

Cardiac Sarcoidosis: A Focus on Advanced Cardiac Imaging

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Outline

- Background
- Diagnosis of Cardiac Sarcoidosis
- Advanced cardiac imaging for cardiac sarcoidosis

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Sarcoidosis

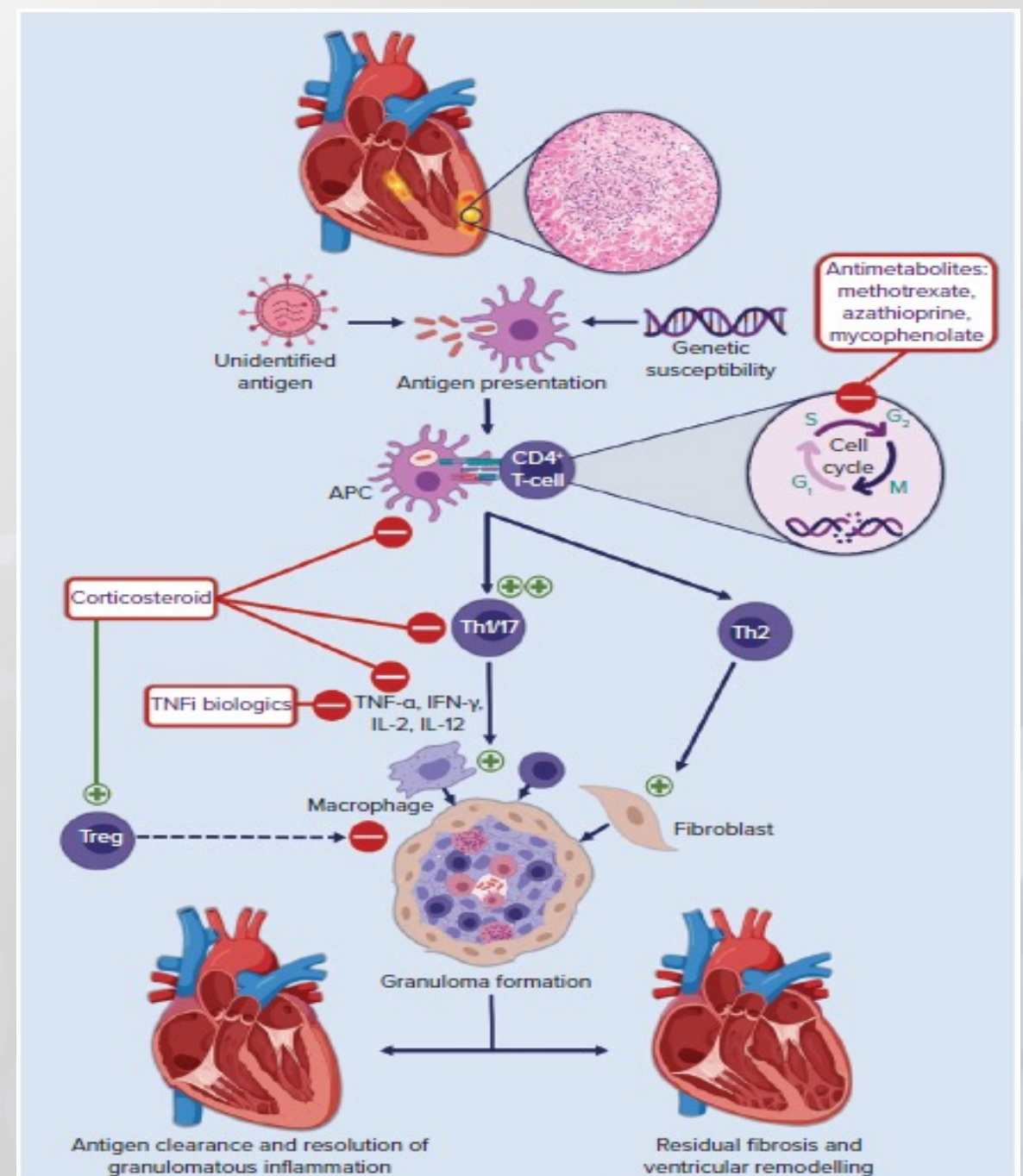
- 1869: Sir Jonathan Hutchinson described the first case of cutaneous sarcoid
- 1899: Norwegian dermatologist, Dr. Caesar Boeck described nodular skin lesions of epithelioid cells that resembled sarcoma cells; hence the designation “sarcoid”.
- 1929: Bernstein, the first to described cardiac involvement in a patient with systemic sarcoidosis



Mrs. Mortimer, Hutchinson’s second patient, as illustrated in Archives of Surgery (London) in 1898

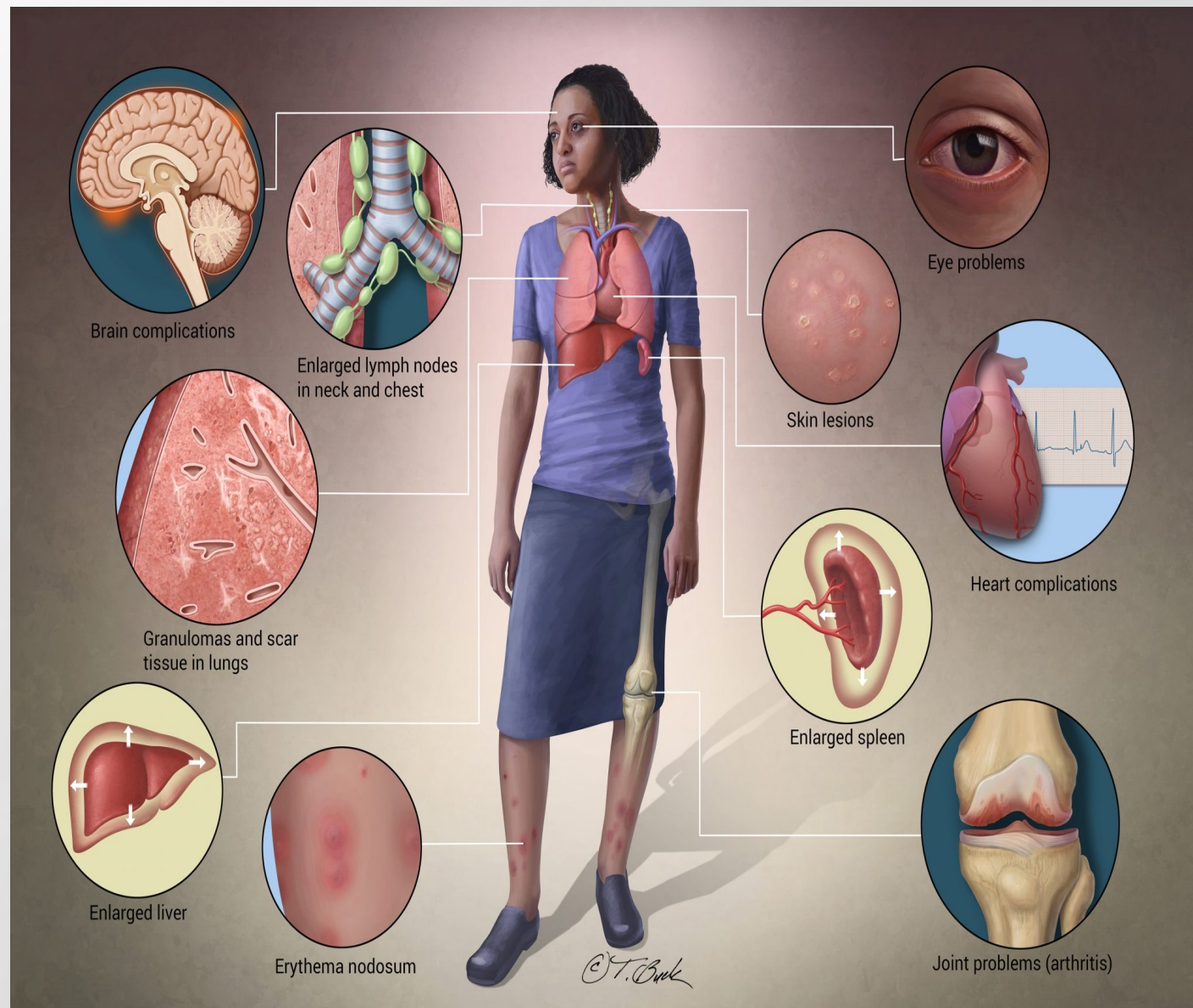
Sarcoidosis

- Granulomatous disease of unknown etiology
- Noncaseating granulomas are the pathological hallmark



Sarcoidosis

- Most often associated with pulmonary involvement (90%)
- Can involve
 - heart
 - liver
 - peripheral lymph node
 - spleen
 - skin
 - eyes
 - phalangeal bones
 - parotid gland



Sarcoidosis

- Rare ...with the annual incidence in the United States
 - 10.9 per 100,000 in whites and 35.5 per 100,000 in African Americans.
- Most disease (70%) occurs in patients aged 25–45 years
 - Europe and Japan: Second peak in women older than 50 years.
- Rare in people younger than 15 or older than 70 years.

Cardiac Sarcoidosis

- **SYMPTOMATIC** cardiac involvement ~5% of the patients with pulmonary/ systemic sarcoidosis.
- If include **ASYMPTOMATIC** cardiac involvement may be ~ 25% based on autopsy and imaging data
- Average age at presentation ~ 50 years

Cardiac Sarcoidosis

Can present essentially anywhere in the heart but from pathology, the common patterns are:

- Focality within the LV**

Multifocal LV more common than unifocal involvement (93.9% versus 6.1%; $P < 0.05$).

- LV segments involved**

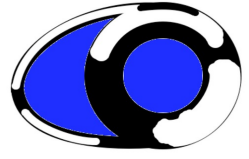
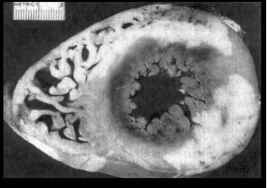
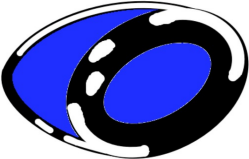
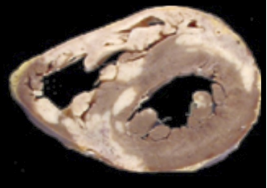

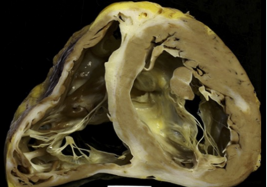

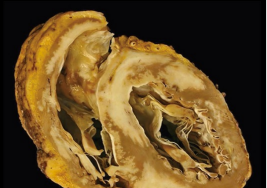


The septal (98%), anterior (75.0%), lateral (71.4%), and inferior (82.5%) segments

- LV levels involved**

The basal and mid LV were almost always involved (97.5% and 100%, respectively),

- Involvement of the RV free wall**

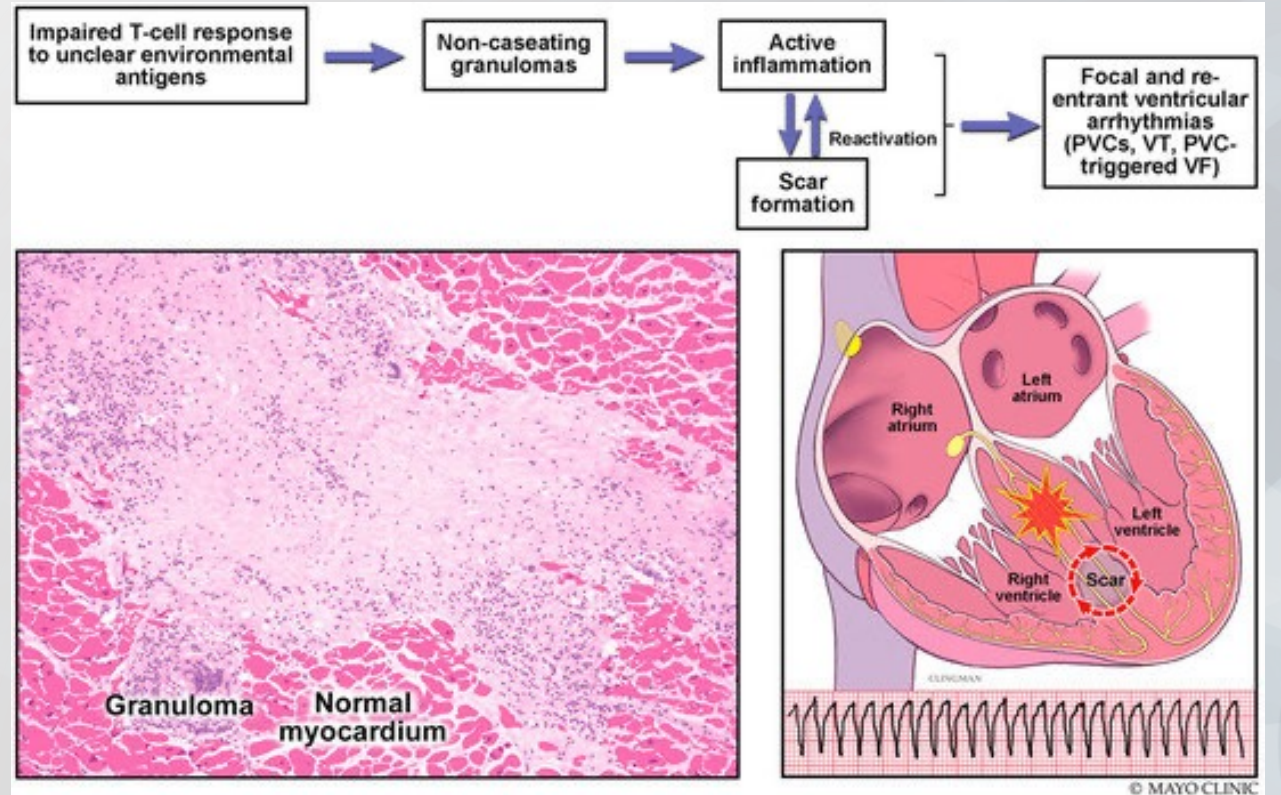
The RV free wall in 90.7%.

Clinical data	Guide	Pathology images	Involvement
A 35-year-old man; sudden death while driving a bus			Epicardial ✓ Multifocal ✓ Septal ✓ RV free wall ✓
B Age and sex unknown; sudden death			Epicardial ✓ Multifocal ✓ Septal ✓ RV free wall ✓
C 53-year-old man; heart transplantation due to cardiac sarcoidosis			Epicardial ✓ Multifocal ✓ Septal ✓ RV free wall ✓
D 53-year-old man; heart transplantation due to cardiac sarcoidosis			Epicardial ✓ Multifocal ✓ Septal ✓ RV free wall ✓
E 53-year-old man; end-stage heart failure due to cardiac sarcoidosis, died of hemorrhagic shock			Epicardial ✓ Multifocal ✓ Septal ✓ RV free wall ✓

Cardiac Sarcoidosis

Cardiac presentations

- Conduction abnormalities
 - AV block
- Ventricular arrhythmias
 - Ventricular tachycardia
- Heart failure



Outline

- Background
- **Diagnosis of Cardiac Sarcoidosis**
- Advanced imaging for cardiac sarcoidosis

Why identifying Cardiac Sarcoidosis is important?

- Cardiac sarcoid is a major cause of death in patient with sarcoidosis (from sudden cardiac death and heart failure)
- Patients **with cardiac sarcoidosis** have worse prognosis than **those without** particularly if they have cardiac symptoms
- May be treatable with immunosuppressant

Prognosis of Pt with Cardiac Sarcoidosis

Circulation: Cardiovascular Imaging

Volume 9, Issue 1, January 2016; Page e003738

<https://doi.org/10.1161/CIRCIMAGING.115.003738>



ORIGINAL ARTICLE

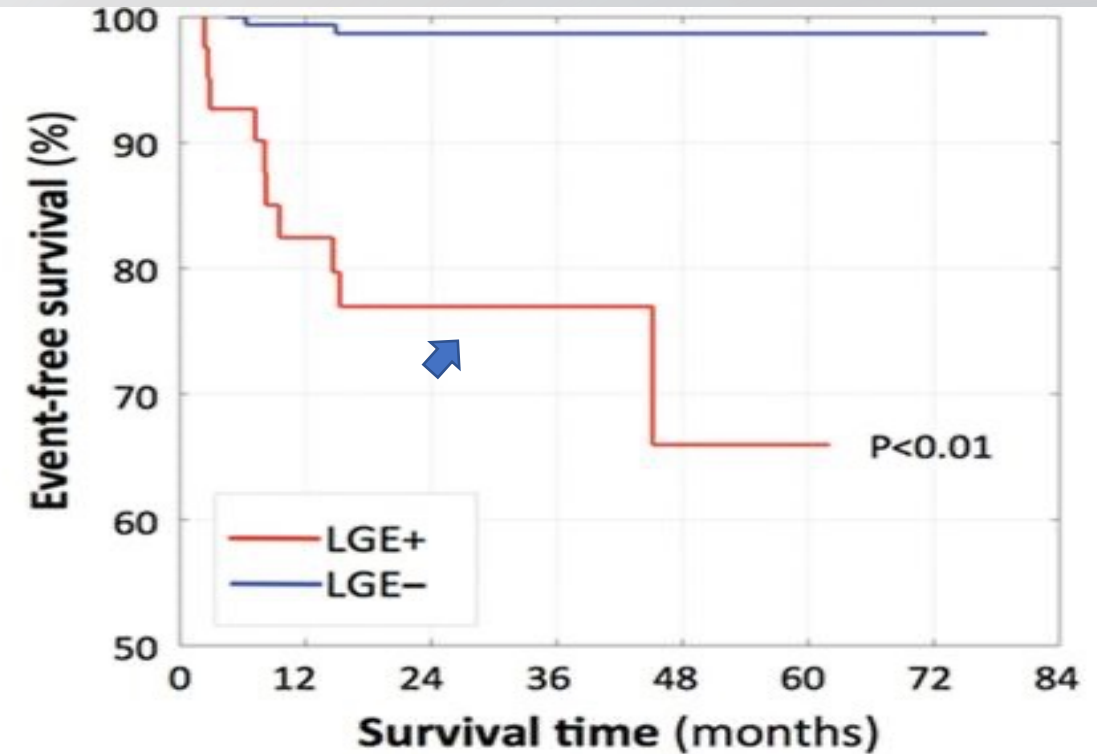
Prognosis of Myocardial Damage in Sarcoidosis Patients With Preserved Left Ventricular Ejection Fraction

Risk Stratification Using Cardiovascular Magnetic Resonance

See Editorial by [Greulich and Mahrholdt](#)

Gillian Murtagh, MD, Luke J. Laffin, MD, John F. Beshai, MD, Francesco Maffessanti, PhD, Catherine A. Bonham, MD, Amit V. Patel, MD, Zoe Yu, MD, Karima Addetia, MD, Victor Mor-Avi, PhD, Joshua D. Moss, MD, D. Kyle Hogarth, MD, Nadera J. Sweiss, MD, Roberto M. Lang, MD, and Amit R. Patel, MD

226 Pts with biopsy proven extracardiac sarcoidosis referred for CMR
Outcome: Death and ventricular tachycardia

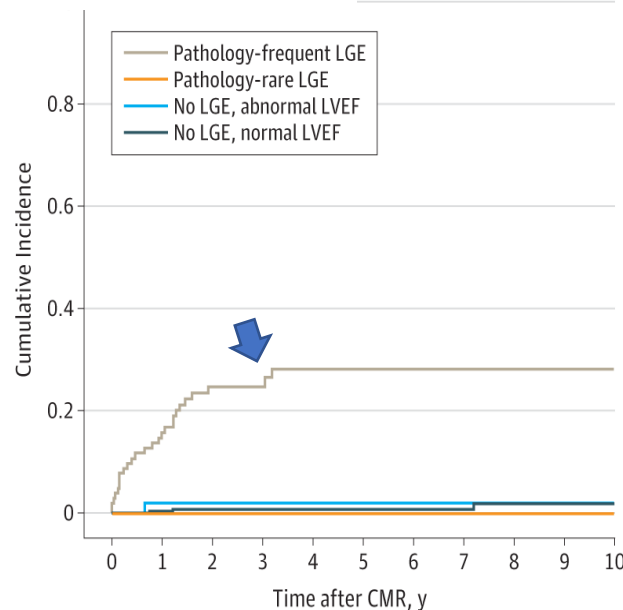


Cardiovascular Magnetic Resonance Imaging Phenotypes and Long-term Outcomes in Patients With Suspected Cardiac Sarcoidosis

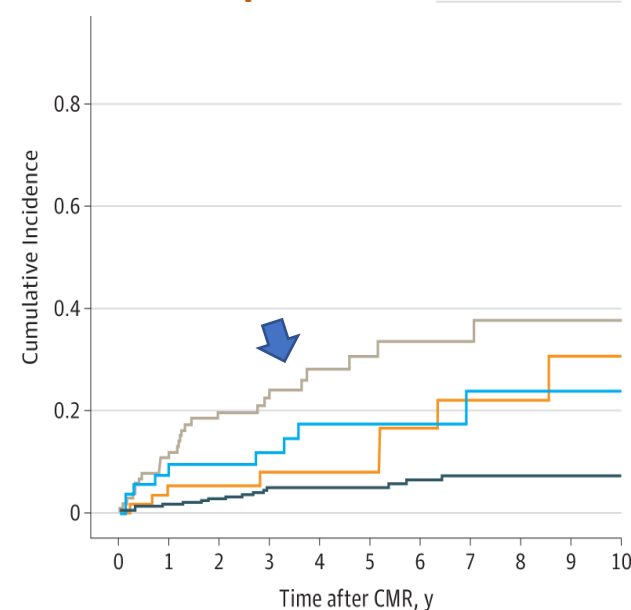
Pal Satyajit Singh Athwal, MBBS; Sanya Chhikara, MBBS; Mohamed F. Ismail, MBBCh; Khaled Ismail, MBBCh; Fredrick M. Ogugua, MBBS, MPH; Felipe Kazmirczak, MD; Parag H. Bawaskar, MD, DM; Andrew C. Elton, BS; Jeremy Markowitz, MD; Lisa von Wald, MSN; Henri Roukoz, MD; Maneesh Bhargava, MD, PhD; David Perlman, MD; Chetan Shenoy, MBBS, MS

504 pts with histologically proven sarcoidosis referred for CMR
Outcome: Arrhythmia including VT/VF, SCD, ICD therapy
Heart failure including death due to HF, HF hospitalization, LVAD, transplant

Arrhythmia end point



Heart failure end point



Who should we suspect Cardiac Sarcoidosis?

Biopsy proven extracardiac sarcoidosis	No known sarcoidosis
<p>Symptoms</p> <ul style="list-style-type: none">• Palpitation lasting > 2 weeks• Pre-syncope/syncope	
<p>Abnormal ECG</p> <ul style="list-style-type: none">• Complete left or right bundle branch block• Unexplained pathological Q waves in 2 or more leads• Sustained 2 or 3 degree AV block• Sustained or non-sustained VT	<p>Abnormal ECG</p> <ul style="list-style-type: none">• Unexplained Mobitz II or 3rd degree AV block in patient aged < 60 years• Sustained Monomorphic VT of Unknown Etiology (reasonable but not a formal recommendation)
<p>Abnormal echocardiogram</p> <ul style="list-style-type: none">• RWMA and/or wall aneurysm• LVEF < 40%	

Diagnosis of cardiac sarcoidosis

- ONLY DEFINITIVE DIAGNOSIS: Endomyocardial biopsy – gold standard.
- EMB has low sensitivity (~ 25%) due to the focal nature of the disease
- Sensitivity increased with electrophysiological or imaging-guided (PET or CMR) biopsy and should be considered

Diagnosis of cardiac sarcoidosis



- Heart rhythm society guideline 2014



- Japanese Circulation Society Guideline for Diagnosis of Cardiac Sarcoidosis 2017

HRS 2014 Criteria for Diagnosis of cardiac sarcoidosis



Expert Consensus Recommendations on Criteria for the Diagnosis of CS

There are 2 pathways to a diagnosis of Cardiac Sarcoidosis:

1. Histological Diagnosis from Myocardial Tissue

CS is diagnosed in the presence of non-caseating granuloma on histological examination of myocardial tissue with no alternative cause identified (including negative organismal stains if applicable).

2. Clinical Diagnosis from Invasive and Non-Invasive Studies:

It is probable* that there is CS if:

a) There is a histological diagnosis of extra-cardiac sarcoidosis

and

b) One or more of following is present

- Steroid +/- immunosuppressant responsive cardiomyopathy or heart block
- Unexplained reduced LVEF (< 40%)
- Unexplained sustained (spontaneous or induced) VT
- Mobitz type II 2nd degree heart block or 3rd degree heart block



Clinical

- Patchy uptake on dedicated cardiac PET (in a pattern consistent with CS)
- Late Gadolinium Enhancement on CMR (in a pattern consistent with CS)
- Positive gallium uptake (in a pattern consistent with CS)



Cardiac imaging

and

c) Other causes for the cardiac manifestation(s) have been reasonably excluded

*In general, 'probable involvement' is considered adequate to establish a clinical diagnosis of CS.³³

Japanese Circulation Society Guideline for Diagnosis of Cardiac Sarcoidosis 2017



Cardiac involvement in sarcoidosis

Histological diagnosis (Positive EMB)

Clinical diagnosis

- Extracardiac sarcoidosis
- Two major criteria **OR**
- One major and two minor criteria

Isolated cardiac sarcoidosis

Histological diagnosis (Positive EMB)

Clinical diagnosis

- No extracardiac sarcoidosis
- ^{67}Ga citrate scintigraphy or ^{18}F -FDG PET with abnormal uptake **AND**
- 3 other major criteria

Major criteria

- High-grade AV block (complete AV block) or fatal ventricular arrhythmia (sustained VT/Vfib)
- Thinning of basal septum or abnormal LV anatomy (aneurysm, thinning of the mid or distal septum, regional thickening)
- LVEF <50%
- Abnormal ^{67}Ga citrate scintigraphy or ^{18}F -FDG PET
- Abnormal LGE CMR

Minor criteria

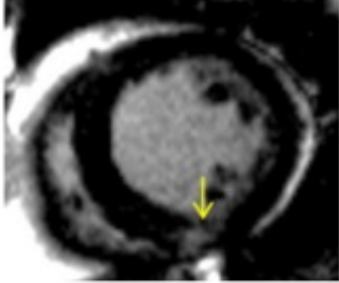

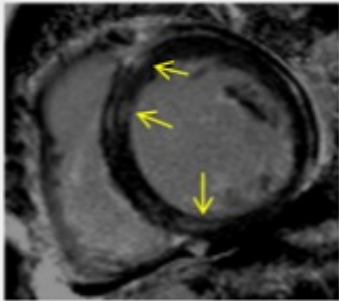

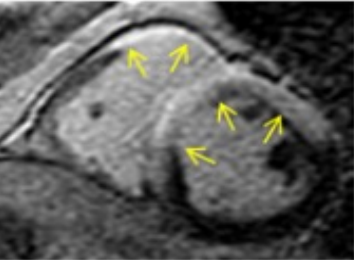

- Abnormal ECG: Ventricular arrhythmias (nonsustained VT, multifocal or frequent PVCs), bundle branch block, axis deviation, or abnormal Q waves
- Perfusion defects on SPECT
- Endomyocardial biopsy: Monocyte infiltration and moderate or severe myocardial fibrosis

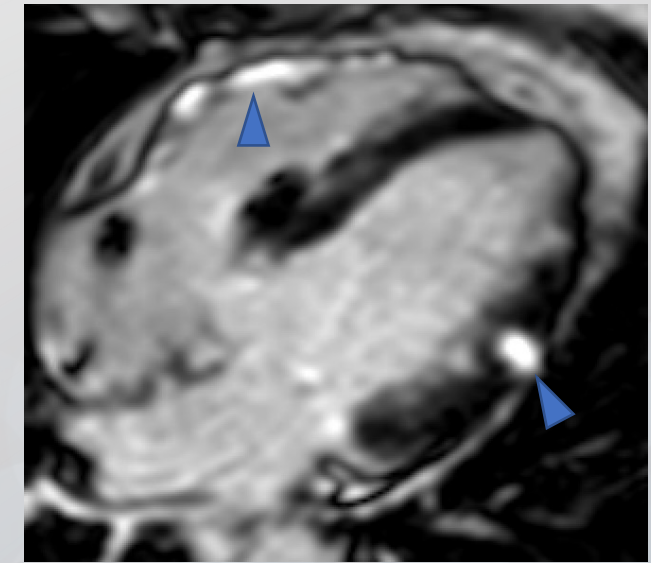
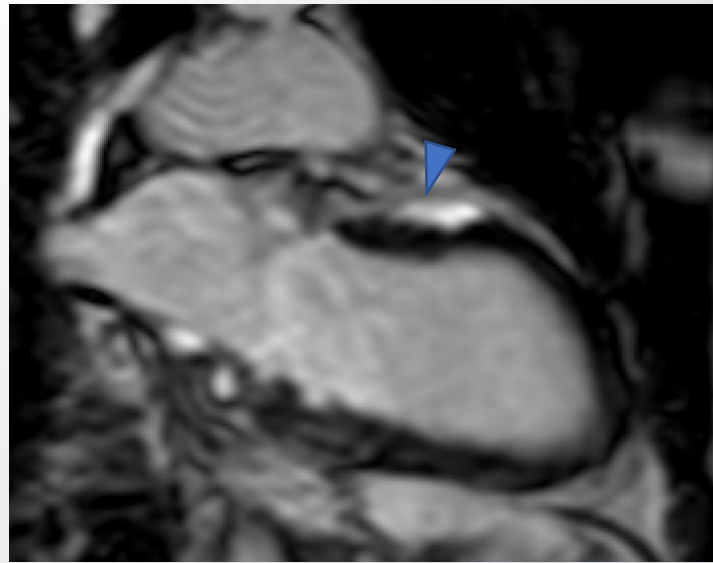
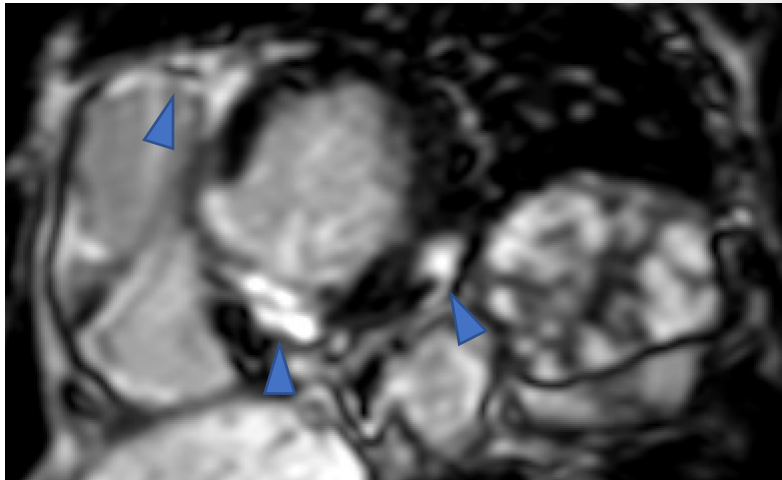
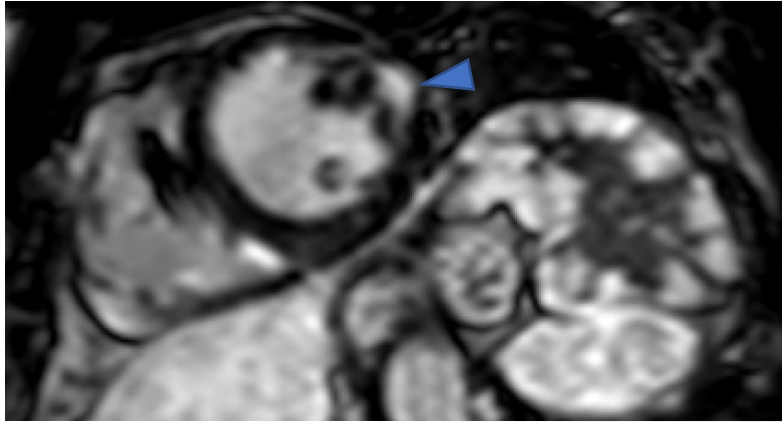
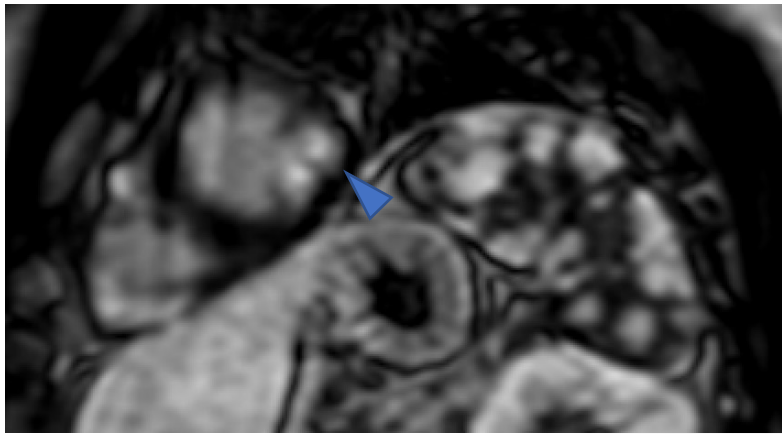
Outline

- Background
- Diagnosis of Cardiac Sarcoidosis
- **Advanced imaging for cardiac sarcoidosis**

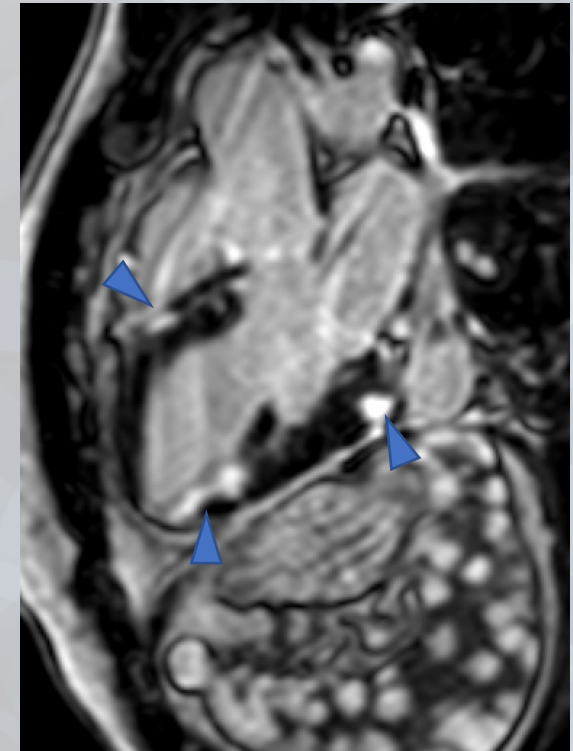
Cardiac MRI findings in Cardiac Sarcoidosis

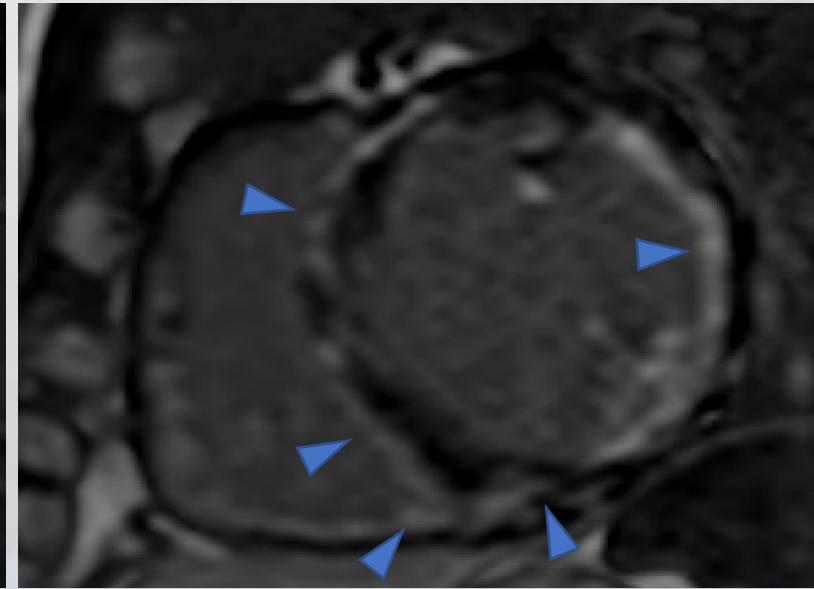
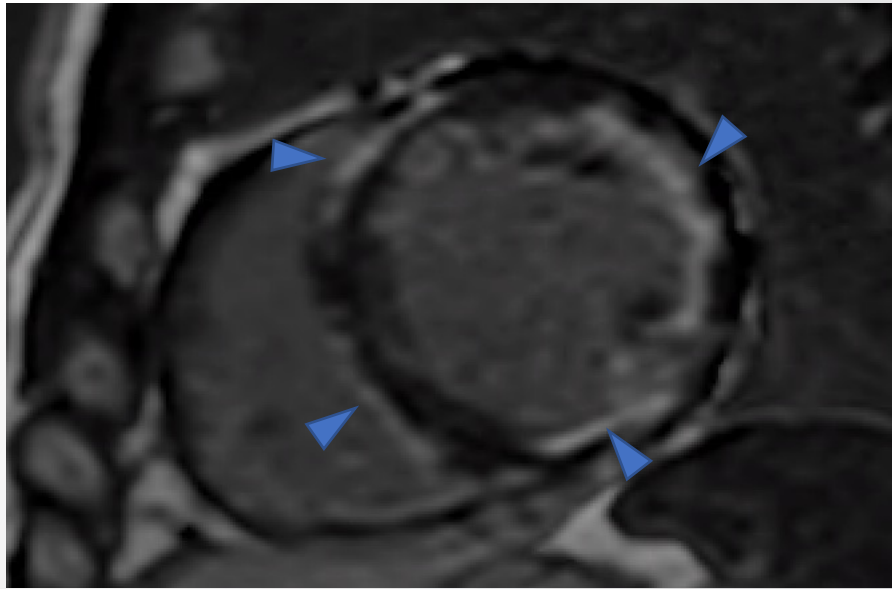
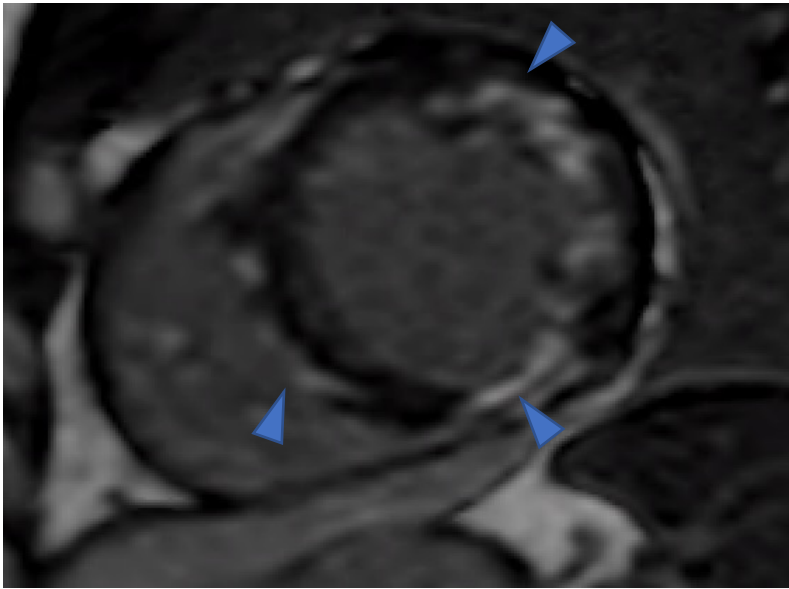
- Relying mainly on detection of late gadolinium enhancement
- The great masquerader – can be any patterns
- T2 images may have role

<p>- One focal areas of LGE but alternative diagnosis was more likely. (e. g. Pulmonary hypertension)</p>		
<p>- Multifocal LGE in a pattern that is likely consistent with CS but cannot rule out other diagnosis (e. g. myocarditis)</p>		
<p>- Multifocal LGE in a pattern strongly consistent with CS with no alternative diagnosis.</p> <p>- The following features were used to identify high likelihood:</p> <ul style="list-style-type: none">→ Intense signal of LGE.→ Prominent involvement of insertion points with direct and contiguous extension across the septum into RV. ("hook sign")		



- 60 M with PPM (unclear reason) presented with syncope.
- PPM interrogation demonstrated VT.
- No obstructive CAD from coronary angiogram
- Splenic biopsy consistent with sarcoidosis



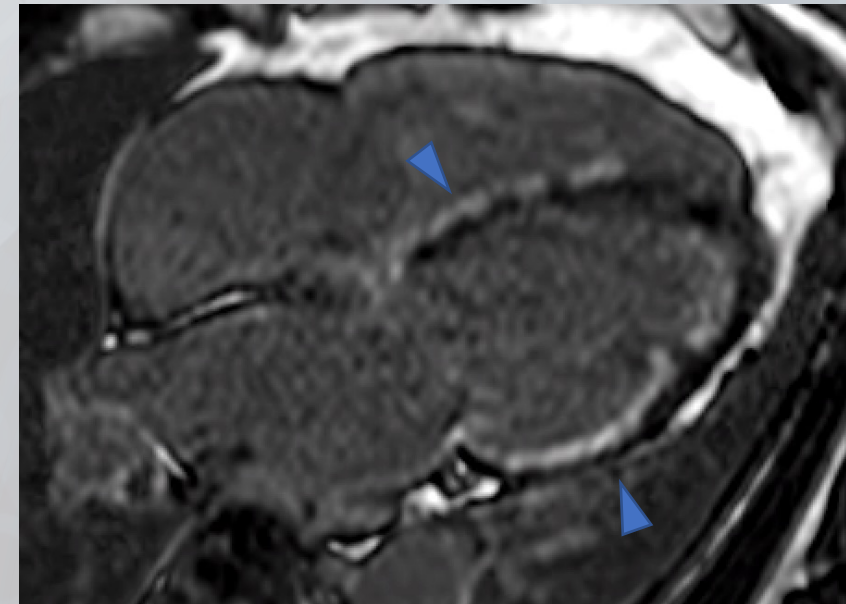


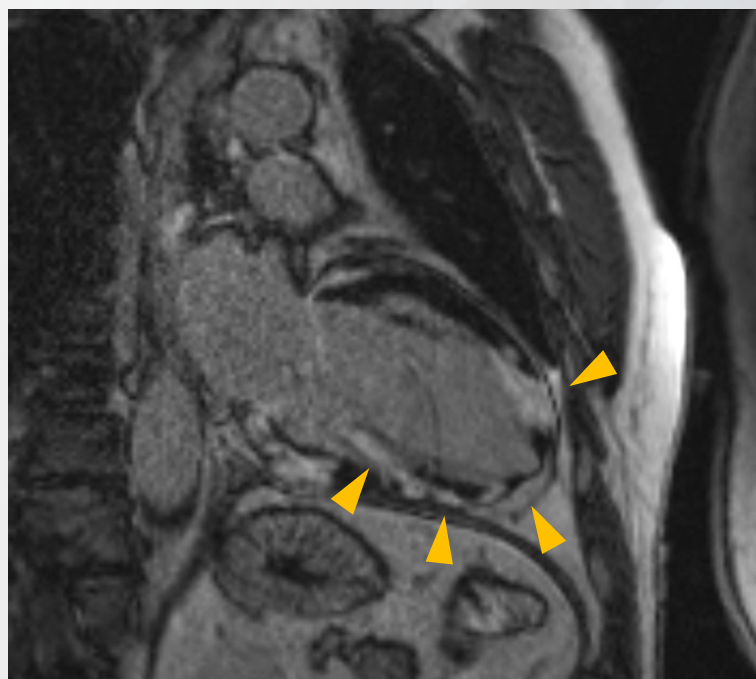
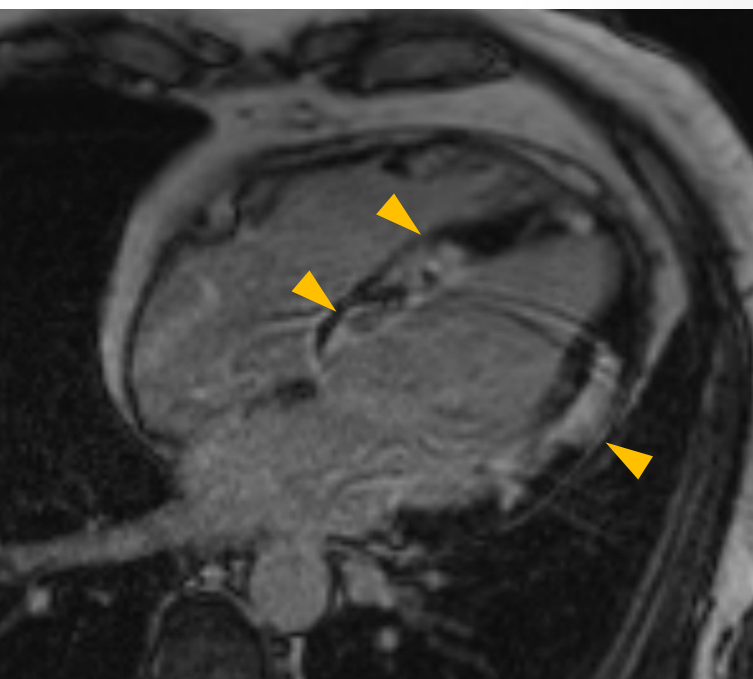
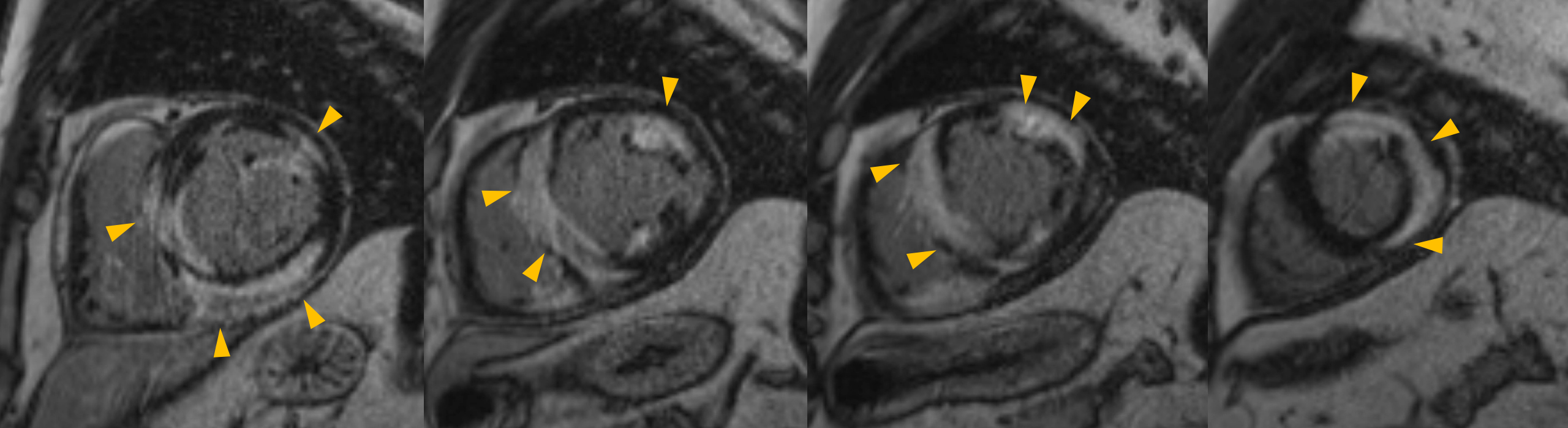
66 M with non-ischemic cardiomyopathy syncope and found to have VT

Repeat angiogram showed no significant CAD

Multifocal subendocardial and epicardial LGE extending to the RV

Endomyocardial biopsy consistent with cardiac sarcoidosis





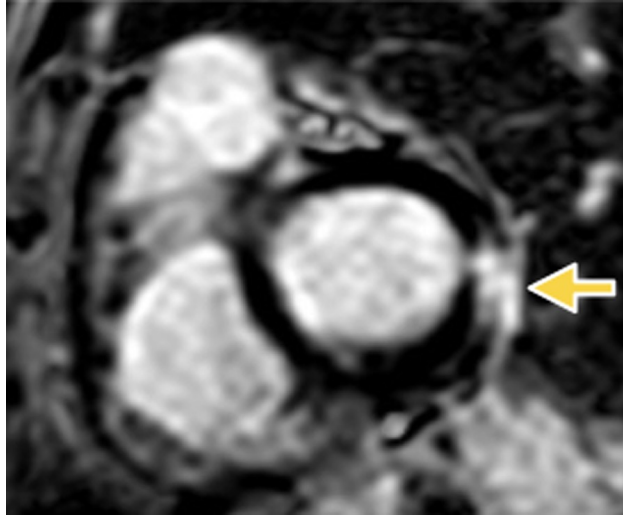
59 M with syncope and VT.

No obstructive CAD from coronary angiogram

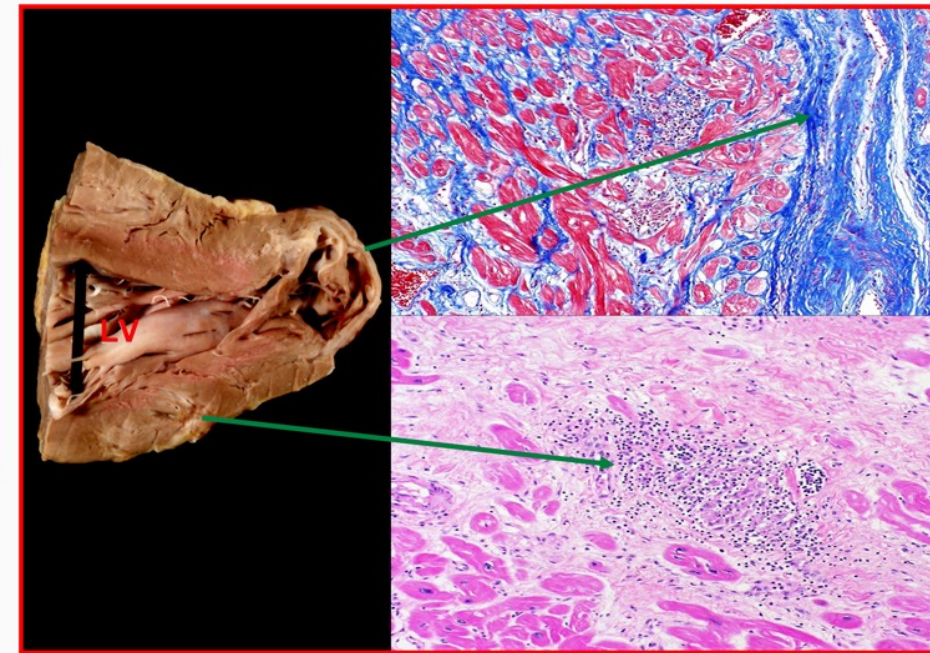
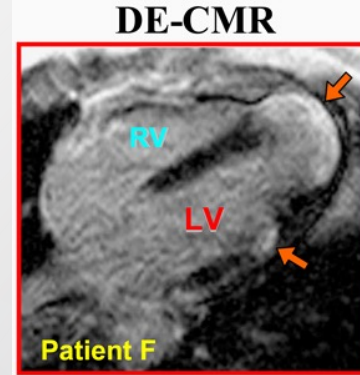
Multifocal epicardial LGE

Endomyocardial biopsy consistent with cardiac sarcoidosis

No specific LGE pattern for sarcoidosis

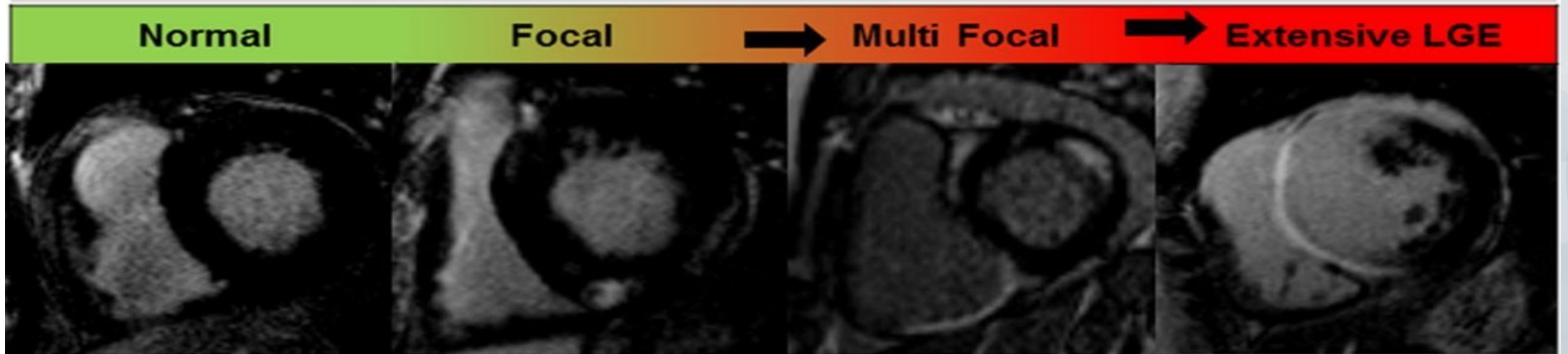


Patel, AR et al. Journal of the American Heart Association. 2019;8:e012715



Patel MR, et al. Circulation. 2009 Nov 17; 120(20): 1969–1977.

Spectrum of Late Gadolinium Enhancement

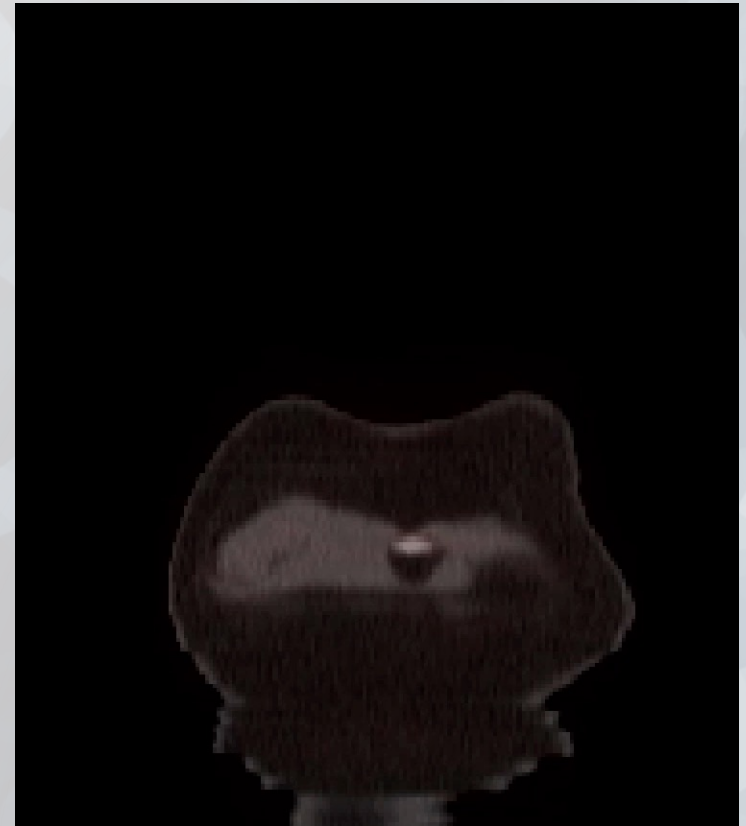


Blankstein, R et al. Circulation: Cardiovascular Imaging. 2016;9

Cardiac PET FDG for Cardiac sarcoidosis

Roles of PET FDG

- Diagnosis of cardiac sarcoidosis
- Follow response to treatment
- Detection of extracardiac sarcoidosis

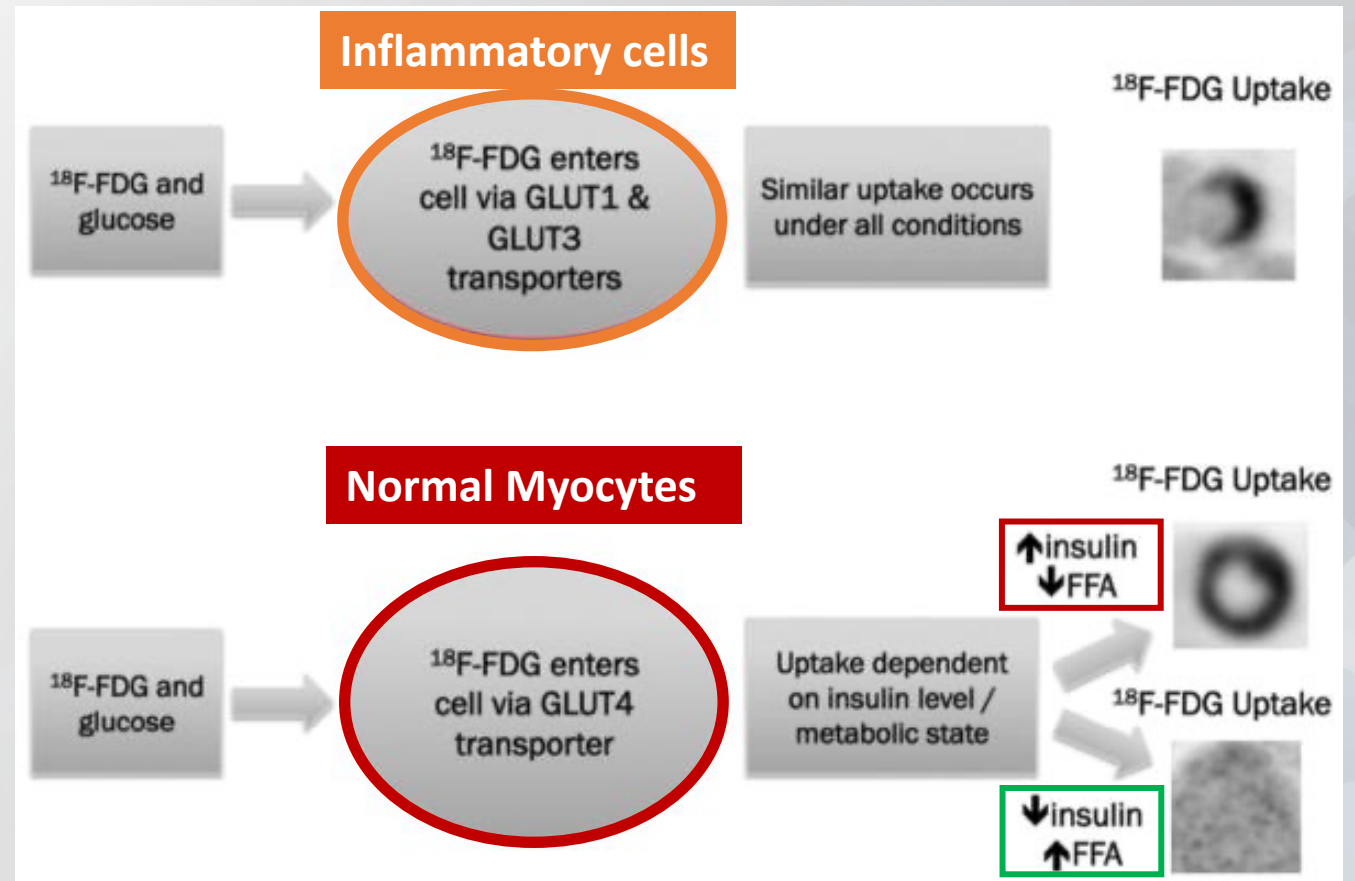


Cardiac PET FDG for Cardiac sarcoidosis

- The ability of ^{18}F -FDG to image inflammation in sarcoidosis is due to the increased uptake of ^{18}F -FDG in macrophage-dense regions
- Macrophages have high metabolic activity and are more reliant than normal cells on external glucose as an energy source
- Heart uses a mixture of free fatty acids and glucose for energy production under normal resting conditions

Cardiac PET FDG for Cardiac sarcoidosis

- **Imaging goal:**
 - Suppress normal myocardium from FDG uptake
 - Allow only inflammatory cells to uptake FDG
- Can be achieved with Pt preparation that change metabolic environment



How to prep the patient?

The SNMMI/ASNC 2017 expert panel recommendation

- The preferred rec: At least **TWO** high-fat (>35 g), low-carbohydrate (<3 g) meals the day prior to the study and then fasting for 4–12 h.
- An alternative regimen is for the patient to fast for >18 h prior to the study
- Adjunctive heparin: 50 IU/kg intravenous bolus of UFH approximately 15 min before ¹⁸F-FDG administration -- conflicting data

Our experience at the Weatherhead PET Center

- Pre-scan diet modification provide better success and is critical
- Start high fat, low carbohydrate diet **48 hours** before scan.
- Specific detailed information need to be given to patient



Weatherhead PET Center
for Preventing and Reversing Atherosclerosis



DIETARY PREPARATION FOR FDG PET IMAGING TO ASSESS MYOCARDIAL INFLAMMATION

Consuming a high fat, very low carbohydrate, diet prior to your PET scan is a **CRITICAL STEP** and significantly increases accuracy of test.

PLEASE READ AND FOLLOW INSTRUCTIONS CAREFULLY. YOU WILL HAVE TO RESCHEDULE OR REPEAT THE PET SCAN AT YOUR OWN COST IF THE DIET WAS NOT FOLLOWED COMPLETELY.

NO EXERCISE on the day prior to your PET scan

For **48 HOURS** before your Sarcoid PET Scan, absolutely **NO** caffeine or sugar or carbohydrates. **NO** desserts (not even desserts labeled sugar free). **NO** milk, coffee, tea, chocolate or any caffeinated beverages (including Sprite or root beer).

START the Sarcoid prep diet **48 HOURS** before your Sarcoid PET scan.

NO food after 7:30pm the night before your appointment. Please only drink water (no other beverages).

HIGH FAT, LOW CARBOHYDRATE DIET SAMPLE MENU (35g fat or more)

BREAKFAST:

- 3 Scrambled eggs (15g fat) cooked in oil or butter
- **AND** 4 slices of bacon (Ex. Applegate Farms no sugar added or similar brand with no sugar (10g fat))
- **AND** 2 oz full fat cheddar cheese (19g fat)

LUNCH:

- 4oz ground chuck beef 80/20 (20g fat) cooked in oil
- **OR** 4 oz dark meat chicken with skin (18g fat) cooked in oil or butter (no breading or batter or flour coating)
- **OR** 4 oz farm raised salmon (14g fat) cooked with oil or butter
- **AND** ½ avocado (10g fat)
- **AND** 1 egg (5g fat) cooked in oil or butter

DINNER:

- 4 oz ribeye steak (20g fat) cooked with oil or butter
- **OR** 4oz ground chuck beef 80/20 (20g fat) cooked in oil
- **OR** 4 oz dark meat chicken with skin (18g fat) cooked in oil or butter (no breading or batter or flour coating)
- **OR** 4 oz farm raised salmon (14g fat) cooked with oil or butter
- **AND** ½ avocado (10g fat)
- **AND** 1 egg (5g fat) cooked in oil or butter

Fry or broil your meat. Do not grill. Do not bread or batter or coat with flour or any other type of coating

CALL OUR OFFICE (713-500-6611 OPTION 3) IF YOU HAVE ANY QUESTIONS BEFORE STARTING YOUR 2-DAY DIET

Our experience at the Weatherhead PET Center

Specific
Detailed
information to
patients help!



YOU CAN EAT/DRINK THE FOLLOWING:

Protein Sources:

- Beef
- Veal
- Lamb
- Pork
- Turkey, with skin
- Chicken, with skin
- Duck, with skin
- Goose, with skin
- Hen, with skin
- Quail, with skin
- Organ Meats (brain, tongue, liver, heart kidneys)
- Cod
- Calamari, not breaded
- Flounder
- Sole
- Haddock
- Halibut
- Sardines, packed in oil
- Swordfish
- Tuna, steak or canned packed in oil
- Trout
- Tilapia
- Salmon
- Catfish
- Bass
- Shrimp

Dairy:

- Cheese (less than 2oz per day)
- Eggs

Seasonings:

- Salt and Pepper
- Vinegar
- Ground Cinnamon
- Yellow Mustard
- Dill weed
- Chives

Oils and Fats:

- Olive oil
- Coconut oil
- Cornflower oil
- Corn oil
- Soybean oil
- Canola oil
- Peanut oil
- Sesame oil
- Avocado oil
- Grapeseed oil
- Soybean oil
- Safflower oil
- Sunflower oil
- Fish oil
- Animal Fat (including lard)
- Vegetable shortening
- Butter

Nuts:

- Pecans
- Walnuts
- Macadamia
- Brazil

Vegetables:

1/2c or less allowed of the following:

- Spinach
- Parsley
- Avocado
- Radish
- Arugula
- Brussel Sprouts
- Kale
- Bok Choy
- Celery

1/4c or less allowed of the following:

- Mushrooms
- Garlic (1/2 clove)
- Cabbage
- Asparagus
- Yellow Squash
- Zucchini
- Cauliflower
- Broccoli
- Cucumber

Beverages:

- Water
- Sparkling water
- Seltzer water

Fry or broil your meat. Do not grill. Do not bread or batter or coat with flour or any other type of coating

CALL OUR OFFICE (713-500-6611 OPTION 3) IF YOU HAVE ANY QUESTIONS BEFORE STARTING YOUR 2-DAY DIET

DO NOT EAT/DRINK THE FOLLOWING:

Many processed products contain hidden sugar!

NO fruits NO sugar or any food containing sugar:

- Honey
- Syrup
- Jam/preserves
- Mayonnaise/Miracle Whip
- Commercial salad dressings (e.g. Ranch, Thousand Islands)
- BBQ sauce
- Steak sauce
- Beer nuts
- Candy/mints
- Chewing gum
- Cough drops
- Ketchup
- Mustard
- Relish
- Molasses
- Peanut butter
- Nut butter
- Nutella

NO root or starchy vegetables:

- Carrots
- Turnips
- Parsnips
- Potatoes
- Beets
- Corn
- Sweet potatoes
- Acorn squash
- Green peas
- Yams
- Butternut squash

NO grains or starches:

- Wheat
- Rye
- Oats
- Barley
- Rice
- Pasta
- Quinoa
- Buckwheat
- Bread
- Bagels
- Buns
- Cereals
- Granola bars
- Cakes
- Cookies
- Muffins

NO beans or legumes:

- Black beans
- Chick peas
- Baked beans
- Peanuts
- Kidney beans
- Split peas
- Lentils

NO dairy products (Cheese is ok if less than 2oz):

- Milk
- Yogurt
- Frozen yogurt
- Pudding
- Yogurt drinks
- Ice cream

NO beverages containing sugar or Aspartame or alcohol or caffeine:

- Coffee
- Tea
- Soda
- Beverages containing chocolate
- Soft drinks
- Flavored water
- Juices
- Fruit drinks (e.g. Kool-Aid, Tang)
- Sports drinks (e.g. Gatorade)
- Non-alcoholic beer
- Beer
- Wine
- Spirits

NO processed meats:

- Deli meat
- Hot dog
- Breaded or battered meat/poultry/fish

Fry or broil your meat. Do not grill. Do not bread or batter or coat with flour or any other type of coating

CALL OUR OFFICE (713-500-6611 OPTION 3) IF YOU HAVE ANY QUESTIONS BEFORE STARTING YOUR 2-DAY DIET

Our experience at the Weatherhead PET Center

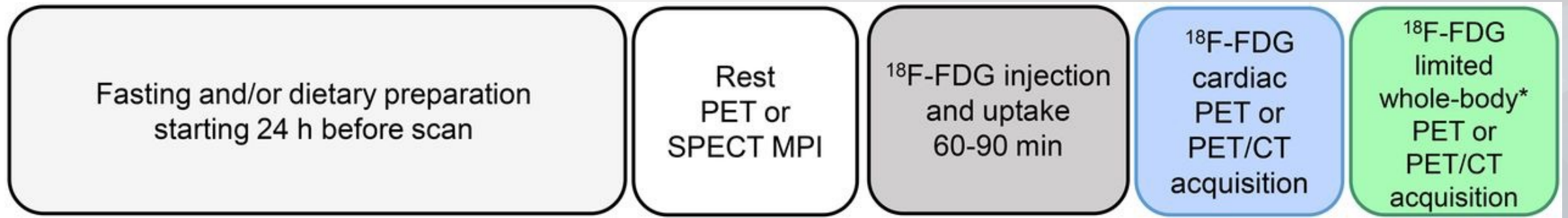
- Write down what they eat
- Staff member to call patient prior to diet prep start to go over details
- If non-compliant to preparation, patient will be rescheduled

NOTES
<i>A staff member will call you 3-4 days before your scheduled appointment to review the diet instructions. If you have questions before then, please feel free to call 713-500-6611 option 3</i>

Fry or broil your meat. Do not grill. Do not bread or batter or coat with flour or any other type of coating

CALL OUR OFFICE (713-500-6611 OPTION 3) IF YOU HAVE ANY QUESTIONS BEFORE STARTING YOUR 2-DAY DIET

Cardiac PET Protocol for Cardiac Sarcoidosis







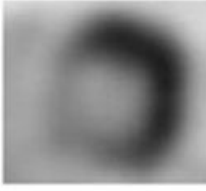







Resting myocardial perfusion – PET or SPECT MPI: Gated images -- LVEF, Wall motion abnormalities

Stress myocardial perfusion (optional): Pts with no prior CAD evaluation

Cardiac PET FDG images



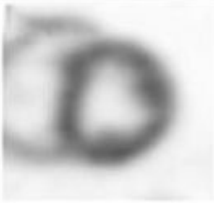

Whole body PET FDG (optional)

Patterns of myocardial perfusion and FDG

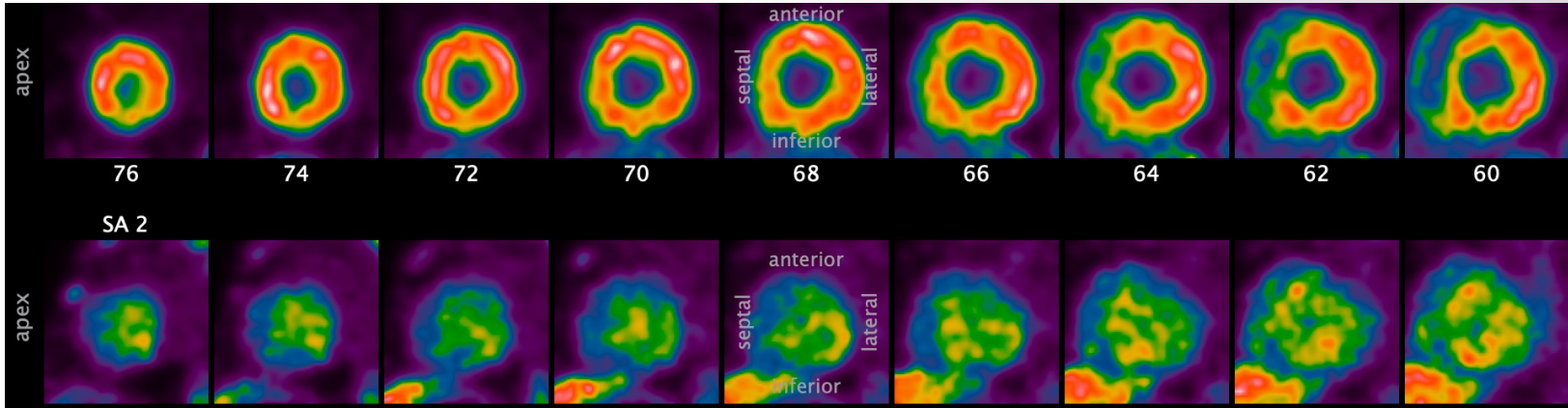
Spectrum of disease by PET/CT to evaluate rest perfusion and metabolism						
	Normal perfusion and metabolism		Abnormal metabolism		Abnormal perfusion and/or metabolism	
Perfusion						
	Normal	Normal	Normal	Abnormal	Abnormal	Abnormal
FDG						
	Normal (Negative)	Diffuse (non-specific)	Focal increase	Focal increase	Focal increase (different areas)	Normal (Negative)
Interpretation	Normal	Non-specific*	Early Disease	Mismatch Pattern	Scar and Inflammation	Scar

Patterns of myocardial perfusion and FDG

Normal perfusion but with FDG uptake

Perfusion		
	Normal	Normal
FDG		
	Diffuse (non-specific)	Focal increase
	Non-specific*	Early Disease

Normal perfusion but with FDG uptake

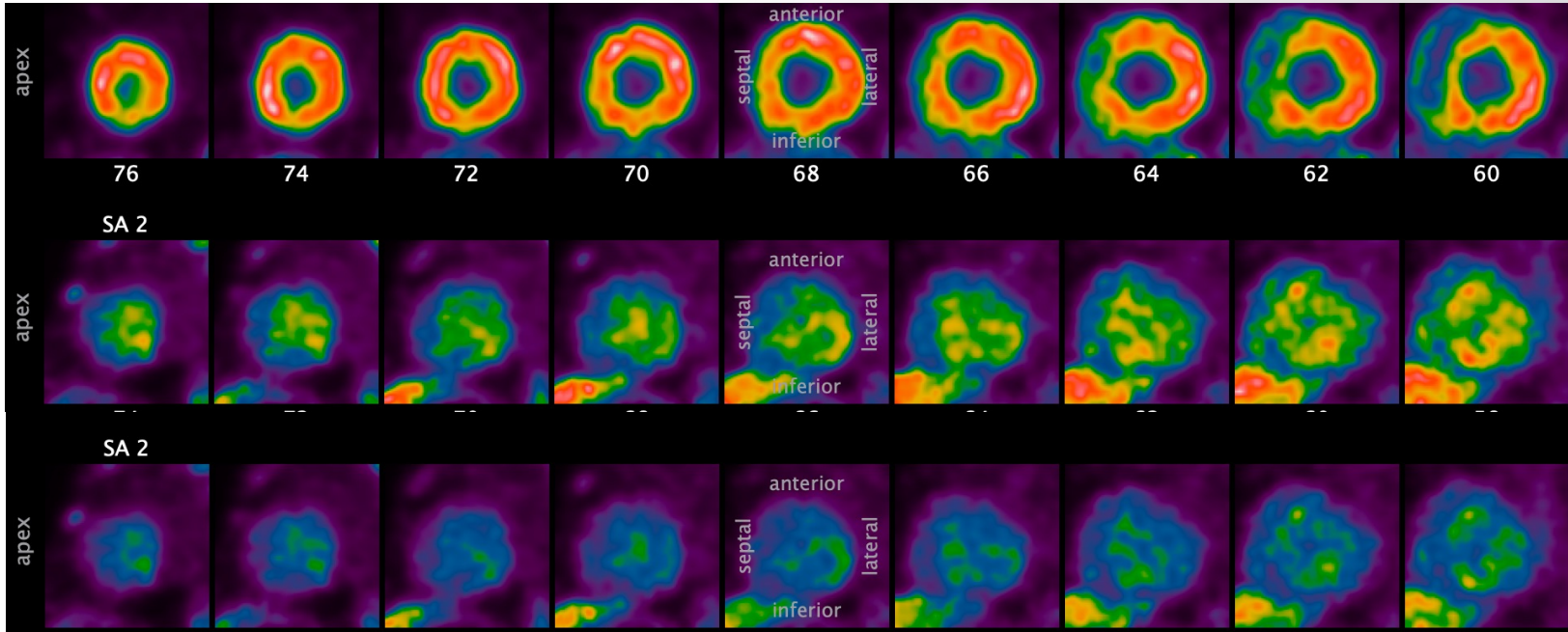


Perfusion

FDG – traditional cardiac display
(normalized to max counts of cardiac
images)

- 45 F with no history of sarcoidosis
- Palpitation with frequent premature ventricular complex

Normal perfusion but with FDG uptake



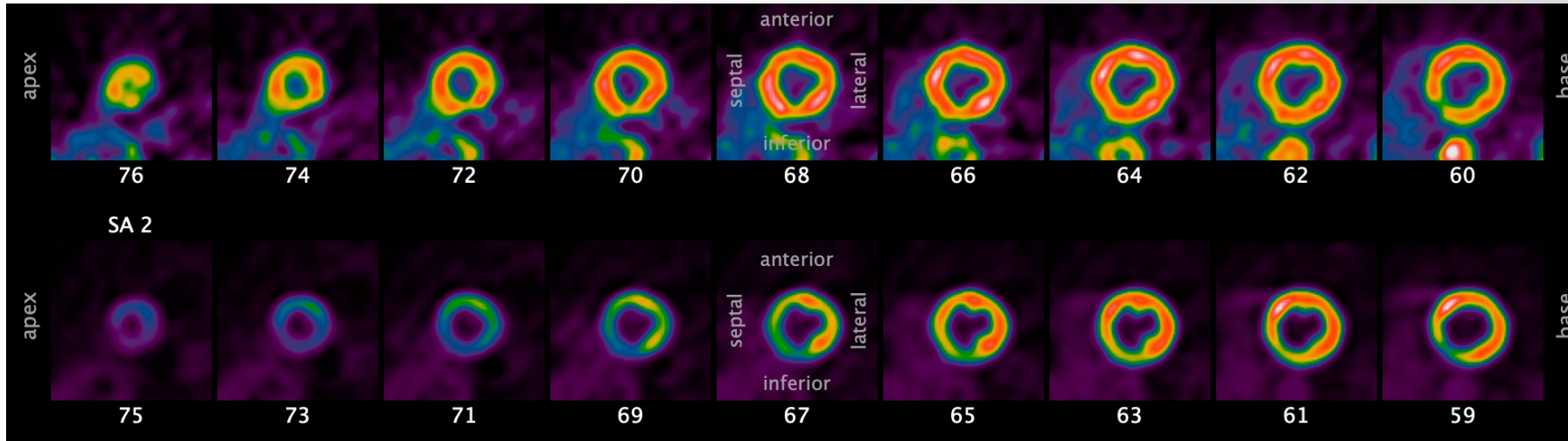
Perfusion

FDG – traditional cardiac display
(normalized to max counts of cardiac
images)

FDG – general nuclear medicine
display (normalized to max counts
outside of the cardiac images)

- The traditional cardiac display can lead to artifactual accentuation of mild ^{18}F -FDG uptake
- ***Always confirmed on the general nuclear medicine display***

Normal perfusion but with FDG uptake

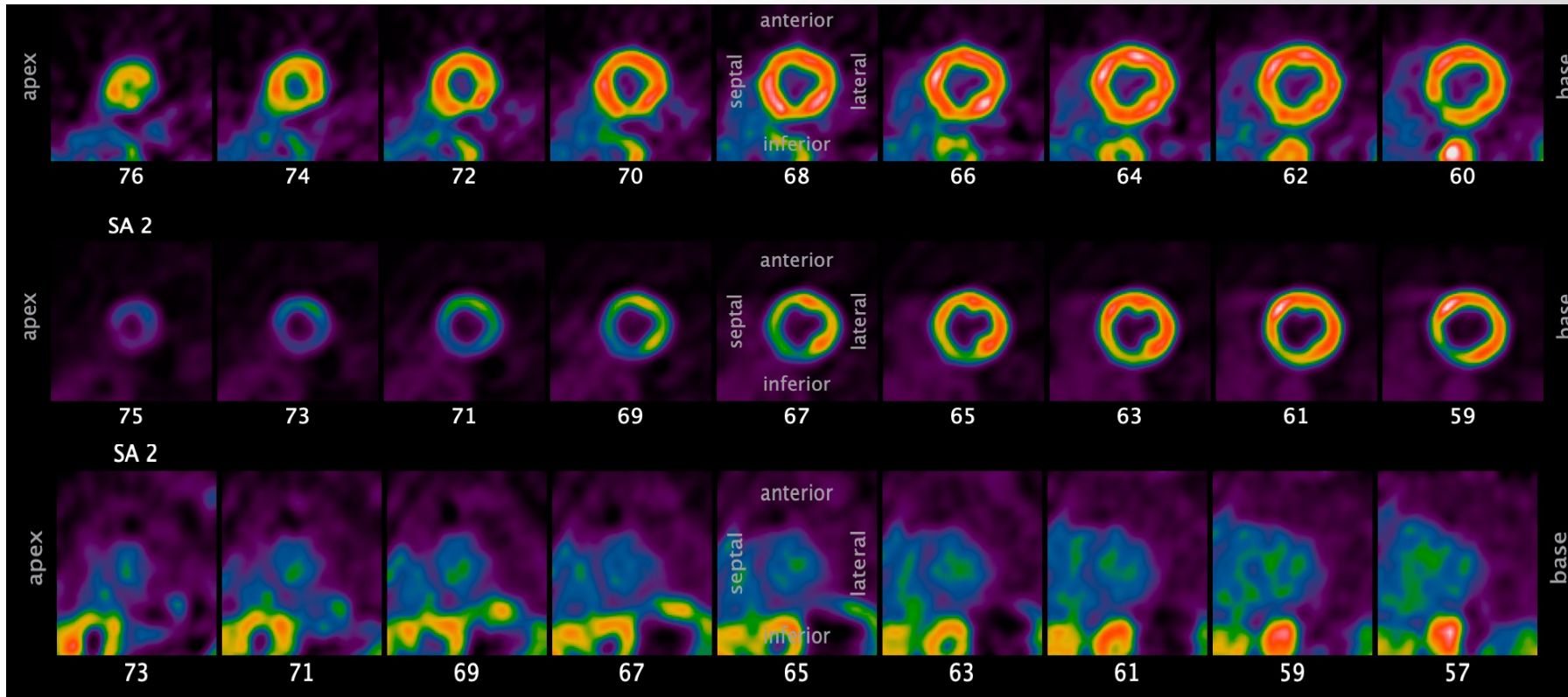


Perfusion

FDG

- 52 F with right bundle branch block and PVCs
- Admit non-compliant to diet preparation
- Diffuse FDG uptake without perfusion defect

Normal perfusion but with FDG uptake



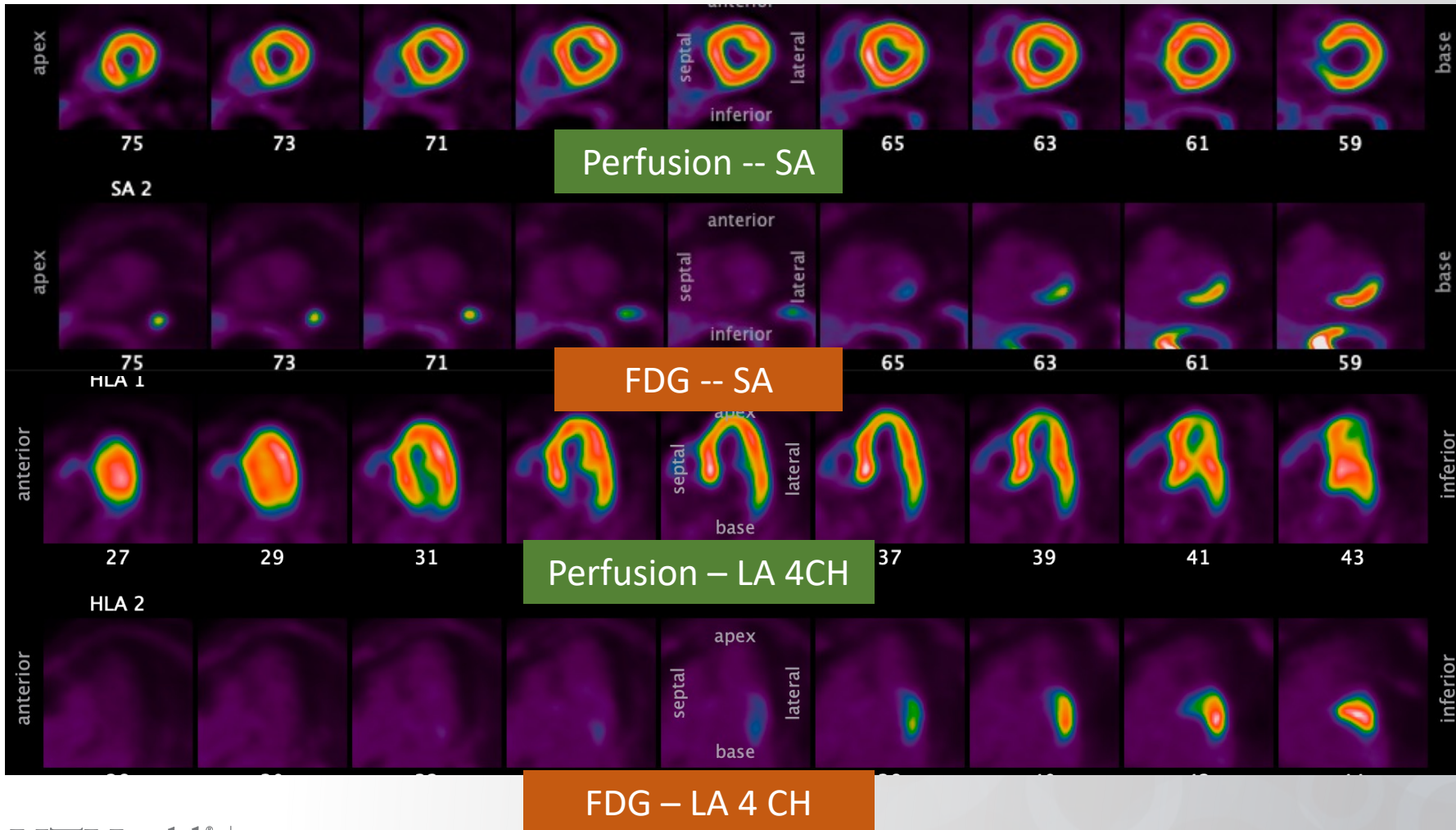
Perfusion

FDG – Diet non-compliant

FDG – Complete diet prep

- ***Diffuse FDG uptake without perfusion defect pattern
Most likely due to incomplete suppression of normal myocardium***

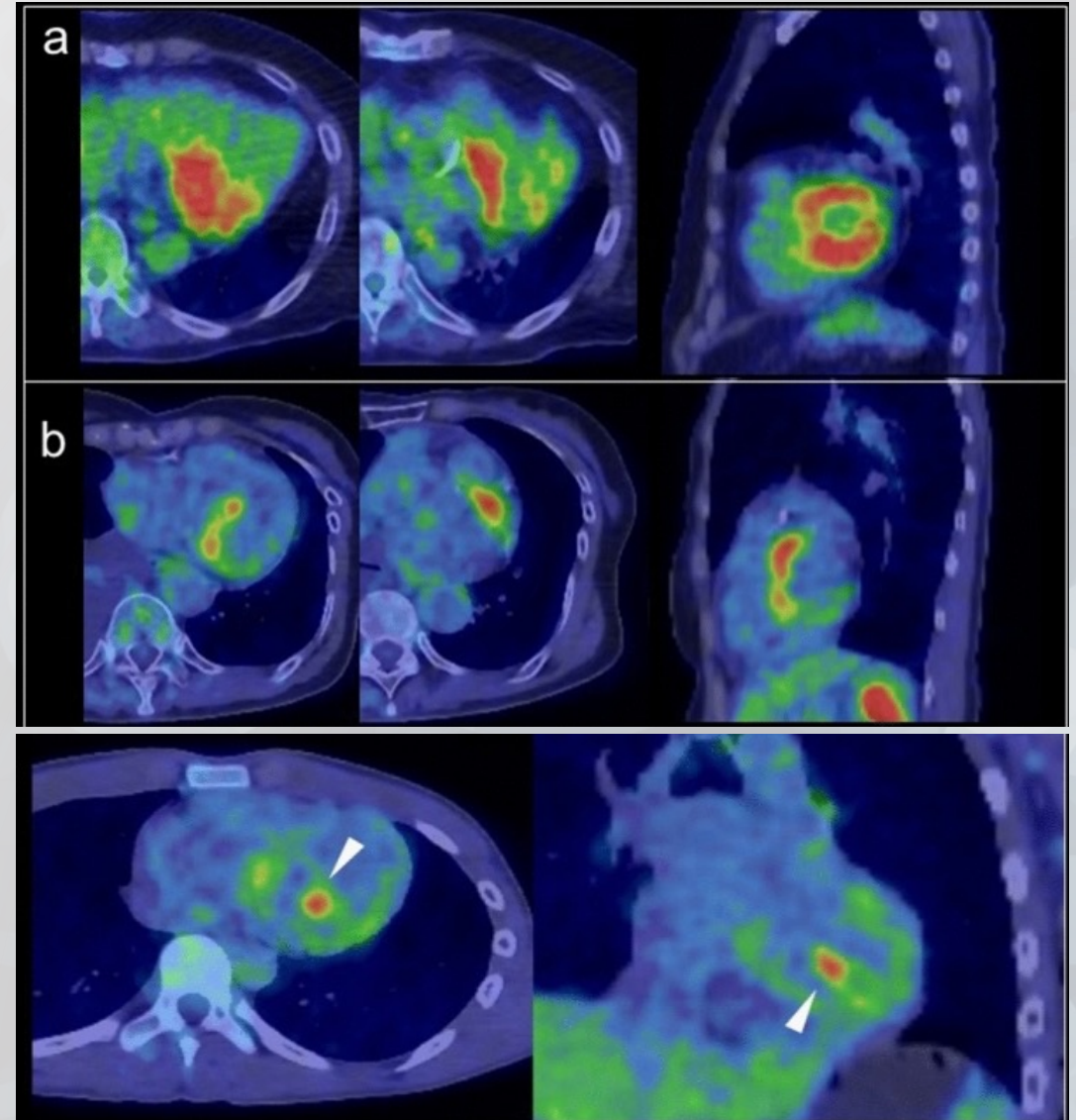
Normal perfusion but with FDG uptake



- 65 M with dizziness, found to have PVCs
- No prior history of sarcoidosis
- Isolated focal lateral wall FDG uptake without perfusion defect
- ***“Focal and homogeneous FDG uptake along the lateral wall without a perfusion defect is often a nonspecific finding”***

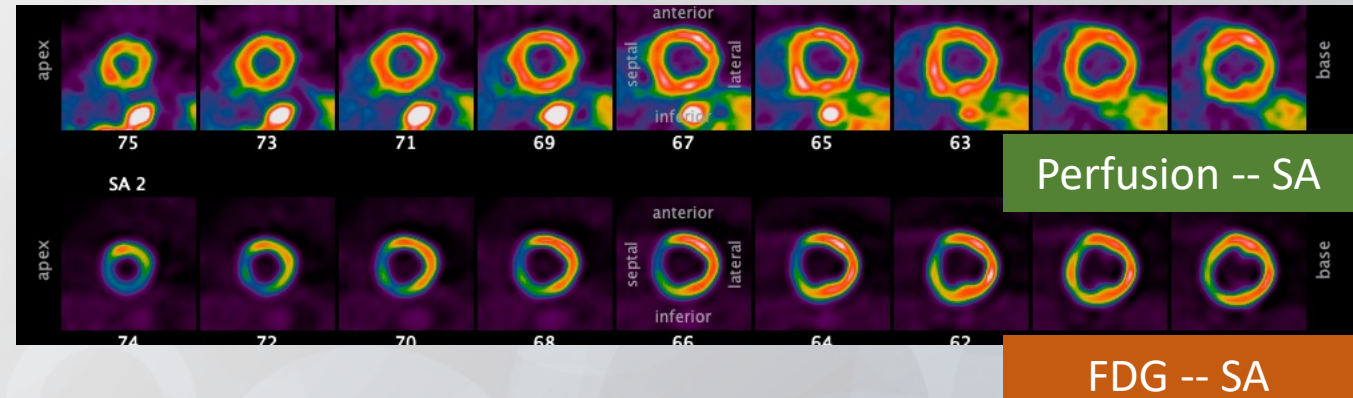
Physiology cardiac FDG uptake

- FDG uptake in the basal segments occurring as ring pattern (A), over-half-ring pattern (B), and focal in diffuse FDG uptake.
- Isolated papillary muscle FDG uptake can be physiologic
- May be higher wall stress at these region compared to other segments thus increased metabolic demand



Normal perfusion but with FDG uptake

- 58 F with pulmonary sarcoidosis
- Palpitation and frequent PVCs and non-sustained VT
- DIFFUSE FDG UPTAKE DUE TO INCOMPLETE SUPPRESSION
- Repeat PET scan



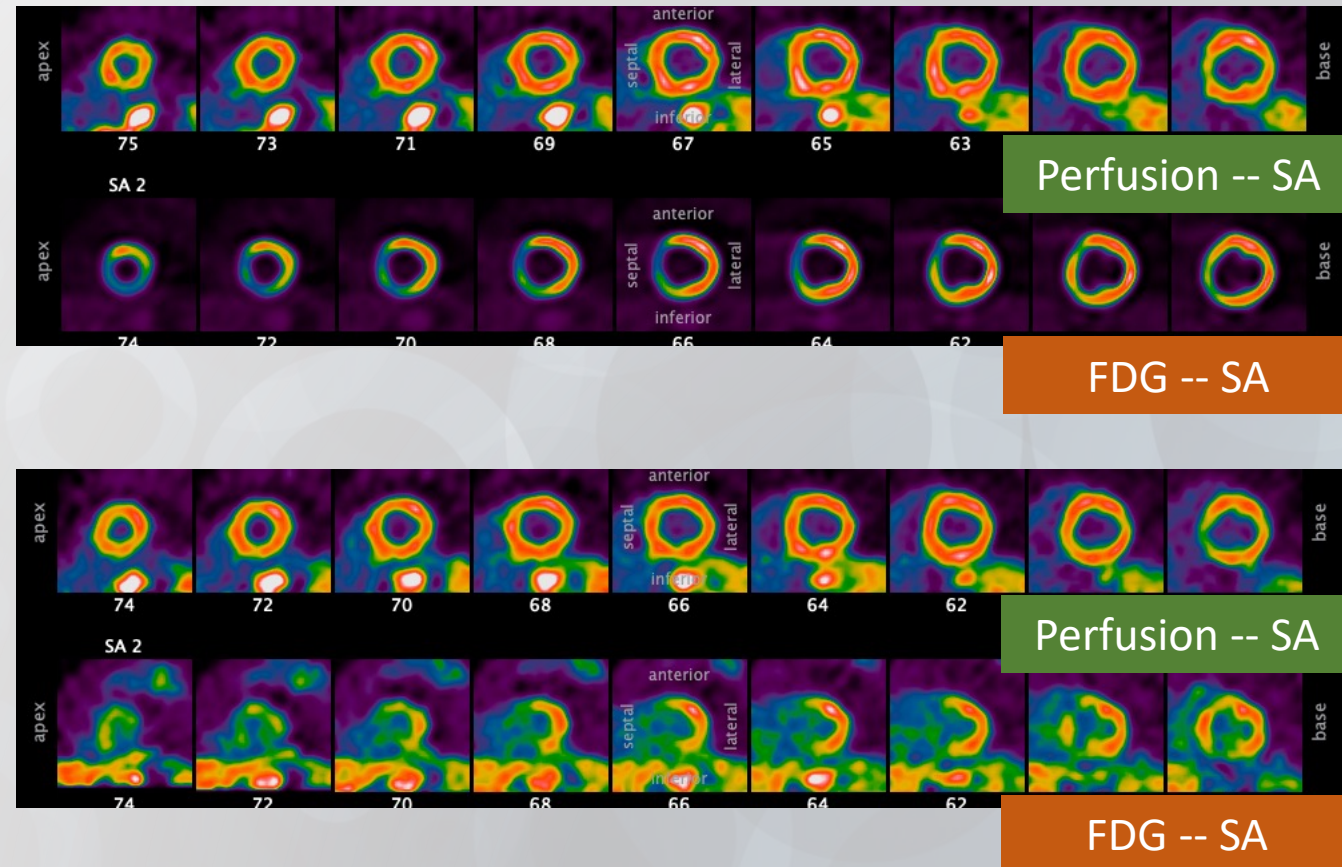
Normal perfusion but with FDG uptake

- 58 F with pulmonary sarcoidosis
- Palpitation and frequent PVCs and non-sustained VT
- DIFFUSE FDG UPTAKE DUE TO INCOMPLETE SUPPRESSION

Repeat PET scan after longer diet prep

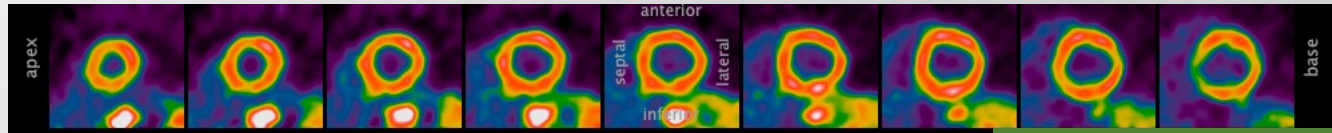


- Multifocal FDG uptake at the basal to mid lateral and septal wall without perfusion defect
- FDG uptake at the perihilar and mediastinal LN
- With ongoing symptoms, decision to start treatment with prednisone



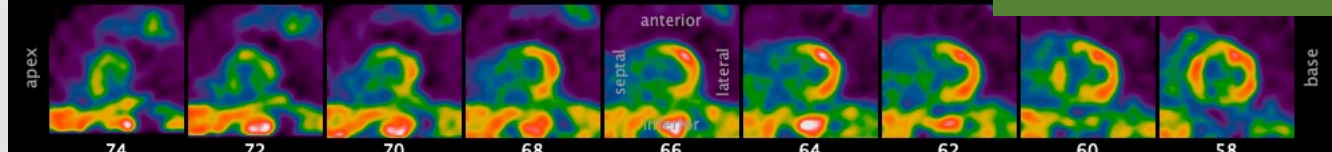
Normal perfusion but with FDG uptake

Cardiac PET prior to treatment



6 Months after Rx

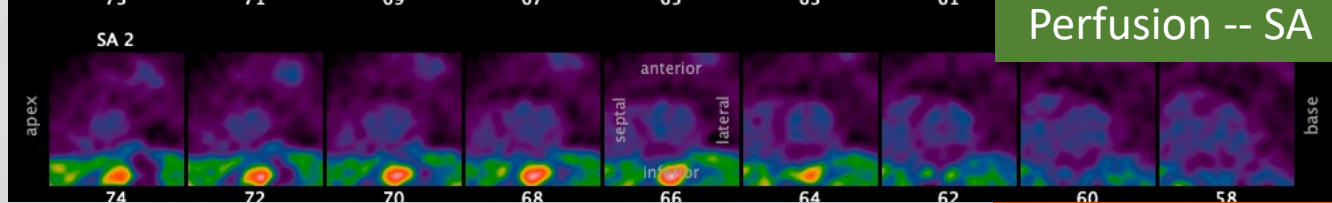
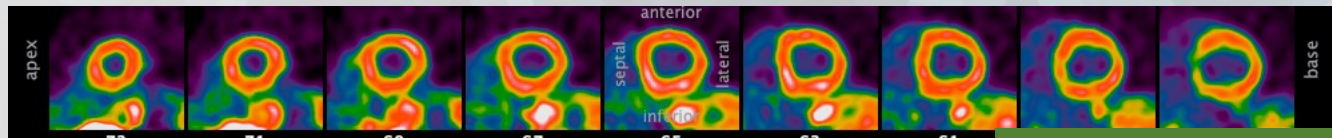
- Clinically improving, PVCs burden has significantly decreased.



Repeat PET



- No FDG uptake



Normal perfusion but with FDG uptake

Most recent cardiac PET -- Asymptomatic



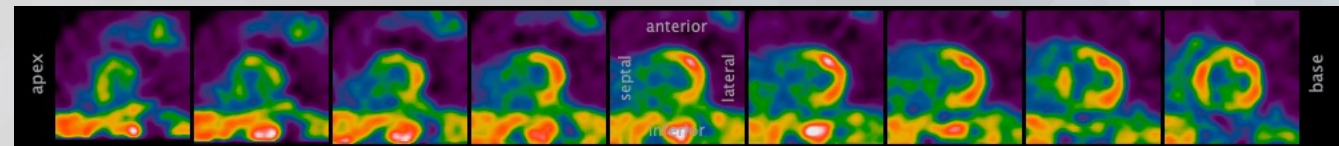
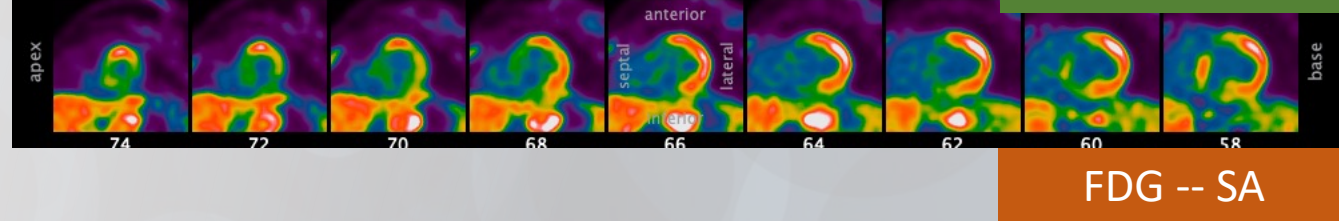
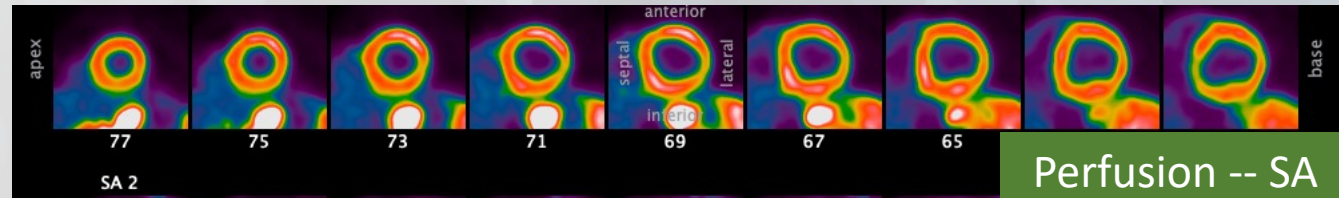
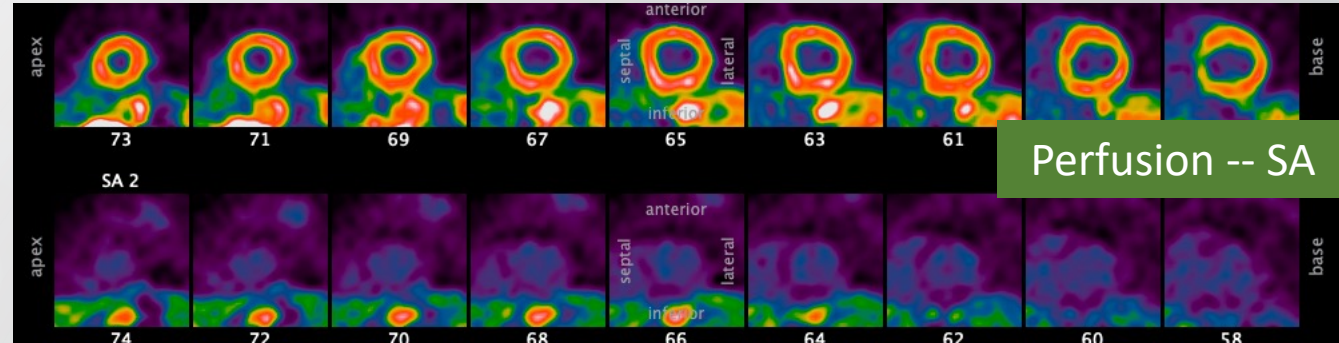
~18 Months later

- PVCs recurred more often after being off sarcoid treatment.

Repeat PET



- Similar pattern of FDG uptake to prior to treatment—multifocal at lateral wall and septum with additional apical anterior wall uptake.
- Treatment restarted.

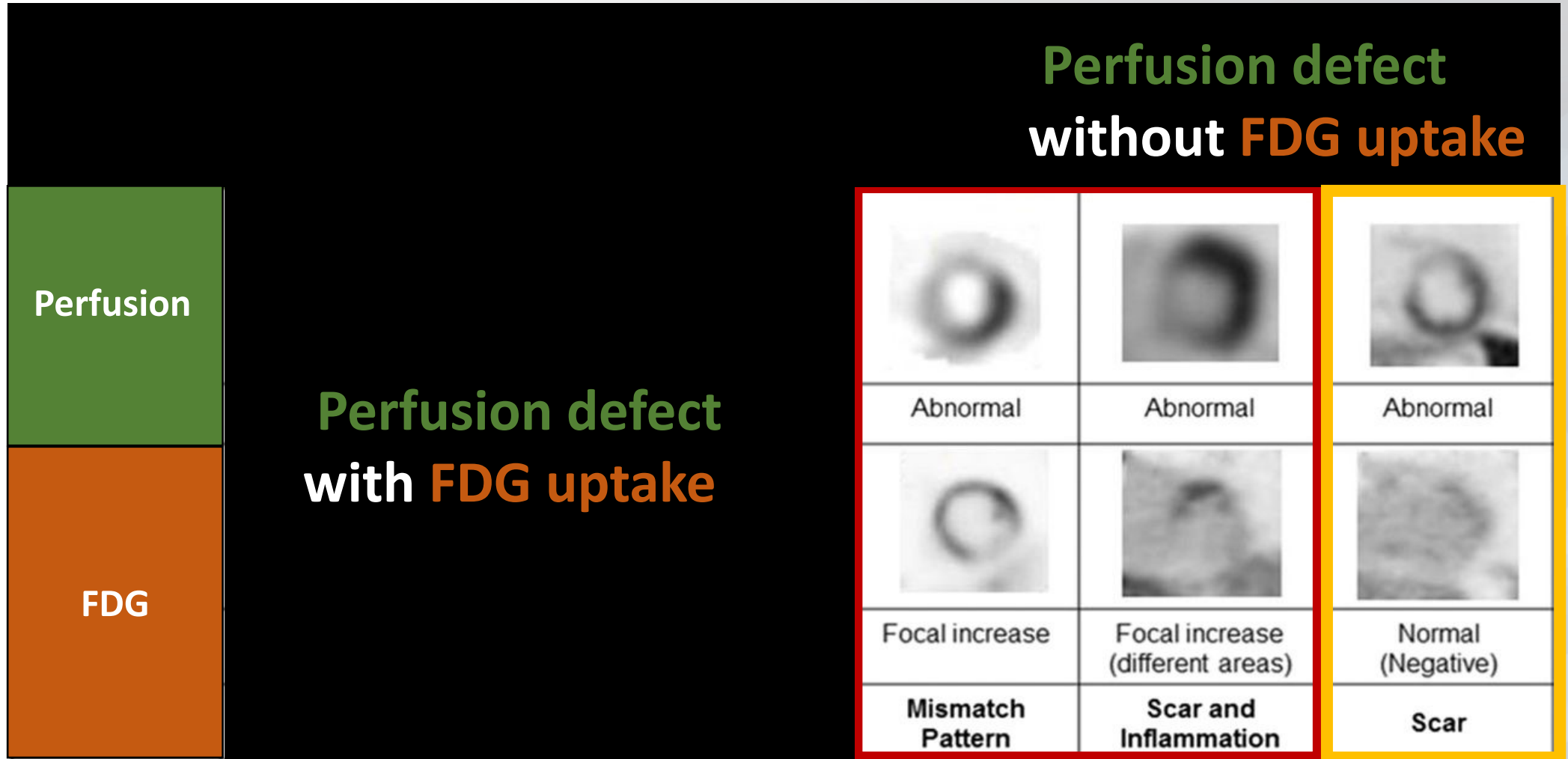


FDG PET Prior to Rx 2 year ago for comparison

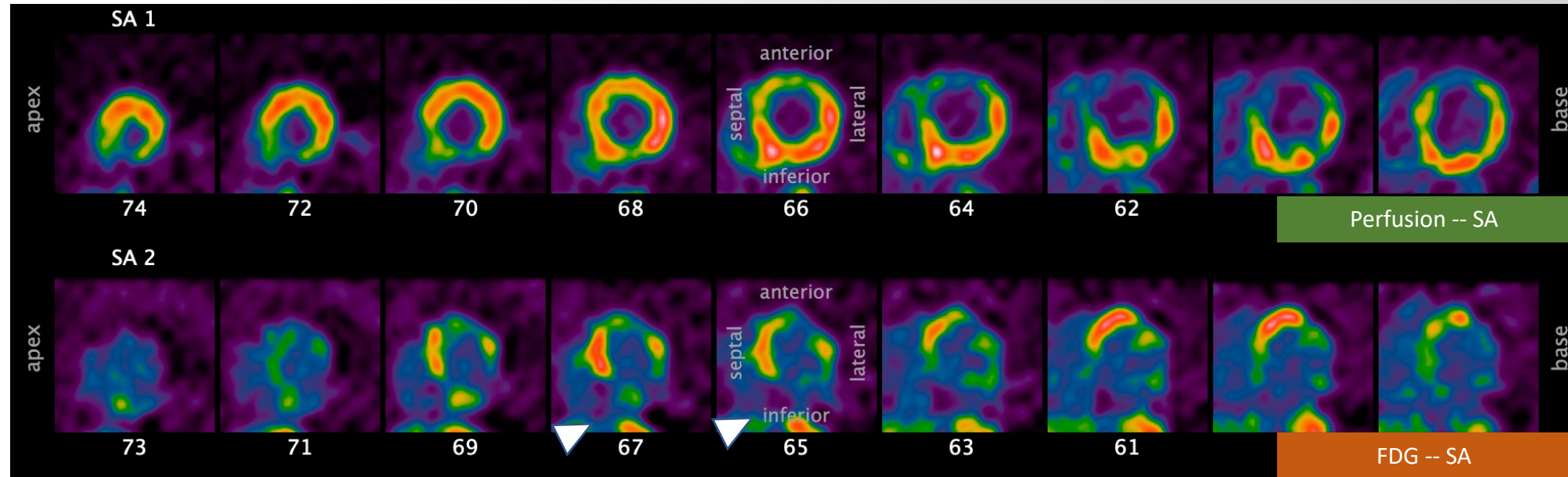
Normal perfusion but with FDG uptake

- Incomplete suppression from suboptimal preparation
- If positive on Cardiac display, always check on general nuclear reading display to confirm
- Can it be physiologic uptake?
 - Focal lateral wall
 - Basal ring pattern
 - Isolated papillary muscle uptake
- Early cardiac sarcoidosis?
 - Consider cardiac MRI – LGE at the same location is helpful
 - Repeat PET scan

Patterns of myocardial perfusion and FDG



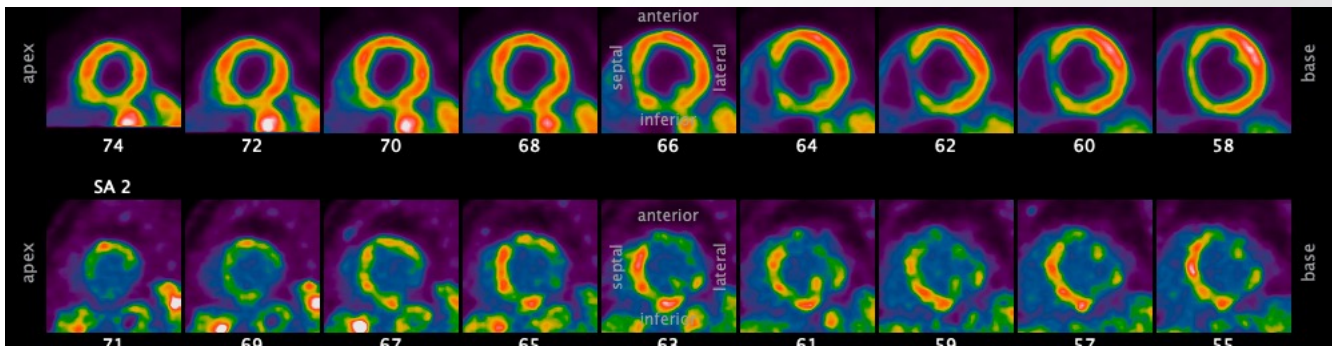
Perfusion defect with or without FDG uptake



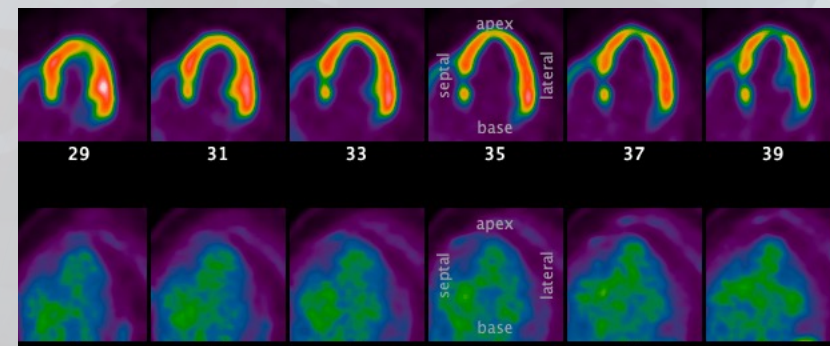
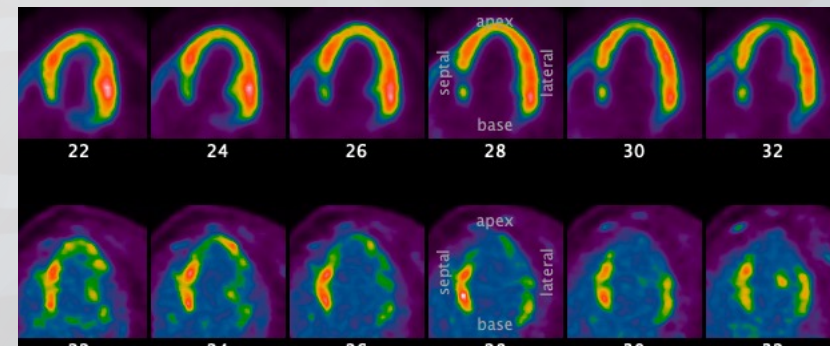
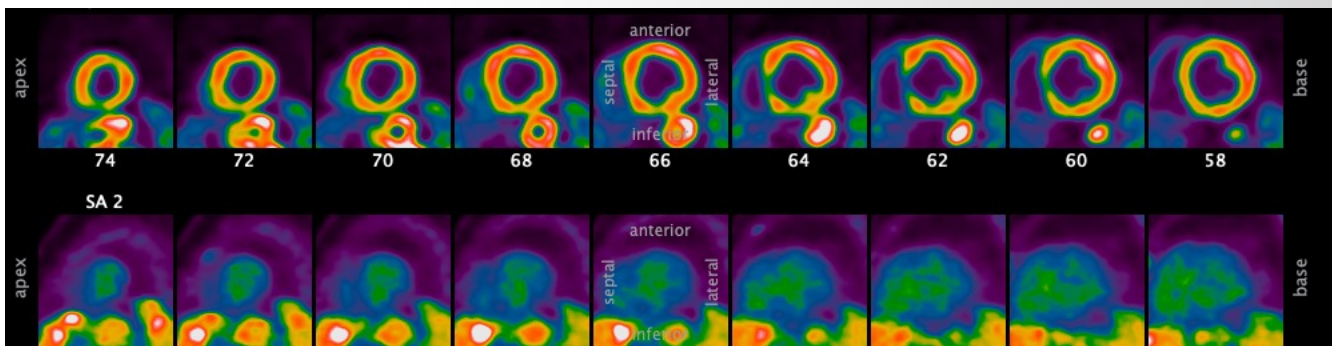
- 65 M, complete heart block s/p PPM at age of 50, later developed non-ischemic CMP, LVEF 30%
- No obstructive CAD on repeat angiogram
- FDG uptake and perfusion defect at the same (mismatch pattern) and different area.
- FDG uptake at the Mediastinal LN → biopsy positive for sarcoidosis

Perfusion defect with or without FDG uptake

65 F biopsy proven sarcoidosis of liver and lung now with frequent PVCs



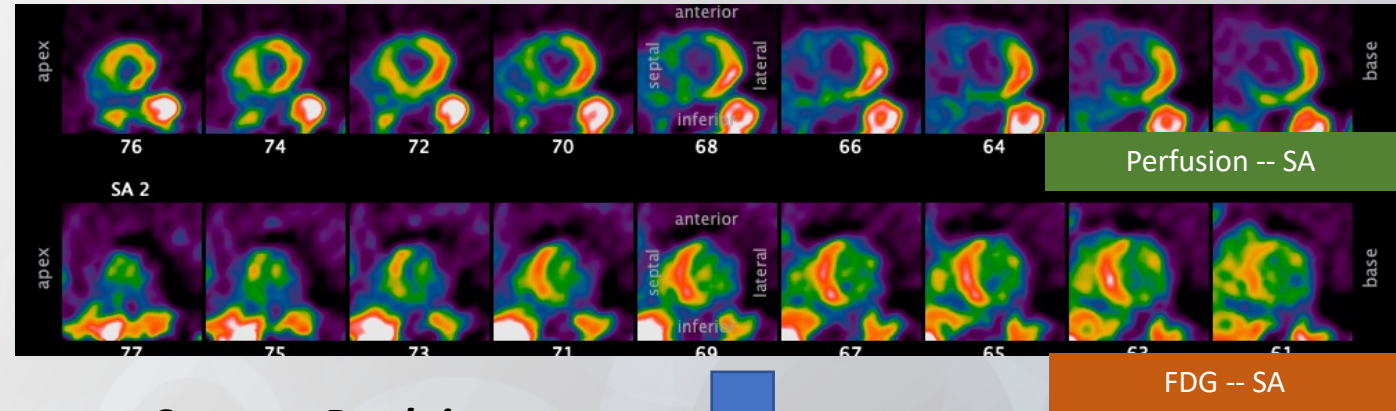
Repeat PET 6 month after prednisone



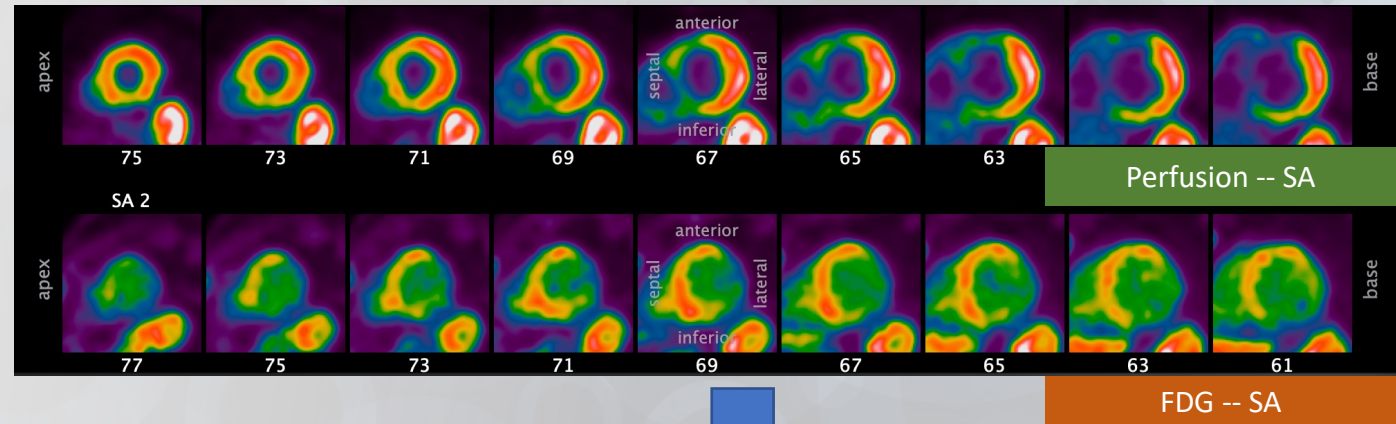
PVCs has improved --- No FDG uptake but resting perfusion defect remains

Perfusion defect with or without FDG uptake

- 62 M, non-ischemic cardiomyopathy Dx 10 years ago, LVEF 35%, LBBB
- Recent CMR raises suspicion about cardiac sarcoidosis.
- 2003 Prostate biopsy with focal granulomatous inflammation
- No extracardiac sarcoidosis



*Start on Prednisone
Repeat PET FDG 6 Months later*



Kept on Prednisone

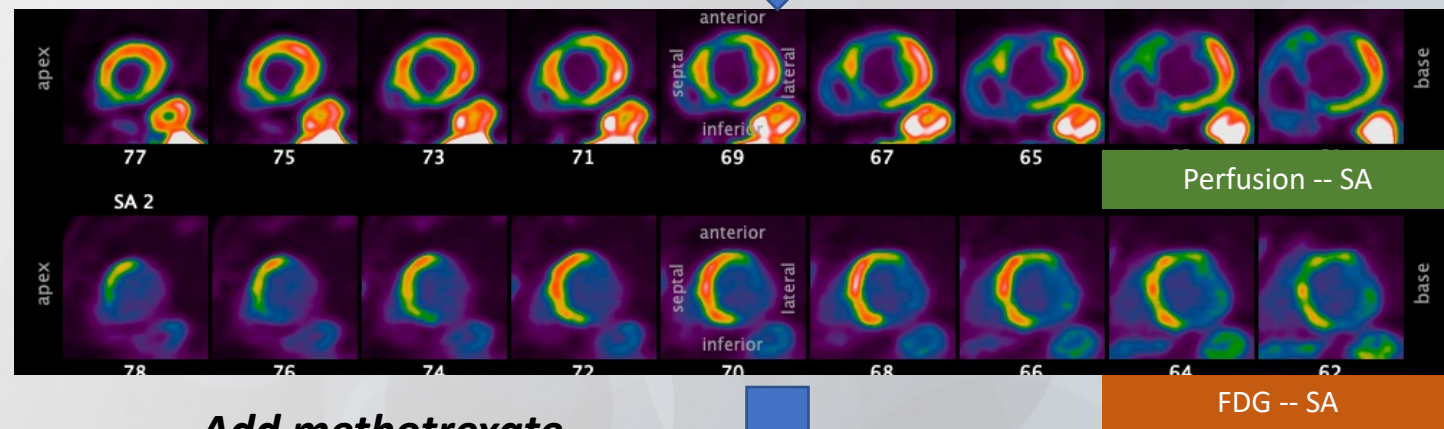
Perfusion defect with or without FDG uptake

62 M with non-ischemic cardiomyopathy

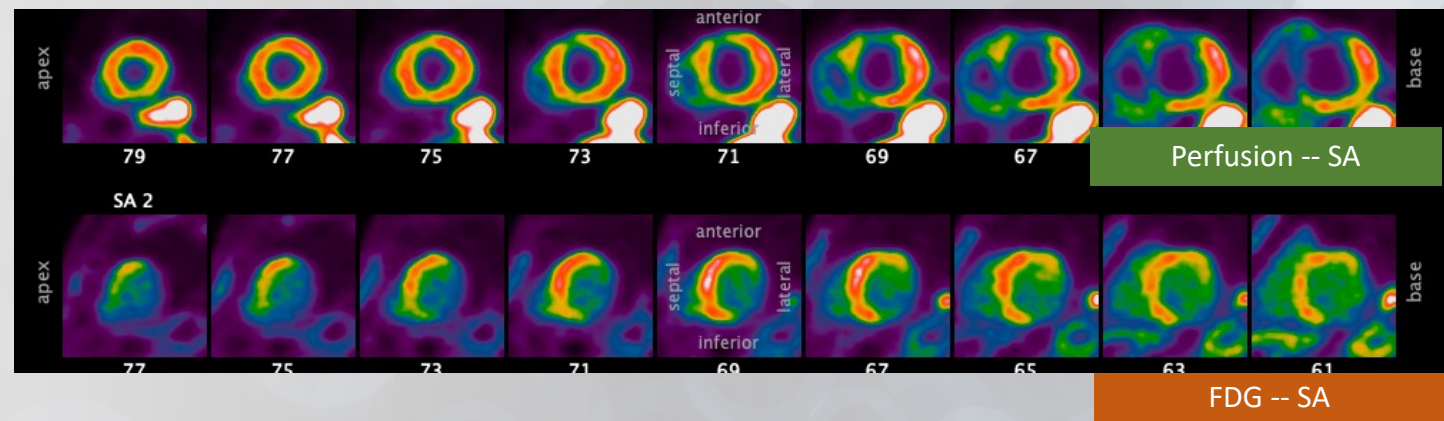
- Repeat whole body FDG – Not suggesting extracardiac sarcoidosis
- EMB – fibrosis but not consistent with sarcoidosis
- Genetic testing negative
 - Including negative DSP mutation

Is this really a cardiac sarcoidosis??

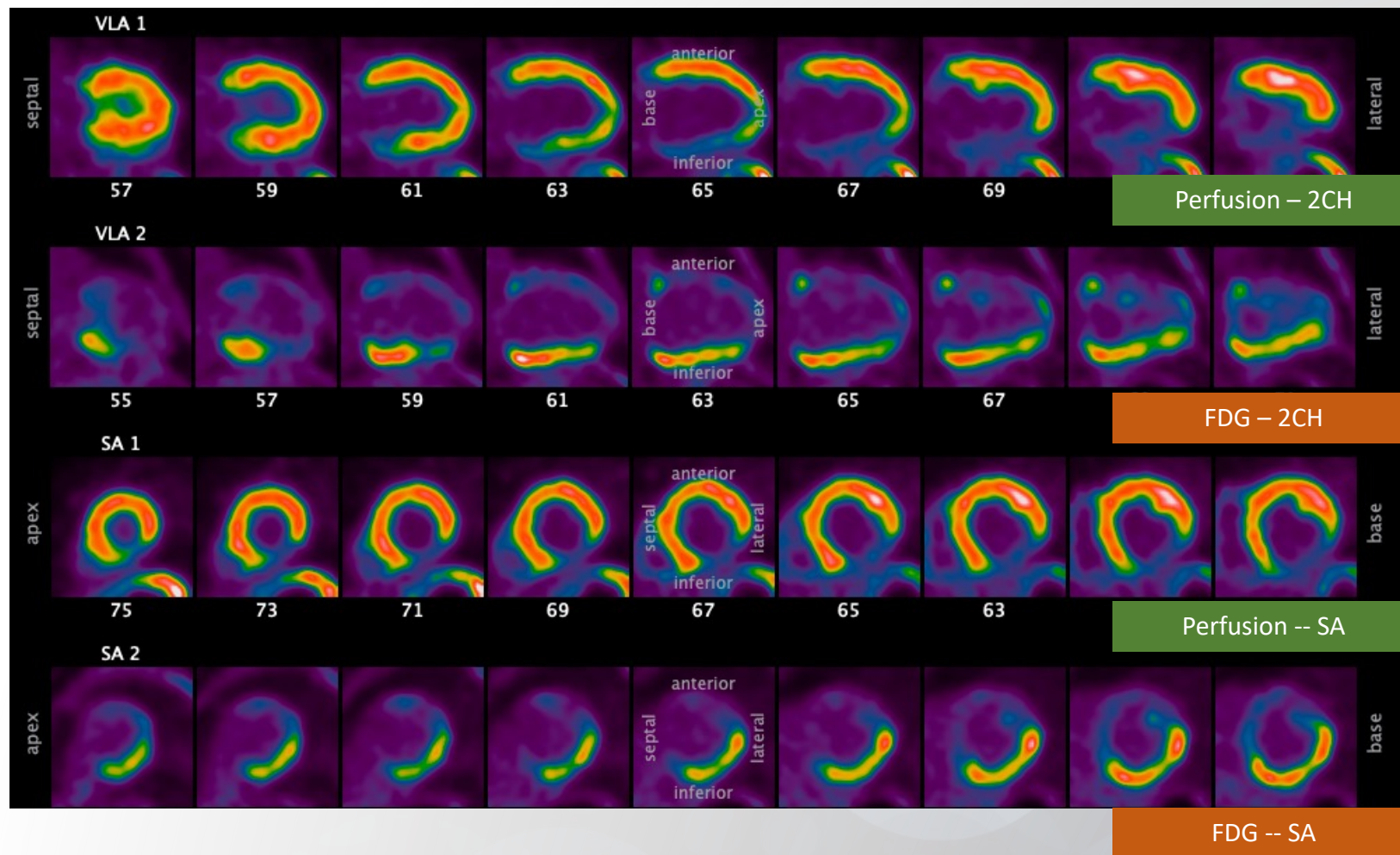
Repeat PET FDG 6 Months later



Add methotrexate
Repeat PET FDG 6 Months later

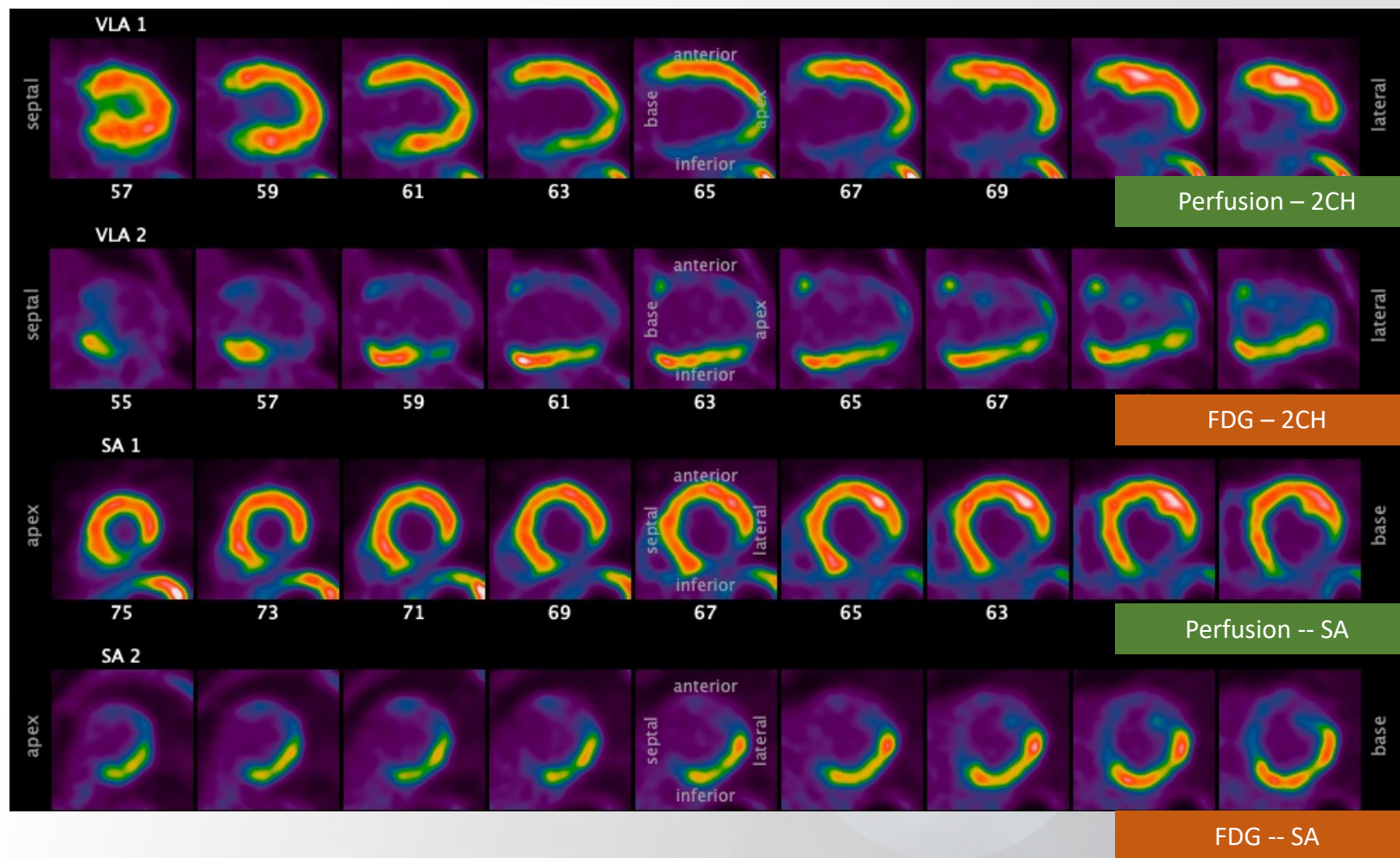


If not Cardiac Sarcoidosis, what can cause positive myocardial FDG uptake?

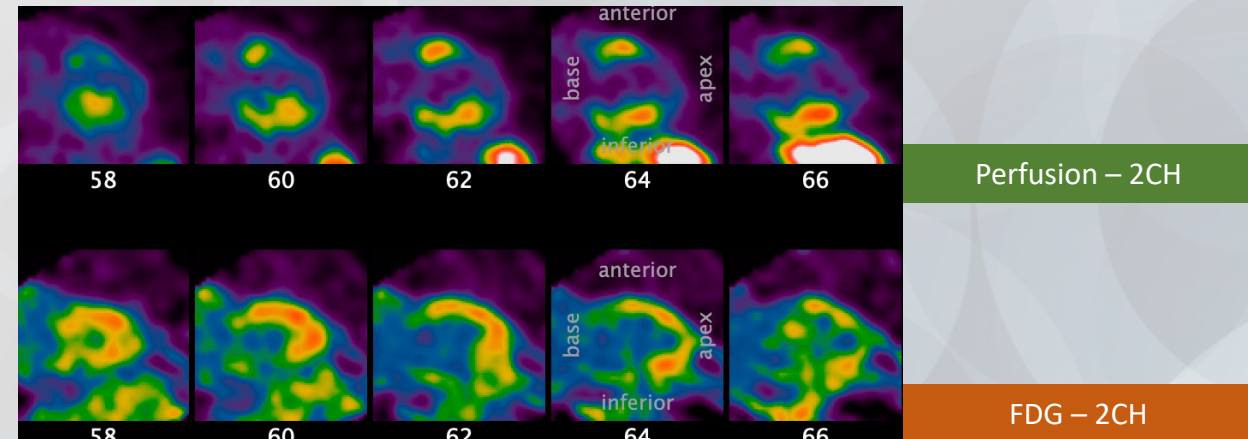
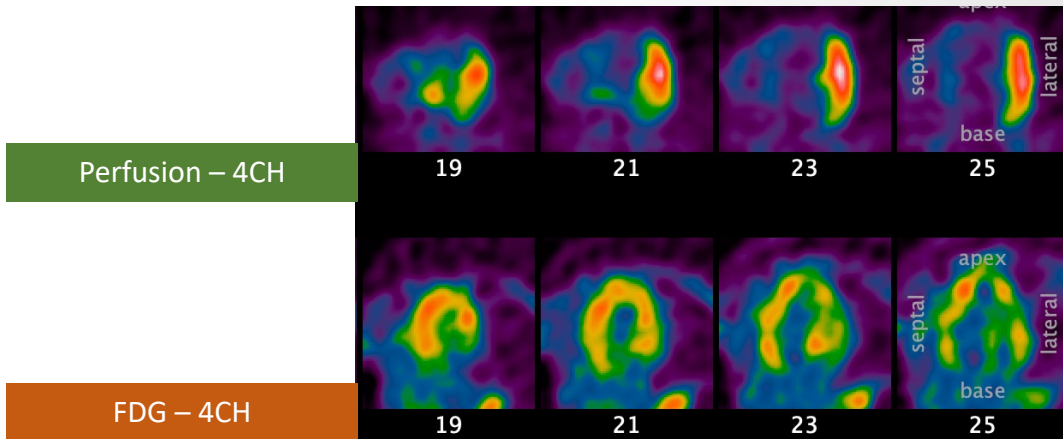
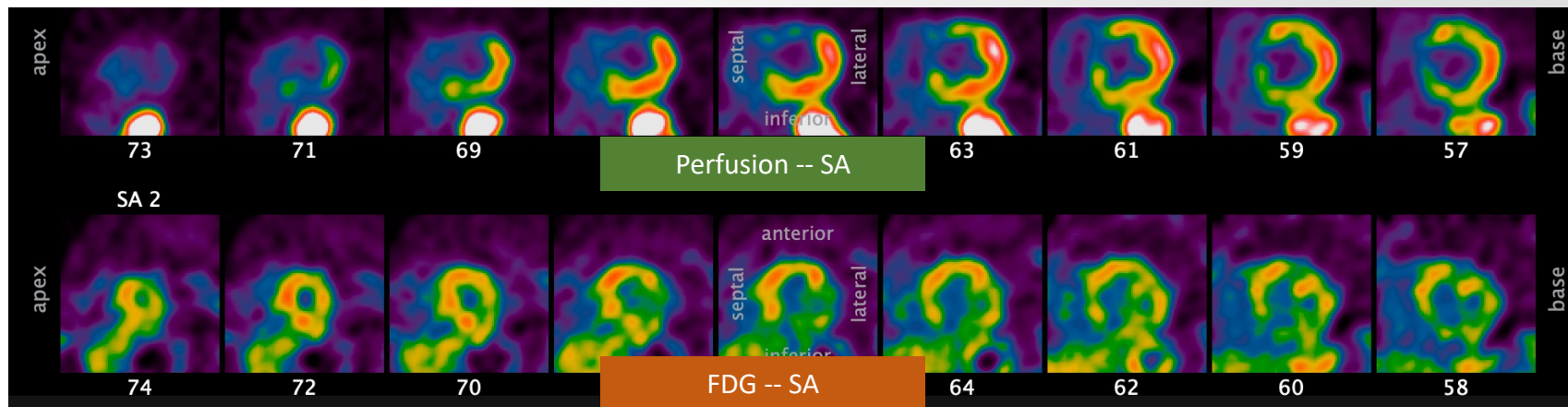


Perfusion defect with FDG uptake at the same location -- Mismatch pattern

Cardiac Sarcoidosis?

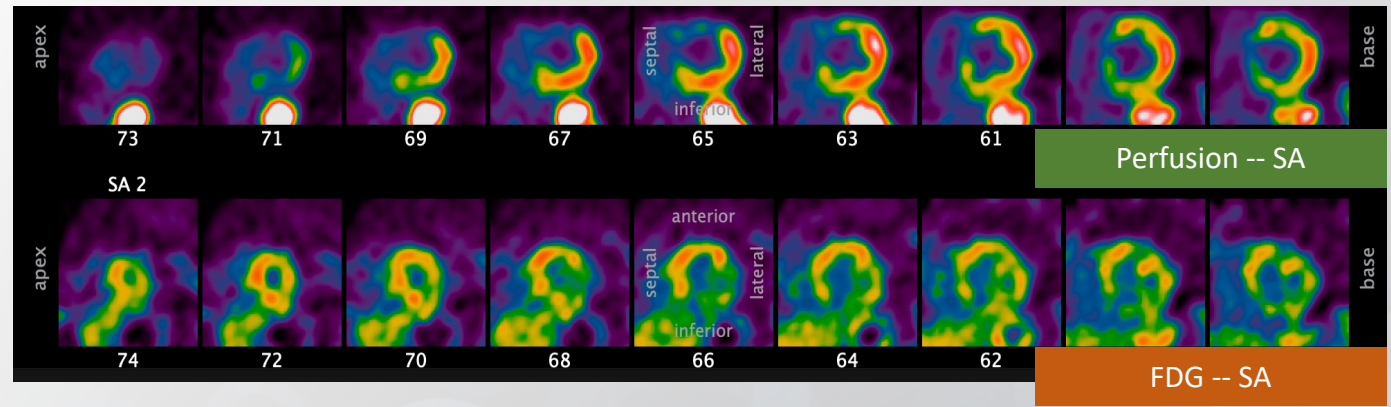


- 64 M with known occluded LCx -- PET FDG done for viability study (not prep with cardiac sarcoid protocol)
 - Hibernating myocardium in LCx distribution
 - ***Always exclude significant CAD!***



- 60 F with recent anterior MI 3 months ago.
- PET FDG done for viability study (not prep with cardiac sarcoid protocol)
- Significant FDG uptake in the LAD distribution.

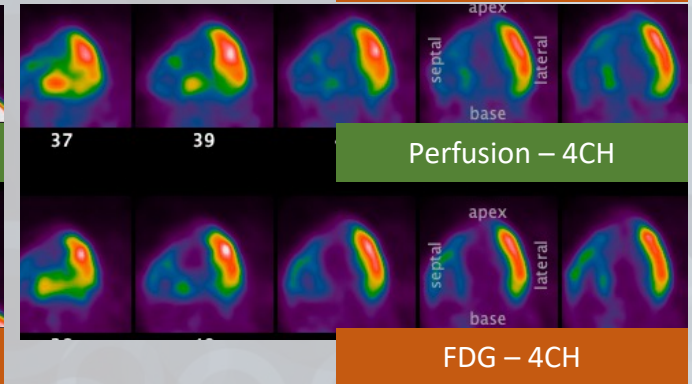
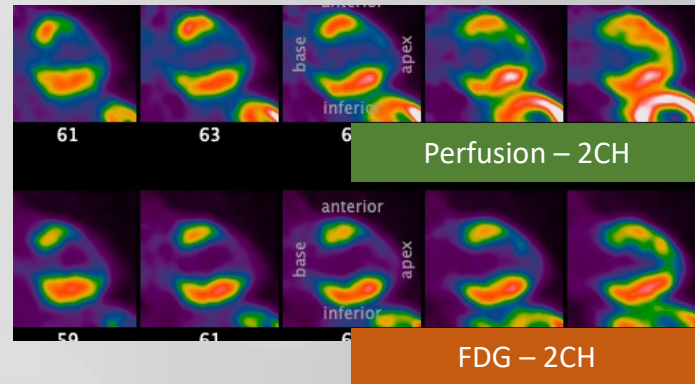
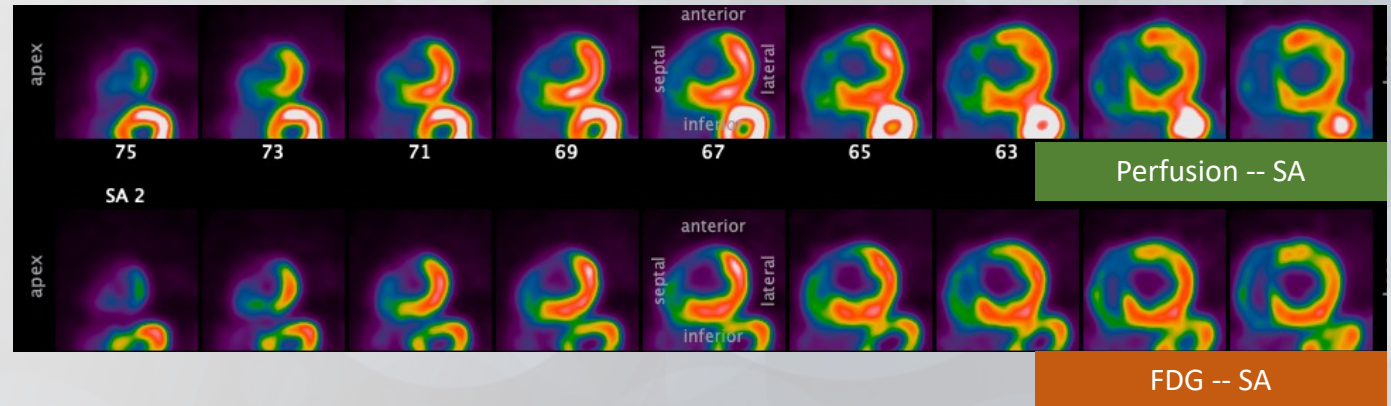
- 60 F with recent anterior MI
- PET FDG done for viability study (not prep with cardiac sarcoid protocol)
- FDG uptake in the LAD distribution.



Repeat PET FDG 3 years later

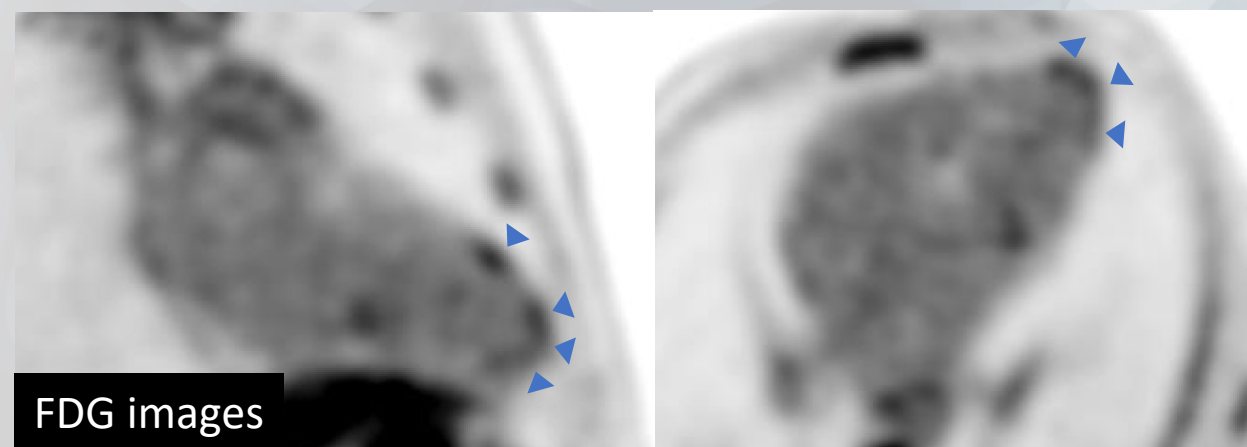
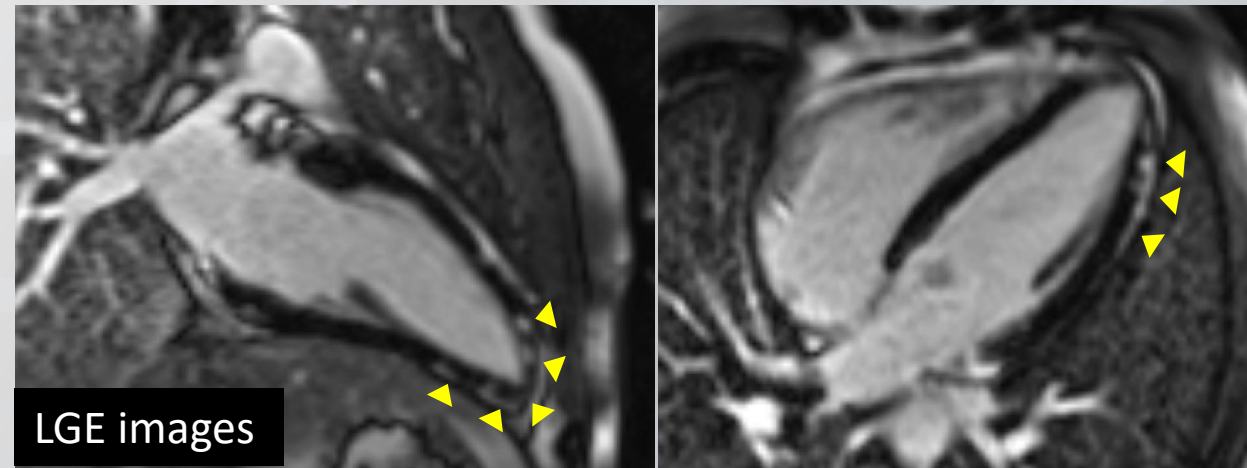
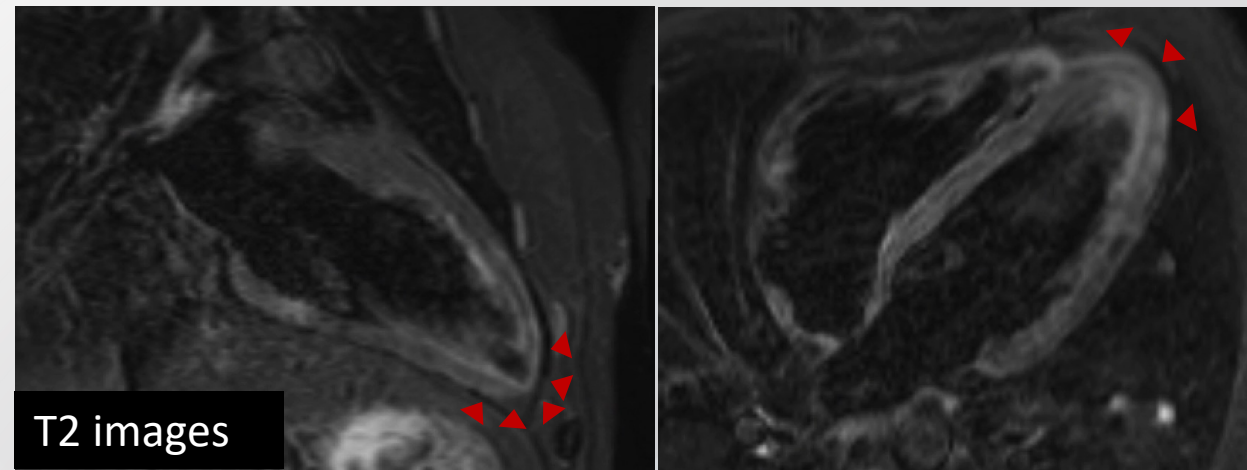


- Repeat PET 3 years later with no significant FDG uptake
- Myocardial inflammation after recent MI, no hibernating myocardium
- ***History of recent MI is very important!***



23 M with chest pain and elevated troponin after COVID vaccination

- CMR show myocardial edema and LGE at the apex and apical lateral wall
- FDG – demonstrate FDG uptake at the same location
- ***COVID vaccine related myocarditis***

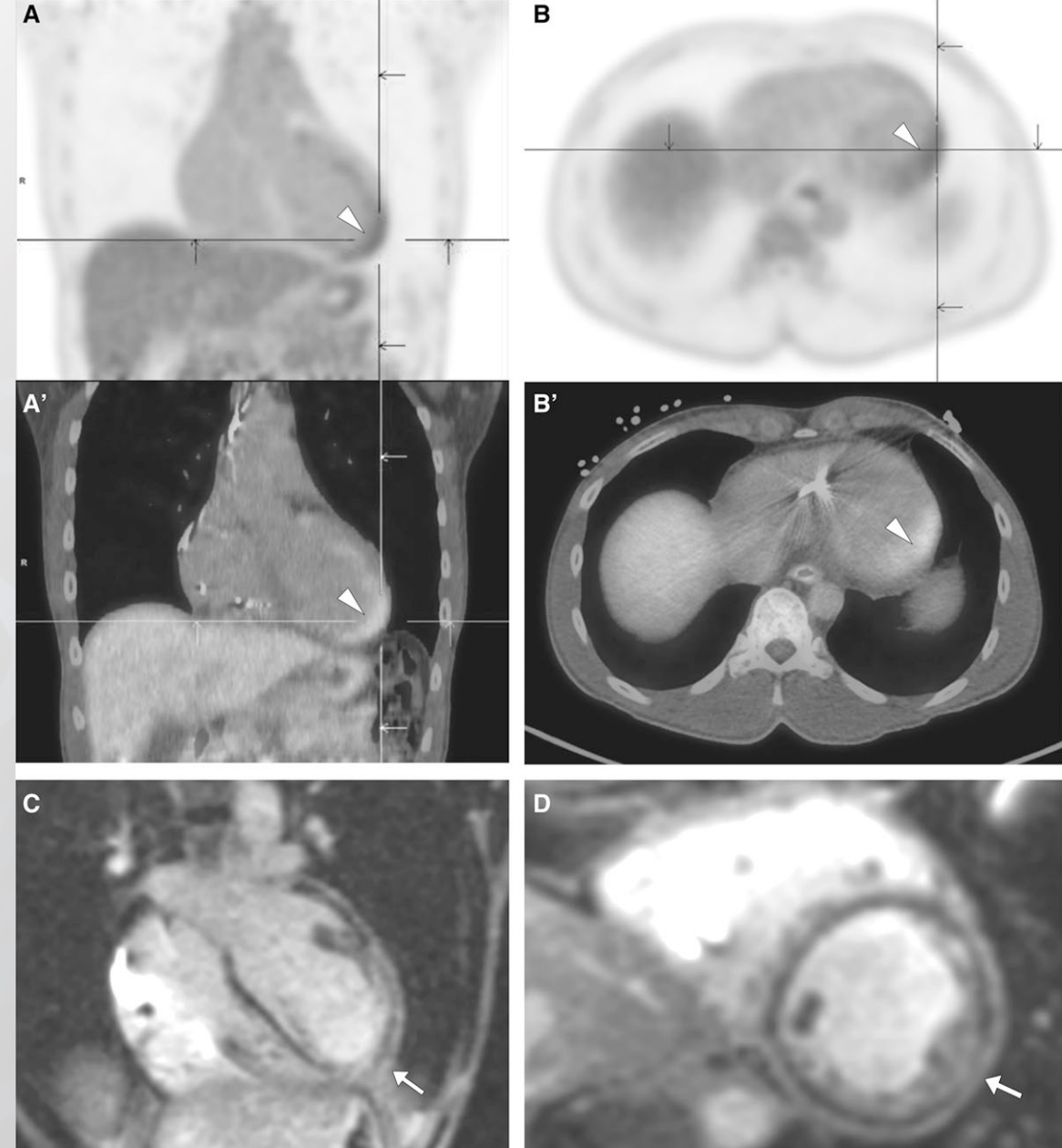


ORIGINAL RESEARCH ARTICLE

Desmoplakin Cardiomyopathy, a Fibrotic and Inflammatory Form of Cardiomyopathy Distinct From Typical Dilated or Arrhythmogenic Right Ventricular Cardiomyopathy

Eric D. Smith, MD, Neal K. Lakdawala, MD, Nikolaos Papoutsidakis, MD, PhD, Gregory

- Desmoplakin cardiomyopathy is a distinct form of arrhythmogenic cardiomyopathy
- Episodic myocardial injury (hot phase), left ventricular fibrosis that precedes systolic dysfunction, and a high incidence of ventricular arrhythmias.
- FDG uptake occur during inflammatory phase
- May be challenging to differentiate from cardiac sarcoidosis



Perfusion defect with or without FDG uptake

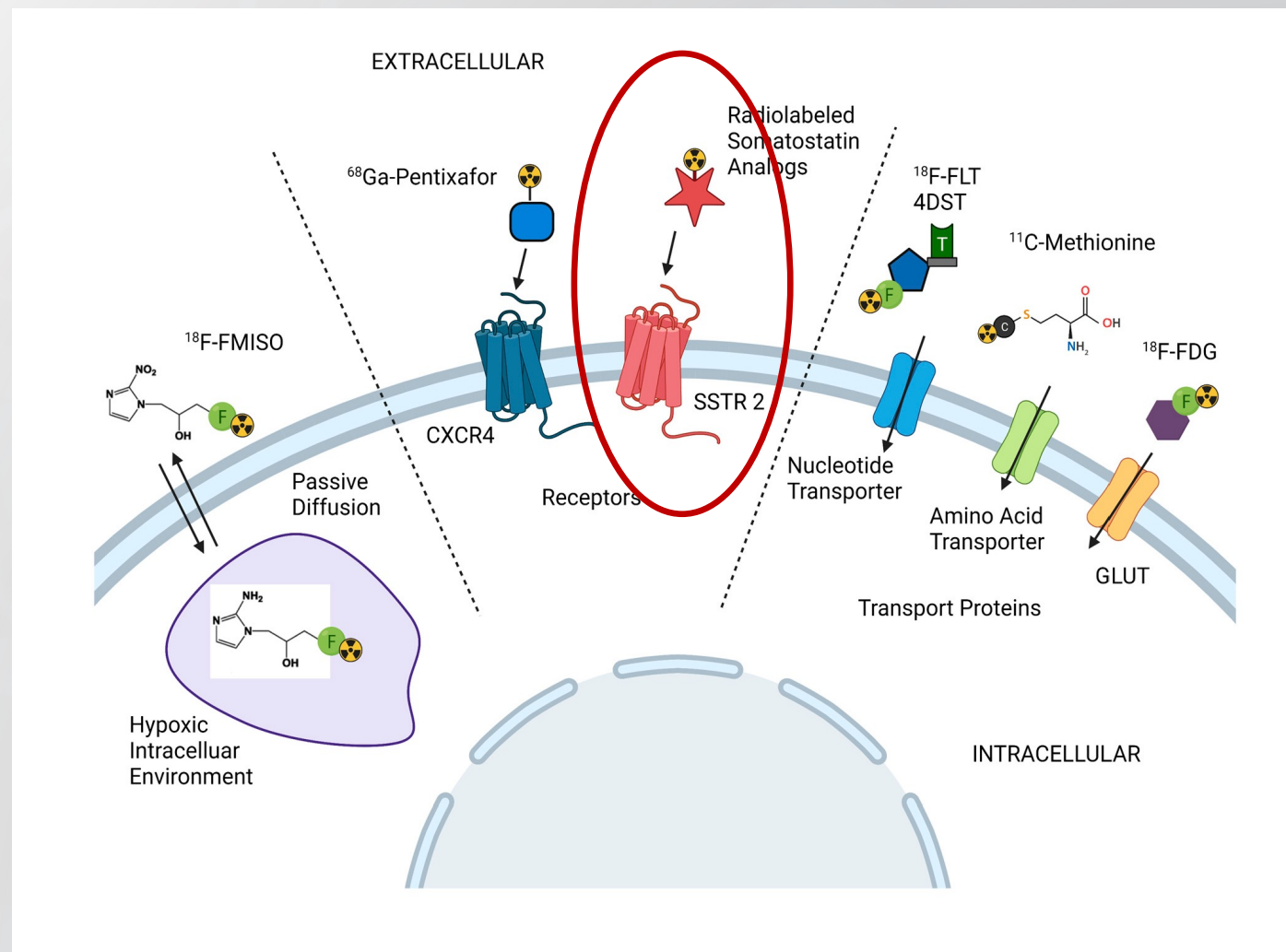
- Cardiac sarcoidosis
 - Scar – NO FDG uptake not exclude cardiac sarcoidosis
 - Active inflammation
- Keep in mind
 - Always exclude CAD – review angiogram, prior myocardial perfusion study
 - Hibernating myocardium
 - Ischemia
 - Post-MI inflammation
 - Myocarditis
 - Inflammatory cardiomyopathy
 - Desmoplakin cardiomyopathy

Novel Tracers for Cardiac Sarcoidosis

- Difficult for patient to undergo pre-scan diet prep
- Inadequate myocardial suppression is an ongoing issue and hard to be sure.
- Goal is to find novel tracer that
 - Not require diet prep
 - Not uptake by normal myocyte
 - Only uptake by inflammatory cell

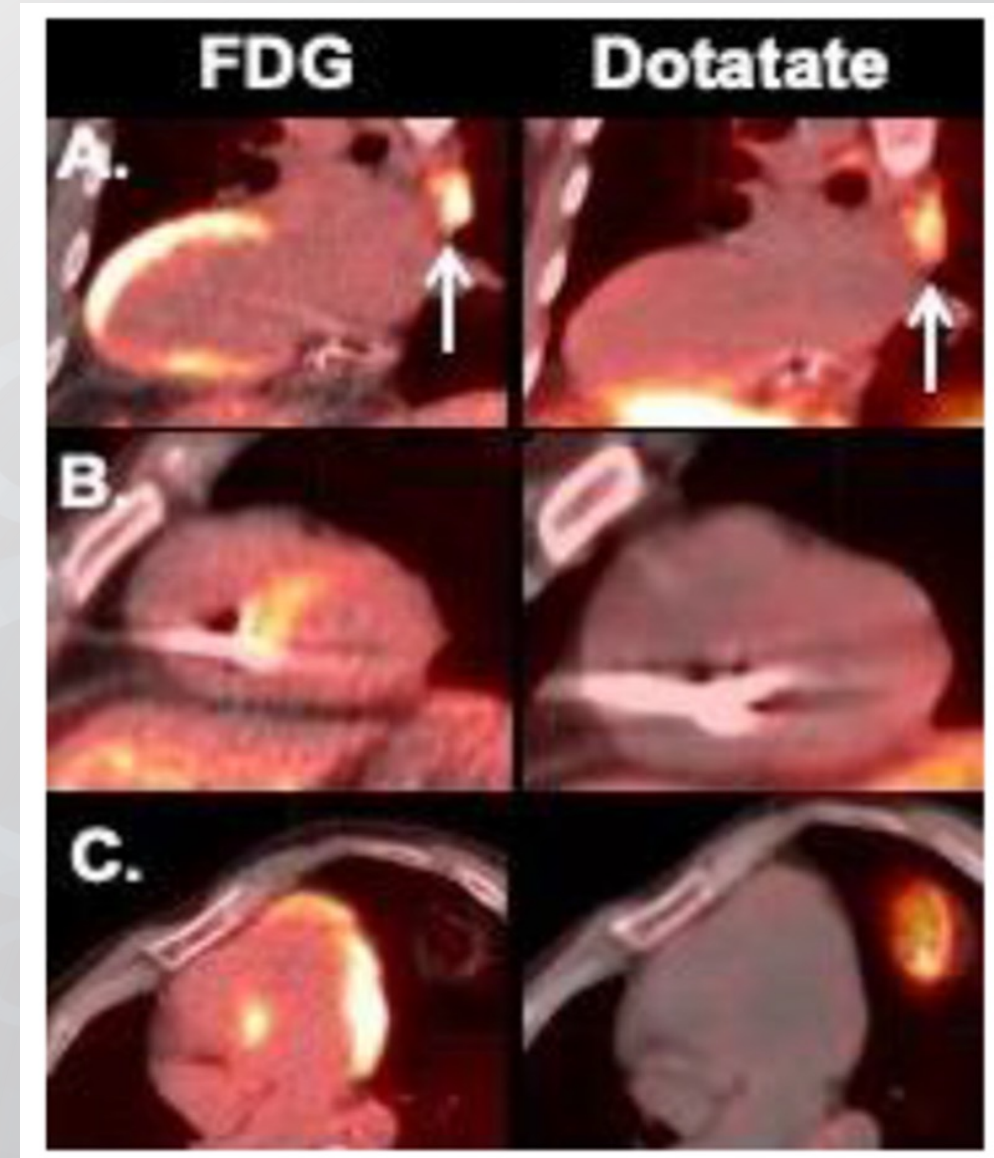
Novel Tracers for Cardiac Sarcoidosis

- **SSTR-2** is the most frequently expressed SSTR subtype on activated lymphocytes, macrophage and found to be overexpressed in sarcoid granulomas
- Not present on normal cardiac myocytes
- No need for diet prep



SSTR-2 Tracer

- ^{68}Ga -DOTATATE, ^{68}Ga -DOTANOC, and ^{68}Ga -DOTATOC are the most commonly used
- Results are promising in most studies (though small sample size)
 - ^{68}Ga SSRT-2 vs. CMR or vs. FDG PET -- concordant results.
- Bravo et al study: Concordance of FDG and DOTATATE uptake was only **54% in the heart and 100% for thoracic nodal activity**.
- In this study, exam of 3 explanted heart with pathology proven sarcoidosis
 - SSTR-2 immunostaining was **weakly seen** within well-formed cardiac granulomas
 - Higher staining in the germinal center of a sarcoid LN
- Possible that there are different stage of sarcoidosis and we are detecting different inflammatory cell in each stage.



Complimentary role of CMR and Cardiac PET FDG for Diagnosis of Cardiac Sarcoidosis

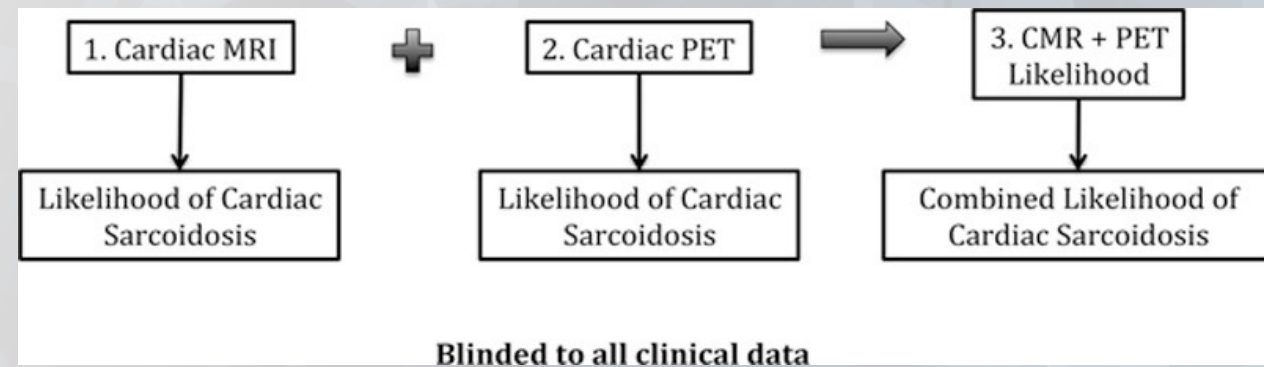
- 107 pts with known or suspected cardiac sarcoidosis underwent CMR and cardiac PET FDG (median time between test = 8 days)
- When PET FDG info added to CMR, **≈45%** of patients were reclassified to having a higher or lower likelihood of CS
 - Mostly with pts in grey zone
- 2 of every 3 pts with abnormal LGE had FDG uptake
 - Having both LGE but FDG -- in creased likelihood and diagnostic yield
 - Identified candidates for immunosuppressive therapies

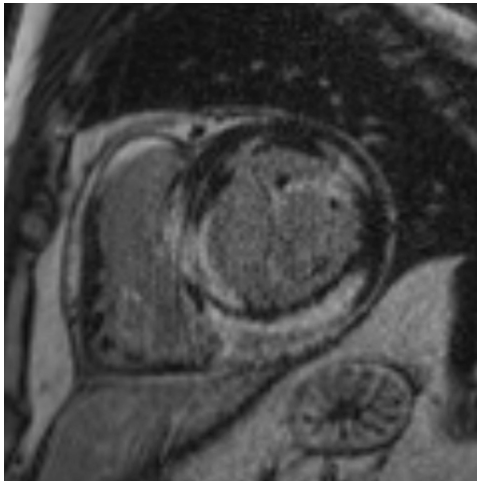
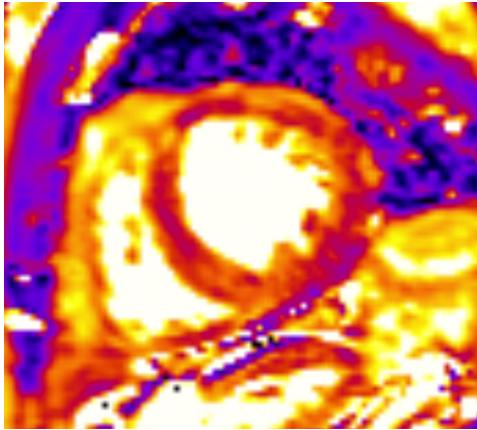
ORIGINAL ARTICLE

Complementary Value of Cardiac Magnetic Resonance Imaging and Positron Emission Tomography/Computed Tomography in the Assessment of Cardiac Sarcoidosis

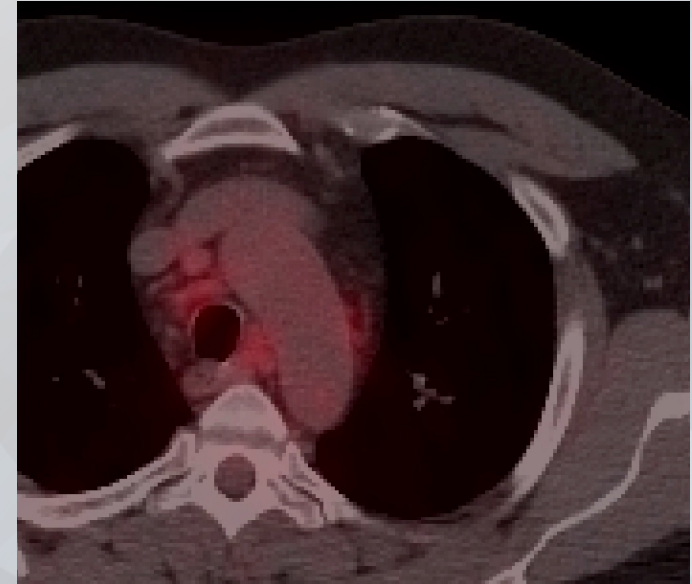
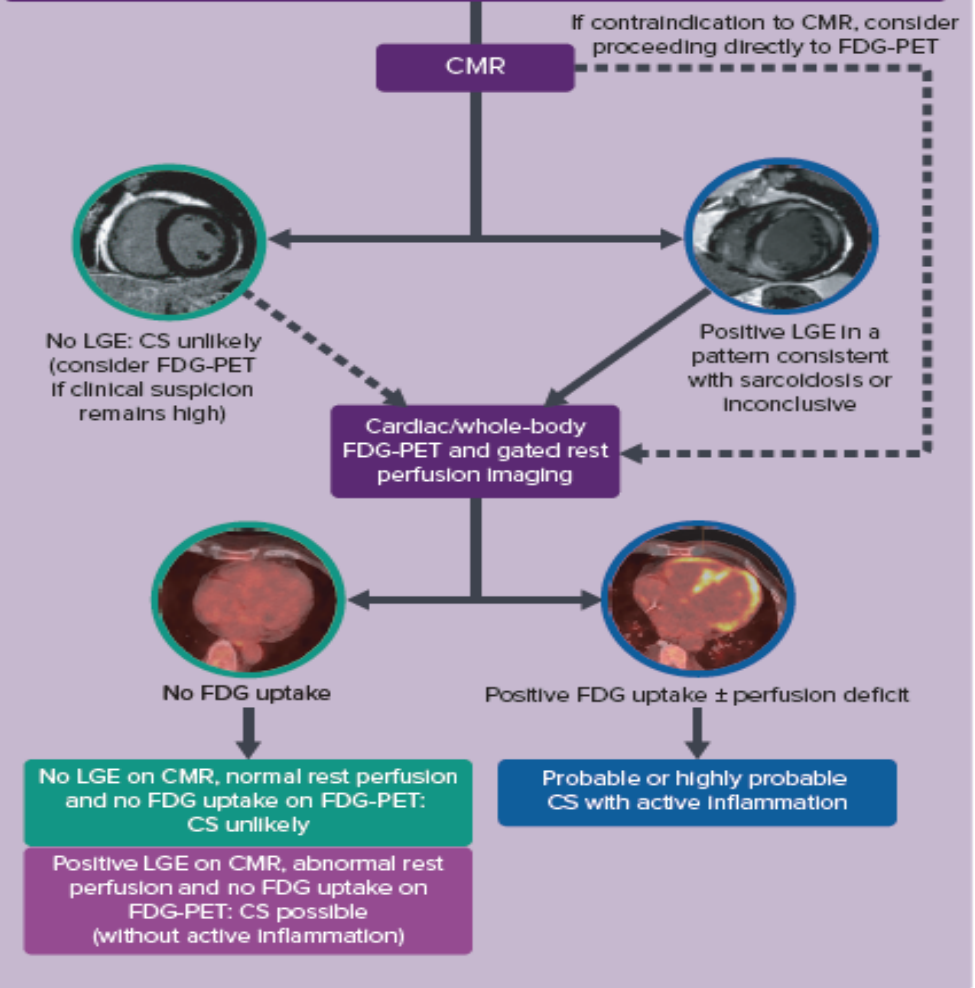
See Editorial by Miller and Culver

Tomas Vita, MD, MPH, David R. Okada, MD, Mahdi Veillet-Chowdhury, MD, Paco E. Bravo,



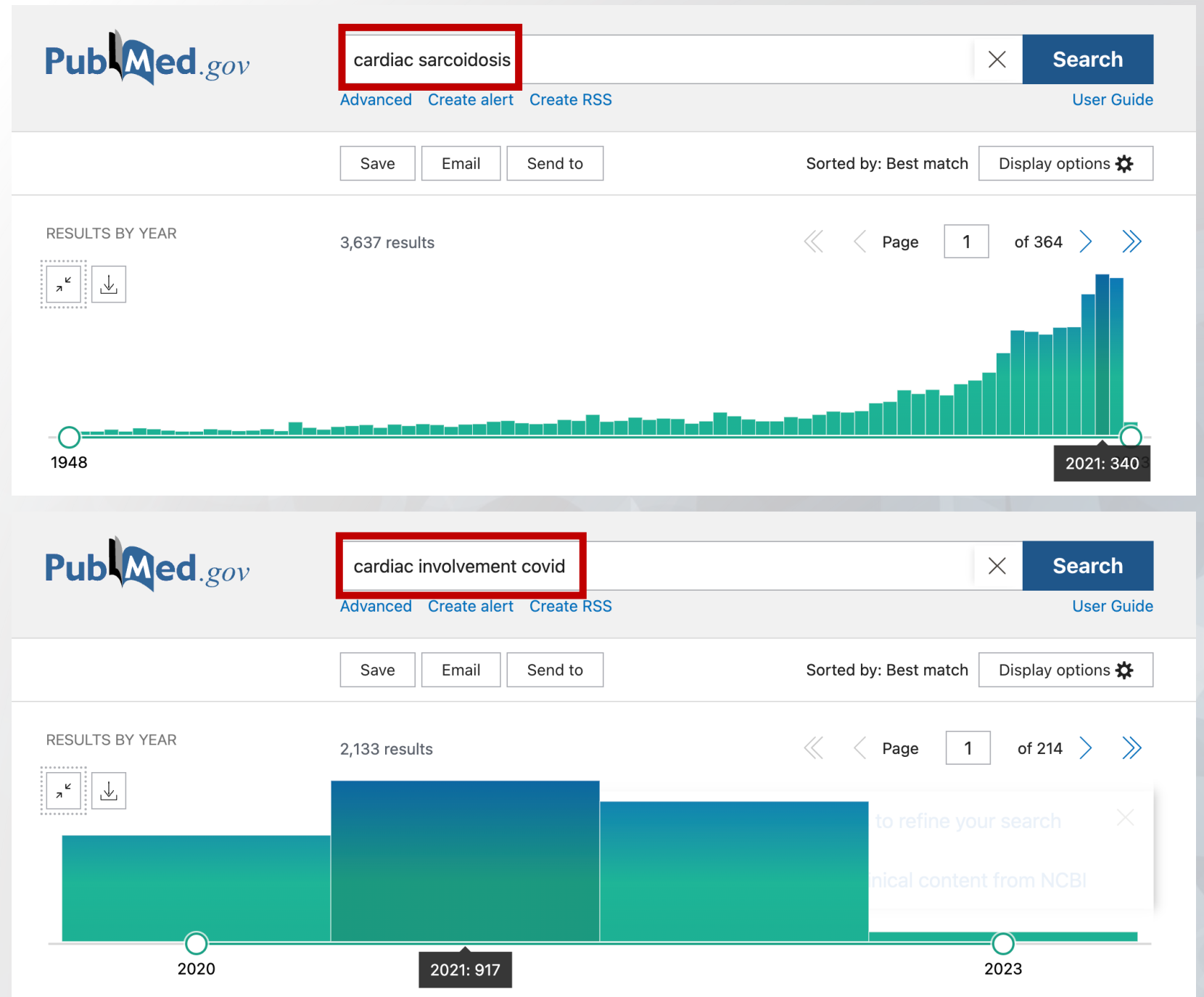


- Clinical suspicion of cardiac sarcoidosis:**
- 1 Unexplained advanced AV block in adults <60 years of age, heart failure or ventricular arrhythmia
AND/OR
 - 2 Radiological ± histological extracardiac sarcoidosis with CV symptoms, abnormal ECG or abnormal echocardiogram
AND
 - 3 Other causes including CAD/myocardial Ischaemia excluded
CMR



Still a lots of unknown in Cardiac sarcoidosis

Need more attention and more data!!



Take home messages

- For cardiac PET FDG -- Patient prep is very very very important
- Positive FDG can be --- but not always --- cardiac sarcoidosis
- Not all pts need both CMR and cardiac PET but they compliment each other for Dx cardiac sarcoidosis



**Thank you for
your attention!**

QUESTIONS??