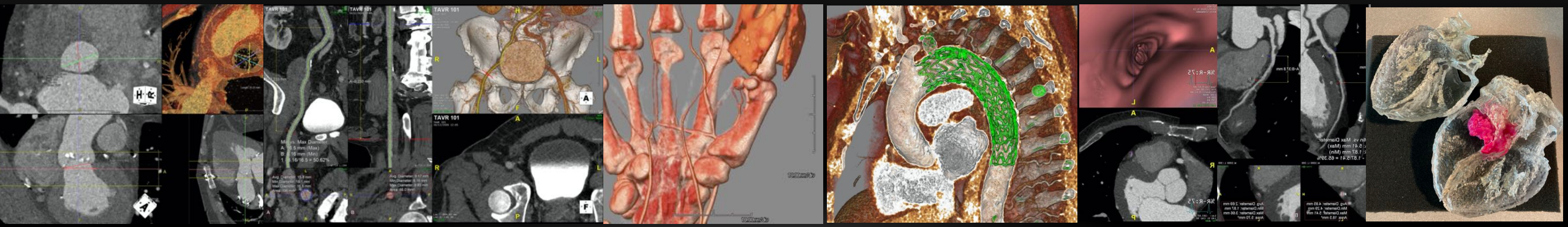
BUILDING PRACTICE PROTOCOLS AND 3D RENDERING



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DISCLOSURES

- None

OVERVIEW

- Benefits of Rational CVI Protocol Design
  - CTA protocol design
  - MR protocol design
  - Implementation / Education
- 3D Rendering
  - Personnel, Protocols, Hardware, Software
  - “Marketing” the service
  - Value-added services (3D printing)

WHY SPEND TIME ON PROTOCOLS?

- Leads to consistent results, decreases variability
- Improves patient care
- Complex exams can become less operator dependent
- Demonstrates value of skill-set
- Vendor protocols and support are limited

CTA PROTOCOLS

CTA PROTOCOL DESIGN: IMPORTANT INPUTS

- Contrast medium (CM) Dynamics
- Weight-based CM dosing
- Scan time
- Tube energy (kV), image noise considerations
  - Low kV scanning
  - Iterative Reconstruction

Rules of Early CM Dynamics:

- **Arterial Enhancement is Proportional to Iodine Flow Rate (Flux)**
  - Increasing the injection flow rate and/or iodine concentration of CM will increase the arterial opacification.
- **Arterial enhancement increases over time as a cumulative effect**
  - Arterial enhancement increases with increasing injection duration.
  - Minimum injection duration of ~ 10 s needed to achieve adequate arterial enhancement.
- **Arterial enhancement is highly variable between individuals**
  - Cardiac output (CO) is inversely proportional to arterial enhancement
  - CO correlates proportionally to body weight / body surface area (BSA)
  - Revising the injection rate and CM volume upward for larger (>90 kg) and downward for smaller (<60 kg) patients will reduce inter-individual variability.
- **Arterial filling may be delayed physiologically and/or pathologically**
  - Even normal coronary arteries need several heartbeats to fully opacify
  - Mixing of opacified and unopacified blood in aneurysms delays peak enhancement

Fleischmann D. Eur Radiol 2002;12:S11-S16

Fleischmann, et al. Radiol Clin N Am 54 (2016) 1–12

TIPS FOR BUILDING INJECTION/SCAN PROTOCOLS

- Scan times dependent on scanner, scan mode chosen
- Bolus track the area of interest
- It takes ~ 6 sec for image reconstruction, table movement, and breath hold instructions
  - I also add 2 sec “fudge factor”

Injection Duration = scan time + 8 + “delay”

Fleischmann, et al. Radiol Clin N Am 54 (2016) 1–12

EXAMPLE: INTEGRATED CT ACQUISITION / INJECTION PROTOCOL: CTA OF THE THORACIC / ABDOMINAL AORTA

Acquisition	64 x 0.6 mm (channels x channel width); automated tube current modulation (250 mAs reference mAs)
Pitch	Variable (depends on volume coverage, usually <1.0)
Scan time	Fixed to 10 s (all patients)
Injection duration	Fixed to 18 s (all patients)
Scanning delay	t_{CMT} + 8 s (scan starts 8s after CM arrival, as established by automated bolus triggering)
Contrast medium	High concentration (350-370 mg I/mL)
Injection flow rates / volumes	**Individualized to body weight:**

Body Weight (kg)	CM Flow Rate (mL/s)	CM Volume (mL)
≤ 55	4.0	72
56-65	4.5	81
66-85	5.0	90
86-95	5.5	99
> 95	6.0	108

MR PROTOCOLS

MR PROTOCOLS: TIPS

- Make protocol as brief as possible
  - 45 min. or less
- Assign protocols as early as possible (EMR integration, etc)
- Coordinate w/ nursing for stress CMR, etc.
- Coordinate w/ EP and short stay for device patients (200-300 per year)

MR PROTOCOLS

- Build common CMR exam protocols:
  - Viability
  - ARVC
  - Pericardium
  - Cardiac Mass
  - Rest/Stress Perfusion
  - Iron Overload

MR PROTOCOLS

- MRA protocols:
  - TAA
  - AAA
  - Coarct
  - UE / LE
  - Non-con MRA

EXAMPLE: VIABILITY (1.5 T)

SEQUENCE	PLANES
Scouts	Multi, VLA, SAX, HLA, 3CH
CINE / FUNCTION	HLA, VLA, 3CH, LVOT, SAX
MORPHOLOGY	T2 maps
PERFUSION	3 SAX + HLA EPI
FLOW	Through plane mitral inflow, AO, PA, INPLANE 3CH
DME	DME PSIR HLA, VLA, 3CH, SAX Single shot SAX, 4CH stacks at TI >600
NOTES:	
peripheral IV 20G or larger	If PowerPICC or Port, call for heparin order
Flush with 3 mL NS to assess patency Obtain GFR if none within 30 days	Flush with minimum 10 mL NS pre- and post- injection; document on medication screen
Baseline BP and HR Inject 0.2 mmol/kg GBCA	

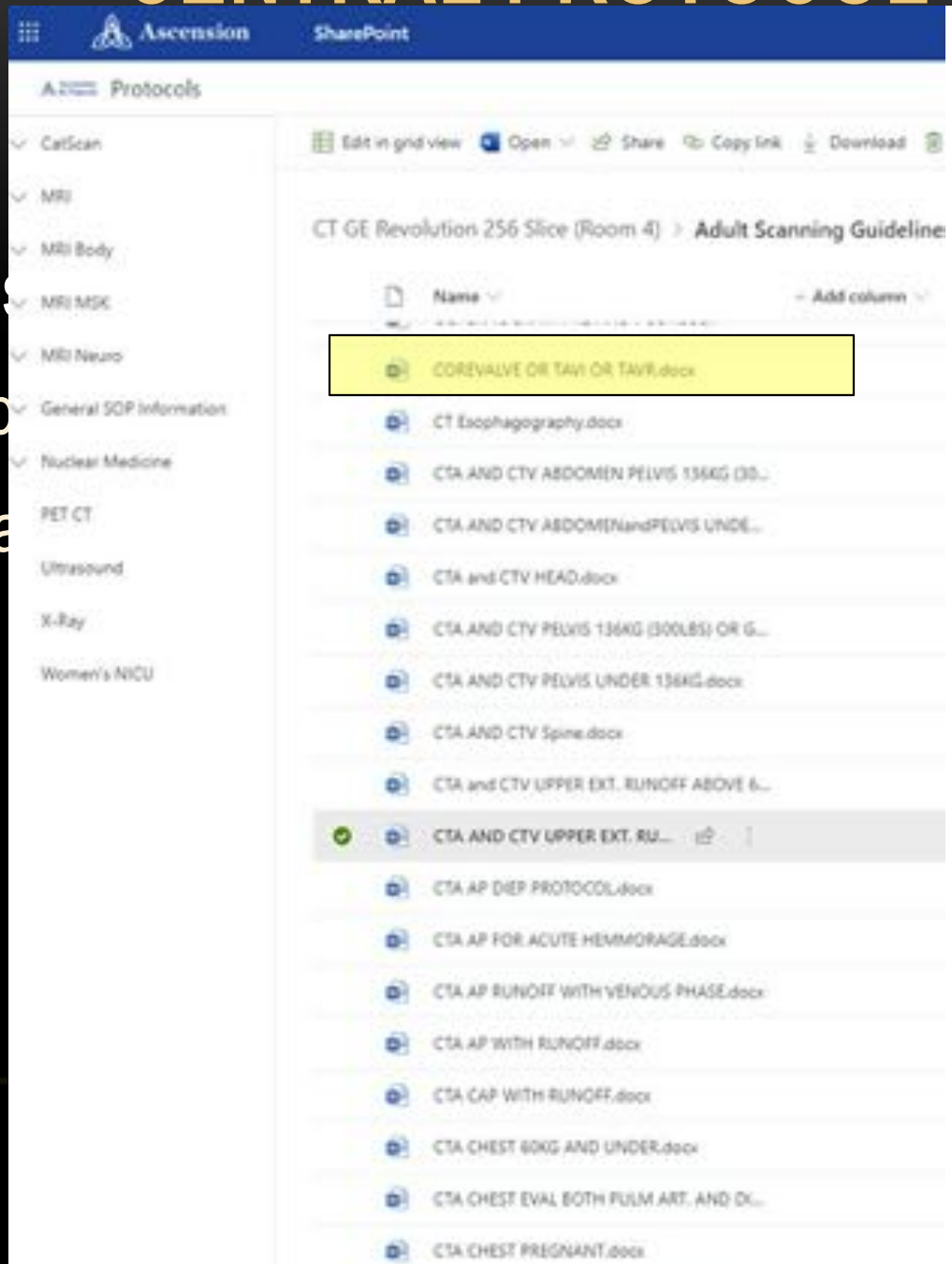
EXAMPLE: COARCTATION MRA (1.5 T)

SEQUENCE	PLANES
Scouts	Multi, VLA, SAX, HLA, 3CH
CINE / FUNCTION	HLA, VLA, 3CH, LVOT, SAX, SFOV AoV
MORPHOLOGY	Black Blood HASTE AX / SAG / COR
ANGIOGRAPHY	3D SPACE SAGITTAL COVER DESC/ASC, 3D MRA OBL SAGITTAL
FLOW	FLASH CINE AORTIC VALVE IN-PLANE FQ CANDY-CANE (3 slices) THROUGH-PLANE FQ Ao, MV THROUGH-PLANE CoA: Above, At, and below THROUGH-PLANE Desc AO near DIAPH
DME	DME Single Shots SAX, HLA, VLA, 3CH
NOTES:	
peripheral IV 20G or larger	If PowerPICC or Port, call for heparin order
Flush with 3 mL NS to assess patency Obtain GFR if none within 30 days	Flush with minimum 10 mL NS pre- and post- injection; document on medication screen
Baseline BP and HR Inject 0.2 mmol/kg GBCA, max 30 mL	

PROTOCOL IMPLEMENTATION, DISTRIBUTION, AND EDUCATION

CENTRAL PROTOCOL REPOSITORY:

- Allows
  - Imp
  - Ada
- Easy



COREVALVE/TAVI/TAVR CTA CHEST/ABD/PELVIS

Indications- COREVALVE / TAVI/ TAVR (Transcatheter Aortic Valve Replacement or Implantation)

Make sure group 1 is Cardiac Large and the check group 2's delay is 3 seconds!!!

PLEASE SCAN SCREENIG WORKSHEET IN PACS
NEED TO DO 0-90% 1.25MM Thick 0.75 Spacing AND SEND THEM TO THE TERA-RECON
PLEASE CALL LYNN BURKET AT 36116 OR DENISE WEATLEY AT 36425 TO SEE IF A DVD NEEDS BURNED IF YES BURN 30%, 40%,60%& 70% ON A DVD and leave upfront with Clerical. Write patient name on DVD.
Please Email Lori Bricker that this to be read Lori@NorthWestRadiology.com
IV needs to be in the rt arm

RM 4 GE REVOLUTION

POSITIONING/LANDMARK	SUPINE, FEET FIRST. ARMS ABOVE HEAD / STERNAL NOTCH.		
INJECTION RATE / VOLUME	1-64 kg:72mL @ 4.5mL/sec Non-Ionic contrast agents 65-85 kg: 80mL @ 5.0mL/sec Non-Ionic contrast agents 86-95 kg: 88mL at 5.5mL/sec Non-Ionic contrast agents. 96 & Above kg: 96mL at 5.5mL/sec Non-Ionic contrast agents. For all the above also use 90ml of 0.9% Sodium Chloride (40ml's pre & 50ml's post) at the same injection rate.		
	W/C GATED HEART (G1-R1-6) R2-30%, R3-40%, R4-60%, R5-70% & R6-0-90%		**W/C NON GATED CHEST ABDOMEN PELVIS (G2-R1&2)**
SCAN TYPE/ ROTATION TIME/ LENGTH	CARDIAC HI RES MODE OFF / 0.35 / NA		HELICAL HI RES MODE OFF/ 0.35 / PLUS
START LOCATION	ABOVE HEART		ABOVE APICES
END LOCATION	BELOW HEART		FEMORAL NECK
ACQUISITION **DETECTOR CONFIGURATION**	0.625 x 256	0.625 x 192 Depends on body habitus	0.625 x 64
DETECTOR COVERAGE(mm)	160	120	40
GANTRY ANGLE	NA		NA
PITCH/SPEED(mm/rotation)	**TABLE POSTION** ONE OR MORE **COVERAGE** SMART COVERAGE (120,160MM) **OVERLAP AMOUNT** MORE **Depends on body habitus**		0.984:1 / 39.36
SFOV/ DFOV(cm)	CARDIAC LARGE / 20		LARGE BODY / 40
KVP	Kv assist 100min-120max		Kv assist 100min-120max
MA/ NOISE INDEX	SmartmA 50min-405max / 30		SmartmA 10min-680max / 9
PREP GROUP (seconds)	NA		3 SECONDS
BOLUS TRACKING OR GAITING (LOCATION) MA/ MONTORING DELAY / ISD / DIAGNOSTIC DELAY	**SMART PREP** (AORITC ROOT) 80/ 5 / 1 /5 **Gating**- Auto Gating Off. Acquisition Window Part 1 Range 0-90% with 100% of mA (300) and Widen for SSF on. Acquisition Window Part 2 Range 5-95% with 100% of mA (300) and Widen for SSF off. HR Variation Allowance 8BPM. Repeat Acquisition Off. Adaptive Gating On.		NA
BREATHING INSTRUCTIONS	GATED INSPIRATION		GATED BREATH
RECON TYPE	STD		STD
THICKNESS(mm)	**R1-6** 0.625MM **PHASE%-** R2-30%, R3-40%, R4-60%, R5-70% all Manual single phase. SnapShotFreeze Off R6- 0-90% interval 10% Manual Multi Phase		**R1** 0.625 **R2** 1.25
INTERVAL(mm)	**R1-6** 0.625MM		**R1** 0.625 **R2** 0.75
RECON OPTION	**R1-6** ASIR-V 50%, Recon Mode Plus Off		**R1** PLUS / ASIR-V 30%/ IQ Enhance ON **R2** PLUS / ASIR-V 30%/ IQ Enhance OFF
DMPR	SEE REFORMATS DOCUMENT		SEE REFORMATS DOCUMENT
DOSE INDEX(CTDIvol)(mGy)	EV: 50 NV:75		EV: 50 NV:75
PACS	R2,R3,R4,R5,R6 BLANK AND LINE SCOUTS		R2
WORKSTATION	R2-6		R2

SHIELD PATIENT APPROPRIATELY FOR EXAM.

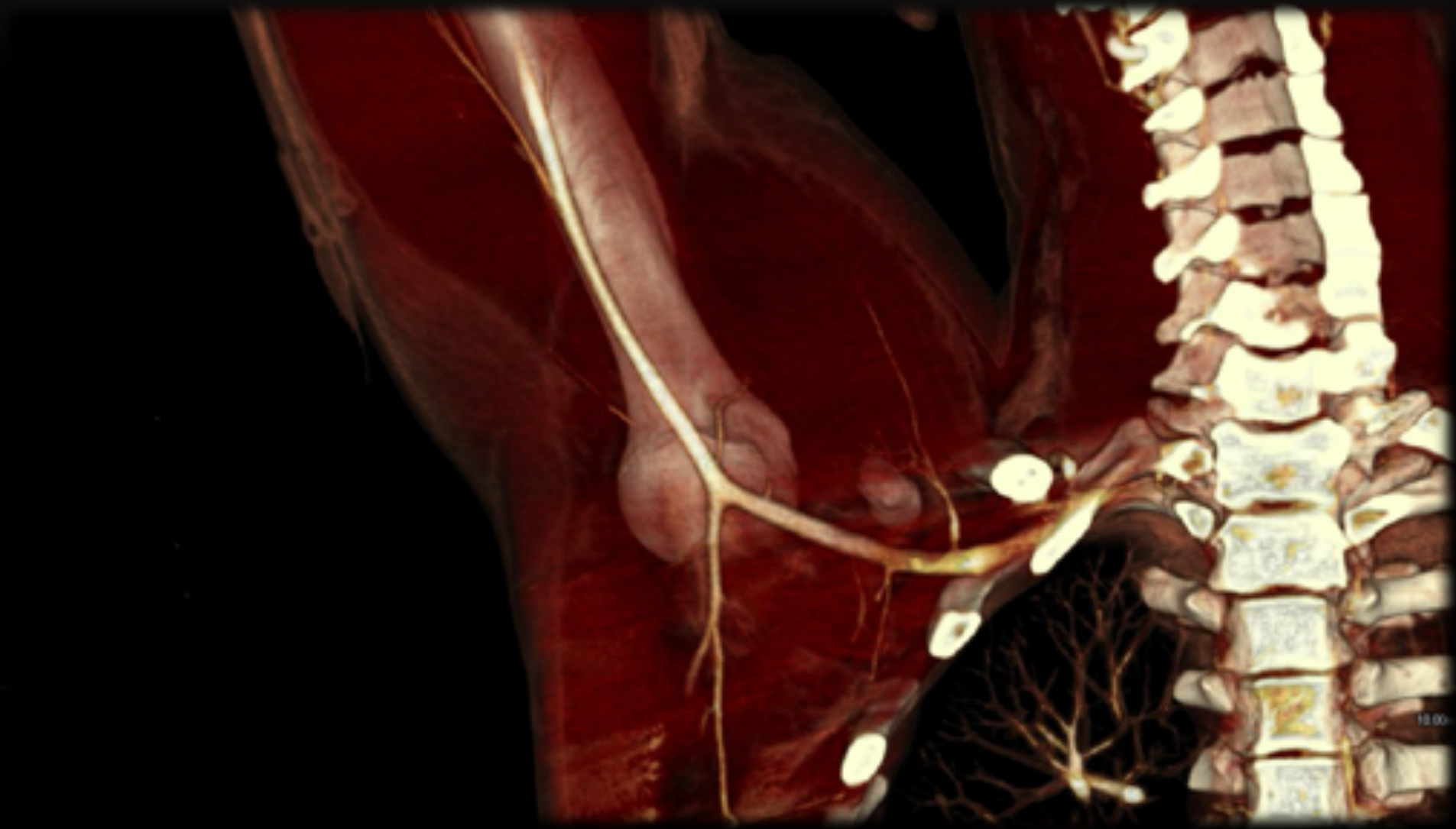
ADJUST DFOV FOR PATIENTS BODY HABITUS. DFOV SHOULD BE LARGE ENOUGH TO INCLUDE ALL SOFT TISSUES

ASIR, AUTO MA AND SMART MA IS UTILIZED TO DECREASE PATIENT DOSE

EDUCATION

- ”If you don’t use it, you lose it”
- Yearly day of protocol revision and discussion w/ radiologists, tech leaders
- Yearly day(s) of educational lectures by MDs for techs, with CE credit

3D RENDERING SERVICES

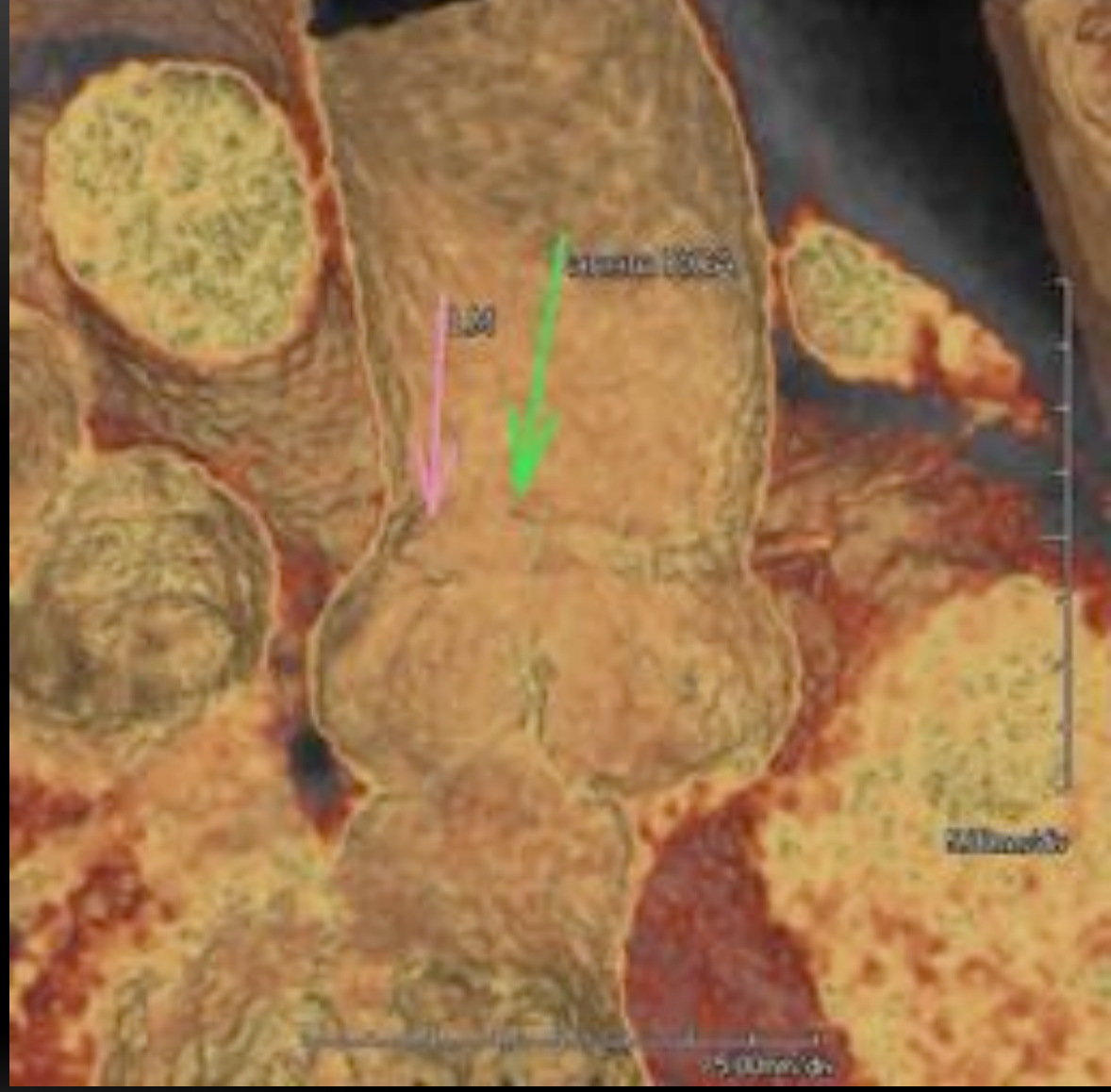


3D RENDERING SERVICES

- Integral to referring services' understanding of complex anatomy
- Wide spectrum of use: from LRD to CMR to TAVR
- What technology?
- Who provides?

3D RENDERING SERVICES

- Integral to referring services' understanding of complex anatomy

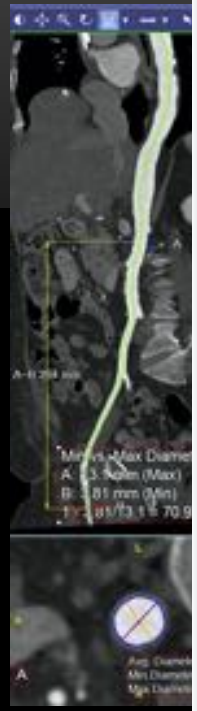


3D RENDERING SOLUTIONS:

- Stand-alone workstation
- “Thick”-client
- “Thin” client
- “NO” client (Zero footprint: Cloud-based)

OUR SETUP

- 3D rendering:
  - Thin Client
- Structural Heart:
  - Watchman, TMVR, TAVR
  - Cloud-based (Zero footprint) client
- Standardized workflow and reporting



TAVR PROTOCOL CTA WORKSHEET **NAME:** **DATE:**

Calcified Aorta	NO MILD MOD SEVERE PORCELAIN
Annular Ca++	Sub-annular Ca++
Major Annulus Diameter (systole)	
Minor Annulus Diameter (systole)	
Annulus PERIMETER (systole)	
Annulus AREA (systole)	mm^2
LVOT 4 mm below annulus:	x mm

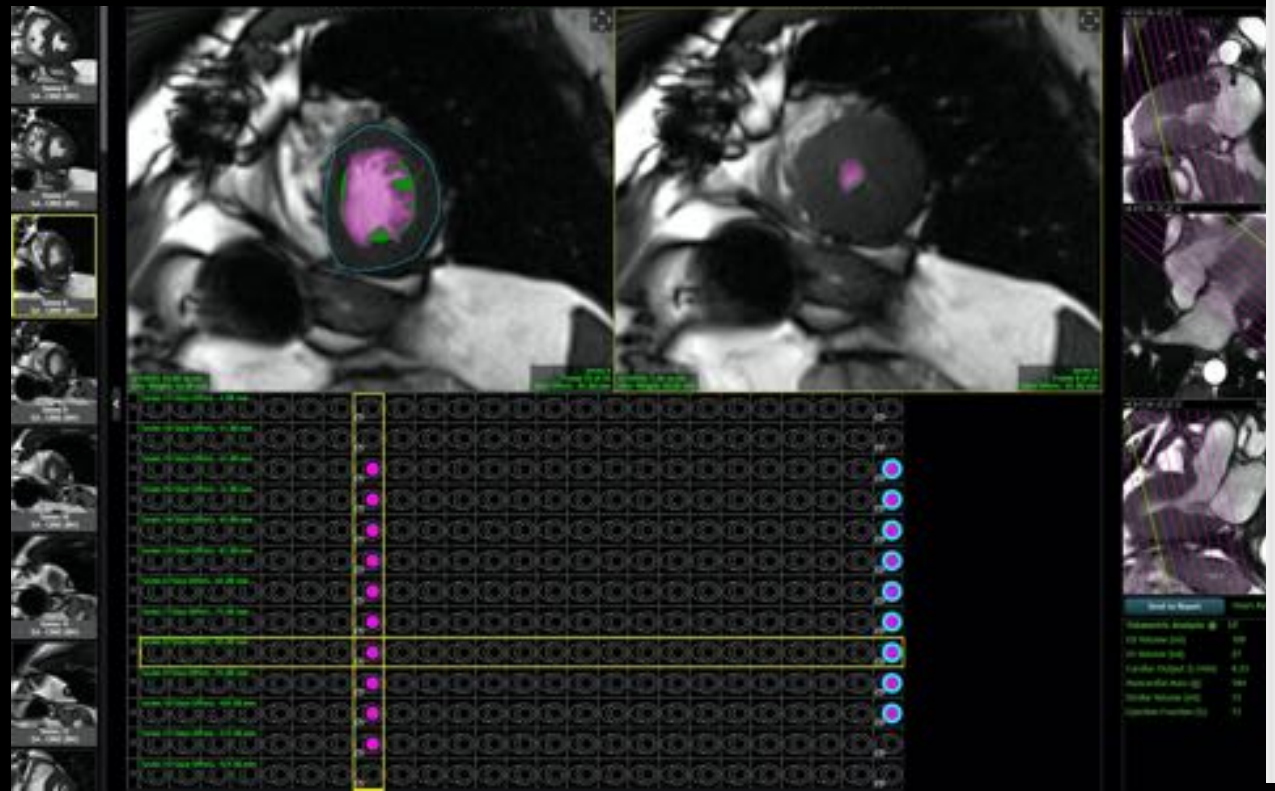
Sinus HEIGHT, RIGHT - Diastole	mm
Sinus HEIGHT, LEFT - Diastole	mm
Sinus HEIGHT, NONCOR - Diastole	mm
Sinus DIAMETER, RIGHT – Diastole	mm
Sinus DIAMETER, LEFT – Diastole	mm
Sinus DIAMETER, NONCOR - Diastole	mm
Distance LM ostium to Annulus	mm
Distance RCA ostium to Annulus	mm

ANGULATION:

LEFT SUBCLAVIAN	MLD=	Tortuosity 0/mild/mod/severe	Calcification 0/mild/mod/severe
RCCA	MLD =	Tortuosity 0/mild/mod/severe	Calcification 0/mild/mod/severe
LCCA	MLD =	Tortuosity 0/mild/mod/severe	Calcification 0/mild/mod/severe
RIGHT ILIOFEMORAL	MLD=	Tortuosity 0/mild/mod/severe	Calcification 0/mild/mod/severe
LEFT ILIOFEMORAL	MLD=	Tortuosity 0/mild/mod/severe	Calcification 0/mild/mod/severe

OUR SETUP

- CMR processing: Cloud-based
- Robust reporting direct to EMR
- Mix of MD / tech post-processing
  - 3D lab techs: training is ongoing



Summary

1) Left ventricle: The left ventricular volume index is decreased. The left ventricular wall thickness is increased moderately in an asymmetric fashion. Maximal wall thickness in the basal anteroseptum is 1.9 cm. The global left ventricular systolic function is normal with a calculated LVEF of 74%. There are no regional wall motion abnormalities noted. No LV thrombus is identified. There is an approximate 15 mmHg peak resting gradient in the left ventricular outflow tract.

2) Myocardial delayed enhancement: Myocardial delayed enhancement imaging is abnormal. There is mid-wall fibrosis in the interventricular septum corresponding to the areas of myocardium with significant hypertrophy. There is also an area of focal mid-wall fibrosis at the inferior RV insertion site. These patterns are consistent with hypertrophic cardiomyopathy. There is no ischemic pathology identified. Visually, I would estimate the amount of myocardial fibrosis at 5-10%

3) Myocardial native T1 mapping: The native T1 relaxation time of the myocardium is increased. The calculated extracellular volume is elevated.

4) Right ventricle: The right ventricular size is normal. The right ventricular global systolic function is normal.

5) Atria: The left atrium is mildly enlarged. The right atrium is normal in size.

6) Valves: There is trivial aortic insufficiency noted. There is mild systolic anterior motion of the chordal apparatus of the mitral valve. There is no evidence of mitral stenosis. There is trivial mitral regurgitation.

7) Pericardium: The pericardium is normal in thickness. There is no significant pericardial effusion.

8) Aorta: The aortic root is normal in size.

Core Exam

Measurements

Volumetric Analysis

		LV	(Reference)	RV	(Reference)
EDV	[ml]	87	(113-196)		(--)
	[ml/m^2]	37.2	(62-97)		(--)
ESV	[ml]	23	(29-74)		(--)
	[ml/m^2]	9.8	(15-37)		(--)
CO	[L/min]	3.71	(--)		(--)
	[L/min/m^2]	1.6	(--)		(--)
MASS	[g]		(--)		(--)
	[g/m^2]		(--)		(--)

VALUE ADDED SERVICES: 3D PRINTING

3D PRINTING

- Review with 3D solutions is often sufficient
- In certain instances, physical 3D models are extremely helpful (trouble-shooting, spatial relationships)
- Barriers to entry: training and resources
- Costs are decreasing but reimbursement still elusive

Model courtesy Shannon Walters, Stanford 3DQ lab

CONCLUSIONS

- Development and implementation of rational CTA / MRA protocols improves consistency / quality and decreases operator dependence.
- System-wide availability of protocols improves tech performance and comfort.
- Education (technologists, referrers) is important
- 3D rendering services are important across CVI but imperative for structural heart / valve therapies

THANK YOU FOR YOUR ATTENTION!!

- Thanks to:
  - Eric Williamson, MD
  - Mike Morris, MD