BRAINLAB

SMARTBRUSH

BRAINLAB ELEMENTS SMARTBRUSH
Version 3.0

Software User Guide
Revision 1.0

Date of issue: 2019-12-05 (ISO 8601)

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1 GENERAL INFORMATION

1.1 Contact Data

Support

If you cannot find information you need in this guide, or if you have questions or problems, contact Brainlab support:

Region	Telephone and Fax	Email
United States, Canada, Central and South America	Tel: +1 800 597 5911 Fax: +1 708 409 1619	us.support@brainlab.com
Brazil	Tel: (0800) 892 1217	brazil.support@brainlab.com
UK	Tel: +44 1223 755 333	support@brainlab.com
Spain	Tel: +34 900 649 115	
France and French-speaking regions	Tel: +33 800 676 030	
Africa, Asia, Australia, Europe	Tel: +49 89 991568 1044 Fax: +49 89 991568 811	
Japan	Tel: +81 3 3769 6900 Fax: +81 3 3769 6901	

Expected Service Life

Brainlab provides five years of service for software applications. During this period of time, software updates as well as field support are offered.

Feedback

Despite careful review, this user guide may contain errors. Please contact us at user.guides@brainlab.com if you have improvement suggestions.

Manufacturer

Brainlab AG
Olof-Palme-Str. 9
81829 Munich
Germany

1.2 Legal Information

Copyright

Brainlab Trademarks

- Brainlab® is a registered trademark of Brainlab AG in Germany and/or the US.
- **SmartBrush**® is a registered trademark of Brainlab AG in Germany and/or the US.

Non-Brainlab Trademarks

Microsoft® and Windows® are registered trademarks of Microsoft Corporation in the United States and other countries.

Patent Information

This product may be covered by one or more patents or pending patent applications. For details, see: www.brainlab.com/patent.

Integrated Third-Party Software

SmartBrush is proprietary software. **SmartBrush** software is protected by copyright. In addition to the **SmartBrush** software, other software applications may also be installed on the **SmartBrush** workstation that are licensed under the GNU General Public License. The proprietary software and the free software are used in compliance with the "mere aggregation" clause defined by the GNU GPL. The full terms and conditions of the GNU General Public License can be found here: http://www.gnu.org/licenses/gpl-2.0.html

This software is based in part on iTextSharp by Bruno Lowagie and Paulo Soares.

This software is based in part on the following work. The full license and copyright notice can be found at the links below:

- Independent JPEG Group (https://github.com/uclouvain/openjpeg/blob/master/LICENSE)
- OpenJPEG (https://github.com/uclouvain/openjpeg/blob/master/LICENSE)
- libjpeg-turbo (https://github.com/libjpeg-turbo/libjpeg-turbo/blob/master/LICENSE.md)
- libtiff 4.0.4 beta (http://www.libtiff.org/misc.html)
- Xerces-C++, developed by the Apache Software Foundation (http://www.apache.org/licenses/LICENSE-2.0)

CE Label

CE 0123

- The CE label indicates that the Brainlab product complies with the essential requirements of European Council Directive 93/42/EEC, the Medical Device Directive (“MDD”).
- Brainlab Elements **SmartBrush** 3.0 is a Class IIb product according to the rules established by the MDD.

Sales in US

US federal law restricts this device to sale by or on the order of a physician.

Report Incidents Related to this Product

You are required to report any serious incident that may have occurred related to this product to Brainlab, and if within Europe, to your corresponding national competent authority for medical devices.

1.3 Symbols

Warnings

Warning

Warnings are indicated by triangular warning symbols. They contain safety-critical information regarding possible injury, death or other serious consequences associated with device use or misuse.

Cautions

Cautions are indicated by circular caution symbols. They contain important information regarding potential device malfunctions, device failure, damage to device or damage to property.

Notes

NOTE: Notes are formatted in italic type and indicate additional useful hints.

1.4 Using the System

Intended Use

Brainlab Elements **SmartBrush** provides an easy interface with tools and views to outline structures in patient image data. The output is saved as 3D DICOM segmentation object and can be used for further processing.

Indications for Use

Brainlab Elements **SmartBrush** can be used in all clinical workflows that require to outline anatomical structures in patient image data. The device itself does not have specific clinical indications.

Intended Use Environment

Elements **SmartBrush** shall be used in:

- Office environments within hospitals or at any other location offering a computer
- Rooms appropriate for surgical interventions

A more specific intended use environment (e.g., a specific planning station or navigation platform) may be present when the device is used in combination with other devices.

Intended User Profile

The application is intended to be used by medical professionals and their assistants with a need to outline structures in patient image data.

In addition, typical users are:

- Neurosurgeons and ear-nose-throat (ENT) surgeons
- Healthcare professionals educated for the planning and execution of neurosurgery procedures. Segmentation is an optional step in these use cases.
- Neuro/Ortho/Spine/Trauma surgeons
- Medical professionals trained for radiation therapy treatment. More specifically, radiation oncologists or dosimetrists for organ at risk outlining

Intended Patient Population

There are no demographic, regional or cultural limitations for patients.

In addition, typical patient populations are:

- All patients/all ages where a reference to a rigid anatomical structure can be established
- Patients with specified indications and relevant modality scan data available

Intended Part of the Body or Type of Tissue Applied to or Interacted With

As the device is software only it does not interact with any body parts or tissue.

The outlining, review and refinement of anatomical structures is not limited to any body part, i.e. that image sets of any body part can be imported and used in the aforementioned way.

For **Spine SRS** treatment, additional functionality is provided to further facilitate the treatment planning workflow.

Plausibility Review

Warning

Before patient treatment, review the plausibility of all information input to and output from the system.

1.5 Compatibility with Medical Devices and Software

Compatible Brainlab Medical Software

Only Brainlab medical software specified by Brainlab may be installed and used with the system. Contact Brainlab support for clarification regarding compatibility with Brainlab medical software.

Non-Brainlab Software

Only authorized Brainlab employees may install software on the Brainlab system. Do not install or remove any software applications.

Updates

Warning

Updates to the operating system (hotfixes) or third-party software should be performed outside clinical hours and in a test environment to verify correct operation of the Brainlab system. Brainlab monitors the released Windows hotfixes and will know, for some updates, if problems can be expected. Contact Brainlab support if any problems to operating system hotfixes are encountered.

Virus Scanning and Malware

Brainlab recommends protecting the system with state-of-the-art anti-virus software.

Be aware that some malware protection software (e.g., virus scanner) settings can negatively affect system performance. For example, if real-time scans are performed and each file access is monitored, then loading and saving patient data may be slow. Brainlab recommends disabling real-time scans and performing virus scans during non-clinical hours.

Warning

Ensure that your anti-virus software does not modify any Brainlab directories, specifically:

- **C:\Brainlab, D:\Brainlab, F:\Brainlab, etc.**
- **C:\PatientData, D:\PatientData, F:\PatientData, etc.**

Warning

Do not download or install updates during treatment planning.

Contact Brainlab support for further information regarding any of these issues.

Microsoft Security Updates for Windows and Driver Updates

Brainlab allows the installation of security patches only. Do not install service packs and optional updates. Verify your settings to ensure updates are downloaded and installed correctly and at a suitable time. Do not update drivers on Brainlab platforms.

See the Brainlab website for more information about settings and a list of Microsoft Security Updates blocked by Brainlab support.

Address: www.brainlab.com/updates

Password: WindowsUpdates!89

1.6 Training and Documentation

Brainlab Training

Before using the system, Brainlab recommends that all users should participate in a training program held by a Brainlab representative to ensure safe and appropriate use.

Responsibility

Warning

This system solely provides assistance to the surgeon and does not substitute or replace the surgeon's experience and/or responsibility during its use. It must always be possible for the user to proceed without the assistance of the system.

Only trained medical personnel may operate system components and accessory instrumentation.

Extended OR Time

Brainlab Navigation Systems are sensitive technical equipment. Depending upon OR setup, patient positioning, calculation durations and complexity, surgery duration using navigation may vary. It is up to the user to decide whether a potential prolongation is acceptable for the respective patient and treatment.

Reading User Guides

This guide describes complex medical software or medical devices that must be used with care.

It is therefore important that all users of the system, instrument or software:

- Read this guide carefully before handling the equipment
- Have access to this guide at all times

2 SOFTWARE OVERVIEW

2.1 Getting Started

Background

SmartBrush provides contouring tools to help you more easily visualize anatomical structures or tumors.

With **SmartBrush**, you can:

- Interactively delineate targets
- Streamline multi-planar definition of 3D volumes
- Expand contours with the click of a mouse or touch of a finger
- Simultaneously consider multiple modalities while outlining

Selecting Data

Before starting **SmartBrush**, select the patient and required data in **Patient Selection**. Refer to the **Patient Data Manager Software User Guide** for more information.

Anomaly Detection

SmartBrush uses anomaly detection if it is present on the system. This means that in a general workflow, **SmartBrush** will focus and zoom in on a detected anomaly.

2.2 Starting and Closing SmartBrush

Starting the Software

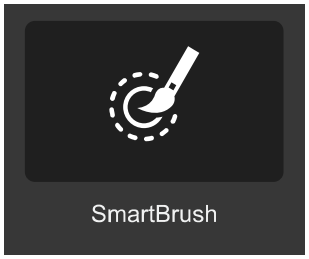


Figure 1

To start the software, first select a patient and then select **SmartBrush** from within the required workflow on the main screen of **Patient Data Manager** (e.g., **Cranial** > **Planning** > **SmartBrush**).

Typical Workflow Options

Depending on your procedure, follow the workflow steps for one of the following:

- General procedures workflow
- **Angio Planning** workflow
- **Spine SRS** workflow

SmartBrush Workflow for General Procedures

Step	
1.	Select an image set.
2.	Create an object by outlining the structure using: • Semi-automatic segmentation via **Smart Brush** • Manual segmentation via **Brush 2D** or **Brush 3D** • Segmentation based on thresholds via **Threshold**
3.	Finalize the object.

SmartBrush Workflow for Angio Planning Procedures

SmartBrush can be used to delineate structures based on 2D DSA images contained in angio bundles that were created with Brainlab Elements **Image Fusion Angio**. An angio bundle contains 2D DSA images, 3D image sets and co-registrations between the 2D and 3D image sets.

Step	
1.	Select an angio bundle.
2.	Create an object by outlining the region of interest (ROI) in the DSA images.
3.	Further refine the created object with any of the **SmartBrush** contouring tools.

SmartBrush Workflow for Spine SRS Procedures

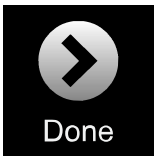
Within a **Spine SRS** workflow, **SmartBrush** automatically generates a clinical target volume (CTV) and an organ at risk (OAR) based on a manually drawn gross tumor volume (GTV) object. This target volume can be used for further planning steps.

Step	
1.	Select an image set.
2.	Select your position of interest.
3.	Create a GTV object by outlining the structure using: • **Smart Brush** for semi-automatic segmentation • **Brush 2D** or **Brush 3D** for manual segmentation • Segmentation based on thresholds via **Threshold**
4.	Review the automatically generated CTV and OAR.
5.	Finalize the objects.

How to Close SmartBrush

Always finalize your current task before closing the software.

Always close the software before shutting down the system. Data is not saved automatically if the system is shut down without properly closing the software.

Step	
	Before closing, finalize your current task by selecting **Done**.

2.3 Shortcuts

Keyboard Shortcuts

Function	Description	Keyboard Shortcut
Zoom	Zoom in and out	Ctrl + mouse wheel
Pan	Move an image within a window	Ctrl + left mouse button and drag
Scroll	Scroll through slices	Mouse wheel
Brush size	Change the brush size when a brush is active	Alt + mouse wheel
Erase	Erase without selecting the **Erase** button, while a brush is active	Right mouse button
Change to next layout	Switch to next view layout	Ctrl + Tab
Change to previous layout	Switch to previous view layout	Ctrl + Shift + Tab

Touchscreen Shortcuts

Function	Description	Touchscreen Shortcut
Zoom	Zoom in and out	Press two fingers on the slice image and pinch inward or outward
Pan	Move an image within a view	Press with two fingers on the slice image and drag to desired location

2.4 Screen Layouts

Screen Layout Overview

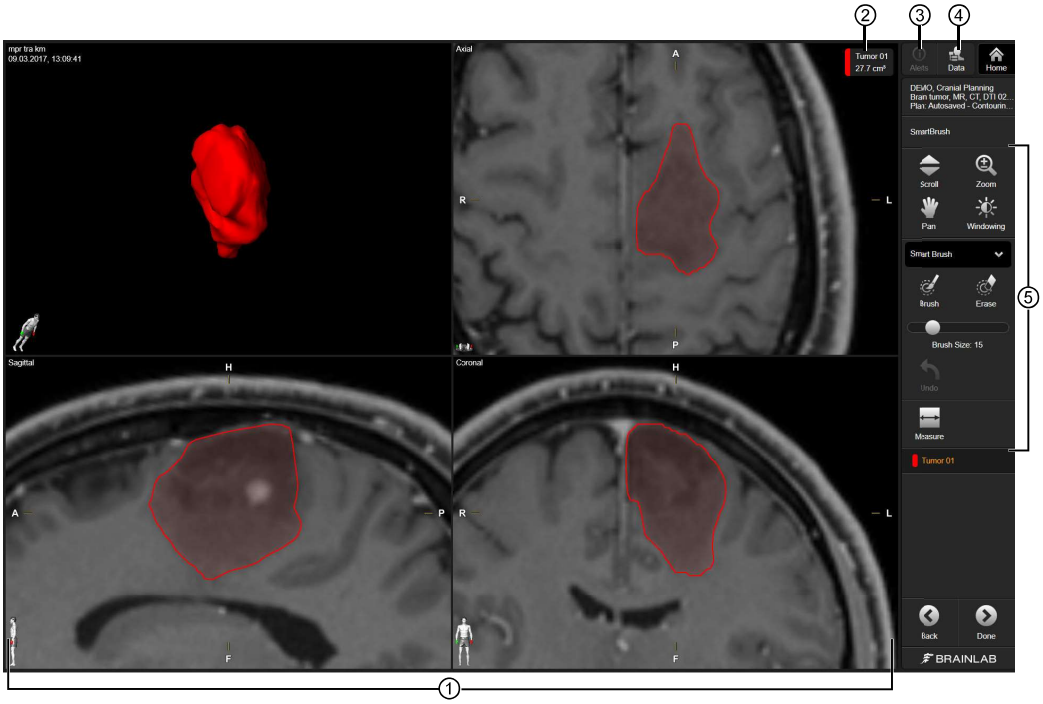
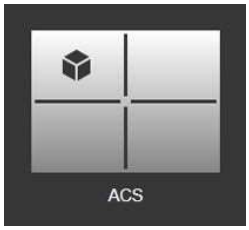


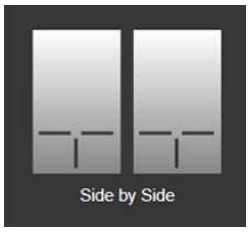
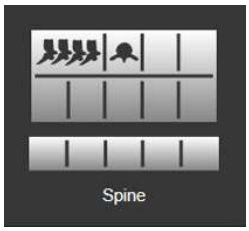
Figure 2

No.	Explanation
①	View area
②	Currently selected object: Select to change object properties.
③	**Alerts**: Contains process information and possible warnings.
④	**Data**: Contains image sets and view layouts.
⑤	Toolbar

Available Layouts

The layouts available when using **SmartBrush** are dependent on the selected workflow:

Layout	General Procedures	Angio Planning Procedures	Spine SRS Procedures
	✓	✓	

Layout	General Procedures	Angio Planning Procedures	Spine SRS Procedures
	✓	✓	✓
	✓		
		✓	
		✓	
			✓

*NOTE: To switch between layouts select **Data**, then select a layout.*

*NOTE: Use **Pan**, **Zoom** and **Scroll** accordingly to review your image set. When an object is selected, the views align to the selected object.*

ACS View

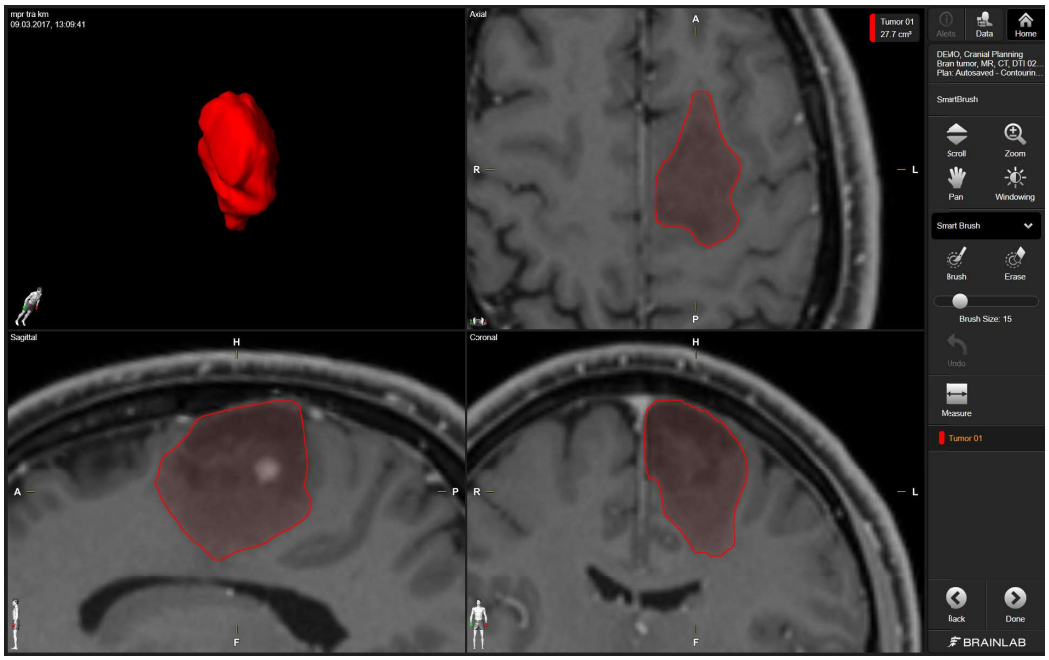


Figure 3

The **ACS** view displays slices of the selected image set in axial, coronal and sagittal (ACS) views. A basic 3D visualization is provided.

Side by Side View

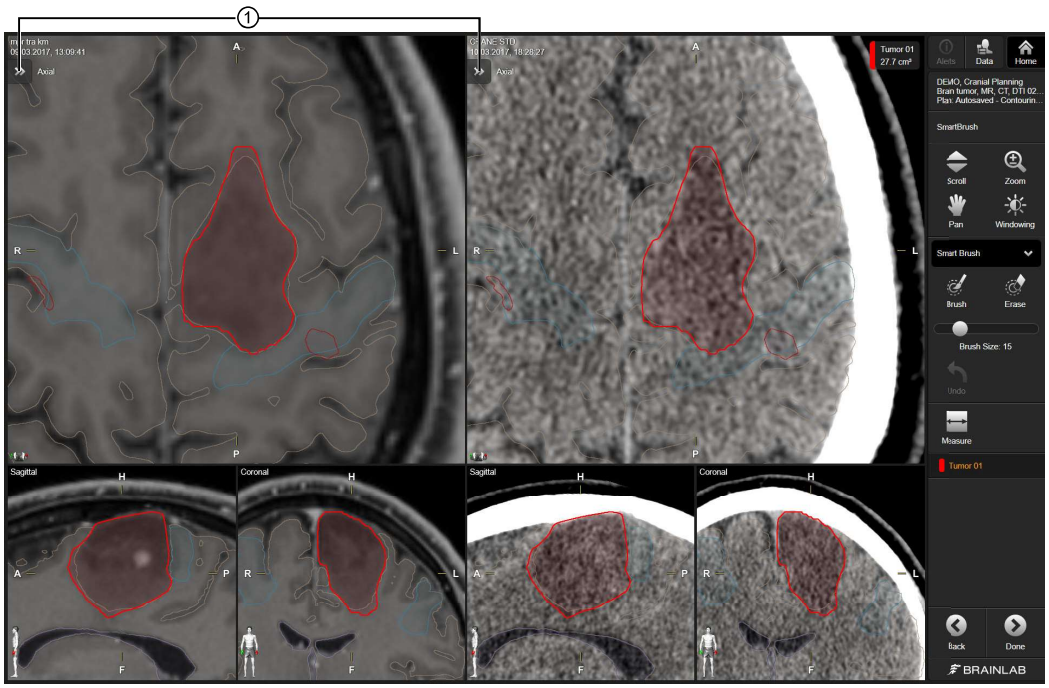


Figure 4

The **Side by Side** view displays two image sets next to each other in an ACS configuration. Select **Data**, then select the right side or left side of the layout to assign or switch image sets.

Use the arrows ① to switch the orientation of the main view to axial, sagittal or coronal for each image set.

Slice Review

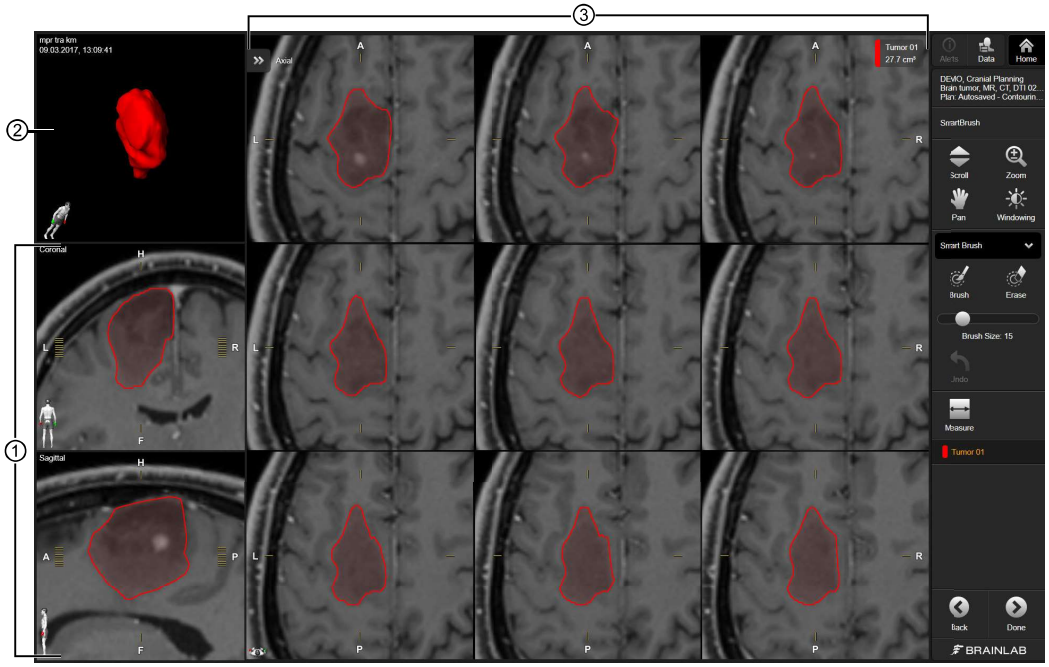


Figure 5

Slice Review for general workflows displays:

- A 3D view ②
- A main view showing 3 x 3 reconstructed consecutive slices in either axial, sagittal or coronal orientation ③. Use the arrows to switch the orientation of the main view.
- Two additional smaller, reconstructed views displaying other ACS orientations ①.

Slice Review Angio

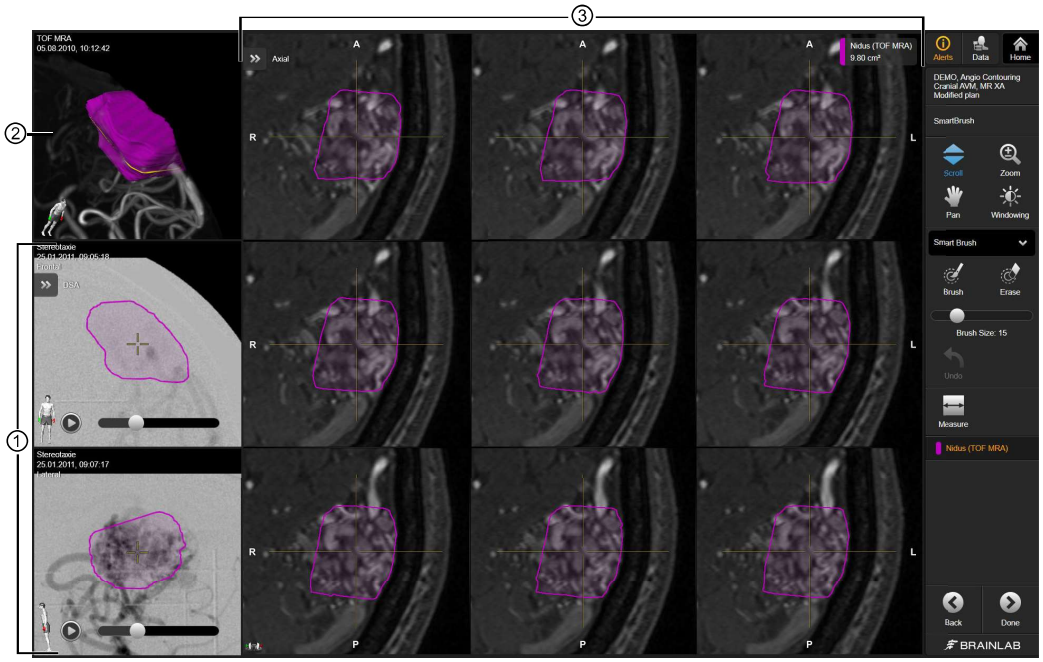


Figure 6

Slice Review for **Angio Planning** workflows displays:

- The selected frontal and lateral DSA images ①
- A 3D view ②
- A main view showing 3 x 3 reconstructed consecutive slices in either axial, sagittal or coronal orientation ③. Use the arrows to switch the orientation of the main view.

Angio View

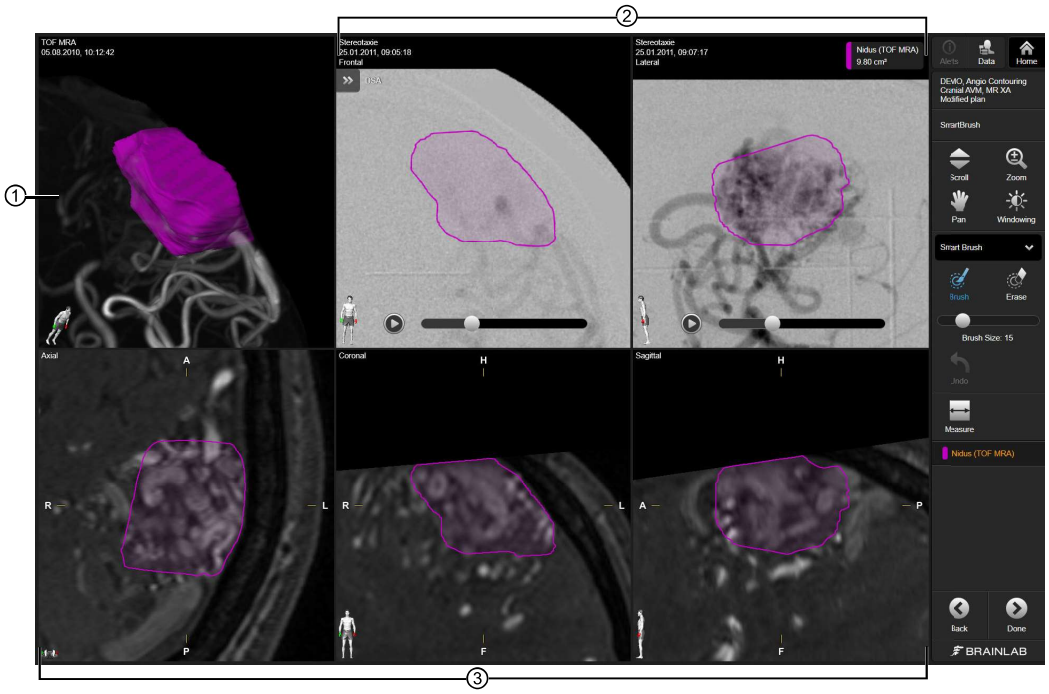


Figure 7

Angio view displays:

- A 3D view ①
- The selected frontal and lateral DSA images ②
- ACS views of the selected image ③

Spine View

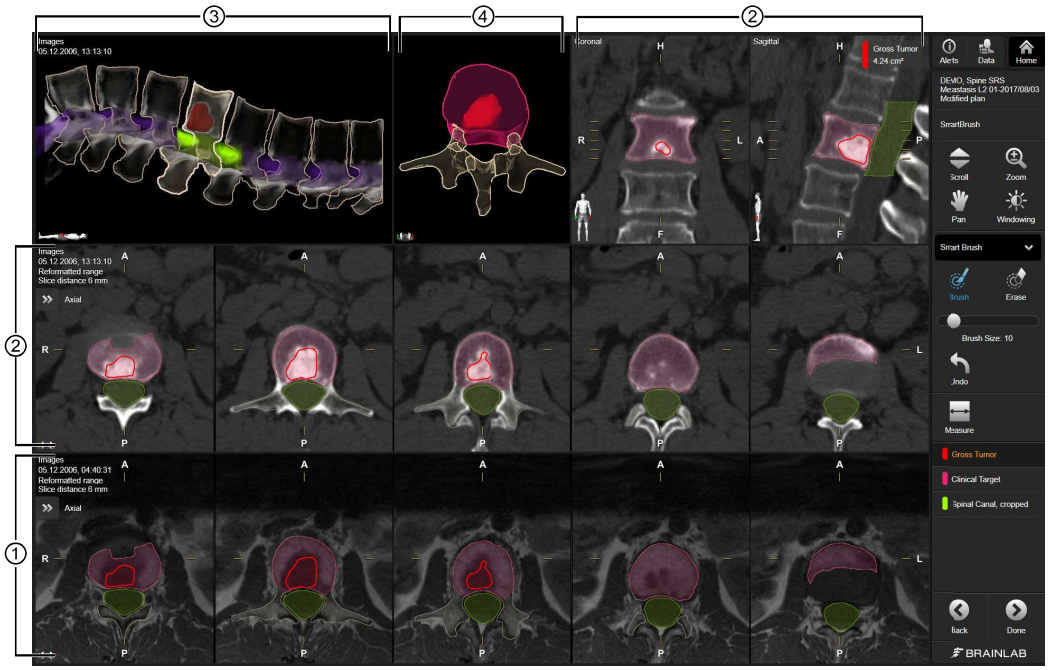


Figure 8

Spine view displays:

- A 3D reconstruction of the spine vertebrae ③
- A 3D reconstruction of the vertebra sectors ④
- ACS views of the selected image set ②
- A second image set in axial, coronal or sagittal orientation ①

Use the arrows to switch the orientation of the ACS views and second image set.

Object Resolution and Slice Number

If the objects resolution corresponds to the resolution of the image set, the original image slices are shown. In this case, the slice number is displayed in the view showing the original image orientation (e.g., for an axial scan, the slice number is shown in the axial view).

2.5 Data Menu

Background

SmartBrush automatically selects the most relevant data set and a default display.

To adjust the default layout, image set and/or object list that is displayed, select **Data** to open the data menu.

Using the Data Menu

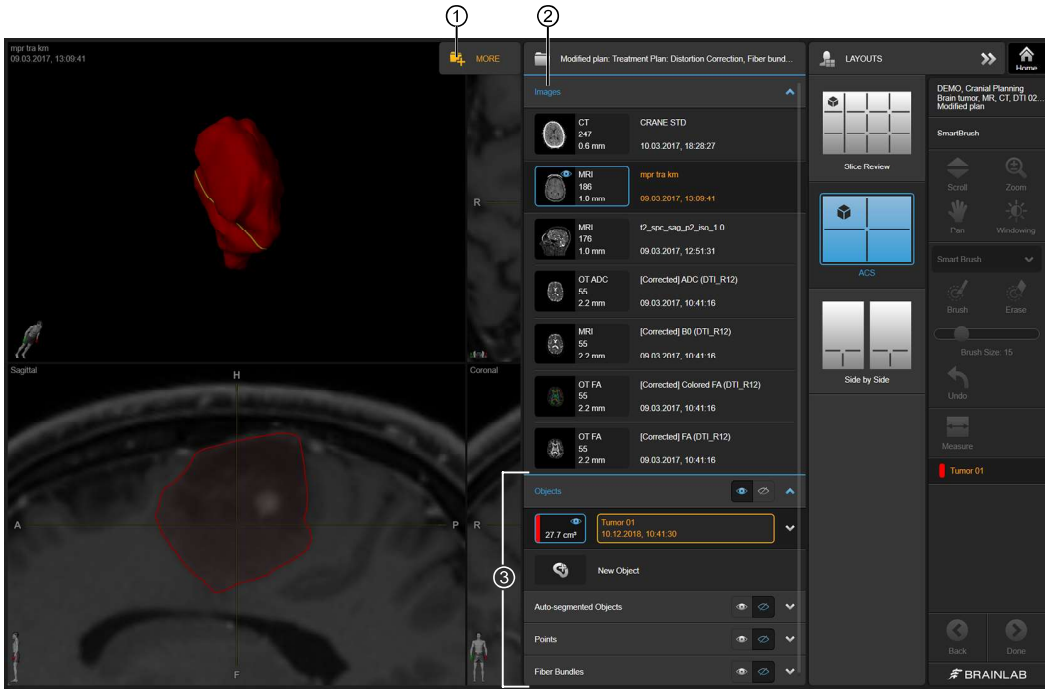


Figure 9

No.	Description
①	Select **MORE** to load additional patient data.
②	List of available image sets *NOTE: A list of 2D DSA image sets is available only when using **Angio** workflows.*
③	Other available content (e.g., **Objects**, **Auto-segmented Objects**, **Points** or **Fiber Bundles**)

Viewing Image Properties

Figure 10

Under **Images**, all image sets are displayed as thumbnail images and show the following properties:

No.	Components
①	• Image modality (e.g., MRI) • Number of slices • Slice distance
②	• Image set name • Date and time of acquisition

Viewing 2D DSA Image Properties

Figure 11

Under **2D DSA Images**, all image sets are displayed as thumbnail images and show the following properties:

No.	Components
①	• Image modality (e.g., X-ray) • Number of frames • Angle at which image was taken
②	• Name of the image • Orientation (e.g., frontal) • Date and time of acquisition

Viewing Object Properties

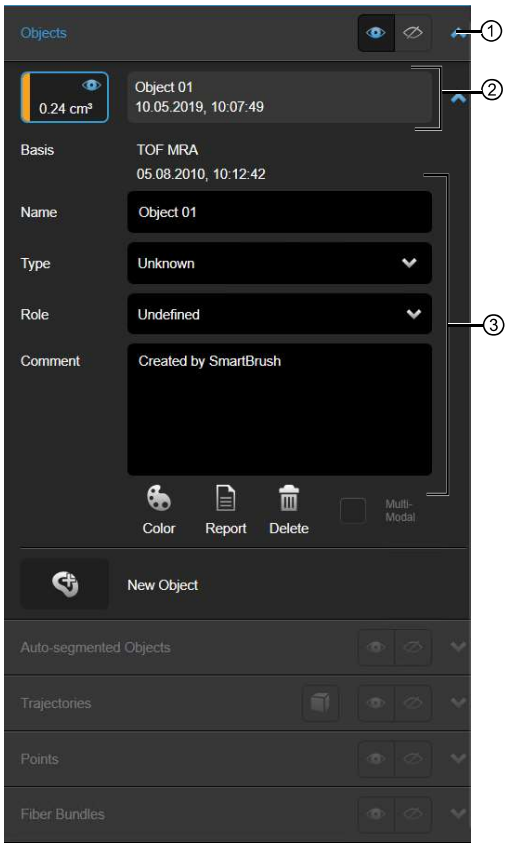


Figure 12

Select the arrow ① to open other content menus, such as **Objects**, **Auto-segmented Objects**, **Trajectories**, **Points** or **Fiber Bundles**.

You can view object properties ② or edit object characteristics at any time ③ via the **Data** menu.

Button	Function
Color	Assign a color to an object.
Report	Create a volumetric report.
Delete	Remove an object from the current selection.
Multi-Modal	Enable multi-modal object creation. *NOTE: When activated the gray values from up to three different image sets are considered by the software's semi-automatic contour expansion.*

Button	Function
	Create a new object.

Visibility Options

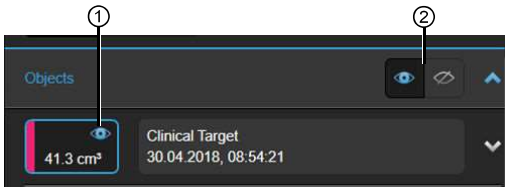


Figure 13

To show/hide a specific object, select the open/closed eye button within the object ①.
Select the open/closed eye buttons ② on the drop-down menu to show/hide all objects.

How to Modify Object Properties

Step	
1.	Select the arrow to open the **Objects** menu.
2.	Select the relevant object from the list.
3.	Edit the properties as needed. The following properties can be edited: • **Name**: Enter your object name. • **Type**: Choose an object type from the drop-down menu. • **Role**: Choose a role attribute from the drop-down menu. • **Comment**: Add applicable comments.

How to Add a New Object by Drawing

Step	
1.	Select an outlining tool (e.g., **Smart Brush** or **Brush 2D**).
2.	Begin drawing in your current view layout.
3.	A new object is added to the list of objects and the default properties are applied. • **Name**: Tumor • **Type**: Tumor • **Role**: Undefined
4.	Continue outlining your object using the outlining tools.

How to Add a New Object Through the Data Menu

Step	
1.	Select **Data** to open the menu.

Step	
2.	Select the arrow to open the **Objects** menu, then select **New Object**. A new object is added to the list of objects and the default properties are applied. • **Name**: Object • **Type**: Unknown • **Role**: Undefined
3.	Continue outlining your object using the outlining tools (e.g., **Smart Brush** or **Brush 2D**).

2.6 Image Viewing Functions

Viewing Options

Use the various image viewing functions available within the toolbar to interact with the views during object review and modification.

Button	Function	Description
Pan	Move a slice within a view	• Move the image detail to the desired location. • Drag the mouse to move the image detail to a desired location. • Select a desired location to center the image around that location.
Scroll	Scroll through all slices within a view	• Drag up/left or down/right to view all slices. • Use the mouse wheel.
Zoom	Zoom in or out	• Drag up/left (zoom out) or down/right (zoom in). • When using a touchscreen, press two fingers on the image and pinch inward (zoom out) or outward (zoom in).
Windowing	Adjust the brightness and contrast of a slice	• Drag down/up to increase/decrease the brightness. • Drag right/left to increase/decrease the contrast level. • Use advanced **Windowing** feature.

Advanced Windowing

Advanced **Windowing** is available for any 3D image set. **Windowing** opens a histogram of the selected 3D image set in a sidebar.

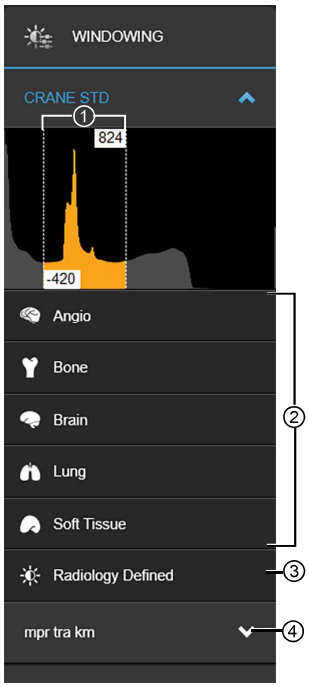


Figure 14

No.	Explanation
①	Adjust the borders to limit the windowing to a specific range.
②	Preset windowing settings are available for CT image sets which are optimized to display particular structures such as bone, lung or soft tissue.
③	Select **Radiology Defined** to return back to the original state.
④	Select the arrows to expand or collapse the histogram for a certain image set when more than one image set is displayed.

Centering Objects

You can center the object you are currently working with by selecting the object name from the toolbar.

2.7 Contouring Tools

Accessing the Tools

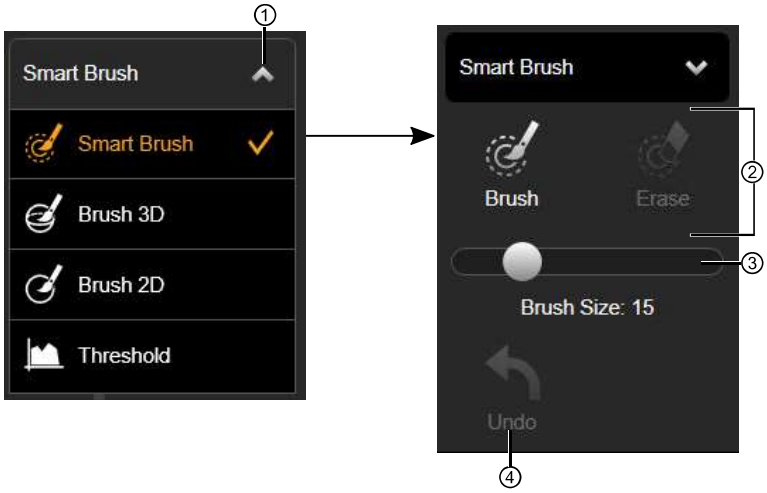


Figure 15

To view all contouring tools, select the drop-down menu ① from the toolbar. Select the contouring tool you need.

*NOTE: If you select a different brush option during a session (e.g., **Brush 2D**), the menu name changes to reflect that name. The default selection is **Smart Brush**.*

In the brush menus, you can:

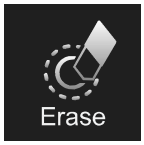
- Select **Brush** or **Erase** ② as required.
- Move the slider to change the **Brush Size** ③.
- Select **Undo** ④ to undo the last change made. Keep selecting to undo multiple changes.

Brush Functions

Function	Smart Brush	Brush 3D	Brush 2D
Outlines any region or structure, taking into account the gray value information of the underlying image set.	✓		
Uses interpolation to convert manually segmented areas into a 3D object.	✓	✓	
Outlines structures in a single plane voxel by voxel.			✓

NOTE: The sensitivity of the tools is dependent on the zoom level.

Smart Brush Options

Options	
	• Segments pixels with similar gray values in the defined area. • Uses 3D interpolation. *NOTE: The tool highlights the area you marked and adds/removes segmented voxels in a small area around the marked area, creating smooth object contours.*
	Smart removal of 3D area around the user input.

Brush 3D Options

Options	
	Outlines area of interest with geometric 3D interpolation. *NOTE: User input remains unchanged by the interpolation.*
	Removes a restricted 3D area considering the user input.

Brush 2D Options

Options	
	Outlines area of interest pixel by pixel. Allows you to correct structures without any interpolation.
	Removes only the marked pixels from the object without interpolation.

Threshold Segmentation Options

Threshold is a contouring tool that allows you to segment objects based on a fixed range of intensity values.

The tool can be used on MR, CT, PET images and images generated with Brainlab Elements **Contrast Clearance Analysis** to extract contrast enhanced structures, such as:

- Bone structures
- Blood vessels
- Burned-in objects (e.g., BOLD fMRI, TMS)
- Activation hot-spot

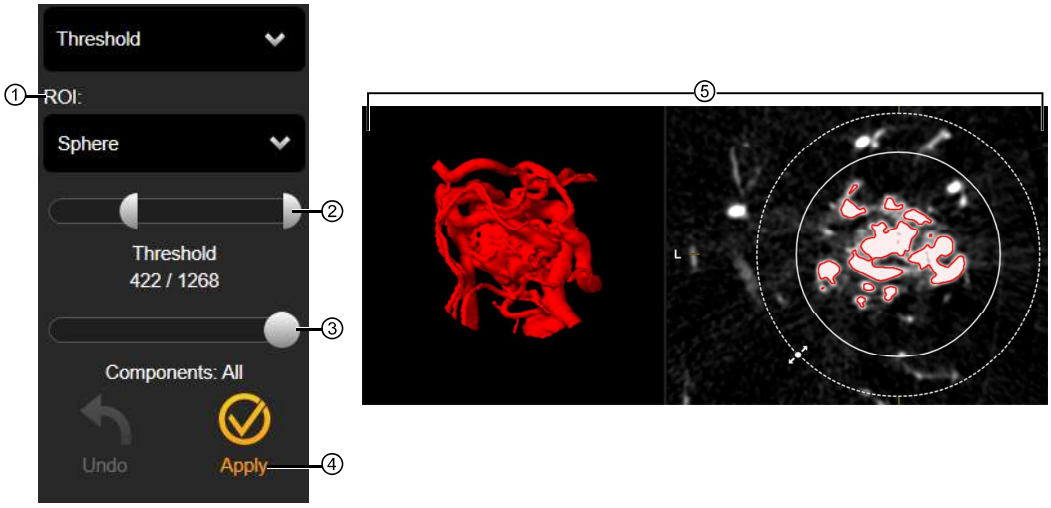


Figure 16

Options	
①	**ROI** ROI for **Threshold** to be applied. Can be set to: • **Sphere**: Uses all voxels inside a user-defined sphere. • **Full Volume**: Uses the complete image set. • Any segmented object that is available.
②	**Threshold** intensity slider: Adjust the intensity range to be used for segmentation.
③	**Components:** • Can be used to set the number of independent components or voxel islands that the segmentation results in. • Set to **1** to use only the biggest voxel island. • Set to **All** to use all voxel islands.
④	Select **Apply** to segment the object based on the values in the controls.
⑤	Example of threshold based segmentation of 3D DSA contrast enhanced image data: Separation of vascular structure with **Sphere** ROI.

*NOTE: In multi-modal view layouts (e.g., **Side by Side**, **Spine**), **Threshold** is always based on the first image.*

2.8 Measurements

Measuring Tool

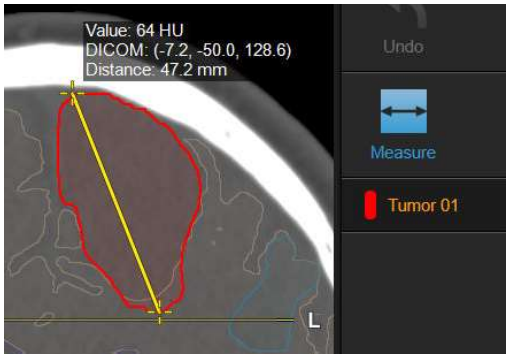


Figure 17

The **Measure** tool allows you to measure intensity values, DICOM coordinates and distances in any given 3D image set. Intensity values are displayed with their corresponding unit (e.g., HU, SUV) or as gray or RGB intensity value.

How to Calculate Point Measurements

Step	
1.	Select the point you would like to measure. The intensity value and DICOM coordinates are displayed.
2.	Drag the point to change the position of the measurement.
3.	Select the point again to remove the measurement.

How to Calculate Distance Measurements

Step	
1.	Select a first point.
2.	Select a second point. The intensity value and DICOM coordinates for the second point will be displayed along with the distance.
3.	Select and drag either point to adjust the measurement.
4.	Select a point to remove it.

Distance measurements do not have to be performed in the same plane. If a part of the measurement line is above the slice, the line is displayed in two different tones of yellow. The bright yellow represents the part above the slice.

3 USING SMARTBRUSH

3.1 Outlining 3D Objects

Getting Started

SmartBrush provides contouring tools to outline anatomical structures in medical image data. Outlining can be done with or without interpolation and with or without consideration of the gray values in the image data.

If the software identifies an anomaly when you start the software, the view is automatically centered on that anomaly.

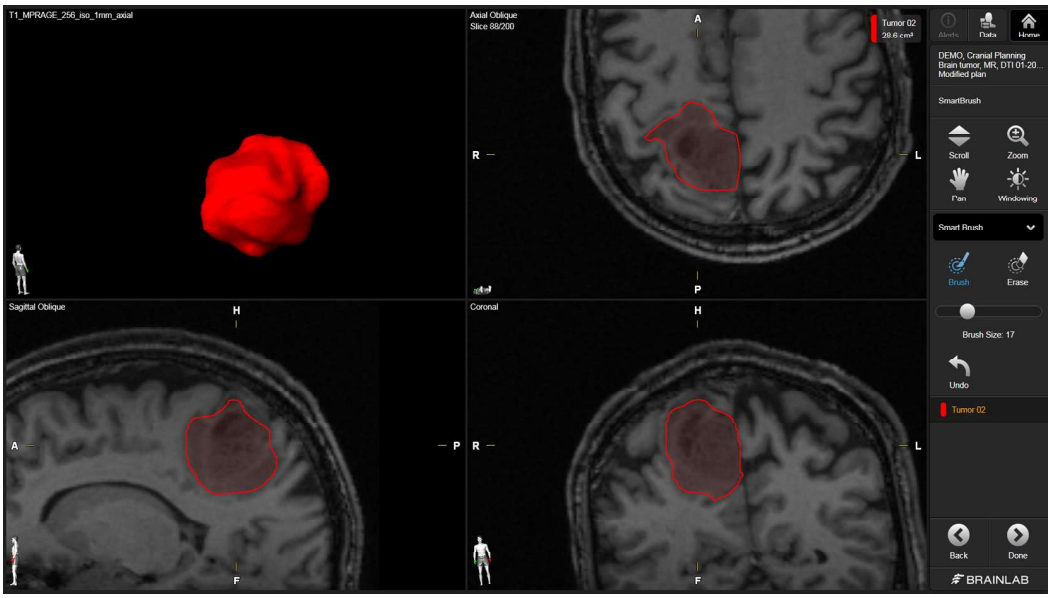


Figure 18

Outlining Objects Successfully

In general, to outline an object with any brush type:

- Highlight the area to be segmented with the desired brush.
- Repeat the process in the next slice or work in a parallel/perpendicular slice until you have created the desired object.

To make corrections:

- If edges of the segmented area are not correctly separated from the surrounding area, use **Erase** to define these borders more accurately.
- With a mouse, use the right mouse button to erase when **Brush** is active.

How to Outline Objects Using Smart Brush

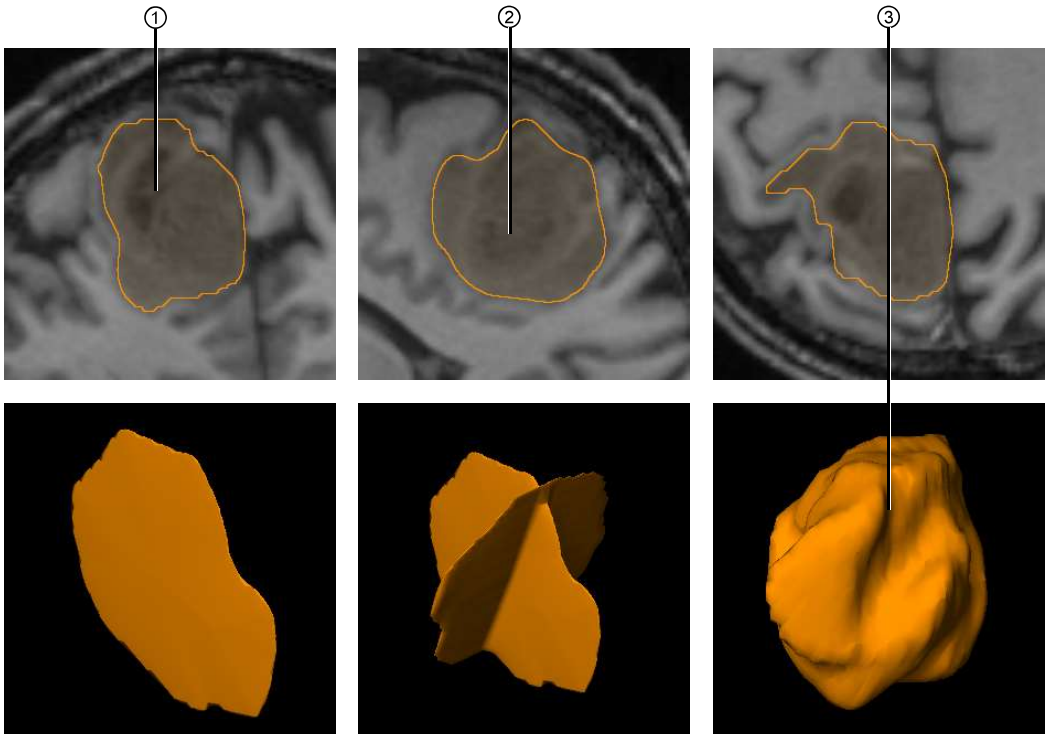


Figure 19

As **Smart Brush** recognizes contrast differences, you can outline objects more effectively by starting at the lesion center and moving the **Brush** toward the border.

Step	
1.	Center and zoom to the ROI using the **Zoom**, **Scroll** and **Pan** functions.
2.	 Select **Brush** from the **Smart Brush** menu.
3.	Outline the shape of the structure ① in one reconstruction (e.g., the coronal view). The outline follows the contours of the object. The region that is outlined is determined by the gray values and the contrast of the image.
4.	Outline the shape of the structure ② in another reconstruction (e.g., the sagittal view).
5.	Interpolation is used to automatically create a 3D object ③. The software segments all connected pixels with similar gray values within the defined area. If you outline a larger area, the potential gray value scale increases.

Using Brush 3D

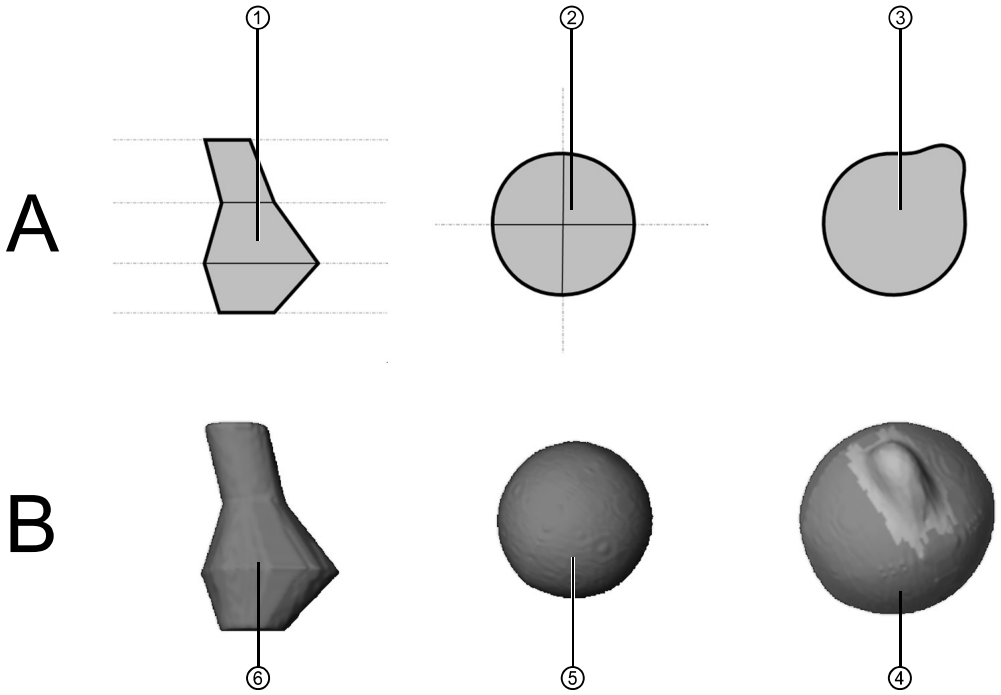


Figure 20

Smart Brush uses multi-modal information for outlining, while **Brush 3D** uses geometric 3D interpolation to create a 3D object. This 3D interpolation can be seen in the graphic and is described below:

(A) If you …	**(B) The software ...**
Outline in parallel slices ①	creates a 3D interpolated object ⑥
Outline in perpendicular slices ②	creates a 3D interpolated object ⑤
Use locally restricted 3D interpolation ③	smoothly adds the marked area to a 3D object ④

How to Outline Objects Using Brush 3D

Step	
1.	Center and zoom to the ROI using the **Zoom**, **Scroll** and **Pan** functions.
2.	 Select **Brush** from the **Brush 3D** menu.
3.	Outline the shape of the structure in one reconstruction (e.g., the coronal view).
4.	Outline the shape of the structure in another reconstruction (e.g., the sagittal view).

Step	
5.	Interpolation is used to automatically create a 3D object. *NOTE: Use **Scroll** to move from one slice to the next. You can also outline an object by:* • *Outlining in parallel reconstructions and skipping some slices. The information between the slices is interpolated.* • *Outlining in a perpendicular reconstruction.*

How to Outline Objects Using Brush 2D

Brush 2D allows you to outline areas of interest manually and is recommended for correcting structures. **Brush 2D** does not use interpolation, so you have complete control over each voxel and you can correct the structure on a slice-by-slice basis.

Step	
1.	Center and zoom to the ROI using the **Zoom**, **Scroll** and **Pan** functions.
2.	 Select **Brush** from the **Brush 2D** menu.
3.	Outline the shape of the structure in one reconstruction (e.g., the coronal view).
4.	Outline the shape of the structure in another reconstruction (e.g., the sagittal view).
5.	Use **Scroll** to move from one slice to the next.

How to Outline Objects in Slices of the Same Reconstruction

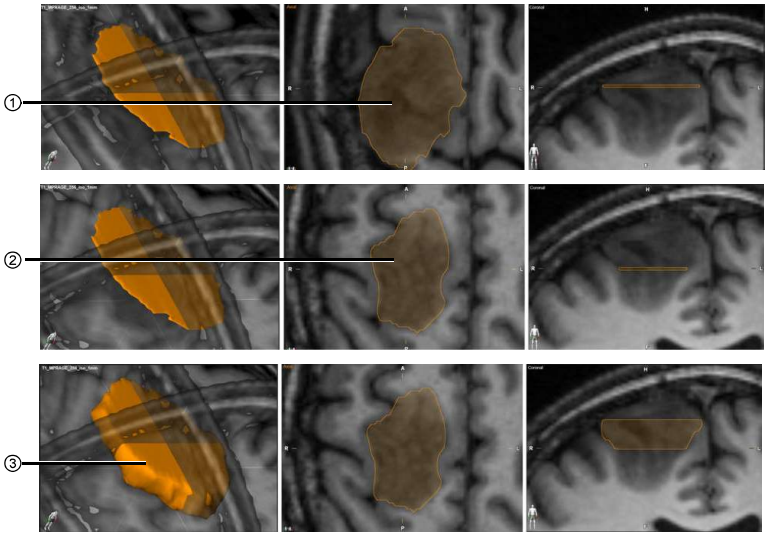


Figure 21

Step	
1.	Create a segmented region on one image slice ① using **Smart Brush** (or **Brush 3D** or **Brush 2D** for adjacent slices).
2.	Scroll through the image slices to the next distinct plane.
3.	Create another segmented region on a different slice ②.
4.	The area between the two slices is interpolated ③, creating a 3D object.

Creating Objects in Reconstructed Views

Creating objects in reconstructed views (i.e., containing images that have been reconstructed from original image slices) differs from creating objects in original slices. As interpolated images are used in reconstructed views, not all expected details may be shown (e.g., borders may be blurred).

Using **Smart Brush** and **Brush 3D** with two non-adjacent slices in the same orientation, the space between the slices is interpolated to create the 3D object.

Selected objects are displayed using the orientation that was used when the object was created. Changing the alignment of an image set after creation does not impact the appearance of the object and the corresponding image when the object is selected or used for outlining.

Verify in 2D views that the shape of a new or modified object is correct before leaving the application.

*NOTE: When using **Brush 2D** in adjacent slices, the space between the adjacent slices is also interpolated. If some slices are skipped, no interpolation is performed.*

Object Resolution

An object is always assigned the resolution (voxel size and slice distance) of either:

- The first image set that is used for segmenting a structure when you start drawing without creating a new object.
- The image set that is selected when you select **New Object**.

It is recommended to use image sets with a resolution that is high enough to represent the structure to be segmented.

NOTE: This may be configured differently depending on the selected workflow. Contact Brainlab Support for more information.

NOTE: Contact Brainlab support to set a fixed resolution for all objects, independent from the image sets used for drawing.

3.2 Multi-Modal Options

About Multi-Modal Options

If you are using image sets co-registered by **Image Fusion**, you can display and modify objects in all fused image sets.

A multi-modal object is created automatically when using different sets for segmentation, but the image sets considered are dependent on the layout in which the drawing was performed:

Layout	Image Sets Considered
Multi-modal layout (e.g., **Side by Side** or **Spine**)	Both image sets displayed in the views are considered by the algorithm.
Mono-modal view layout	The first two image sets in which the object is drawn are considered by the algorithm. *NOTE: If you select a third image set, the first image set is deselected and no longer displayed.*

*NOTE: Multi-modal only works with **Smart Brush**.*

Example Containing Multi-Modal Image Sets

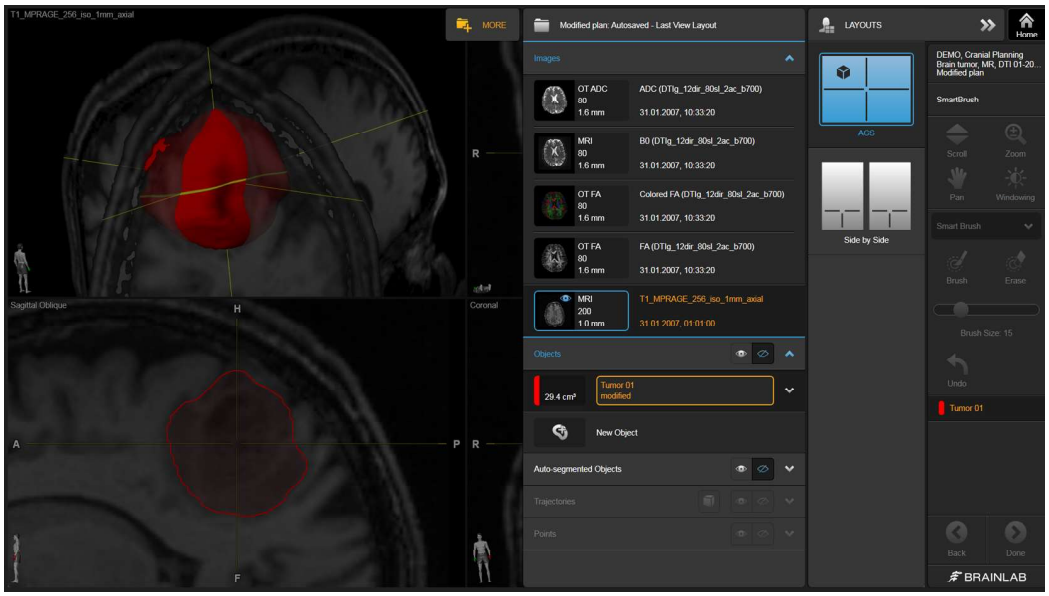


Figure 22

Option	Data Used for Outlining
Outline the tumor in an MR-T1 set.	MR-T1 set
Switch view to a fused MR-T2 set and continue outlining.	MR-T1 and MR-T2

NOTE: Only the gray values of two image sets are used. If you select a third image set, the first image set is deselected and no longer displayed.

3.3 Outlining Objects in Angio Planning Procedures

Background

SmartBrush provides additional functionality for cerebrovascular planning procedures when angio bundles generated in Brainlab Elements **Image Fusion Angio** are available upon start of the application.

*NOTE: A corresponding **SmartBrush Angio** license is required.*

Saving the Nidus Object

The 3D nidus object is saved in the workflow upon selecting **Done**.

The default naming convention for the 3D nidus object is **Nidus**.

Viewing Options

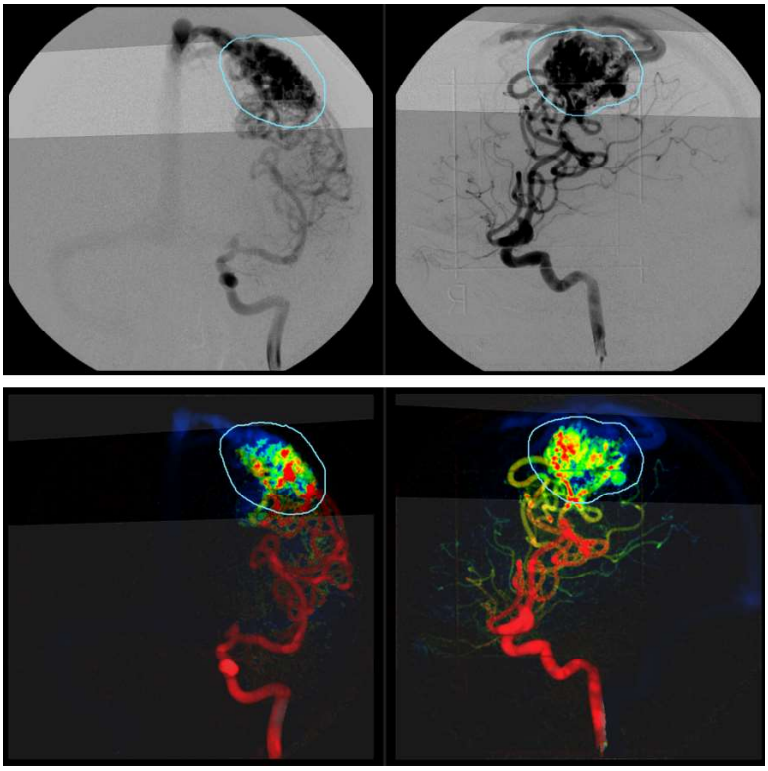


Figure 23

Options	Explanation
DSA view	Digital Subtraction Angiography: Displays the angiography imaging in gray-scale.
CIP view	Color Intensity Projection: Dynamic angio flow with color-coded time information based on DSA images *NOTE: For further information on interpreting CIP images refer, to the **Image Fusion Angio Software User Guide**.*

Reviewing Results

To verify your results, consider the following:

- Review/compare with projective images.
- Review CIP images.

ROI (Region of Interest)

When starting the application with angio bundles created in Elements **Image Fusion Angio**, an ROI definition dialog is displayed automatically. The dialog can be used to define an ROI (e.g., a nidus) on a pair of angiograms.

Figure 24

No.	Explanation
①	View area: Displays a pair of DSA or CIP images.
②	**DSA**/**CIP** control: Switch between **DSA** and **CIP** views to help identify ROIs more easily.
③	Toolbar
④	Select **Skip** to skip ROI definition and proceed to the next step.
⑤	Select **OK** to keep the ROI and proceed to the next step.

How to Use ROI Definition Dialog

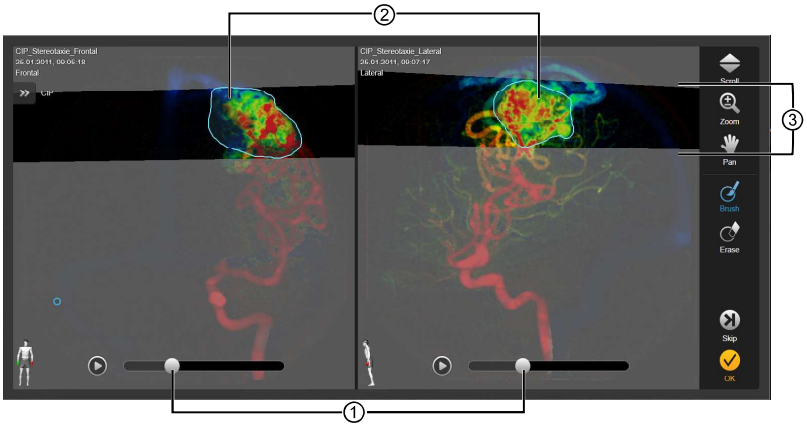
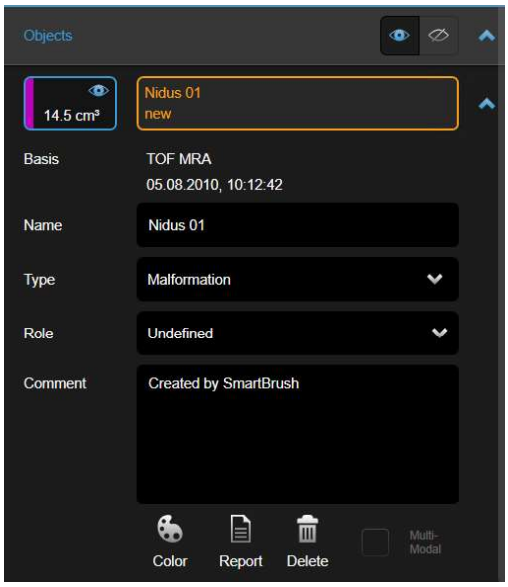
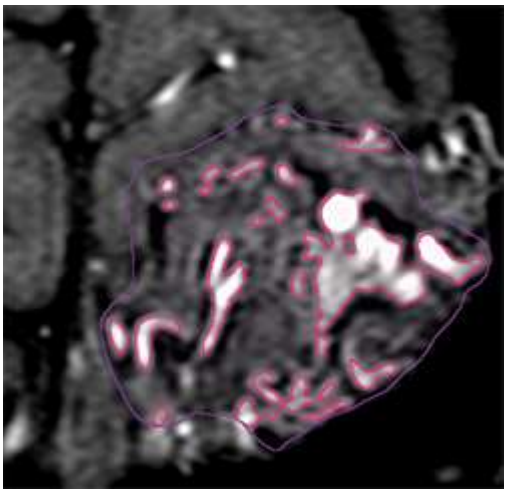
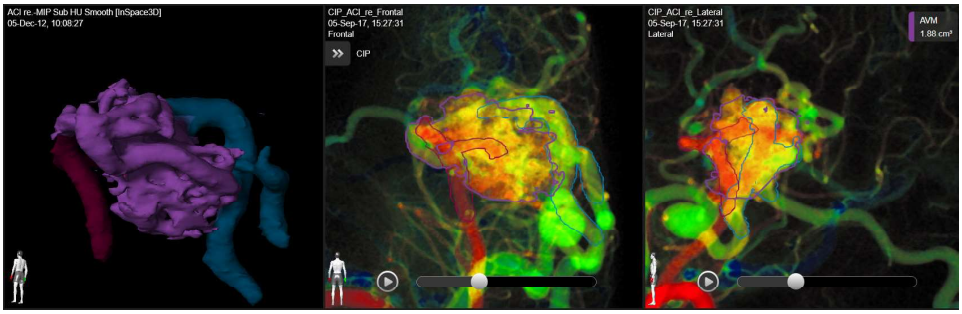


Figure 25

Step	
1.	Scroll through the images using the sliders ① to find ROIs. *NOTE: This can also be done by using the mouse wheel or scroll function.*
2.	Select **Brush**.
3.	Highlight an ROI in one view by drawing an outline ②. The area is marked in blue and creates a ray ③ in the other view.
4.	Highlight the ROI in the other view. *NOTE: If the rays in both views fail to intersect, **OK** is disabled.*
5.	Verify the **ROI** by scrolling through the images.
6.	Select **OK**.

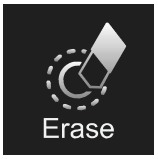
How to Proceed

Step	
1.	 Once **OK** is selected, the application uses the input from the ROI outlining as a starting point to create a 3D object with the following properties: • **Name**: Nidus • **Type**: Malformation • **Role**: Undefined

Step	
2.	 The new object is created based on the ROI and gray values in the 3D image set that is co-registered to the 2D DSA images. If no suitable segmentation can be found, the resulting object will be an intersection of the defined regions of interest. You can continue outlining or further refining the object using the available contouring tools: • **Smart Brush**: For refinement of contrast enhanced areas. • **Brush 3D**: For contouring in areas without contrast enhancement. • **Brush 2D**: For small local changes. • **Threshold**: To extract the contrast enhanced vascular details inside the outlined nidus object, which can also be used as the ROI for this tool.
3.	 Repeat the process to manually outline single vessel branches in order to separate arteries and veins.

How to Erase in 2D DSA Images

You are able to remove parts of the segmented object by using the **Erase** tool in the 2D DSA views.

Step	
1.	 Select **Erase** or use the right-mouse click when **Brush** is selected.
2.	Mark the area that shall be erased in the 2D DSA view. Voxels below the marked area are removed from the 3D segmentation.

How to Re-Open the ROI Definition Dialog

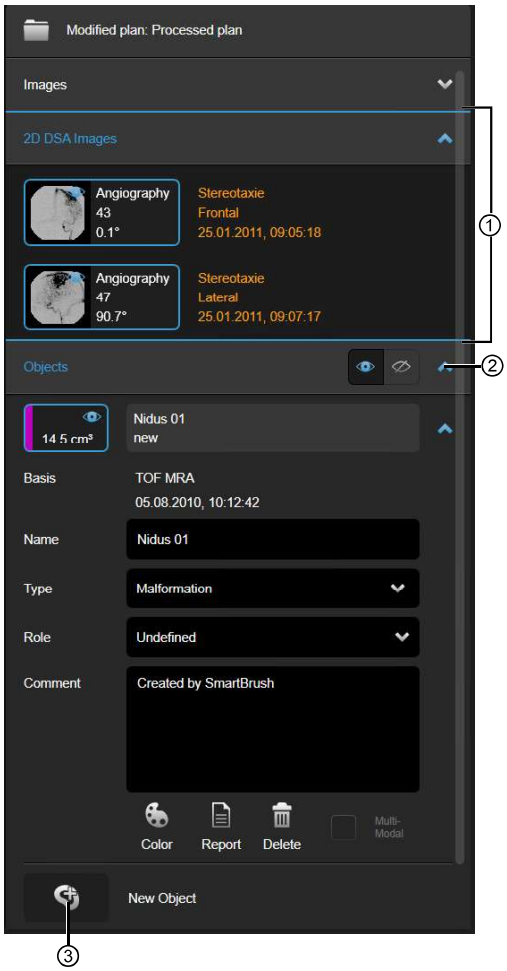


Figure 26

Step	
1.	Select **Data**.
2.	Select the relevant pair of 2D DSA images ①.
3.	Open the **Objects** menu by selecting the arrow ②.
4.	Select **New Object** ③.

3.4 Outlining Clinical Target Volumes in Spine Planning Procedures

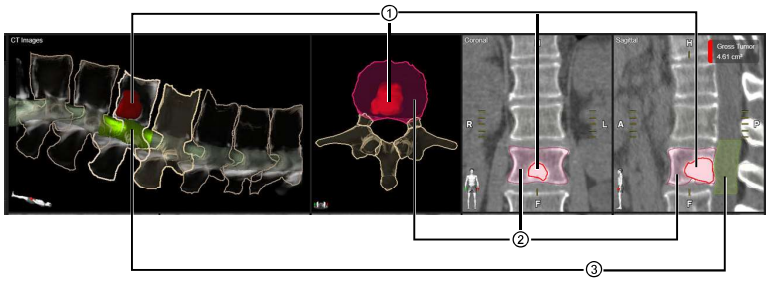
Guidelines for Generating Clinical Target Objects

The automatic generation of clinical target objects follows the guidelines as published by Brett W. Cox, et al. in 2012.

1. Cox BW, Spratt DE, Lovelock M, et al. International Spine Radiosurgery Consortium consensus guidelines for target volume definition in spinal stereotactic radiosurgery. *Int J Radiat Oncol Biol Phys.* 2012; 83:e597-605.

SmartBrush generates a cropped OAR that is calculated based on the position of the clinical target (i.e., the cropped OAR covers the length of the spine where the CTV is located +/- 5 mm from top/bottom). This is visible in both 2D and 3D views.

About Clinical Target Objects



As soon as you start outlining a GTV ①, **SmartBrush** generates:

- CTV ②
- OAR (e.g., spinal canal, cropped) ③

How to Outline Objects with SmartBrush in a Spine SRS Workflow

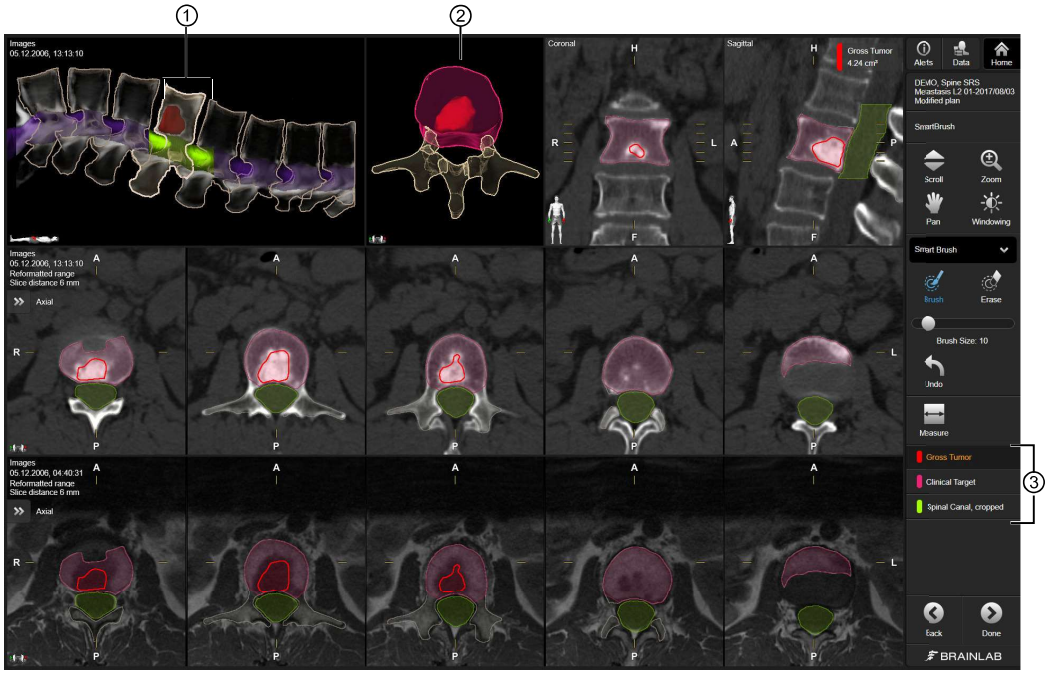


Figure 27

Step	
1.	Select the relevant vertebra ①.
2.	Center and zoom to the ROI using the **Zoom**, **Scroll** and **Pan** functions.
3.	Select an outlining tool from the menu.
4.	Outline the area to be segmented. As soon as you begin to outline an object, a corresponding CTV and OAR are generated. The CTV and OAR update automatically.
5.	Scroll to next slice or continue outlining in a perpendicular reconstruction.
6.	Repeat steps until the object has been created in all relevant slices.
7.	Verify the drawn and automatically generated objects ② by selecting them in the toolbar ③ and reviewing them.

Object Linking

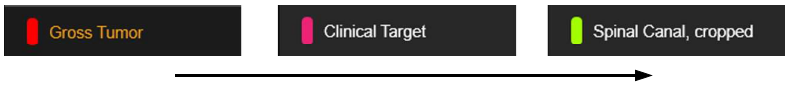


Figure 28

All three objects are linked. Changes to one object affects the next object (e.g., changing the GTV will also change the CTV and cropped OAR).

The flow is unidirectional.

In addition, the application can detect changes to the vertebra that the CTV is based on. When a vertebra is changed outside the application during runtime, the CTV is updated accordingly.

*NOTE: Vertebra should be segmented prior to using **SmartBrush** (e.g., in Brainlab Elements **Anatomical Mapping**).*

*NOTE: In best practice, the GTV, CTV and cropped OAR objects should be modified without leaving **SmartBrush**.*

Rules for the Automatic Outlining of the CTV

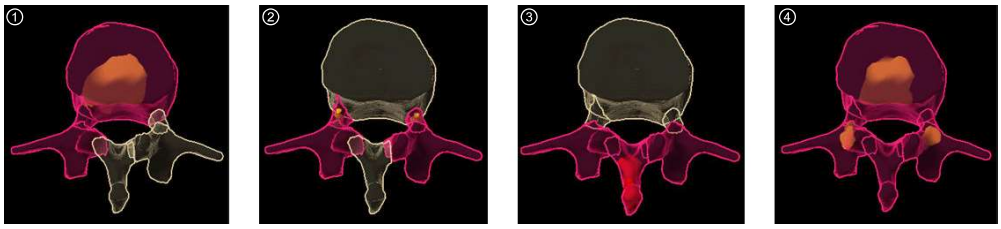


Figure 29

SmartBrush automatically creates the CTV based on the location of the GTV according to the following rules:

No.	GTV Location	Anatomical Regions Included in the CTV
①	• Vertebral body • At least one pedicle	• Entire vertebral body • Pedicle(s) • Transverse process(es)/lamina(e)

No.	GTV Location	Anatomical Regions Included in the CTV
②	• At least one pedicle	• Pedicle(s) • Transverse process(es)/lamina(e)
③	• Spinous process	• Entire spinous process • Bilateral transverse processes/lamina
④	• Vertebral body • Bilateral transverse processes/lamina	• Entire vertebral body • Bilateral pedicles • Transverse processes/lamina(e) • Entire spinous process

Rules for Automatic Outlining of CTVs in Spine Planning Procedures

The automatic generation of a clinical target object follows these rules:

When the GTV	involves the unilateral pedicle,	then	the pedicle and ipsilateral transverse/lamina	are included in the CTV.
	involves the spinous process,		the entire spinous process and bilateral laminae	
	involves the vertebral body and bilateral pedicle/transverse processes,		the entire vertebral body, bilateral pedicles, transverse process/laminae and spinous process	
	involves the vertebral body and one unilateral pedicle,		the entire vertebral body, pedicle and ipsilateral transverse process/laminae	
	involves a unilateral lamina,		the lamina/transverse process, the ipsilateral pedicle and the spinous process	

Additional rules for clinical target generation:

- When the intersection between the GTV and one sector is not empty, this sector is included in the CTV.
- When changes occur to the GTV, the sector selection dynamically updates.
- Every change to the GTV triggers a CTV update except for changes to the name, color or comments.

NOTE: If you leave the software without reviewing the automatically generated objects, a dialog is displayed.

Objects with Disconnected Volumes

Ensure that any object created is a contiguous object or it will be treated as a disconnected volume.

An object is treated as a disconnected volume if the total object volume minus the volume of the biggest component is bigger than 0.1 cm^3.

If you leave the software after generating or editing objects with disconnected volumes without reviewing them, a dialog is displayed.

*NOTE: **Spine SRS** does not support disconnected volumes for dose planning.*

4 ADDITIONAL FUNCTIONS

4.1 Volumetric Report

About Volumetric Reports

A volumetric report contains information about the volume of an object, the Macdonald Criteria and the Response Evaluation Criteria in solid tumors (RECIST). Macdonald Criteria is a 2D tumor criteria for gadolinium-enhancing T1-weighted lesions. The algorithm gives the longest diameter of the object within original slices multiplied by the longest perpendicular diameter within the same slice. RECIST is an evaluation criteria for gadolinium-enhancing T1-weighted lesions. The algorithm gives the longest diameter of the object within original slices.

Handling Volumetric Information

A volumetric report:

- Is created for an object and stored with the object if you select **Report**.
- Stays valid as long as the associated object is not modified.
- Is stored with the patient data as long as the object is not modified.
- Calculates object volume to two decimal places if it is less than 10 cm^3. Anything greater is calculated to one decimal place.

The shape and position of an object must be verified in **SmartBrush** before creating a report. The report itself only gives information about volumetric measurements.

Values calculated from an outlined object depend on the resolution of the corresponding image set, including the object. Take this into account if you use the calculated values to make decisions about further treatment.

NOTE: The Macdonald criteria calculated on the volumetric report is performed using the original slices. Hence, the orientation to which the Macdonald criteria is applied is equal to the scan direction. The resolution of the image series determines the accuracy of the method. Therefore, the object displayed in the software might have a slightly different result due to interpolation.

NOTE: Contact Brainlab support for further information.

Reviewing and Exporting Reports

Existing reports can be reviewed using **Viewer**. Existing reports can be stored/exported using the **Export** function of **Patient Data Manager**.

How to Create a Volumetric Report

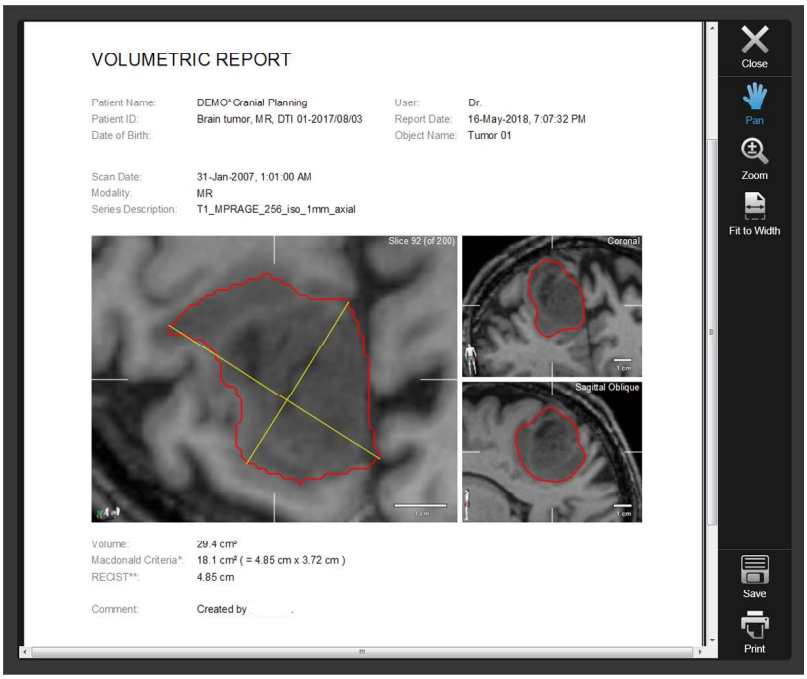


Figure 30

Step	
1.	Select **Data**. The **Data** menu opens.
2.	Select the relevant object in the **Objects** drop-down menu.
3.	Select **Report** from the menu. The software generates a volumetric report.

4.2 Volumetric Report Functions

Functions

Button	Function
	Pans around the report.
	Zooms in to an area of the report.
	Fits the report to the width of the screen.
	Closes the report.
	Saves the report to a specified location.
	Sends the report to a specified printer.

4.3 Export

How to Export

For information on exporting from the system, see the **Patient Data Manager Software User Guide**.

NOTE: If the data generated by the application (i.e., objects, segmentations) are used within follow-up applications, the results must be inspected carefully after the import into the follow-up application.

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