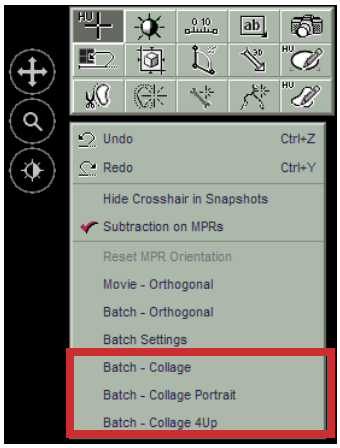


Create a Collage Batch

Create a single batch that includes the MPR and perfusion map views in one screen. Choose between a 4-up or 6-up format. The Collage Portrait format produces images in a portrait orientation, suitable for PACS monitors.

NOTE: The Collage Portrait option is only available in the 6-up view.

11. Right-click in a perfusion map view and select **Batch - Collage, Batch - Collage Portrait** or **Batch - Collage 4-up**.



IV. Distribute Findings

The snapshots you save in the Viewer window are saved to the Report window.

1. Click Report at the bottom of the window.

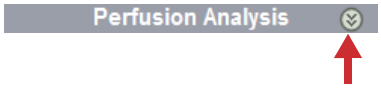
2. Export your findings or create a report.

   See the **Distribute Findings** chapter of the **VitreaAdvanced-VitreaWorkstation General Education and Reference Guide** for instructions on exporting findings, restoring workflow, and creating reports.

Additional Procedures

This section addresses some less common procedures to complete your workflow.

TIP: You may need to click next to **Perfusion Analysis** in order to display the tools mentioned in this section.



Display the Summary Map

The Brain Perfusion Summary Map displays color-coded regions, based on a derivative of the hemispherical comparisons of all the other maps, where perfusion values appear to be increased or decreased based on the contralateral hemisphere.

The Summary Map image can be used to communicate the results of a CT Perfusion exam and to provide tissue classification.

For areas marked as Yellow, VitreaAdvanced uses a relative value where TTP is increased, in seconds, compared to the reference hemisphere.

For areas marked as Red, VitreaAdvanced uses a relative value where CBV is decreased, in percent, compared to the reference hemisphere.

See the Appendix for exact rules for Yellow and Red.

CAUTION: Use the Summary Map in conjunction with the other perfusion maps. Do not use the Summary Map by itself to make diagnostic decisions.

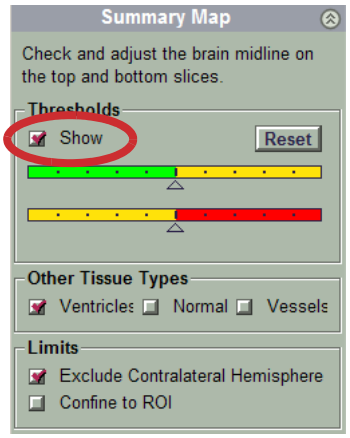
1. Complete the workflow and display the perfusion maps as outlined in the Perform Analysis section.

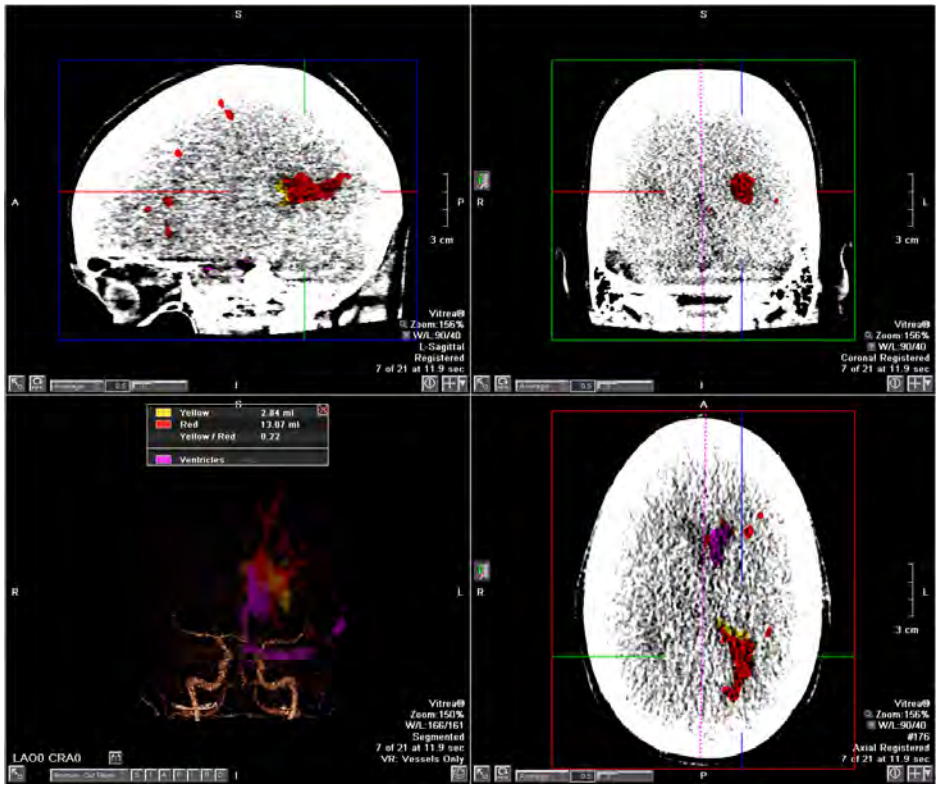
2. Display and edit the brain midline as described in the Perform Analysis section.

3. Select the **Show** check box.

   The Summary Map displays in the MPR and 3D views.

   - Yellow indicates areas where TTP is above the threshold
   - Red indicates areas where CBV is below the threshold
   - Magenta indicates ventricles
   - Green indicates normal areas (when **Normal** check box is selected)





NOTE: The Volume, in ml, is the total volume of Yellow or Red areas for all slices. The Yellow/Red ratio is also displayed.

- To hide the magenta areas that indicate ventricles, clear the **Ventricles** check box. Hiding the magenta area will still show any tissue classification (yellow or red) for that same area.

  NOTE: Hiding the ventricles may increase the volume values given for Yellow and Red since that same area was not included in the volumes when the tissue was classified as “Ventricles.”

- To show unaffected areas shaded in green, select the **Normal** check box.
- To show vessels shaded in light pink, select the **Vessels** check box.
- To show the data that displays on the contralateral hemisphere, clear the **Exclude Contralateral Hemisphere** check box.
- To show the data that displays in the cerebellum, clear the **Exclude Cerebellum** check box.
- To show only data within a defined region of interest, draw an ellipse or ROI on the view, then select **Confine to ROI**.

NOTE: Use of the Exclude Contralateral Hemisphere or Confine to ROI check boxes will affect the volumes displayed in the Yellow or Red.

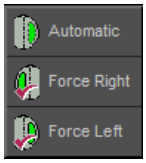
Set Reference Hemisphere

When Vitrea displays the Summary Map, it uses the TTP value to attempt to determine the unaffected hemisphere as a reference for perfusion normalization. An indicator or displays on the appropriate side of the viewer to correlate with the unaffected side.

NOTE: It is important that you verify that Vitrea has correctly identified the unaffected side to be the reference hemisphere.

Re-set the Reference Hemisphere if necessary.

1. Click the Hemisphere Indicator or .
2. Choose **Force Left** or **Force Right** from the dropdown.



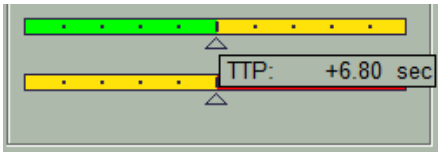
Edit the Summary Map Thresholds

Use the Thresholds slider bars to edit the rules for determining areas of Yellow and Red.

NOTE: It is your responsibility to adjust the sliders to the proper thresholds and to use the proper definitions of “Normal,” “Yellow,” and “Red.” Review the other perfusion maps as a guide.

See the Appendix for details on tissue classification.

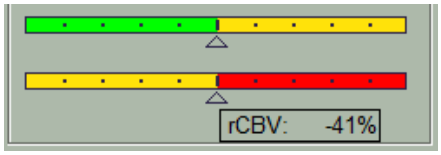
3. Adjust the top slider bar to define the threshold between Normal and Yellow. Use the values in the tool tip as a guide.



- Move the slider left for more aggressive rules for Yellow.
- Move the slider right for less aggressive rules for Yellow.

See the Appendix for definitions of Normal and Yellow.

4. Adjust the bottom slider bar to define the threshold between Yellow and Red. Use the values in the tool tip as a guide.



- Move the slider left for more aggressive rules for Red.
- Move the slider right for less aggressive rules for Red.

See the Appendix for definitions of Red.

Change the Artery Location

To change the artery location, draw ROIs to specify a new location.

1. Right-click and drag left and right to scroll temporally, and drag forward and back to scroll spatially, to locate the earliest enhancing artery, typically the internal carotid or a cerebral artery.

2. Right-click and select .

3. Click and drag in the view to draw a generous contour around the artery location.

   TIP: Be sure to avoid any clip or coil.

   TIP: Avoid selecting an artery on the affected side.

4. Click

.

   TIP: Vital recommends you use an ROI to specify the earliest artery location. Using the Crosshair tool to select an artery is possible but not advised because the software calculates the findings for that exact location, and the suitability of that location cannot be ensured.

Change the Vein Location

To change the vein location, manually specify a new location.

1. Right-click and drag left and right to scroll temporally, and drag forward and back to scroll spatially, to locate the densest enhancing vein.

2. Click and drag in the view to draw a generous contour around the vein location, typically the superior sagittal sinus or transverse sinus vein.

3. Click

.

   TIP: Vital recommends you use an ROI to specify the densest enhancing vein location. Using the Crosshair tool to select an artery is possible but not advised because the software calculates the findings for that exact location, and the suitability of that location cannot be ensured.

Re-compute the Results

Once you change the artery or vein location (or both locations), you need to re-compute the perfusion results.

- Click

.

Examine the CTA-V View

Display the CTA-V view to examine the arteries and veins.

1. Click .

2. Use 3D mouse functions to rotate, pan, and zoom the view.

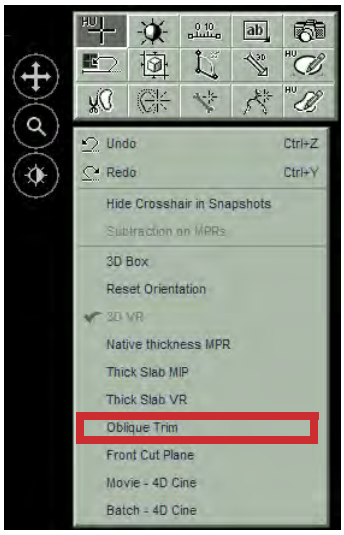
To	Mouse Button
Rotate **TIP:** Click then drag right away	Click and drag
Pan	Middle-click and drag
Zoom	Left + Middle click and drag

Trim the DSA or CTA-V View on an Oblique Plane

Displaying the DSA and CTA-V views in the orthogonal plane may not reveal the image you want, trim the 3D image in an oblique plane.

1. Click .

2. Right-click in the DSA view and select **Oblique Trim**.



The Oblique Trim box displays on both the DSA and CTA-V view indicating the oblique trim position.

TIP: Data “closer to you” than the trim plane is removed.

3. With active, click and drag in the view to rotate about the point indicated by the yellow cross.

To	Mouse Action
Move the axis of rotation	Click the yellow cross
Rotate the plane around	Middle-click and drag the image
Move the trim plane forward or backward	Right-click and drag the cut plane

Sculpting

Sculpt in the 3D or MPR views just like any other study in Vitrea.

Oblique MPR Mode

Rotate the crosshairs in the MPR views to adjust the orientation of the views just like any other study in Vitrea.

1. Click in the lower right corner of the view to switch to oblique mode.

2. In one of the MPR views, position the cursor over one of the crosshairs .

   TIP: This view remains in Orthogonal mode, and the other two views display images at oblique angles.

3. Drag the crosshair in the view while watching the other views.

   TIP: As you drag, the crosshairs rotate around their intersection point, staying perpendicular to each other.

   TIP: Rotate crosshairs in more than one view.

   TIP: Rotating the crosshairs in the MPR views also rotates the crosshairs in the perfusion map views.

4. To “walk” a vessel, press and hold CTRL , and drag in the view.

   TIP: The center of the crosshairs act as a fulcrum point.

Apply Digital Subtraction to the MPR Views

Apply digital subtraction to the MPR views similar to the DSA view in 3D.

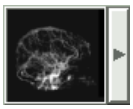
1. Select one of the following MPR rendering modes:
   - MIP
   - Inverted MIP
   - MinIP
   - Inverted MinIP
   - Volume Render
2. Right-click and select **Subtraction on MPRs**.

Change the Appearance of the Views

When Vitrea processes a CT Brain Perfusion 4D study, it segments the bone, tissue, veins, and arteries. Change the appearance of those regions. For example, make the skull semi-transparent to view landmarks.

TIP: Click in the view to activate it before you apply the changes.

Select a Preset:

1. Click a **Preset** button  .

   TIP: The graphic on the **Preset** button changes depending on the view you select.
2. Click a preset from the Preset Selector.

   TIP: To use the bone as a landmark, select **Semi-Transp. Bone.**

Change the Window/Level by region:

1. Select a region in the Region Management area.
2. Right-click and select .
3. Click and drag in the view.

Display only the arteries in 4D (CTA-V view only):

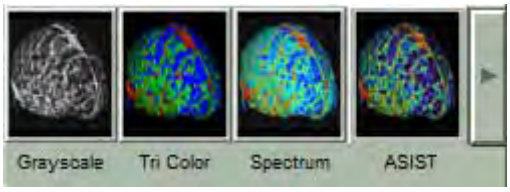
1. Select **Veins** in the Region Management area.

2. Adjust the **Transparency Slider** to 100%.

Set Measurement Colors

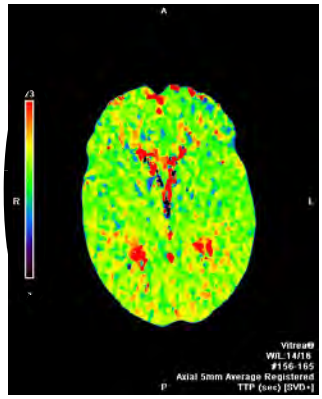
Change the color on any of the perfusion map images to highlight areas of the brain in different color schemes.

1. Select a color scale visualization preset button.



OR

2. Use the color scale bar:



   a. Click the color scale bar in any view.

   b. Hover the cursor on each color scale to see the name and a preview of each one.

   c. Click the desired color scale.

   OR

   Press CTRL then click the color scale to apply to all maps.

   d. To invert the color scale, click ▞ under the color scale bar.

Display Measurements for Crosshair Positions

Use the crosshairs to display perfusion measurements for a particular location in the view.

1. Right-click and select .
2. Click and drag in any of the images.

   TIP: Vitrea displays the perfusion measurements for that location in each view.

   The Time-Density Graph displays:

   - "density over time" curve, the area under the curve, and the transit time for this crosshair location in green, and
   - the gamma approximation curve (of the crosshair curve) for this crosshair location in gray

Place User-defined ROI Contours

To place ROIs, draw your own contours. Mirror ROI contours display in the contralateral hemisphere on the axial view. Edit any ROI, including mirrored ROIs, or ROIs that are part of a template.

NOTE: User-defined ROI contours are only available in orthogonal orientation. They are not supported in oblique MPRs.

1. Check the Auto Mirror check box Auto Mirror in the View Options area.
2. Right-click and select .
3. Click and drag in any image to draw a contour.

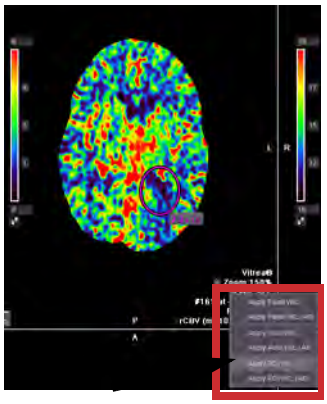
   TIP: Vitrea places matching ROI contours in the axial view.

4. Manage the contours:

To	Then
Edit the size or shape of a contour	**1.** Hover the cursor over the edge of a contour. **TIP:** The cursor changes to a pencil. **2.** Click the edge of the contour and drag.
Move a contour	**1.** Hover the cursor near the center of the contour. **TIP:** A small circle displays inside the contour. **2.** Click and drag the small circle.
Delete a contour	**1.** Click the contour to select it. **TIP:** The contour turns pink. **2.** Press DELETE.
Delete all contours	**1.** Press CTRL-A to select all the contours. **2.** Press DELETE.

Normalize the Map Window/Level Values Based On a ROI

Set the window/level values for a map based on an ROI of the affected area for better visual contrast of the hemispheres.



1. Click

or

.

2. Draw a contour on the map.

   TIP: If there is more than one contour on the image, select one.

3. Click the Window/Level dropdown in a perfusion map.

4. Select **Apply ROI W/L**.

Customize the ROI Templates

Customize the ROI templates by type, size and number, and whether to fit the ROIs within the skull. The types of ROIs are:

- Orbital
- Conical
- Conical with deep gray nuclei
- Vascular territories

- Customize the template:

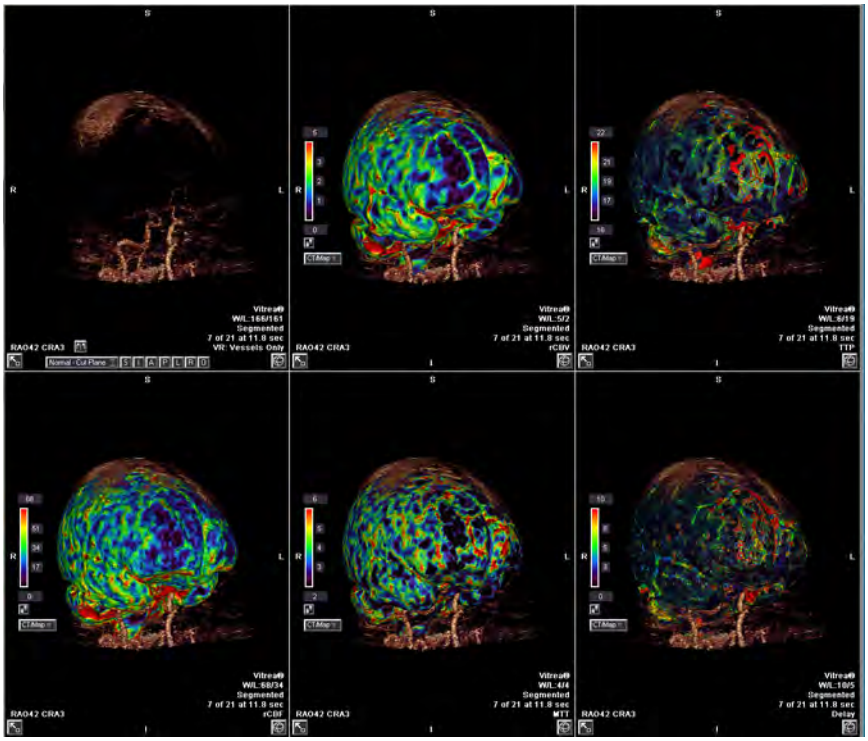
To	Then
Change the type of template	**1.** Click next to the template button. **2.** Click the button for the template type.
Change the size of ROIs	**1.** Click in the Diameter field Diameter 20 mm. **TIP:** This field is labeled Thickness if you are using a Conical type. **2.** Enter a new number.
Change the number of ROIs	**1.** Click in the Count field Count 10. **2.** Enter a new number.
Display the ROIs as true mirror images	• Clear the Tight Fit check box Tight Fit.
Fit the ROIs within the skull	• Check the Tight Fit check box Tight Fit.

Review the CT/Perfusion Map Fusion View

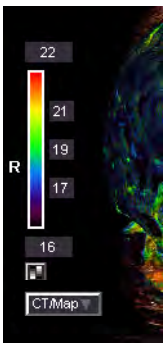
Display a CT view overlaid with a perfusion map view.

1. Click Viewer window layout.

   TIP: You may need to click one of the Viewer window layout dropdown buttons to display the Six-up Alt button.



   TIP: To switch to the Perfusion Map only view, click the **CT Map** dropdown.



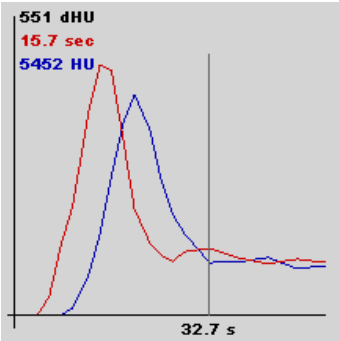
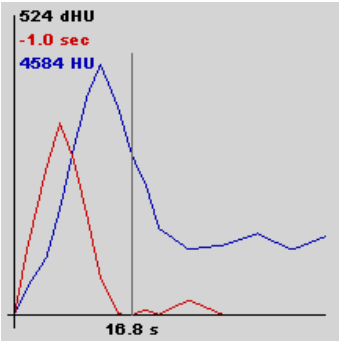
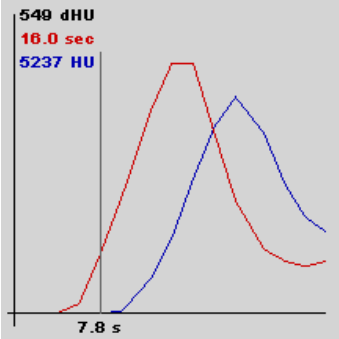
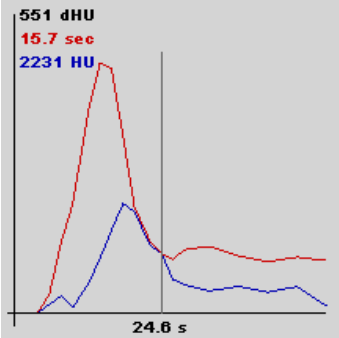
TIP: To change the rendering of the CT portion of the overlay view, click the rendering dropdown in the CT view.

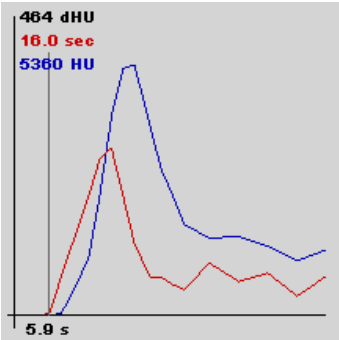
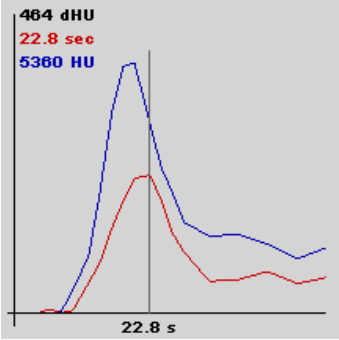
Troubleshooting

Vitrea uses an early-peaking, dense input artery as a reference input in the perfusion computations. The artery selection affects the CBF and MTT maps. A late-peaking, dense vein reference is used as an internal reference in the brain to normalize the blood volume results. The vein selection affects the CBV map.

The Time-Density Graph displays the “density over time” curve and the transit time for the artery in red. The Time-Density Graph displays the “density over time” curve, the area under the curve, and the total density for the vein in blue.

CAUTION: Review the slices and Time-Density graph to verify that Vitrea has marked the artery and vein locations correctly. Verify that the artery and vein peak times are well separated and that the artery and vein curve shapes are similar, with the vein curve more dispersed. If the relationship between the artery and vein curves does not look appropriate, re-evaluate the artery and vein selections and, if needed, find new vessel positions. See the table below for examples of Time-Density graphs.

Graph	Description
	Good Choice • The artery and vein curves start after time 0. • The artery and vein curves show some time after wash-out. • The artery curve peaks first and the vein curve peaks later. • Both curves are smooth, bell-type curves.
	Bolus Timing - Scan Starts Too Late • The curves start increasing before time 0. • This may cause inaccurate results.
	Bolus Timing - Scan Stops Too Early • The curves end before wash-out. • This may cause inaccurate results.
	Artery and Vein Curves - Vein Not Dense • Vein peak is small. • This may cause inaccurate results. • Edit the vein selection.

Graph	Description
	Artery and Vein Curves - Artery Not Dense, Has Artifacts • Artery peak is small. • This may cause inaccurate results. • Edit the artery selection.
	Artery and Vein Curves - Artery Too Late (Affected Side Selected) • May occur if artery in affected side is selected. • Artery peak is small. • Artery curve peaks after the vein curve. • This may cause inaccurate results. • Edit the artery selection.

Appendix

Calculations

The following guidelines help you interpret the brain perfusion measurements and the Time-Density Graph calculations.

Automatic Artery/Vein Selection

The software selects artery and vein locations from over the whole brain or from within specified regions of interest. To correct the auto-selected locations, use the ROI method to specify new locations.

Automatic artery/vein selection identifies vessels using the following rules:

- Early artery rule: The time-to-peak of the artery curve is smaller than the average time-to-peak of vessels in the ROI.
- Late vein rule: The time-to-peak of the vein curve is larger than the average time-to-peak of vessels in the ROI.
- Dense vessels rule: The area under the artery and vein curves is larger than the average area under the curve of the respective vessel types in the ROI.
- Dense vessels rule: The artery and vein curves with the highest peak enhancement, subject to the previous rules, are the ones selected.

Manual Artery/Vein Selection Effect on Reproducibility

When you select an artery or vein using the Crosshair tool, the software uses the concentration curves from the exact locations you specified and does not ensure their suitability for obtaining correct perfusion measurements.

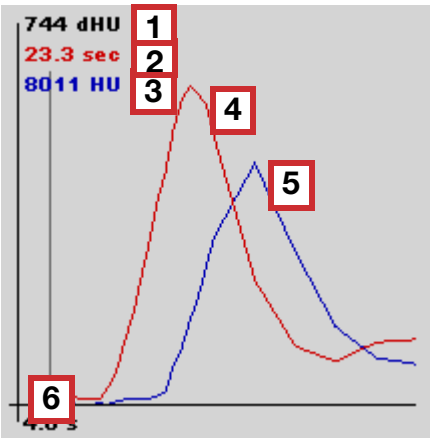
Effects of vein location selection include:

- Area under the first pass of the vein curve directly scales CBV and CBF values (this does not introduce relative differences in either CBV or CBF, but affects scale).

- The time span for all calculations is restricted to the first pass of contrast estimated from the vein curve (this can introduce variability in the MTT and CBF maps since it controls what portion of the artery curve is used in computations).

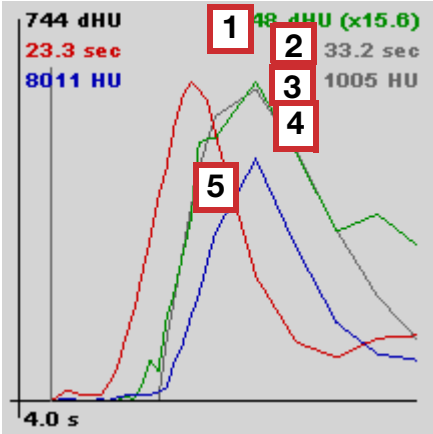
Effect of artery location selections includes the MTT and CBF computation which is affected by the shape (not scale) and time of peak enhancement of the artery curve.

Time-Density Graph (Artery and Vein Locations)



No.	Description	Details
1	Range of density	The difference between the peak and baseline of either the artery or the vein, whichever difference is greater
2	Transit time for the artery location	Mean time for the first pass of contrast to reach the artery location
3	Total density for the vein location	Area under the vein curve
4	Artery (red) curve	Density over time for the artery location
5	Vein (blue) curve	Density over time for the vein location
6	Cross-reference line	Includes corresponding time value

Time-Density Graph (Crosshair Location)



No.	Description	Details
1	Range of density	The difference between the peak and baseline of the crosshair location (the number in parentheses is the factor used to scale the curve to fit the graph)
2	Transit time for the crosshair location	Mean time for the first pass of contrast to reach the crosshair location
3	Total density for the crosshair location	Area under the gamma curve
4	Crosshair (green) curve	Density over time for the crosshair location
5	Gamma (gray) curve	Gamma approximation of the crosshair curve

Perfusion Results

Vitrea uses the earliest input artery and densest output vein positions to calculate the brain perfusion measurements. Once Vitrea calculates the results, you select a layout that contains the computed color maps displays.

Vitrea uses the SVD+ algorithm during post-processing.

Value	Unit of Measure	Description	Extreme Ranges
Regional Cerebral Blood Volume (rCBV)	ml/100g of tissue	The ratio of the area under the tissue curve and the area under the curve of the vein curve, computed over the first pass of the bolus. A correction factor accounting for the difference in large-vessel and small-vessel hematocrit is used (0.85), and the conversion into units of ml/100g tissue assumes average brain tissue density of (1.1 g/ml).	0 - 20 ml/100g
Time to Peak (TTP)	seconds	The time at which the density reaches a maximum value.	0 - 100 seconds
Mean Transit Time (MTT)	seconds	The area under the normalized (impulse) residue function. The residue function is computed by non-parametric deconvolution using a delay-insensitive method.	0 - 20 seconds
Regional Cerebral Blood Flow (rCBF)	ml/100g/ minute	The ratio of rCBV and MTT, converted into the appropriate units.	0 - 150 ml/100g/ min
Delay	seconds	The time when the computed residue function reaches the maximum, relative to the time of contrast arrival in the artery.	-50 - 50 seconds
Region of Interest (ROI) measurement	cm^2 in the 2D view, applicable UOM in other views	Average value in the region ± standard deviation (as indicated). Pixels that have been identified as vessels are ignored during the perfusion calculations. Average/Std values in ROIs exclude any detected vessel pixels.	

CAUTION: Some vessels may not be detected by the segmentation algorithm— a circumstance that will skew the results.

NOTE: Use only relative comparisons between affected and unaffected hemispheres for stroke diagnosis (absolute values would be required to calculate clinical values).

Summary Map

The Summary Map is a simplified derivative of the other perfusion maps. The software compares the two hemispheres to make distinctions of “maintained,” “reduced,” and “increased.”

Categories by Relative Value

The numbers that display in the tool tip when you adjust the slider bars are based on the software-generated distinctions.

If the top slider shows a TTP value of +5 seconds, that means that TTP values that are more than 5 seconds greater than the average TTP within the contralateral MCA territory are considered “increased.”

Similarly, if the bottom slider shows a CBV value of -20%, that means that CBV values that are more than 20% below the average CBV within the contralateral MCA territory are considered “reduced.”

Tissue Classifications

The software assesses which tissue is Normal, Yellow, or Red by applying the following logical rules to the categorized perfusion map data.

Tissue Classification	Rule
Red	(**rel. CBV** ↓ **AND** (**TTP** ↑ or **Delay** ↑)) **OR** **abs. CBV** ↓↓ **OR** **MTT** ↓↓ Relative CBV is reduced and either TTP or Delay is increased, or absolute CBV is extremely reduced, or MTT is extremely reduced. **NOTE:** CBV is reduced compared with the reference hemisphere, but, because it is possible to have a locally reduced CBV in healthy white matter, the software also looks for an increase in TTP or Delay. For computational reasons, extremely reduced CBV (in absolute terms) or extremely reduced MTT (in relative terms) are also marked Red.

Tissue Classification	Rule
Yellow	(**TTP** ↑ or **Delay** ↑ or **CBF** ↓) **AND CBV** → TTP is increased, or Delay is increased, or CBF is decreased, and CBV is maintained. **NOTE:** TTP or Delay is increased or CBF is decreased. In order to differentiate Yellow from Red, this rule states that CBV must not be reduced.
Normal (Green)	**TTP** → **AND Delay** → **AND CBV** → TTP, Delay, and CBV are all maintained. **NOTE:** All indicators are normal.

MR Tumor Volume

Contents

MR Tumor Volume Overview

MR Tumor Volume Lesson

- **I** Select Study
- **II** Choose Protocol and Preset
  - Data Manager
  - Gallery Window
- **III** Perform Analysis
  - Draw Contour Lines on Selected Slices
  - Display Tumor Volume Measurements
  - Edit Contour Lines Around Tumors
  - Take Snapshots
- **IV** Distribute Findings

Additional Procedures

- Examine the Tumor in 3D

MR Tumor Volume Overview

Measure the volume of single or multiple non-contiguous tumors within a region of interest using the Vitrea Tumor Volume Measurement feature. The tumor volume measurement feature is intended for the analysis/

quantification of tumor volumes obtained from MR brain series scans using a special 2D view in the **Head MR** protocol.

- Review an MR series of the brain for a patient.
- Identify regions you suspect to be brain tumors.
- The controls of Vitrea define the regions that contain the brain tumors.
- Select the tumor volume measurement feature to display highlighting of the tumors and tumor volume measurements in cubic centimeters.

NOTE: In Vitrea, the term tumor refers to any suspected or known brain lesion indicated on an MR image. The Vitrea software contains tools to help the physician measure noncontiguous tumors within a region of interest.

CAUTION: A Vitrea algorithm detects tumors based on the shape, density, and location of voxel values. Some data with values above the dynamically calculated voxel value will not indicate the presence of a tumor. You must carefully review the highlighting and tumor volume measurements to ensure accuracy. Once Vitrea has identified the tumors within the user-designated region of interest, it measures tumor volumes.

CAUTION: For best results, you must use only volumes created from MR series of the brain scanned with the manufacturer's recommended Head MR settings. This measuring tool is not intended for measuring tumors in other anatomical regions or for measuring volumes created from MR series of the brain scanned at different settings other than the manufacturer's recommended Head MR settings.

MR Tumor Volume Lesson

I. Select Study

Load a MR brain study.

See the instructions for your Vitrea type (VitreaAdvanced Through the Data Manager or VitreaWorkstation) in the **Select Study** chapter of the **VitreaAdvanced-VitreaWorkstation General Education and Reference Guide**.

II. Choose Protocol and Preset

Use one of these procedures:

Data Manager

- Double-click the **Brain MR** application thumbnail.

Gallery Window

5. On the Gallery window, select the **Brain MR** protocol.

   The Gallery choices update automatically.

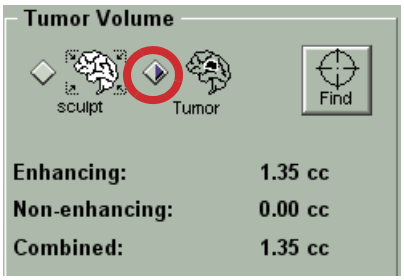
6. Click Pick next to the **2D Tumor Measurement** preset.

III. Perform Analysis

1. In the 2D Viewer window, roll the mouse wheel to view the image. The image initially displays in black.

Draw Contour Lines on Selected Slices

2. Select **Tumor**.



3. From the Analysis tab, click

.

4. Right-click on the image and scroll to locate the tumor.

5. Move one slice beyond the margin and click and drag to create a generous contour.

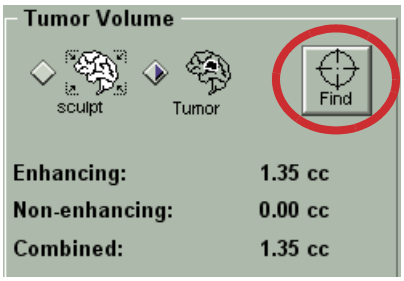
   Optional To adjust the shape of the contour line, click and drag its border. The line adjusts as you drag.

6. Move one slice beyond the margin of the end of the tumor and click and drag to create a contour.

Display Tumor Volume Measurements

7. Click

.



   Vitrea calculates the measurements.

   - Enhancing tissue is circled in yellow.

     To add the enhancing (yellow) contour line, press and hold the Ctrl key.

- Non-enhancing tissue is circled in pink.

  To add the unenhanced contour (pink), press and hold the Shift key and trace with the mouse.

- Values for enhancing, non-enhancing, and combined are reported on the left.

8. Verify Tumor is selected.

CAUTION: MR tumor volume measurements may be inaccurate when performed on studies acquired with variable slice spacing.

CAUTION: In some cases, tumor volume measurements can represent measurements of tissue that is neither malignant nor abnormal growth. Such measurements can occur if a clinician measures a volume representing nonmalignant or normal tissue or when the effect on the data of visual settings of either Vitrea or the scanning device causes parts of the volume to be measured as a tumor.

Edit Contour Lines Around Tumors

CAUTION: The accuracy of the tumor volume measurements can be affected by the accuracy of the contour lines. It is important to review and, if needed, edit the contour lines, so the contour lines surround the region that you have determined to be tumorous or cystic. If Vitrea draws contour lines

for tumors or cysts around regions for healthy or non-tumorous tissue, the measurements will include the regions for healthy or non-tumorous tissue.

9. Scroll to the slice containing the contour line you want to change.

10. Position the cursor over the contour line you want to change.

    TIP: The cursor changes to look like a pencil.

11. Click and drag exactly where you want the border to display.

12. Repeat as needed to get the desired shape.

    Vitrea recalculates all of the tumor volume measurements.

    NOTE: Edit the contour lines in the 2D or MPR views. Vitrea does not allow editing the contour lines in the 3D views.

Take Snapshots

13. Right-click and select (or press S) to activate the camera.

14. Move the cursor to the image and click.

    Snapshots, measurements, rulers, W/L, or segmentation option can be restored from the Report page or the Study Directory.

IV. Distribute Findings

The snapshots you save in the Viewer window are saved to the Report window.

1. Click

at the bottom of the window.

2. Export your findings or create a report.

    See the **Distribute Findings** chapter of the **VitreaAdvanced-VitreaWorkstation General Education and Reference Guide** for instructions on exporting findings, restoring workflow, and creating reports.

Additional Procedures

Examine the Tumor in 3D

1. Switch to a 4-up Viewer window format.

2. Click the **Tumor Only** preset button.

3. Rotate the 3D view to examine the Tumor region.

Index

A
Add Additional Anatomy 39
Adjust Measurement Colors 68
Apply a Visibility Preset Setting 14
Apply Preset Window/Level Setting for the MPR View 65
Apply Preset Window/Level Settings 127
Artery button 67, 101, 141
Auto Mirror check box 69, 105, 147
Automatic Artery/Vein Selection 72, 112, 154
Automatic Curved Reformats 26
Average Reference Method Lesion button 15

B
Batch-MPR Collage 4-up option 61, 96, 136
Batch-MPR Collage option 61, 96, 136
Batch-Orthogonal option 60, 96, 136
Brain Midline check box 57, 94, 133

C
CBF 75, 79
CBV 75, 79
Centerline Angle button 20
Centerline Length button 20
Change the Appearance of the Views 103, 145
Change the Artery Location 101, 141
Change the Vein Location 102, 142
Cine Speed slider 127
Cine Through the DSA View 126
Compute button 55, 67, 102, 142
Compute the Results 55
Conical ROI button 71, 107, 149
Conical with deep gray nuclei ROI button 71, 107, 149
Correct for Motion if Necessary 53
Correct the Artery Location 67
Correct the Vein Location 67
Create a Collage Batch 60, 96, 136
Create an Automatic MIP 26
Create an Orthogonal Batch or Movie 60, 96, 136
Create Centerline Angles 20
Create MPR Image Batches 42
CTA-V View format button 142, 143
Customize the ROI Templates 107, 149

D
Deconvolution Method button 68
Define a Lesion 14
Delay 75, 79
Display Measurements for Crosshair Positions 69, 104, 147
Display the Perfusion Maps 56, 91, 130
Display Tumor Volume Measurements 164
Draw Contour Lines on Selected Slices 164
DSA View 85, 122
DSA View format button 135
Dual Reference Method Lesion button 16

E
Edit Contour Lines Around Tumors 165
Edit the Midline 57, 94, 133
Examine the CTA-V View 142
Examine the Tumor in 3D 167
Extend a Probed Vessel 13
Extend button 13

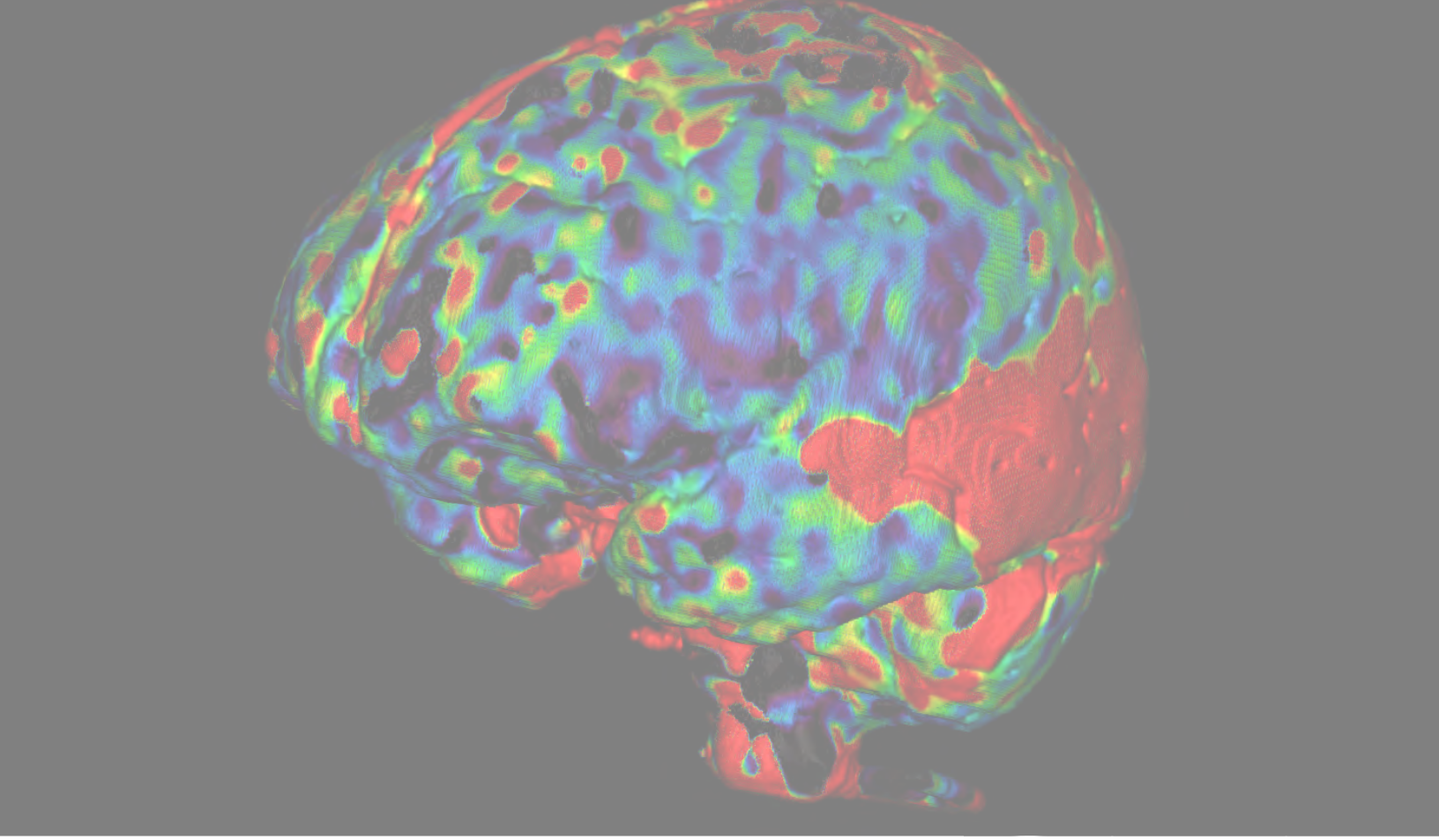
F
Find button 164
Force Left 64
Force Right 64

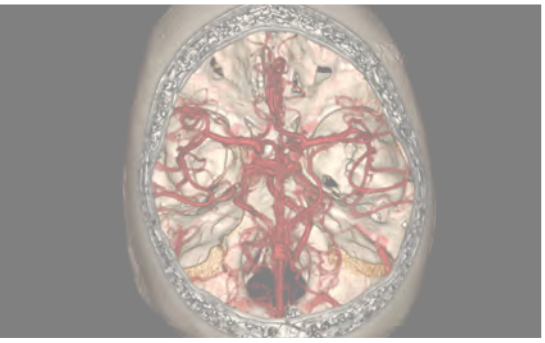
I
Invert Color Scale button 68

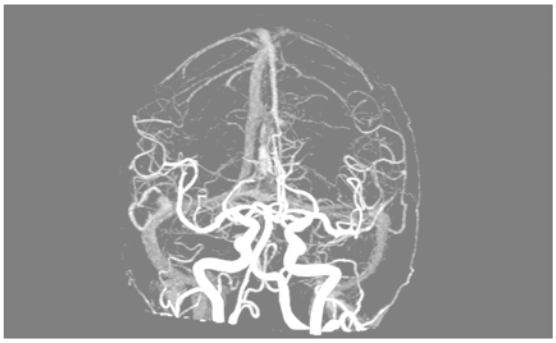
L
Lesion Volume button 17

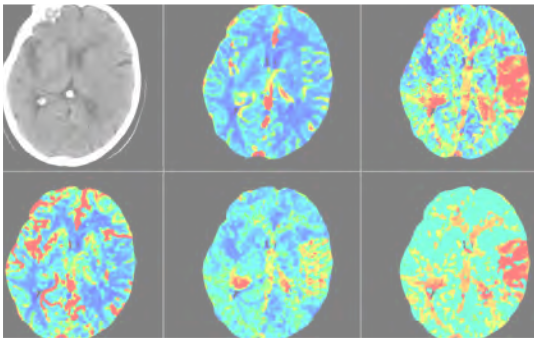
M
Manual Artery/Vein Selection Effect on Reproducibility 112, 154
Manual Stenosis Measurements 23
Measure Centerline Length 20
Measure Density in CPR Views 25
Motion Correction button 53
Movie-Orthogonal option 60, 96, 136
MTT 75, 79

N
Normalize the Map Window/Level Values Based On a ROI 106, 148









VITALU®

5850 Opus Parkway, Suite 300 | Minnetonka, MN 55343 | 866.433.4624 | www.vitalueducation.com

VPMC-XXXXXA

O
Oblique MPR Mode 102, 144
Oblique Trim check box 143
Orbital ROI button 71, 107, 149

P
Perform Volume Measurements 41
Perfusion Analysis 128
Perfusion Maps 49, 86, 123
Perfusion Results 114, 156
Place User-defined ROI Contours 69, 105, 147
Play Cine button 126
Point-of-Interest View Mode 22, 40, 128
Preset Selector 41
Probe the Carotids 11
Probe Vessels 38

R
Re-compute the Results 102, 142
Reference Hemisphere 100, 140
Remove Fragments 40
Remove Fragments button 40
Rename option 12
Review Artery and Vein Positions 55, 90, 129
ROI button 59, 95, 134
ROI Count field 71, 107, 149
ROI Diameter field 71, 107, 149
ROI Templates 59
Rotate CPR Views 23

S
Scroll the Series to Look for Motion 53
Sculpt button 38, 39, 164
Sculpt From One MPR 38
Sculpt Multiple MPRs 41
Select a Deconvolution Method 68
Select button 12, 38
Select Slice Levels 53
Set Measurement Colors 104, 146
Single Reference Lesion button 14
Summary Map 62, 97, 137
Summary Map Thresholds 64, 100, 140

T
Tight Fit check box 71, 107, 149
Time Slice slider 126, 135
Time-Intensity Graph (Artery and Vein Locations) 113, 155
Time-Intensity Graph (Crosshair Location) 114, 156
Tint/MPR check box 39
Trim CPR Views 25
Trim the DSA or CTA-V View on an Oblique Plane 143
Trim the DSA View on an Orthogonal Plane 127
TTP 75, 79
Tumor option 164

U
Undo Motion Correction button 53
Use the ROI Templates 94, 133

V
Vascular 4D Analysis 126
Vascular Territories ROI button 107, 149
Vein button 67, 102, 142

W
W/L Preset dropdown button 65, 66, 93, 127, 132