Digital Imaging and Communications in Medicine (DICOM)

Supplement xxx: Ophthalmic Tomography Angiographic (OCT-A) En Face Image Storage SOP Classes

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Scope and Field of Application

This Supplement defines Storage SOP Classes to enable en face angiography images based upon ophthalmic computed tomography (OCT) technology.

En Face angiography images are derived from images obtained using the spectral domain OCT technology. With special image acquisition sequences and post hoc image processing algorithms, En Face angiography detects the motion of the blood cells in the vessels to produce images of blood flow in the retina and choroid with capillary-level resolution. The resultant en face images are similar to images obtained in retinal angiography with contrast dye is administered intravenously, though subtle difference is observed when comparing these two modalities. This technology enables a high resolution visualization of the retinal and choroidal vascular network to detect the growth of abnormal blood vessels, and to provide additional insights in diagnosing and managing a variety of retinal diseases including diabetic retinopathy, neovascular age-related macular degeneration, and retinal vein occlusion.

Open Issues:

1 – Consider adding Window Center/Window Width for OPT as type 3 and explain it is useful when using 12 or 16 bit.

2 – Modify Ophthalmic FOV in wide field to convey “horizontal” FOV.

Changes to NEMA Standards Publication PS 3.2

Digital Imaging and Communications in Medicine (DICOM)

Part 2: Conformance

Item: Add to table A.1-2 categorizing SOP Classes:

25 The SOP Classes are categorized as follows:

Table A.1-2
UID VALUES

UID Value	UID NAME	Category
…	…	…
1.2.840.10008.5.1.4.1.1.77.xxx	**Ophthalmic Tomography Angiographic En Face Image Storage**	**Transfer**
1.2.840.10008.5.1.4.1.1.77.y.y.y	**Ophthalmic Tomography Angiographic Adjunctive Image Storage**	**Transfer**
…	…	…

Changes to NEMA Standards Publication PS 3.3

Digital Imaging and Communications in Medicine (DICOM)

Part 3: Information Object Definitions
Part 3 Additions

Modify PS3.3 Table A.1-1 to add new IODs for Wide Field Ophthalmic Photography Images

IODs **Modules**	…	**OPT**	**OPT ENF**	**OPT ADJ**	**…**
Patient		M	**M**	**M**	
Clinical Trial Subject		U	**U**	**U**	
General Study		M	**M**	**M**	
Patient Study		U	**U**	**U**	
Clinical Trial Study		U	**U**	**U**	
General Series		M	**M**	**M**	
Clinical Trial Series		U	**U**	**U**	
Segmentation Series					
Whole Slide Microscopy Series					
Intravascular OCT Series					
Ophthalmic Thickness Map Series					
Corneal Topography Map Series					
Ophthalmic Tomography Angiographic En Face Series			**M**		
Ophthalmic Tomography Angiographic Adjunctive Series				**M**	

Frame of Reference		C	**M**	**M**	
Synchronization		C			
Cardiac Synchronization		C			
General Equipment		M	**M**	**M**	
Enhanced General Equipment		M	**M**	**M**	
General Image			**M**	**M**	
Image Pixel		M	**M**	**M**	
Palette Color Lookup Table			**C**		
Supplemental Palette Color Lookup Table				**C**	
Enhanced Contrast/Bolus		C			
Cine				**C**	
Multi-frame				**M**	
Multi-frame Functional Groups		M			
Multi-frame Dimension		M		**M**	
Bitmap Display Shutter					
Surface Segmentation		**C**			
Device					
Specimen					
VL Image					
Slide Coordinates					
Whole Slide Microscopy Image					
Optical Path					
Multi-Resolution Navigation					
Slide Label					
Ophthalmic Photography Image			**M**		

Wide Field Ophthalmic Photography Stereographic Projection					
Wide Field Ophthalmic Photography 3D Coordinates					
Wide Field Ophthalmic Photography Quality Rating					
Ocular Region Imaged		M		**M**	
Ophthalmic Photography Acquisition Parameters					
Ophthalmic Photographic Parameters					
Ophthalmic Tomography Image		M			
Ophthalmic Tomography Parameters		M		**M**	
Ophthalmic Tomography Acquisition Parameters		M			
Ophthalmic Thickness Map					
Ophthalmic Thickness Map Quality Rating					
Corneal Topography Map Image					
Corneal Topography Map Analysis					
Intravascular OCT Image		M			
Intravascular OCT Acquisition Parameters		M			

Intravascular OCT Processing Parameters		C			
Intravascular Image Acquisition Parameters		M			
Ophthalmic Tomography Angiographic En Face Image			**M**		
Ophthalmic Tomography Angiographic Adjunctive Image				**M**	
Segmentation Image					
Overlay Plane					
Common Instance Reference		U	**U**	**U**	
Acquisition Context		M		**M**	
ICC Profile					
SOP Common		M	**M**	**M**	
Frame Extraction		C		**C**	

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Modify PS3.3 Annex A to update OPT IOD

A.52.3 Ophthalmic Tomography Image IOD Modules

45 **Table A.52.3-1. Ophthalmic Tomography Image IOD Modules**

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
	Clinical Trial Subject	C.7.1.3	U
Study	General Study	C.7.2.1	M
	Patient Study	C.7.2.2	U
	Clinical Trial Study	C.7.2.3	U
Series	General Series	C.7.3.1	M

IE	Module	Reference	Usage
	Clinical Trial Series	C.7.3.2	U
	Ophthalmic Tomography Series	C.8.17.6	M
Frame of Reference	Frame of Reference	C.7.4.1	C - Required if Ophthalmic Photography Reference Image available
	Synchronization	C.7.4.2	C - Required if Ophthalmic Photography Reference Image available
Equipment	General Equipment	C.7.5.1	M
	Enhanced General Equipment	C.7.5.2	M
Image	Image Pixel	C.7.6.3	M
	Enhanced Contrast/Bolus	C.7.6.4b	C - Required if contrast was administered
	Multi-frame Functional Groups	C.7.6.16	M
	Multi-frame Dimension	C.7.6.17	M
	Acquisition Context	C.7.6.14	M
	Cardiac Synchronization	C.7.6.18.1	C - Required if cardiac synchronization was used
	Ophthalmic Tomography Image	C.8.17.7	M
	Ophthalmic Tomography Acquisition Parameters	C.8.17.8	M
	Ophthalmic Tomography Parameters	C.8.17.9	M
	Ocular Region Imaged	C.8.17.5	M
	Surface Segmentation	**C.8.23.1**	**C - Required if SOP Instance was used for angiography. May be present otherwise.**
	SOP Common	C.12.1	M
	Common Instance Reference	C.12.2	U
	Frame Extraction	C.12.3	C - Required if the SOP Instance was created in response to a Frame-Level retrieve request

Modify PS3.3 Annex A to add new IODs

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A.aa Ophthalmic Tomography Angiographic (OCT-A) En Face Image Information Object Definition

This Section defines an Information Object to be used with several types of en face angiographic images that are derived from images obtained using the spectral domain OCT technology. En Face angiography detects the motion of the blood cells in the vessels to produce images of perfused vasculature of the choroid and retina with capillary-level resolution.

A.aa.1 Ophthalmic Tomography Angiographic En Face Image IOD Description

The Ophthalmic Tomography Angiographic En Face Image IOD specifies a single frame image derived from images obtain using OCT technology. This IOD can be used to encode a single derived en face image.

A.aa.2 Ophthalmic Tomography Angiographic En Face Image IOD Entity-Relationship Model

The Ophthalmic Tomography Angiographic En Face Image IOD uses the DICOM Composite Instance IOD Entity-Relationship Information Model defined in Section A.1.2. The Series IE contains only an Image IE."

A.aa.3 Ophthalmic Tomography Angiographic En Face Image IOD Modules

Table A.aa-1 specifies the Modules of the Ophthalmic Tomography Angiographic En Face Image IOD.

Table A.aa-1
Ophthalmic Tomography Angiographic En Face Image IOD Modules

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
	Clinical Trial Subject	C.7.1.3	U
Study	General Study	C.7.2.1	M
	Patient Study	C.7.2.2	U
	Clinical Trial Study	C.7.2.3	U
Series	General Series	C.7.3.1	M
	Ophthalmic Tomography Angiographic En Face Series	C.8.xx.1	M
	Clinical Trial Series	C.7.3.2	U
Frame of Reference	Frame of Reference	C.7.4.1	M
Equipment	General Equipment	C.7.5.1	M
	Enhanced General Equipment	C.7.5.2	M
Image	General Image	C.7.6.1	M
	Image Pixel	C.7.6.3	M
	Palette Color Lookup Table	C.7.9	C - Required if Photometric Interpretation (0028,0004) has a value of PALETTE COLOR

	Ophthalmic Tomography Angiographic En Face Image	C.8.xx.2	M
	Ocular Region Imaged	C.8.17.5	M
	SOP Common	C.12.1	M
	Common Instance Reference	C.12.2	U

A.aa.4 Ophthalmic Tomography Angiographic En Face Image Image IOD Content Constraints

The following constraints on Series and Image attributes take precedence over the descriptions given in the Module Attribute Tables.

A.aa.4.1 Bits Allocated, Bits Stored, and High Bit

These Attributes shall be determined based upon the Photometric Interpretation (0028,0004):

Photometric Interpretation (0028,0004)	Bits Allocated (0028,0100)	Bits Stored (0028,0101)	High Bit (0028,0102)
MONOCHROME2	8	8	7
	16	12	11
	16	16	15
PALETTE COLOR	8	8	7

A.bb Ophthalmic Tomography Angiographic (OCT-A) Adjunctive Image Information Object Definition

This Section defines an Information Object to be used with several types of ophthalmic photographic imaging devices that generate wide field OP images, including fundus cameras, slit lamp cameras, scanning laser ophthalmoscopes, stereoscopic cameras, video equipment and digital photographic equipment.

A.bb.1 Ophthalmic Tomography Angiographic Adjunctive Image IOD Description

The Ophthalmic Tomography Angiographic Adjunctive Image IOD specifies a multi-frame image acquired …….

A.bb.2 Ophthalmic Tomography Angiographic Adjunctive Image IOD Entity-Relationship Model

The Ophthalmic Tomography Angiographic Adjunctive Image IOD uses the DICOM Composite Instance IOD Entity-Relationship Information Model defined in Section A.1.2. The Series IE contains only an Image IE.

A.bb.3 Ophthalmic Tomography Angiographic Adjunctive Image IOD Modules

Table A.bb-1 specifies the Modules of the Ophthalmic Tomography Angiographic Adjunctive Image IOD.

Table A.bb-1
Ophthalmic Tomography Angiographic Adjunctive Image IOD Modules

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
	Clinical Trial Subject	C.7.1.3	U
Study	General Study	C.7.2.1	M
	Patient Study	C.7.2.2	U
	Clinical Trial Study	C.7.2.3	U
Series	General Series	C.7.3.1	M
	Ophthalmic Tomography Angiographic Adjunctive Series	C.8.yy.1	M
	Clinical Trial Series	C.7.3.2	U
Frame of Reference	Frame of Reference	C.7.4.1	M
Equipment	General Equipment	C.7.5.1	M
	Enhanced General Equipment	C.7.5.2	M
Image	General Image	C.7.6.1	M
	Image Pixel	C.7.6.3	M
	Cine	C.7.6.5	C - Required if there is a sequential temporal relationship between all frames
	Multi-frame	C.7.6.6	M
	Acquisition Context	C.7.6.14	U
	Ophthalmic Tomography Angiographic Adjunctive Image	C.8.yy.2	M
	Ocular Region Imaged	C.8.17.5	M
	Ophthalmic Tomography Angiographic Adjunctive Parameters	C.8.17.4	M
	Supplemental Palette Color Lookup Table	C.7.6.19	C - Required if Photometric Interpretation (0028,0004) has a value of PALETTE COLOR
	SOP Common	C.12.1	M
	Common Instance Reference	C.12.2	U
	Frame Extraction	C.12.3	C - Required if the SOP Instance was created in response to a Frame-Level retrieve request

A.bb.4 Wide Field Ophthalmic Photography 3D Coordinates Image IOD Content Constraints

The following constraints on Series and Image attributes take precedence over the descriptions given in the Module Attribute Tables.

A.bb.4.1 Bits Allocated, Bits Stored, and High Bit

These Attributes shall be determined based upon the Photometric Interpretation (0028,0004):

Photometric Interpretation (0028,0004)	Bits Allocated (0028,0100)	Bits Stored (0028,0101)	High Bit (0028,0102)
MONOCHROME2	8	8	7
	16	16	15
PALETTE COLOR	8	8	7

Modify PS3.3 Annex C

C.8.xx.1 Ophthalmic Tomography Angiographic En Face Series Module

Table C.8.xx.1-1 specifies the Attributes that identify and describe general information about the Ophthalmic Tomography En Face Series.

Table C.8.xx.1-1 Ophthalmic Tomography Angiographic En Face Series Module Attributes

Attribute Name	Tag	Type	Attribute Description
Modality	(0008,0060)	1	Type of equipment that originally acquired the data used to create the images in this Series. Enumerated Values: **OPTENF** See Section C.7.3.1.1.1 for further explanation.
Series Number	(0020,0011)	1	A number that identifies this Series.
Referenced Performed Procedure Step Sequence	(0008,1111)	1C	Uniquely identifies the Performed Procedure Step SOP Instance to which the Series is related. Only a single Item shall be included in this Sequence. Required if a Performed Procedure Step SOP Class was involved in the creation of this Series.
>Include Table 10-11 "SOP Instance Reference Macro Attributes"			

C.8.xx.2 Ophthalmic Tomography Angiographic En Face Image Module

125 Table C.8.xx.2-1 specifies the Attributes that describe the Ophthalmic Tomography En Face Image Module.

Table C.8.xx.2-1
Ophthalmic Tomography Angiographic En Face Image Module Attributes

Attribute Name	Tag	Type	Attribute Description
Image Type	(0008,0008)	1	Image identification characteristics. See Section C.8.xx.2.1.6 for specialization.
Instance Number	(0020,0013)	1	A number that identifies this image.
Samples per Pixel	(0028,0002)	1	Number of samples (planes) in this image. Enumerated Value: **1**
Photometric Interpretation	(0028,0004)	1	Specifies the intended interpretation of the pixel data. See Section C.8.xx.2.1.5 for specialization.
Pixel Spacing	(0028,0030)	1C	Nominal physical distance at the focal plane (in the retina) between the center of each pixel, specified by a numeric pair - adjacent row spacing (delimiter) adjacent column spacing in mm. See Section 10.7.1.3 for further explanation of the value order. Note These values are specified as nominal because the physical distance may vary across the field of the images and the lens correction is likely to be imperfect. Shall not be sent when Two Dimensional to Three Dimensional Map Sequence (0022,1518) or X Coordinates Center Pixel View Angle (0022,1528) and Y Coordinates Center Pixel View Angle (0022,1529) are present. Otherwise, required when Acquisition Device Type Code Sequence (0022,0015) contains an item with the value (R-1021A, SRT, "Fundus Camera"). May be present otherwise.
Content Time	(0008,0033)	1	The time the image pixel data creation started.
Content Date	(0008,0023)	1	The date the image pixel data creation started.
Source Image Sequence	(0008,2112)	1	A Sequence that identifies the Images that were used to derive this Image. One or more Items shall be included in this sequence.

Attribute Name	Tag	Type	Attribute Description
			See Section C.7.6.1.1.4 and C.8.xx.2.1.1 for further explanation.
>Include Table 10-3 "Image SOP Instance Reference Macro Attributes"			
>Purpose of Reference Code Sequence	(0040,A170)	1	Describes the purpose for which the reference is made, that is what role the source image or frame(s) played in the derivation of this image. Only a single Item shall be included in this Sequence.
>>Include Table 8.8-1 "Code Sequence Macro Attributes".			*Defined CID 7202 "Source Image Purposes of Reference".* *If the derived En Face image is based upon OPT structure information, the concept code shall be (aaaaaa, DCM, "Source structural image for imaging processing operation").* *If the derived En Face image is based upon OPT flow information, the concept code shall be (bbbbbb, DCM, "Source flow image for imaging processing operation").*
Derivation Algorithm Sequence	(00gg,ee12)	1	Software algorithm that performed the derivation. Only a single Item shall be included in this Sequence.
>Include Table 10-19 "Algorithm Identification Macro Attributes"			*Defined Context ID 42aa shall be used for Algorithm Family Code Sequence (0066,002F)*
En Face Image Label Code Sequence	(00gg,ee15)	1	A label used to identify this SOP Instance See Section C.8.xx.2.1.3 for further explanation.
>Include Table 8.8-1 "Code Sequence Macro Attributes".			*Defined CID is 42bb*
En Face Image Label Description	(00gg,ee16)	3	Description of the en face image label.
Window Center	(0028,1050)	1C	Window Center for display. Required if Bits Allocated (0028,0100) is 16. See Section C.11.2.1.2 for further explanation.
Window Width	(0028,1051)	1C	Window Width for display. See Section C.11.2.1.2 for further explanation. Required if Window Center (0028,1050) is sent.
Ophthalmic FOV	(0022,1517)	3	The horizontal field of view used to capture the ophthalmic image, in degrees. The field of view is the maximum image size displayed on the image plane, expressed as the angle subtended at the exit pupil of the eye by the maximum dimension 2r (where r equals the radius).

Attribute Name	Tag	Type	Attribute Description
OPT Surface Segmentation Layer Label(s)	(00gg,ee20)	1	One or more surface segmentation layer labels conveyed in the SOP Instance referenced by the Source Image Sequence (0008,2112) and Attribute Segment Label (0062,0005). See Section C.8.xx.2.1.2 for further explanation.
En Face Anatomic Reference Code Sequence	(00gg,ee22)	1C	Identifies an anatomic reference within the eye that may be seen in this SOP Instance. Note: This Attribute is used to provide the user with a general reference point when viewing the image. If the implementation is able to identify a precise anatomic location, it will convey that information in Attribute En Face Anatomic Reference Location Sequence (00gg,ee24). Required if En Face Anatomic Reference Location Sequence (00gg,ee24) is not present.
>Include Table 8.8-1 "Code Sequence Macro Attributes".			*Defined CID is 4207*
En Face Anatomic Reference Location Sequence	(00gg,ee24)	1C	Establishes the en face anatomic reference point within the eye and its coordinate location for this SOP Instance. Required if En Face Anatomic Reference Code Sequence (00gg,ee22) is not present
>En Face Anatomic Reference Location Code Sequence	(00gg,ee25)	1	Identifies the anatomic reference point of the eye for this SOP Instance.
>>Include Table 8.8-1 "Code Sequence Macro Attributes".			*The concept code shall be (T-AA621, SRT, "Fovea centralis") or (T-AA630, SRT, "*Optic nerve head*").*
En Face Anatomic Reference Point Location	(00gg,ee26)	1	Location of the en face anatomic reference point identified by Attribute En Face Anatomic Reference Location Code Sequence (00gg,ee25). The re Given as column\row. Column is the horizontal offset and row is the vertical offset. Image relative position specified with sub-pixel resolution such that the origin at the Top Left Hand Corner (TLHC) of the TLHC pixel is 0.0\0.0, the Bottom Right Hand Corner (BRHC) of the TLHC pixel is 1.0\1.0, and the BRHC of the BRHC pixel is Columns\Rows (see figure C.10.5-1). The values must be within the range 0\0 to Columns\Rows. This location shall anchor the anatomic reference at the x, y and z coordinates of 0.0, 0.0, 0.0, in mm. See C.8.xx.2.1.4 for further explanation.
Include 'General Anatomy Mandatory Macro' Table 10-5			*The concept code for Anatomic Region Sequence (0008,2218) shall be (T-AA000, SRT, "Eye"), and Defined Context ID 244 shall be used for Anatomic Region Modifier Sequence (0008,2220).*

Attribute Name	Tag	Type	Attribute Description
			Defined Context ID 4266 shall be used for Primary Anatomic Structure Sequence (0008,2228). Only a single Item shall be permitted in this sequence. Note: Although Primary Anatomic Structure Sequence (0008,2228) is Type 3, it is important to convey this information if able to be determined.
Lossy Image Compression	(0028,2110)	1	Specifies whether an Image has undergone lossy compression (at a point in its lifetime). Enumerated Values: **00** Image has NOT been subjected to lossy compression. **01** Image has been subjected to lossy compression. Once this value has been set to 01 it shall not be reset. See Section C.7.6.1.1.5.
Lossy Image Compression Ratio	(0028,2112)	1C	Describes the approximate lossy compression ratio(s) that have been applied to this image. See Section C.7.6.1.1.5.2. Required if Lossy Image Compression (0028,2110) is "01".
Lossy Image Compression Method	(0028,2114)	1C	A label for the lossy compression method(s) that have been applied to this image. See Section C.7.6.1.1.5.1. Required if Lossy Image Compression (0028,2110) is "01".
Presentation LUT Shape	(2050,0020)	1C	Specifies an identity transformation for the Presentation LUT, such that the output of all grayscale transformations defined in the IOD containing this Module are defined to be P-Values. Enumerated Values: **IDENTITY** output is in P-Values. Required if Photometric Interpretation (0028,0004) is MONOCHROME2
Calibration Image	(0050,0004)	3	Indicates whether a reference object (phantom) of known size is present in the image and was used for calibration. Enumerated Values: **YES** **NO**

Attribute Name	Tag	Type	Attribute Description
Burned In Annotation	(0028,0301)	1	Indicates whether or not image contains sufficient burned in annotation to identify the patient and date the image was acquired. Enumerated Values: **YES** **NO**
Recognizable Visual Features	(0028,0302)	3	Indicates whether or not the image contains sufficiently recognizable visual features to allow the image or a reconstruction from a set of images to identify the patient. Enumerated Values: **YES** **NO** If this Attribute is absent, then the image may or may not contain recognizable visual features.

C.8.xx.2.1 Ophthalmic Tomography Angiographic En Face Image Module Attribute Descriptions

C.8.xx.2.1.1 Source Image Sequence

OCT-A En Face images are derived from images obtained using spectral domain OCT technology. The Source Image Sequence (0008,2112) in the General Image Module (Section C.7.6.1) shall convey the SOP Instance(s) used to derive this SOP Instance.

A typical example of the image processing stages performed to generate En Face images is shown in Figure C.8.xx-1

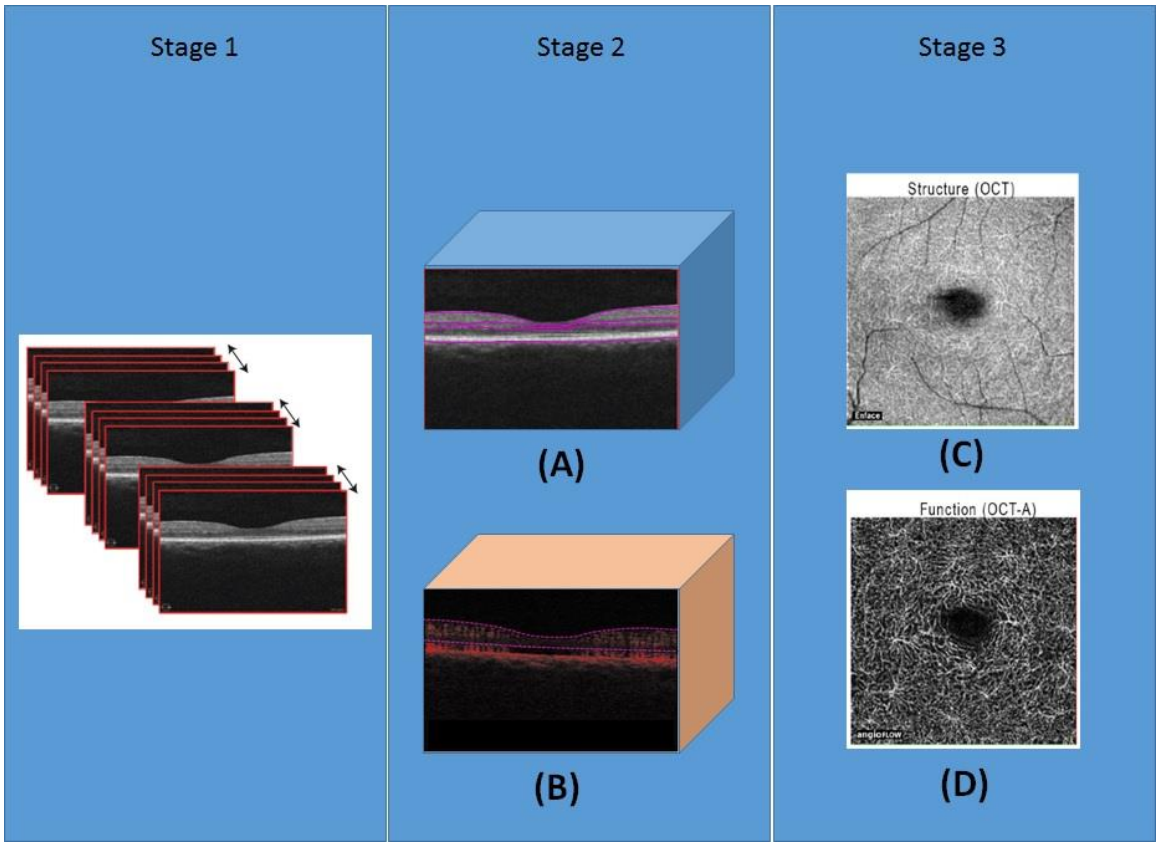

Figure C.8.xx-1: Example of the Image Process Performed to Generate En Face Images

Stage 1: OCT technology is used to acquire a volumetric dataset from a retinal region of interest. This volumetric dataset consists multiple B-scans in a raster pattern, and multiple frames are acquired at each B-scan location. The stacks of B-scans of the volumetric data acquired at this stage uses manufacturer's proprietary format for analysis and storage. If this information is stored in DICOM, it uses the Raw Data SOP Class.

Stage 2: The OCT proprietary data (or DICOM Raw Data IOD) is then analyzed to derive two volumetric datasets of equal dimension. The structural OCT information is represented in (A) and stored in the Ophthalmic Tomography (OPT) Image Storage SOP Class. Inside the OPT SOP Instance, OCT segmentation is applied to the structural OCT volume (A) to delineate the anatomical boundaries. Multiple layers may be segmented. The segmentation is captured in the Surface Segmentation Module. Secondly, the difference in signal between the frames of each individual B-scan is analyzed to produce the OCT angiographic flow volume information which is represented in (B). The flow volume information is stored in the Ophthalmic Tomography Angiographic (OCT-A) Adjunctive Image SOP Class.

Stage 3: Clinicians typically make their assessment based on the OCT En face images derived from OCT structure and/or flow volumetric data. The en face image can be derived by analyzing pixel information between two segmented surfaces. For example, a structural OCT en face image (C) is derived by using pixel information in the OCT structural volume (A) between the two segmented surfaces and stored via the Ophthalmic Tomography Angiographic (OCT-A) En Face Image Storage SOP Class. The OPT Image SOP Instance used for the derivation is referenced in Attribute Source Image Sequence (0008,2112). Similarly, a vascular OCT enface image (D) may be derived using the OCT angiographic flow volume data and is stored in a second SOP Instance via the OCT-A En Face Image Storage SOP Class. The OCT-A Adjunctive Image SOP Instance used for the derivation is referenced in Attribute Source Image Sequence (0008,2112).

En face images are typically derived by the acquisition modality that generated the OPT Image and OCT-A Adjunctive SOP Instances or image workstations that received the respective OPT Image and OCT-A Adjunctive SOP Instances via DICOM Storage.

The OPT Image, OCT-A Adjunctive Image and the OCT-A En Face Image SOP Instances all reside in different DICOM series. They share the same spatial Frame of Reference which is identified in Attribute Frame of Reference UID (0020,0052). Figure C.8.xx-2 illustrates the relationships between the OCT-A based SOP Instances.

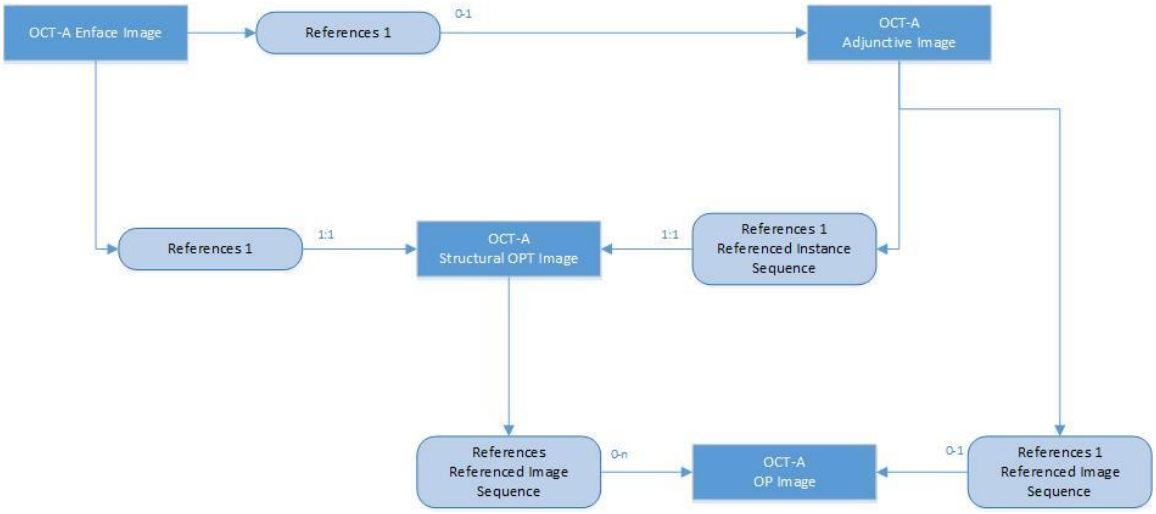

Figure C.8.xx-2: Relationships Between OCT-A Based SOP Instances

C.8.xx.2.1.2 OPT Surface Segmentation Layer Label(s)

The OPT Image SOP Instance uses the Attribute Segment Label (0062,0005) of the Surface Segmentation Module to delineate anatomical boundaries (layers) captured in the OPT Image SOP Instance. Ophthalmic Tomography Surface Segmentation Layer Label(s) (00gg,ee12) identifies one or more segmentation layer(s) used to generate the derived en face image. The values conveyed in Ophthalmic Tomography Surface Segmentation Layer Label(s) (00gg,ee12) are taken from Segment Label (0062,0005) within the referenced OPT Image SOP Instance.

C.8.xx.2.1.3 En Face Image Label Code Sequence

Implementations may generate many different types of derived en face images. Figure C.8.xx-3 illustrates various derived enface image types. The En Face Image Label Code Sequence (00gg,gg10) is the label used to identify the type of derived en face image.

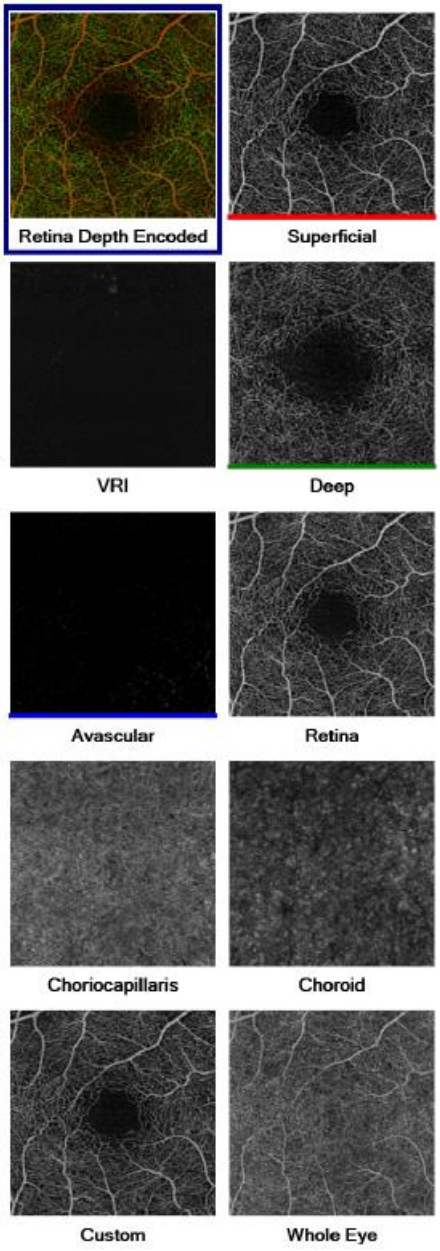

Figure C.8.xx-3: Examples of En Face Images Types

C.8.xx.2.1.4 En Face Anatomic Reference Location Sequence

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C.8.xx.2.1.5 Photometric Interpretation

Specifies the intended interpretation of the pixel data.

Enumerated Values:

MONOCHROME2
195 **PALETTE COLOR**

C.8.xx.2.1.6 Image Type

The Image Type attribute (0008,0008) (General Image Module, Section C.7.6.1) identifies important image characteristics in a multiple valued data element. For the Ophthalmic Tomography En Face Image IOD, Image Type is specified as a Type 1 attribute and further specialized as follows:

a. Value 1 shall identify the Pixel Data Characteristics in accordance with Section C.7.6.1.1.2.

Enumerated Values:
DERIVED identifies a Derived Image

b. Value 2 shall identify the Patient Examination Characteristics in accordance with Section C.7.6.1.1.2

Enumerated Values:
PRIMARY identifies a Primary Image
SECONDARY identifies a Secondary Image

c. Value 3 shall identify any Image IOD specific specialization in accordance with Section C.7.6.1.1.2 (optional)

Defined Terms:
MONTAGE identifies a Montage Image

d. Other Values that are implementation specific in accordance with Section C.7.6.1.1.2 (optional)

Note: A Montage Image is constructed out of several individual images, which also can be exchanged separately. The images used to create the montage image will be included in the source image sequence if those images are also exchanged. A Montage Image is identified as Image Type DERIVED\PRIMARY\MONTAGE

C.8.yy.1 Ophthalmic Tomography Angiographic (OCT-A) Adjunctive Series Module

Table C.8.yyy.1-1 specifies the Attributes that identify and describe general information about the Ophthalmic Tomography En Face Series.

Table C.8.yy.1-1 Ophthalmic Tomography Angiographic Adjunctive Series Module Attributes

Attribute Name	Tag	Type	Attribute Description
Modality	(0008,0060)	1	Type of equipment that originally acquired the data used to create the images in this Series. Enumerated Values: **OPTADJ** See Section C.7.3.1.1.1 for further explanation.
Series Number	(0020,0011)	1	A number that identifies this Series.
Referenced Performed Procedure Step Sequence	(0008,1111)	1C	Uniquely identifies the Performed Procedure Step SOP Instance to which the Series is related. Only a single Item shall be included in this Sequence. Required if a Performed Procedure Step SOP Class was involved in the creation of this Series.
>Include Table 10-11 "SOP Instance Reference Macro Attributes"			

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C.8.yy.2 Ophthalmic Tomography Angiographic Adjunctive Image Module

Table C.8.yy.2-1 specifies the Attributes that describe the Ophthalmic Tomography Angiographic Adjunctive Image Module.

230 **Table C.8.yy.2-1**
Ophthalmic Tomography Angiographic Adjunctive Image Module Attributes

Attribute Name	Tag	Type	Attribute Description
Image Type	(0008,0008)	1	Image identification characteristics. See Section C.8.xx.2.1.5 for specialization.
Instance Number	(0020,0013)	1	A number that identifies this image.
Samples per Pixel	(0028,0002)	1	Number of samples (planes) in this image. Enumerated Value: **2**
Photometric Interpretation	(0028,0004)	1	Specifies the intended interpretation of the pixel data. See Section C.8.xx.2.1.4

Changes to NEMA Standards Publication PS 3.4

235 ## Digital Imaging and Communications in Medicine (DICOM)

Part 4: Service Class Specifications

Add to PS3.4 Annex B.5.

B.5 Standard SOP Classes

240 **Table B.5-1**
STANDARD SOP CLASSES

SOP Class Name	SOP Class UID	IOD (See PS 3.3)
…		
Ophthalmic Tomography Angiographic En Face Image Storage	**1.2.840.10008.5.1.4.1.1.77.xxx**	**Ophthalmic Tomography Angiographic En Face Image Storage**
Ophthalmic Tomography Angiographic Adjunctive Image Storage	**1.2.840.10008.5.1.4.1.1.77.y.y.y**	**Ophthalmic Tomography Angiographic Adjunctive Image Storage**

Add to PS3.4 Annex I.4.

I.4 Media Standard Storage SOP Classes

Table I.4-1
Media Storage Standard SOP Classes

SOP Class Name	SOP Class UID	IOD (See PS 3.3)
…		
Ophthalmic Tomography Angiographic En Face Image Storage	**1.2.840.10008.5.1.4.1.1.77.xxx**	**Ophthalmic Tomography Angiographic En Face Image Storage**
Ophthalmic Tomography Angiographic Adjunctive Image Storage	**1.2.840.10008.5.1.4.1.1.77.y.y.y**	**Ophthalmic Tomography Angiographic Adjunctive Image Storage**

Changes to NEMA Standards Publication PS 3.6

Digital Imaging and Communications in Medicine (DICOM)

Part 6: Data Dictionary

Add to PS3.6 Annex A

UID Value	UID NAME	UID TYPE	Part
…			
1.2.840.10008.5.1.4.1.1.77.xxx	**Ophthalmic Tomography Angiographic En Face Image Storage**	**SOP Class**	**PS 3.4**
1.2.840.10008.5.1.4.1.1.77.y.y.y	**Ophthalmic Tomography Angiographic Adjunctive Image Storage**	**SOP Class**	**PS 3.4**

Add to PS3.6 the following Data Elements to Section 6, Registry of DICOM data elements:

Tag	Name	Keyword	VR	VM
(00gg,ee12)	Derivation Algorithm Sequence	DerivationAlgorithmSequence	SQ	1
(00gg,ee15)	En Face Image Label Code Sequence	EnFaceImageLabelCodeSequence	SQ	1
(00gg,ee16)	En Face Image Label Description	EnFaceImageLabelDescription	LO	1
(00gg,ee20)	OPT Surface Segmentation Layer Label(s)	OPTSurfaceSegmentationLayerLabel(s)	LO	1-n
(00gg,ee22)	En Face Anatomic Reference Code Sequence	EnFaceAnatomicReferenceCodeSequence	SQ	1
(00gg,ee24)	En Face Anatomic Reference Location Sequence	EnFaceAnatomicReferenceLocationSequence	SQ	1

Modify Table A3 to PS3.6 for new CIDs

Table A-3. Context Group UID Values

Context UID	Context Identifier	Context Group Name
1.2.840.10008.6.1.xxxx	**CID 42aa**	**Surface Processing Algorithm Families**
1.2.840.10008.6.1.yyyy	**CID 42bb**	**En Face Image Labels**

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Changes to NEMA Standards Publication PS 3.16

Digital Imaging and Communications in Medicine (DICOM)

Part 16: Content Mapping Resource

Add the following codes to Part 16 Annex B DCMR CID 7202 (Normative)

CID 7202 Source Image Purposes of Reference

Type: **Extensible**
Version: **2016mmdd**

Table CID 7202. Source Image Purposes of Reference

Coding Scheme Designator	Code Value	Code Meaning
DCM	121320	Uncompressed predecessor
DCM	121321	Mask image for image processing operation
DCM	121322	Source image for image processing operation
DCM	121329	Source image for montage
DCM	121330	Lossy compressed predecessor
DCM	121358	For Processing predecessor
DCM	113130	Predecessor containing group of imaging subjects
DCM	**aaaaaa**	**Source structural image for imaging processing operation**
DCM	**bbbbbb**	**Source flow image for imaging processing operation**

Add the following definitions to Part 16 Annex B DCMR Context Groups (Normative)

CID 42aa Surface Processing Algorithm Families

Context ID 42aa
Surface Processing Algorithm Families
Type: Extensible **Version: 2016mmdd**

Coding Scheme Designator (0008,0102)	Code Value (0008,0100)	Code Meaning (0008,0104)
DCM	cccccc	Amplitude decorrelation
DCM	dddddd	Complex variance
DCM	eeeeee	Speckle variance
DCM	ffffff	Phase variance
DCM	gggggg	Correlation mapping
DCM	hhhhhh	Doppler OCT

CID 42bb En Face Image Labels

Context ID 42bb
En Face Image Labels
Type: Extensible Version: 2016mmdd

Coding Scheme Designator (0008,0102)	Code Value (0008,0100)	Code Meaning (0008,0104)
DCM	iiiiii	Retina depth encoded
DCM	jjjjjj	Retina
DCM	kkkkkk	VRI
DCM	llllll	Superficial Capillary Superficial Retina Superficial
DCM	mmmmmm	Deep Capillary Deep Retina Deep
DCM	nnnnnn	Outer Retina Avascular
DCM	oooooo	Choroicapillaris
DCM	pppppp	Choroid
DCM	qqqqqq	Whole Eye

(Add the following definitions to Part 16 Annex D DICOM Controlled Terminology Definitions (Normative)

Annex D DICOM Controlled Terminology Definitions (Normative)

Code Value	Code Meaning	Definition	Notes
aaaaaa	Source structural image for imaging processing operation		
bbbbbb	Source flow image for imaging processing operation		
cccccc	Amplitude decorrelation	Jia et al. proposed a split-spectrum amplitude-decorrelation angiography (SSADA), in which the decorrelation (i.e., the inverse correlation) between two consecutive B-scans from the narrowed spectral bands was computed, and all the decorrelation values within certain repeated B-scans were averaged to visualize blood vessels. The concept of decorrelation to contrast blood flow is the same as that of the correlation mapping approach.	Methods and algorithms for optical coherence tomography-based angiography: a review and comparison Anqi Zhang ; Qinqin Zhang ; Chieh-Li Chen ; Ruikang K. Wang (2015) See http://biomedicaloptics.spiedigitallibrary.org/article.aspx?articleid=2464650#QuantitativeComparisons
dddddd	Complex variance	Angiography Based on the Complex Optical Coherence Tomography Signal. The first demonstration of OCT angiography within this category, to our knowledge, was proposed by Wang et al., in 2007, in which a novel processing method was presented to explore the changes in signal frequency embedded in raw spectrum in k-space. There are a number of factors that may cause a change in the OCT signal frequency relative to the signal due to static tissue background. These factors include, for example, the Doppler effect that induces optical frequency shift and the change in backscattering due to the particles that are moving in and out of the OCT-probe volume during imaging. The changes in signal frequency cause the changes in phase of the OCT signal. This new optical angiography approach was initially termed as OAG, and later renamed as OMAG.	
eeeeee	Speckle variance	We may describe the intensity or speckle of the OCT signal as the random interference pattern produced by the coherent backscattered light from a random medium. The speckle pattern is associated with the movement of scattering particles in random medium since such movement would cause phase shift in the backscattered light that consequently would lead to a change in random interference pattern.41,42 Hence, the temporal and spatial statistics of the speckle pattern contain the information of the motion of the scattering particles. If an OCT image is acquired from a stationary object, the speckle pattern is temporally stationary; in contrast, if an OCT image is acquired from an object of moving particles, for example, intralipid solution, the speckle pattern	

		would vary with time. By analyzing the temporal or spatial statistics of the intensity or speckle from OCT images, blood vessels can be identified.	
ffffff	Phase variance	Doppler OCT utilizes the phase resolved information to provide the velocity of flow. In 2007, Fingler et al. proposed the use of phase variance between adjacent B-scans to visualize transverse flow and later proposed the phase variance-based volumetric microvascular imaging of human retina.	
gggggg	Correlation mapping	Jonathan et al. proposed a so-called correlation mapping method that was further investigated by Enfield et al. Correlation mapping allows for the differentiation of flow regions since static regions usually have high correlation values while flow regions have lower correlation values.	
hhhhhh	Doppler OCT	The first demonstration of OCT blood flow imaging based on phase information dated back to Doppler OCT using the time-domain OCT in 1997, in which the flow monitoring was based on the fact that the Doppler shift in backscattered light induced by moving objects is additive to the carrier frequency associated with the reference arm. Doppler broadening due to moving particle is observed, which has been utilized to measure the transverse blood flow velocity.	
iiiiii	Retina depth encoded	Pseudo color image with multiple OPTENF images encoded with different colors.	
jjjjjj	Retina	Generated with pixels from ILM to IS/OS. This image intends to illustrate vasculature of entire retina.	
kkkkkk	VRI	Generated with pixels anterior to ILM, either to the start of the image frame, or x pixels anterior to ILM.	
llllll	Superficial Capillary Superficial Retina Superficial	Generated with pixels from ILM to approximately GCL/IPL. This image depicts the superficial vascular circulation within the retina.	
mmmmmm	Deep Capillary Deep Retina Deep	Generated with pixels from IPL to OPL. This image depicts the inner vascular pattern at the plexiform level with the retina.	
nnnnnn	Outer Retina Avascular	Generated with pixels in the translucent layers, from OPL to IS/OS. In normals, this OPTENF image should be featureless. In diseased eyes, there is potential to see the vascular pattern in this space.	
oooooo	Choroicapillaris	Generated with pixels just below RPE.	
pppppp	Choroid	Generated with pixels at a distance posterior to RPE.	
qqqqqq	Whole Eye	Sums all flow signal in entire scan. This image depicts the vasculature of entire posterior segment, including retina and choroid.	

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Changes to NEMA Standards Publication PS 3.17 Digital Imaging and Communications in Medicine (DICOM)

Part 17: Explanatory Information

Add to PS3.17 Annex UUU

Annex UUU Ophthalmology Tomography En Face Angiography Use Cases (Informative)

UUU.1 Ophthalmic Tomography Angiography Use Cases

OCT-Angiography (OCT-A) en face images are derived from images obtained using the existing spectral domain OCT technology. With special image acquisition sequences and post hoc image processing algorithms, OCT-A en face detects the motion of the blood cells in the vessels to produce images of retinal and choroidal blood flow with capillary level resolution. The resultant en face images are similar to images obtained in retinal fluorescein angiography with contrast dye is administered intravenously, though differences are observed when comparing these two modalities. This technology enables a high resolution visualization of the retinal and choroidal capillary network to detect the growth of abnormal blood vesselsto provide additional insights in diagnosing and managing a variety of retinal diseases including diabetic retinopathy, neovascular age-related macular degeneration, retinal vein occlusion and others.

The following use cases are examples of how the ophthalmic tomography angiography DICOM objects may be used.

UUU.1.1 Clinical Use Cases

UUU.1.1.1 Diabetic Macular Ischemia

A 54 year old female patient with an 18 year history of DM2 presents with unexplained painless decreased visual acuity in both eyes. The patient was on hemodialysis (HD) for diabetes related renal failure. She had a failed HD shunt in the right arm and a functioning shunt in the left. SD-OCT testing showed no thickening of the macula. Because of her renal failure and HD history IVFA was deferred and OCT-A of the maculae was performed. This showed significant widening of the foveal avascular zone (FAZ) explaining her poor visual acuity and excluding treatment opportunities.

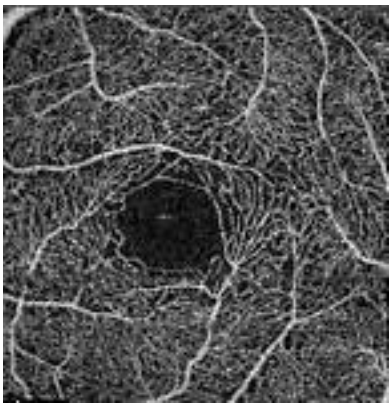

Figure UUU.1.1-1: Diabetic Macular Ischemia example

UUU.1.1.2 Age related Macular Degeneration

A 71 year old male patient presents with a 3 month history of decreased visual acuity and distorted vision on the right eye. He demonstrates a small well defined elevation of the deep retina superior-temporally to the fovea OD by biomicroscopy that correlates to a small pigment epithelial detachment (PED) shown by SD-OCT. OCT-A demonstrated a subretinal neovascular network. This was treated with intravitreal anti-VEGF injection monthly for three months with resolution of the PED and incremental regression of the subretinal neovascular membrane by point to point registration OTC-A , and finally non-perfusion of the previous SRN.

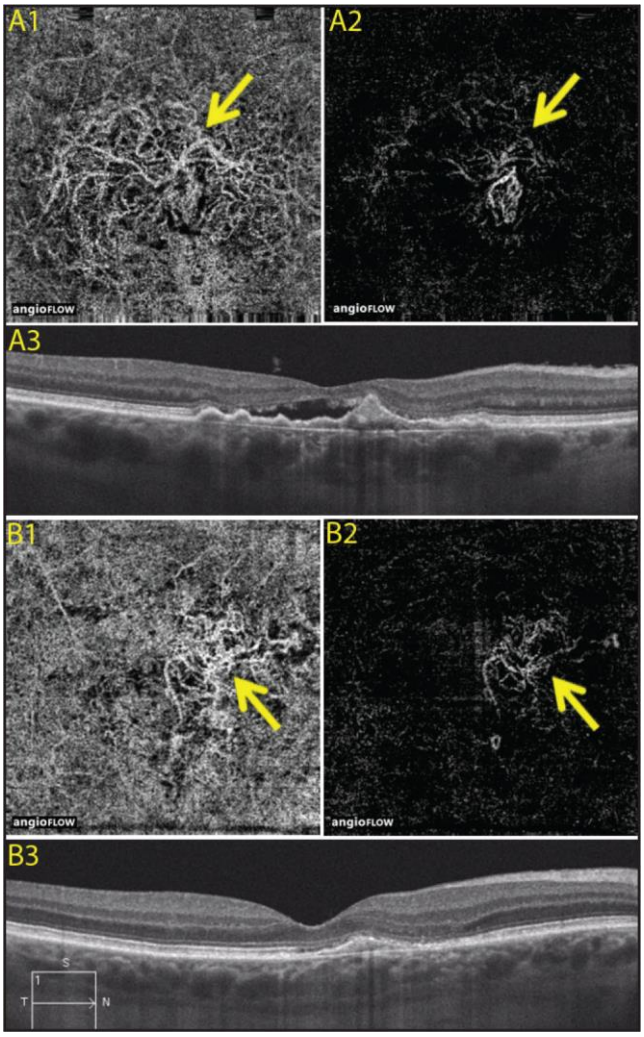

Figure UUU.1.1-2: Age related Macular Degeneration example

UUU.1.1.3 Brach Retinal Vein Occlusion

A 59 y/o male patient with hypertension and long smoking history presents with a six week history of painless decrease in vision in the right eye. Ophthalmoscopy showed dilated and tortuous veins inferior temporally in the right eye with a superior temporal distribution of deep retinal hemorrhages that extended to the mid-periphery, but did not include the macula. SD-OCT showed thickening of the macula and OCT-A showed rarefaction of the retinal capillaries consistent with ischemic branch retinal vein occlusion and macular edema.

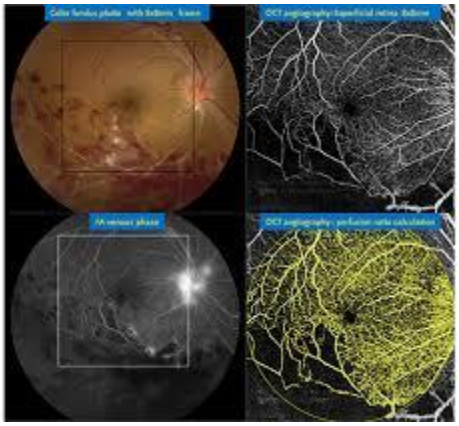

Figure UUU.1.1-3: Brach Retinal Vein Occlusion example

UUU.1.2 Research Use Cases

UUU.1.2.1 Proliferative Diabetic Retinopathy

A 38-year-old male patient with 26 year history of type 1 diabetes examined for evaluation of 10-day history ofscant vitreous hemorrhage fue to neovascularization of the optic disc.

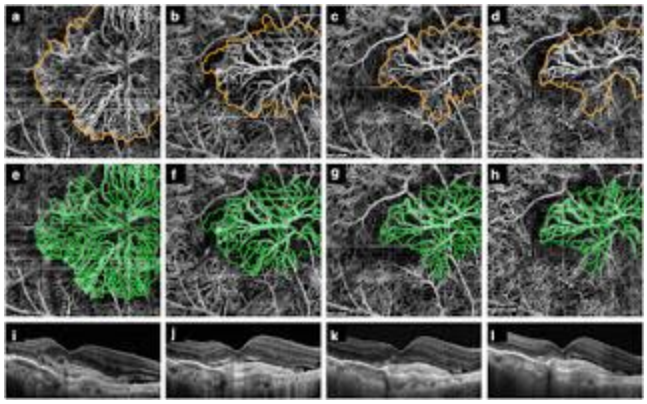

Figure UUU.1.2.1-1: Proliferative Diabetic Retinopathy example

UUU.1.2.2 Central Retinal Vein Occlusion with Optic Disc Neovascularization

50-year-old male patient received two anti-VEGF injections OD for cystoid macular edema due to central retinal vein occlusion. Patient was lost to follow-up for 8 months, and presents for evaluation of decreased vision of count fingers at one foot, OD.

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