Twelve

The 3D Curved MPR Viewer

This Chapter describes how to visualize and reformat a 3D dataset in a Curved MPR plane: Curved Planar Reformation (CPR). The 3D Curved MPR Viewer is a window opened from the 2D Viewer.

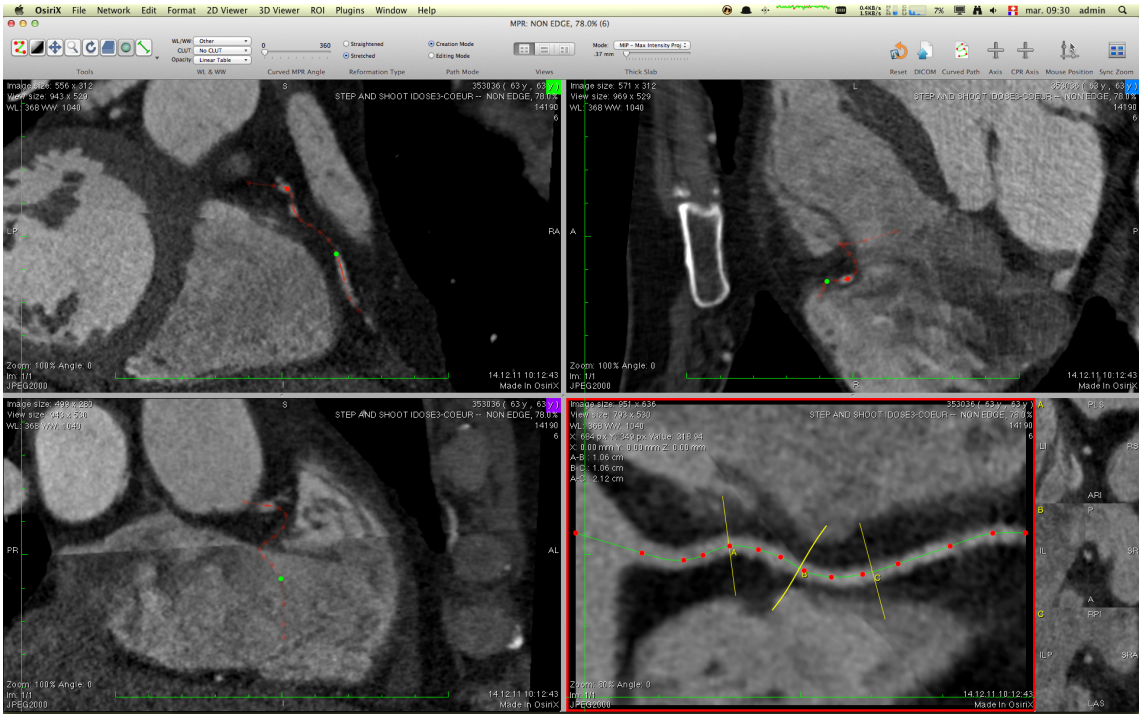


Figure 12.1: 3D Curved MPR Viewer Window

This viewer produces a Curved MPR rendered image from a 3D dataset. The Curved MPR plane can be defined in any direction and angle on the original dataset. This plane is defined as a 3D Bezier path. The Curved MPR plane is rendered as a *straightened* (12.2.1) or *stretched* (12.2.2) view.

Four views are displayed in this window. The first three views show an orthogonal MPR plane in relation to the other views. It allows the user to move in a precise manner and to place and edit the 3D Bezier path. The lower right view displays the 3D Bezier path as a *straightened* or *stretched* curved MPR image. The user can rotate around this 3D Bezier path and display three perpendicular views along this path (views A, B and C).

The Curved MPR views and the corresponding perpendicular views can be exported as new DICOM images in the database.

12.1 The Anatomy of the 3D Curved MPR Viewer

The window of the 3D Curved MPR Viewer is divided into 3 parts:

- The toolbar
- The three MPR Views
- The Curved MPR view rendered as a *straightened* or *stretched* view, including 3 perpendicular views (views A, B and C)

The toolbar contains several buttons allowing the user to access the most useful functions available. As with any other toolbar, it can be customized: see 1.7.3.1.

The MPR views are the place where the DICOM images are reformatted as orthogonal views and where the 3D Bezier path is defined by the user. The Curved MPR view is the place where the 3D Bezier path is rendered as a curved plane image. The three views on the right side of the Curved MPR view show three images, corresponding to three perpendicular views along the 3D Bezier path. These three perpendicular views are strictly perpendicular to the Bezier path, but are not necessary parallel to each others, if the 3D Bezier path is not a straight line.

You can double-click in any of these views to display it as fullscreen. Double-click again to reduce it to its normal size. You can also click and move the separators between these views to adapt the views size. And finally you can change the orientation of the Curved MPR view by using the Views toolbar item (12.1.1.8): horizontally or vertically rendered.

You can interact with these views using the mouse and the keyboard and by using several tools that are described in this chapter.

12.1.1 Toolbar

The 3D Curved MPR Viewer window provides a variety of tools and functions that can be accessed through icons displayed on the toolbar or through items listed in the *3D Viewer* menu. This section describes each tool available in the toolbar.

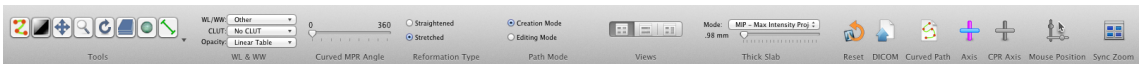


Figure 12.2: 3D Curved MPR Viewer Window Toolbar

12.1.1.1 Mouse Tools

Allows the user to select a tool for the mouse left-click, used when clicking on a MPR view.

You can choose to assign one of the following tools to the left mouse button:

- Curved Path (12.2.4)
- WL/WW *[default left click]* (5.5.1.1)
- Pan (5.5.1.2)
- Zoom (5.5.1.3)
- Rotate (5.5.1.4)
- Scroll (5.5.1.5)
- Plane Rotate (10.2.2)

The left mouse tool can also be one of the following ROI tools:

- Length (5.6.1.1)
- Angle (5.6.1.2)
- Rectangle (5.6.1.3)
- Oval (5.6.1.4)
- Text (5.6.1.5)
- Arrow (5.6.1.6)
- Opened Polygon (5.6.1.8)
- Closed Polygon (5.6.1.7)
- Pencil (5.6.1.9)
- Point (5.6.1.10)
- Brush (5.6.1.11)

12.1.1.2 WL/WW

This allows the user to change the settings for WL/WW using presets.

12.1.1.3 CLUT

This allows the user to change the settings for the CLUT using presets.

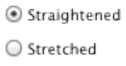
12.1.1.4 Opacity

This allows the user to change the settings for the opacity table using presets.

12.1.1.5 Curved MPR Angle

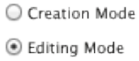
This slider displays the current rendering angle for the Curved MPR plane. You can change this angle by moving the slider handle or by moving the mouse cursor on the Curved MPR view and scrolling the mouse wheel.

12.1.1.6 Reformation Type



You can select the rendering mode for the Curved MPR plane: *straightened* (12.2.1) versus *stretched* (12.2.2).

12.1.1.7 Path Mode



You can select the mode for the drawing of the path: *Creation Mode* versus *Editing Mode*. The *Creation Mode* allows you to create a new path and add new points (see 12.2.4.1). The *Editing Mode* allows you to edit the existing points of a path (see 12.2.4.2).

12.1.1.8 *Views*

You can select here the positions and the orientation of the Curved MPR plane. Three modes are available:

- Three MPR views with an horizontally rendered Curved MPR plane.
- One MPR views with an horizontally rendered Curved MPR plane.
- Two MPR views with a vertically rendered Curved MPR plane.

12.1.1.9 *Thick Slab*

This displays a thick slab rendering of the selected Series. You can choose the rendering algorithm from the following:

- MIP
- MinIP
- Mean

12.1.1.10 *Reset*

This resets the 3 MPR views to the default view settings and delete the Curved Path, if it exists. It changes the following view settings to the default value:

- Zoom
- Rotation
- Pan

12.1.1.11 *Save as DICOM*

You can use this tool to create new DICOM images based on the Curved MPR view. The new images are indexed and added to the database. You can choose from the following options:

- The name of the resulting Series
- The size of the resulting images, from the following options:
  - Current
  - 512×512
  - 768×768
- The image format:
  - Screen Capture in 8-bit RGB
  - 16-bit black and white

- The sequence to record:
  - The current image only
  - A series with the following settings:
    - A rotation, choosing:
      - the number of frames to render (from 1 to 360)
      - the amplitude of the rotation (180° or 360°)
    - A slab, choosing:
      - the export thickness (from 1 to 200 mm)
      - the slice interval (from 1 to 200 mm)
    - Transverse views, choosing:
      - the slice interval (from 1 to 50 mm)
- Include the CPR View and the Transverse Views
- Mark the resulting images as key images: on/off.
- Send the resulting images to a DICOM node: on/off.

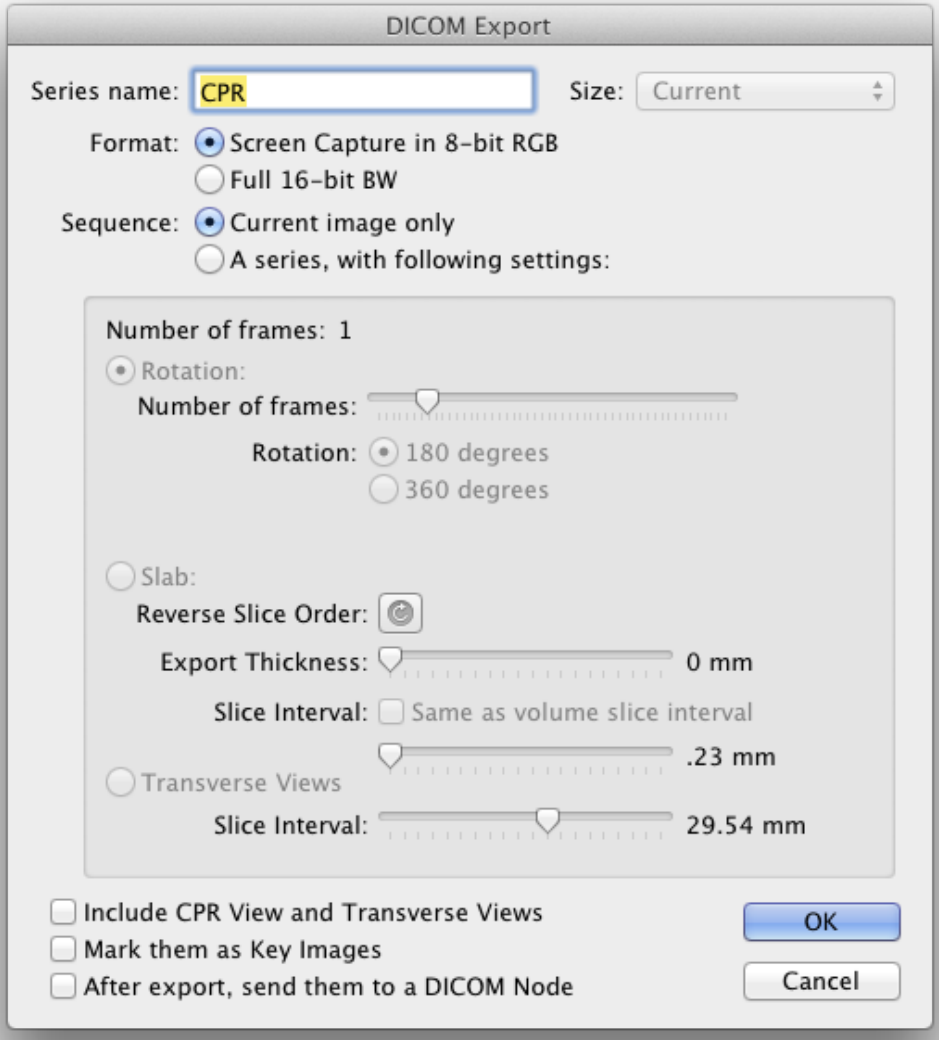


Figure 12.3: Export options

12.1.1.12 *Curved Path*

This allows you to save the Curved Path in a file. This file contains only the 3D points of the path, not the dataset itself. You can easily load the path by dropping a Curved Path file on the 3D Curved MPR Viewer window.

12.1.1.13 *Axis Colors*

This allows the user to change the colors of the axis corresponding to each MPR view. For each axis, the user can choose any color from the standard Mac OS X color picker.

12.1.1.14 *Axis & CPR Axis*

This allows the user to choose to display or to hide the axis corresponding to each MPR view and on the Curved MPR view. You can turn the axis display on or off.

12.1.1.15 Mouse Position

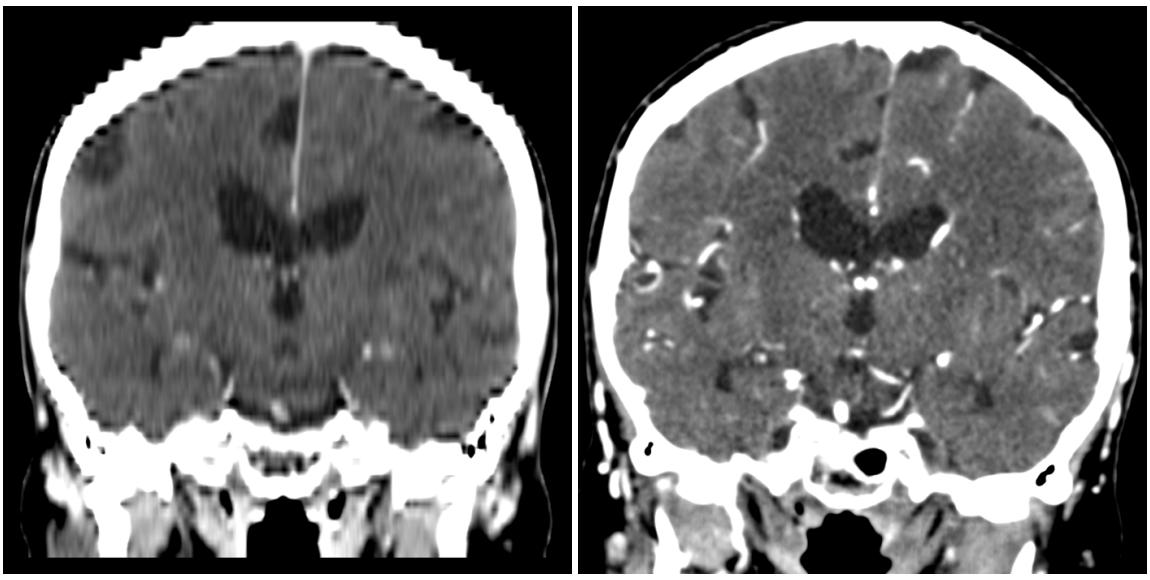
This allows the user to choose to display or to hide the position of the mouse on the other MPR views. You can choose to turn on or off the display of the mouse position.

12.1.1.16 Sync Zoom

This allows the user to choose to sync or not to sync the zoom parameter of the 3 MPR views. You can turn the zoom sync on or off.

12.2 3D MPR VIEWING FUNCTIONS

Curved Multiplanar reformatting (Curved MPR) or Curved Planar Reformation (CPR) is a technique used in two-dimensional tomographic imaging (computed tomography and magnetic resonance) to create a new plane along a path from a series of original sections. For a good image quality, a small slice interval between the original images is needed, otherwise there will be geometric distortions along the Z axis, such as the *stair-step*. Therefore, the slice interval (Z axis) of the original series should not be larger than two times the pixel resolution (X and Y axis). This information is displayed in the *Calibrate Resolution* item of the *2D Viewer* menu (see 13.6.8).



(a) Large Slice Interval (b) Small Slice Interval

Figure 12.4: Example of two different series with (a) a large slice interval (low quality along Z axis) and (b) a small slice interval (good quality along Z axis). Look at the *stair-step* artifact on the bones.

The Curved MPR rendering technique can help to better understand the anatomy of complex structures, such as vessels. It allows to unroll curved structures (e.g., blood vessels, bronchi and colon). The goal of CPR visualization is to make a tubular structure visible in its entire length within one single image. The whole length of the tubular structure is displayed within a single image by this technique. Vascular abnormalities (e.g., stenoses, occlusions, aneurysms and vessel wall calcifications) are then easily investigated. These methods enhance the accuracy of diagnostic decisions and are greatly appreciated by the referring physicians, such as surgeons, as they aid in the creation of appropriate treatment plans.

Curved MPR requires a first step where you define the curved path with sequential points on the orthogonal views. The resulting quality depends directly on the position of these points.

There are several Curved MPR rendering techniques. OsiriX includes two modes:

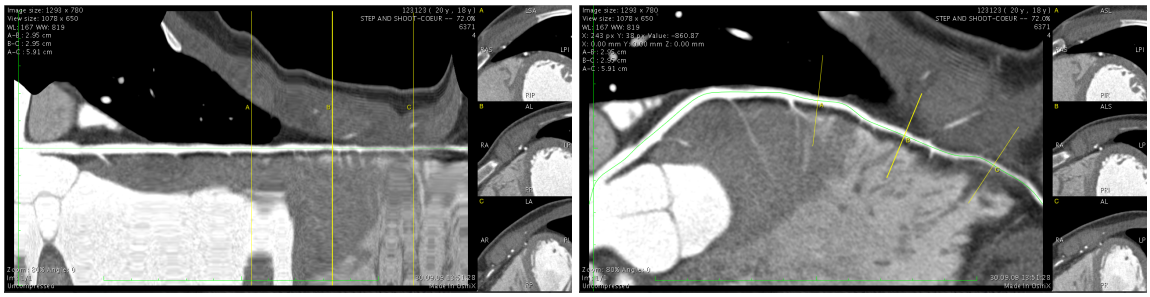
- Straightened Rendering (12.2.1)
- Stretched Rendering (12.2.2)

12.2.1 Straightened Rendering

This type of curved planar reformation fully straightens the tubular structure. This CPR method generates a linear representation of the vessel with varying diameter. The advantage is the easy perception of variances of the diameter. Due to the elimination of curvature of the central-axis the only varying property along the central-axis is the structure's diameter. The disadvantage is the inability to measure distances in a non-orthogonal direction: you can only measure distance along the length or in the perpendicular direction, corresponding respectively to the length and the diameter of the structure.

12.2.2 Stretched Rendering

The main advantage of this CPR type is the preserved isometry (resolution along the X and Y axis are equals, you can measure distances), which is important for accurate preoperative planning of endovascular stent-graft treatment of aortic aneurysms. The lengths of normal and abnormal vascular segments need to be determined accurately for sizing the endovascular prosthesis. This is possible in the case of a stretched CPR, but not in the case of a straightened CPR: you can measure structures in any directions in the plane.



(a) Straightened Rendering (b) Stretched Rendering

Figure 12.5: The two different renderings of the same Curved Path and dataset.

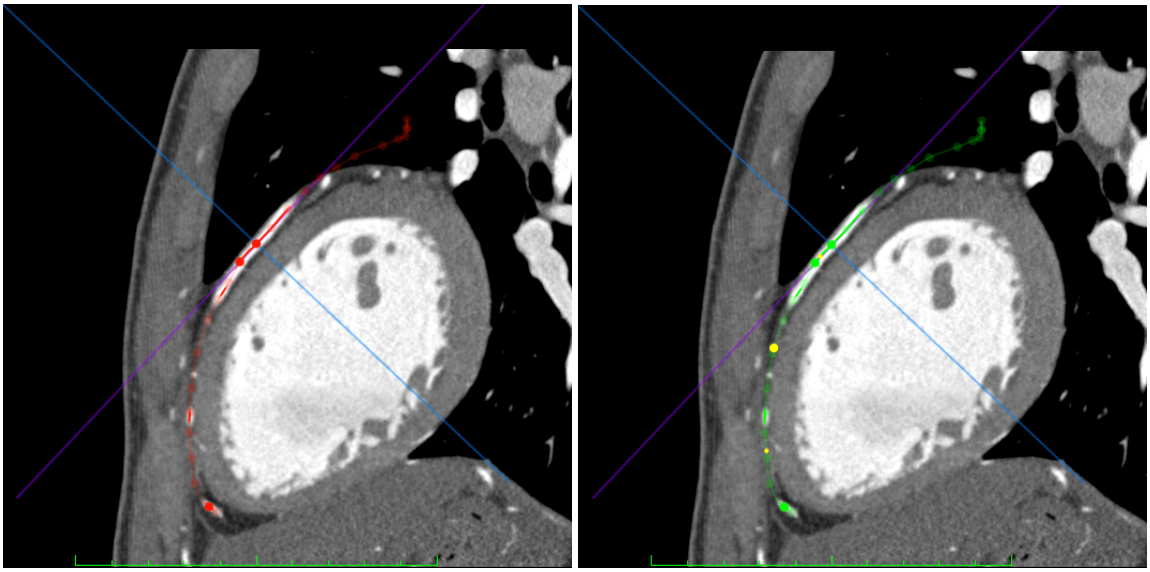
12.2.3 Curved MPR Engine

The 3D Curved MPR Viewer uses a different engine compared to the 2D Orthogonal MPR Viewer and to the 3D MPR Viewer. The ability to display a curved plane requires a more complex engine computation. As a result, it is slower compared than the 2D Orthogonal MPR Viewer. The 3D Curved MPR Viewer uses a built-in algorithm based on the method described by A. Kanitsar et al. [5] (compared to the VTK algorithm used for the 3D MPR Viewer). The 3D Curved MPR Viewer engine is multi-processor and multi-core enhanced (it fully utilizes all the available processors and cores). Performance is linked to the CPU performance, it doesn't depend on the GPU performances. If you use the *Thick Slab* feature of the 3D Curved MPR Viewer,

you should choose a MacPro computer with a maximum number of processors and cores.

12.2.4 Curved Plane Creation

The curved plane is defined by a list a 3D points. OsiriX computes a 3D Bezier path to link these points. You can put an unlimited number of points.



(a) Creation Mode (b) Editing Mode

Figure 12.6: The two different modes available: *Creation Mode* (red path) and *Editing Mode* (green path).

12.2.4.1 Creation Mode

In *Creation Mode* the path is displayed in red.

To start the creation of the path, select the Curved Path tool (see 12.1.1.1). You can then drop points on any of the orthogonal MPR views: the new point is added to the path as the last point. The orthogonal MPR views will be automatically centered on this last point. When you are done with the path creation, double-click on the last point, to switch to the *Editing Mode* (see 12.2.4.2). To start over, you can press the escape or delete key (⌫) on your keyboard: the entire path is deleted. At anytime you can hide or show the Axis cross-reference lines (see 12.1.1.14) by pressing the space bar on the keyboard. By displaying, modifying the orientation and then hiding the Axis cross-reference lines, you can progressively and easily navigate in a complex and curved structure, such as a coronary vessel, and define the Curved Path.

If you press on the control key (^) when adding new points, these new points will always be placed in the same plane. This feature can be useful for creating a plane without angular deformations, for example, in dental scanners.

12.2.4.2 Editing Mode

In *Editing Mode* the path is displayed in green.

The path is always displayed on the MPR views, even if the MPR plane is not positioned *on* the path. Hence, the path could be located in front or in back according to the MPR plane. That means the path displayed in green is the 2D projection of the 3D Bezier path on the MPR plane. If the path is crossing the MPR view, the path is displayed in plain and bold green color, if the path is positioned back or front according to the MPR plane, it is displayed in darker and transparent green.

By simply clicking on a point, you move the center of the orthogonal MPR views to this point: it will be displayed in plain green. Hence, the 3D point position itself is not modified.

By clicking, maintaining the mouse button pressed AND moving a point, you move this point to the current position of the MPR view. Hence, the 3D point position is modified.

In *Editing Mode* you can add new points in the path by clicking on the path line, but you cannot add new points to the end of the path (*Creation Mode*). You can also move an existing point: first click on the point to center the orthogonal MPR views on this point, then move it by maintaining the mouse button pressed. And finally you can remove a point by clicking and maintaining the mouse button pressed on a point and by pressing the delete key (⌫) at the same time.

You can go back to the *Creation Mode* (red color path) from the *Editing Mode* (green color path) by double-clicking on the last point or by selecting the mode in the toolbar tool (see 12.1.1.1).

12.2.5 MPR views

The MPR views are the place where the DICOM images are reformatted as orthogonal views and where the 3D Bezier path is defined by the user. The functions and manipulation methods of these views are identical to the 3D MPR Viewer (see 10). You can do several actions on the MPR views:

- You can hide and show the position of the MPR axis by pressing the space bar.
- You can move the position of the planes by clicking and moving the center of the axis cross.
- You can move the position of the planes by using the mouse's scroll wheel.
- You can change the angle of the planes by clicking and rotating the axis.
- You can change the zoom level by using the right button of the mouse.
- You can measure distances by using the Length ROI from the ROI tools (see 5.6.1.1).
- You can display the view in fullscreen by double-clicking in the view. Double-click again to reduce it to its normal size.
- You can press the tab key (⇥) to show or hide the annotations on the view.

12.2.6 Curved MPR view

The Curved MPR view displays the view corresponding to the defined path. This image is calculated in realtime and automatically adjusted to the length of the path. There are also three perpendicular (to the curved plane) views on the right part of this view: views A, B and C. These three views represent cross-sectional views, according to the three yellow lines (A, B, C) displayed on the Curved MPR image. The position of these three perpendicular views are also displayed on the MPR views, represented as yellow dots along the 3D Bezier path.

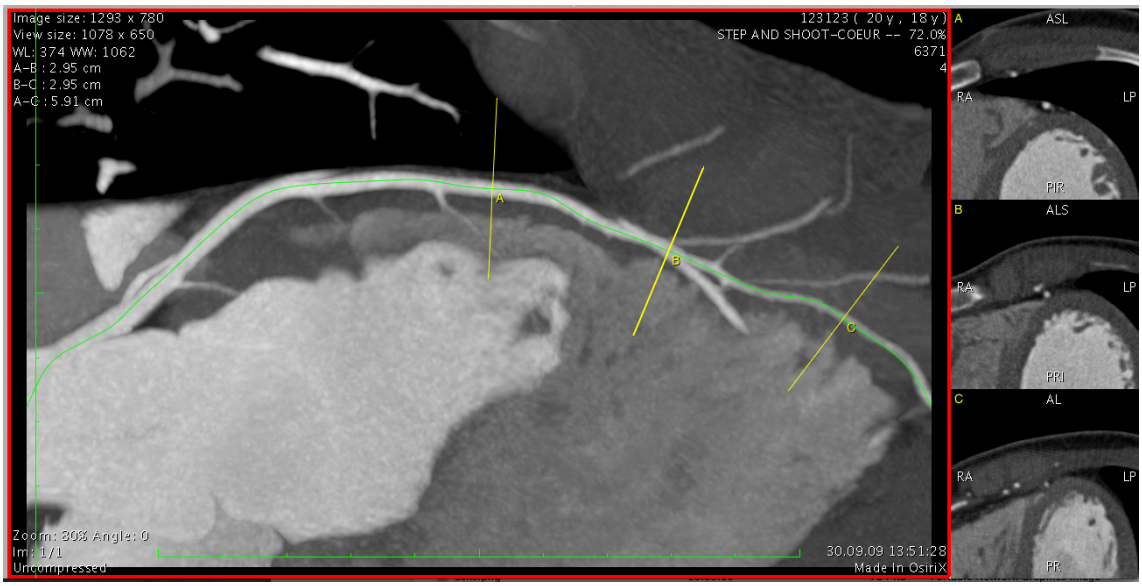


Figure 12.7: The Curved MPR view and the three orthogonal views (A, B, C)

You can do several actions on the Curved MPR view:

- You can change the rotation of the plane by using the mouse's scroll wheel.
- You can change the position of the perpendicular views along the curved plane by using the mouse's scroll wheel and maintaining the option key (⌥) pressed.
- You can change the position of the perpendicular views along the curved plane by clicking and dragging the B yellow line.
- You can change the interval of the perpendicular views along the curved plane by using the mouse's scroll wheel and maintaining the command key (⌘) pressed.
- You can change the interval of the perpendicular views along the curved plane by clicking and dragging the A or C yellow line.
- You can change the zoom level by using the right button of the mouse.
- You can measure distances by using the Length ROI from the ROI tools (see 5.6.1.1).
- You can display the Curved MPR view in fullscreen by double-clicking in the view. Double-click again to reduce it to its normal size.
- You can press the tab key (⇥) to show or hide the annotations on the view.

When using the Length ROI, you can only draw orthogonal lines horizontally or vertically, if the *Stretched Rendering* is selected (see 12.2.2). Indeed, in a stretched curved view, only the orthogonal distances represent real distances. For oblique measurements, select the *Straightened Rendering* mode (see 12.2.1).

You can do several actions on the perpendicular views:

- You can change the position of the perpendicular planes along the curved plane by using the mouse's scroll wheel.
- You can change the interval of the perpendicular planes along the curved plane by using the mouse's scroll wheel and maintaining the command key (⌘) pressed.

- You can zoom in or zoom out by using the right button of the mouse.
- You can measure lengths or surfaces by using the ROI tools (see 5.6.1.1).
- You can display the Curved MPR view in fullscreen by double-clicking in the view. Double-click again to reduce it to its normal size.
- You can press the tab key (⇥) to show or hide the annotations on the view.

12.2.7 Thick Slab

By default the Curved MPR view is rendered as a thin slice with a thickness identical to the original dataset. You can increase this thickness by using the toolbar *Thick Slab* item (see 12.1.1.9). By adjusting the cursor position in the *Thick Slab* item, you can modify the slice thickness in millimeters.

Three rendering algorithms are available:

- Mean
- MIP
- MinIP

12.2.8 Image Fusion

The 3D Curved MPR Viewer doesn't support image fusion for the Curved MPR view. That means that if you open the 3D Curved MPR Viewer window from a 2D Viewer containing a series fused with another one (see 5.5.9), you cannot see the fused series on the Curved MPR view. The fused dataset will be displayed only in the MPR views.

12.2.9 4D Dataset

The 3D Curved MPR Viewer window doesn't support 4D datasets (see 3.1.1.2).

12.2.10 ROIs

When you use the standard ROIs on the MPR views. The Curved MPR view supports only two kinds of ROIs:

- Length (5.6.1.1)
- Text (5.6.1.5)

When using the Length ROI, you can only draw orthogonal lines horizontally or vertically, if the *Stretched Rendering* is selected (see 12.2.2). Indeed, in a stretched curved view, only the orthogonal distances represent real distances. For oblique measurements, select the *Straightened Rendering* mode (see 12.2.1).

You can add these ROIs, such as Lines, Ovals or Angles, in the 3D Curved MPR Viewer, but they will not be added to the 2D Viewer and they will disappear when moving the position of the MPR views or when closing the 3D Curved MPR Viewer window. ROIs displayed in the 2D Viewer will not be displayed in the 3D Curved MPR Viewer.

12.3 EXPORTING DICOM IMAGES

Images rendered in the 3D Curved MPR Viewer can be exported in DICOM format and added to the database as new series of images. These images can then be exported to a PACS or another DICOM compliant workstation for display.

There are several settings described in the toolbar section (see 12.1.1.11) of this chapter.

By exporting a series in 16-bit, you can create a new series without losing dynamic information and you can keep diagnostic quality.

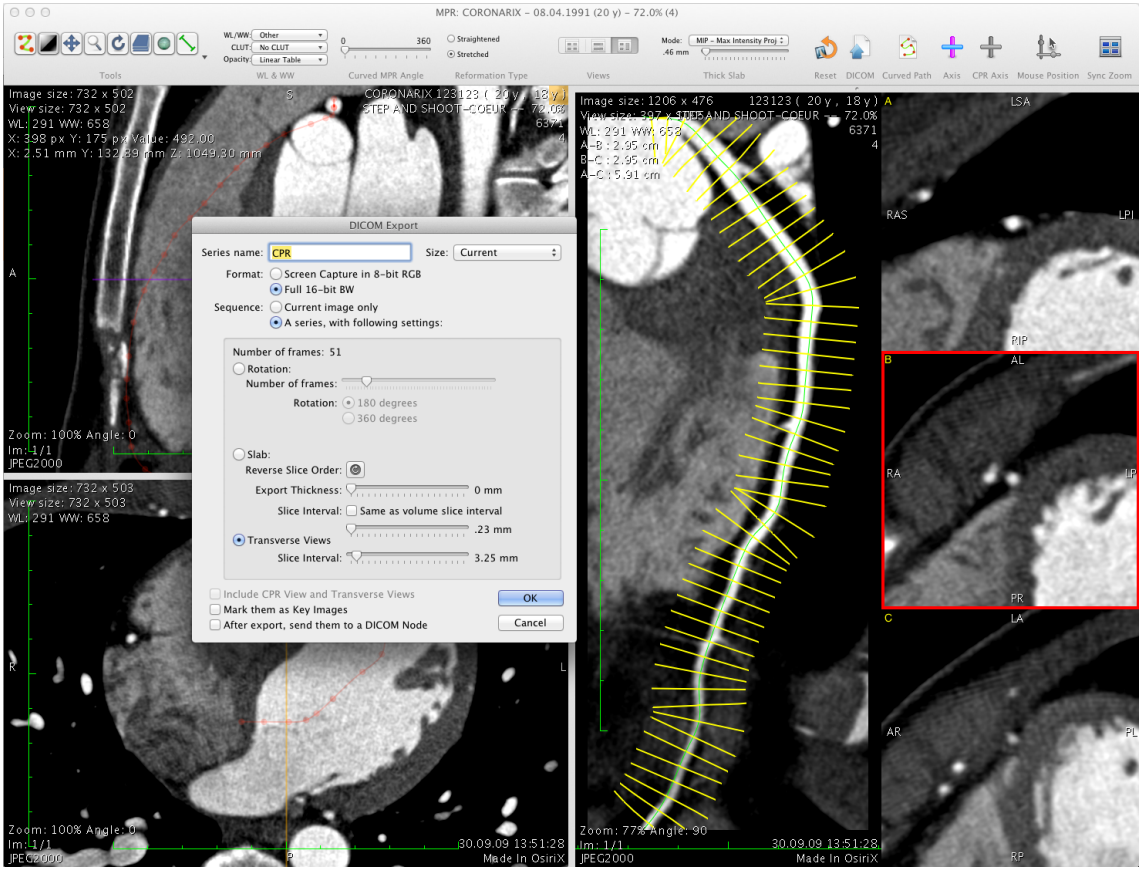


Figure 12.8: Exporting a transverse series