Infiltrative Heart Disease - Focus on Advanced Cardiac Imaging

Frederick L. Ruberg, MD

Section of Cardiovascular Medicine and Amyloidosis Center

Department of Radiology

Boston University School of Medicine

Boston Medical Center

September 4, 2013

Boston Medical Center is the primary teaching affiliate
of the Boston University School of Medicine.

DISCLOSURE INFORMATION

- Financial Disclosure: Consultant to Pfizer and Alnylam Pharmaceuticals, Cambridge MA
- Grant Support: American Heart Association, Amyloidosis Foundation
- Unlabeled/unapproved uses
  - Late gadolinium enhancement in cardiac MR
  - Tafamidis (Pfizer) and diflunisal are TTR stabilizers not currently FDA approved for treatment of cardiac amyloidosis

DIFFERENTIAL DIAGNOSIS:

Disease	Etiology	Chamber Remodeling	Associated Clinical Findings
Amyloidosis	Immunoglobulin light-chain (AL) or transthyretin (TTR)	Concentric	Proteinuria, neuropathy, low ECG voltage
Sarcoidosis	Granulomatous inflammation	None, concentric, or eccentric	Pulmonary fibrosis, heart block
Hemochromatosis	Iron accumulation	Concentric or eccentric	Liver disease
Fabry	a-galactosidase A deficiency	Concentric	Renal failure, skin findings
Denon	Lysozome-associated membrane protein 2 deficiency	Concentric	Skeletal myopathy, cognitive delay
Friedreich ataxia	Trinucleotide (GAA) repeats (chrom 9)	Concentric	Muscle weakness, ataxia
Mucopolysaccharidoses	Lysosomal enzyme deficiencies	Concentric	Cognitive delay
Wegener granulomatosis	Granulomatous inflammation	Eccentric	Renal failure

OVERVIEW OF CARDIAC AMYLOIDOSIS

- Nomenclature and epidemiology
- Clinical presentation
- Diagnosis with focus on imaging
- Prognosis/Treatment

BU AMYLOID TREATMENT PROGRAM

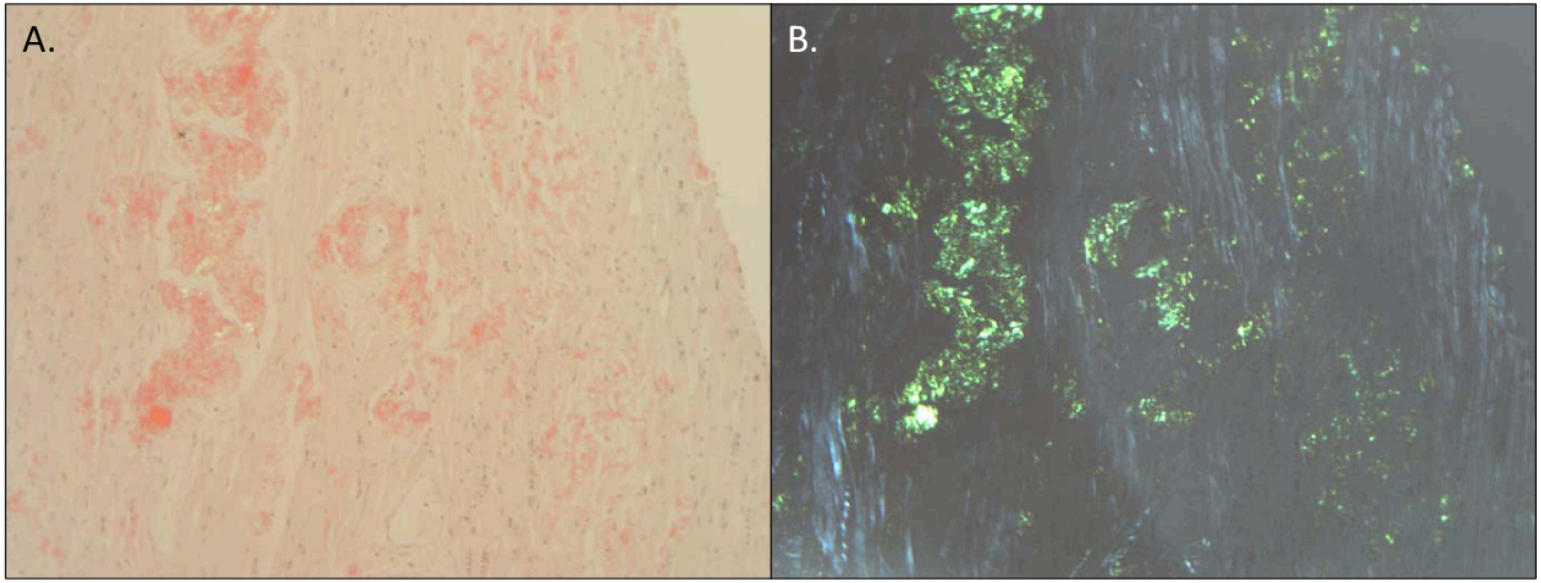
- National referral center, program started in 1976
  - One of 2 major referral centers in US
- Over 400 cases per year seen
  - Approximately 50-75 new cases of amyloid cardiomyopathy
- Registry of over 2400 patients
- Autologous stem cell transplant program for AL
  - Over 500 transplants performed, 50 per year
- Numerous clinical trials

WHAT IS AMYLOID?

- Amyloid is a protein folding disorder
  - Protein that aggregates as a β-sheet stains with Congo Red (green birefringence)
- Systemic amyloidoses classified by precursor protein
  - deposition of amyloid in soft tissue, visceral organs, peripheral nervous tissue
- Implication in pathogenesis of Alzheimer's disease (Aβ amyloid/Tau)

ENDOMYOCARDIAL BIOPSY

Endomyocardial Biopsy with Green Birefringence



Congo red

Polarized light

Ruberg *Circulation* 2012

PRIMARY OR LIGHT CHAIN (AL)

- Plasma cell dyscrasia (clonal proliferation similar to multiple myeloma)
  - 12-15% patients with myeloma have AL
- Immunoglobulin light chains (κ or λ)
- Incidence is 1 in 100,000 in Western countries or approximately 3000 new cases annually in US
  - Similar burden as Hodgkin's lymphoma
- Age can be 30 - 80 years

Gertz *Hem/Onc Clin N Am* 1999: Merlini *NEJM* 2003

HEREDITARY AMYLOIDOSIS

- Mutations in proteins produced by liver
- Symptoms are polyneuropathy (FAP) and cardiomyopathy (FAC)
- Age of onset varies with mutation
- Nearly all FAP and FAC cases caused by mutations in **transthyretin (TTR)** gene
- Protein mutations have geographical and ethnic distributions globally

SENILE SYSTEMIC AMYLOID (SSA)

- AKA Senile Cardiac Amyloidosis or Age-related disease
- TTR-based non-genetic (ie, TTR wild-type)
- Cardiac predilection (but also soft tissue hence systemic)
- Male gender, Caucasian, onset after age 60
- Wild-type TTR can be found in up to 25-30% elderly (>75-80 years) hearts
  - Probably significantly under-appreciated

Mirzoyev, AHA 2010: Tanskanen *Ann Med* 2008: Cornwell *Am J Med* 1983

TTR CARDIAC AMYLOIDOSIS

Table 1. Characteristics of Wild-Type and Common Variant Transthyretin Cardiac Amyloidosis

Mutation	Origin	Prevalence	Male:Female Ratio	Onset	Organs
SSA	Worldwide	25% >85 y	25:1 to 50:1	>60 y	Heart, ST
V122I	United States, Caribbean, Africa	4% Black	1:1 Gene (+) 3:1 Disease	>65 y	Heart, PNS, ST
V30M	Portugal, Sweden, Japan	1:1000	2:1	>50 y	PN/ANS, heart
T60A	United Kingdom, Ireland	1% Northwest Ireland	2:1	>45 y	Heart, PNS/ANS

SSA indicates senile systemic amyloidosis, wild-type (no mutation); ST, soft tissue; PNS, peripheral nervous system; and ANS, autonomic nervous system.

- TTR amyloid demonstrable in 25-30% autopsy hearts age > 80-85 years
- Probably about 5-10% have clinical phenotype of SSA

Ruberg and Berk, *Circulation* 2012

SECONDARY AMYLOIDOSIS (AA)

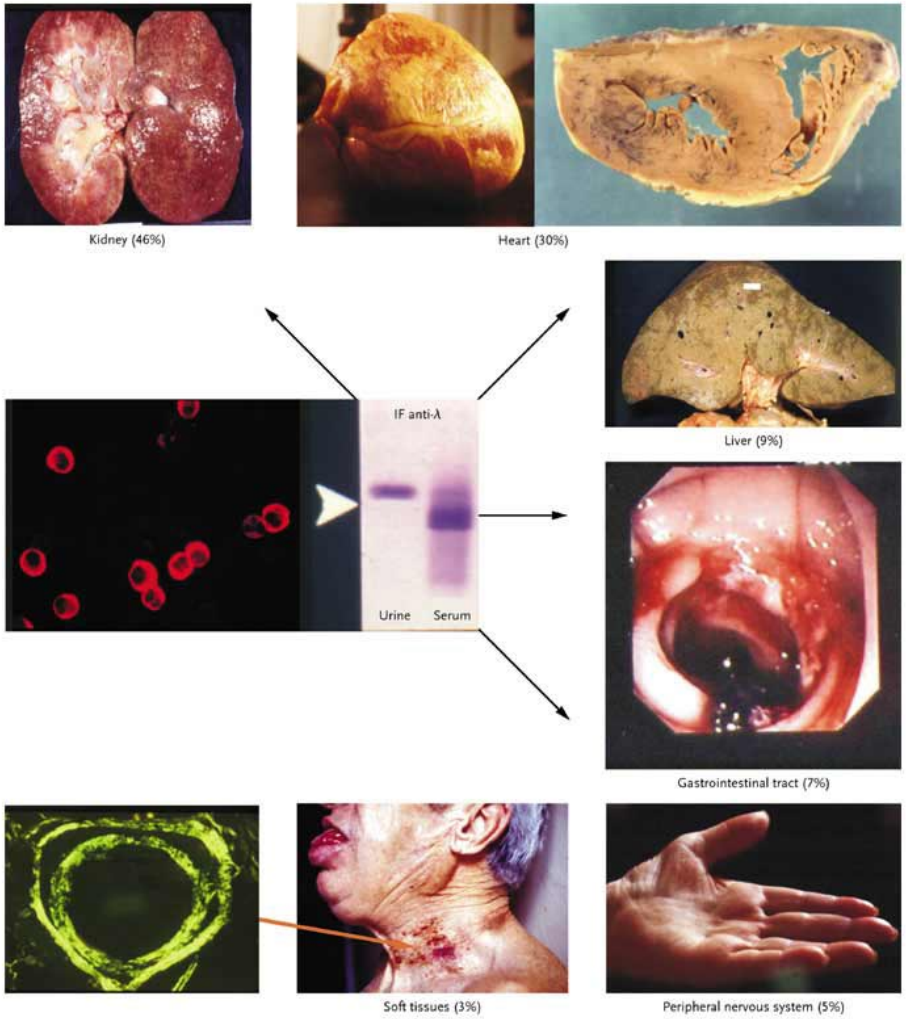
- Serum Amyloid A is precursor
- Acute phase reactant associated with chronic inflammatory states
- Kidney most commonly affected, heart rarely so
- Underlying inflammatory disorders most commonly rheumatoid arthritis (50%) and familial Mediterranean Fever (20%)

Dember *NEJM* 2007

OVERVIEW OF CARDIAC AMYLOIDOSIS

- Nomenclature and epidemiology
- Clinical presentation
- Diagnosis
- Prognosis/Treatment

DIVERSE MANIFESTATIONS OF AL DISEASE



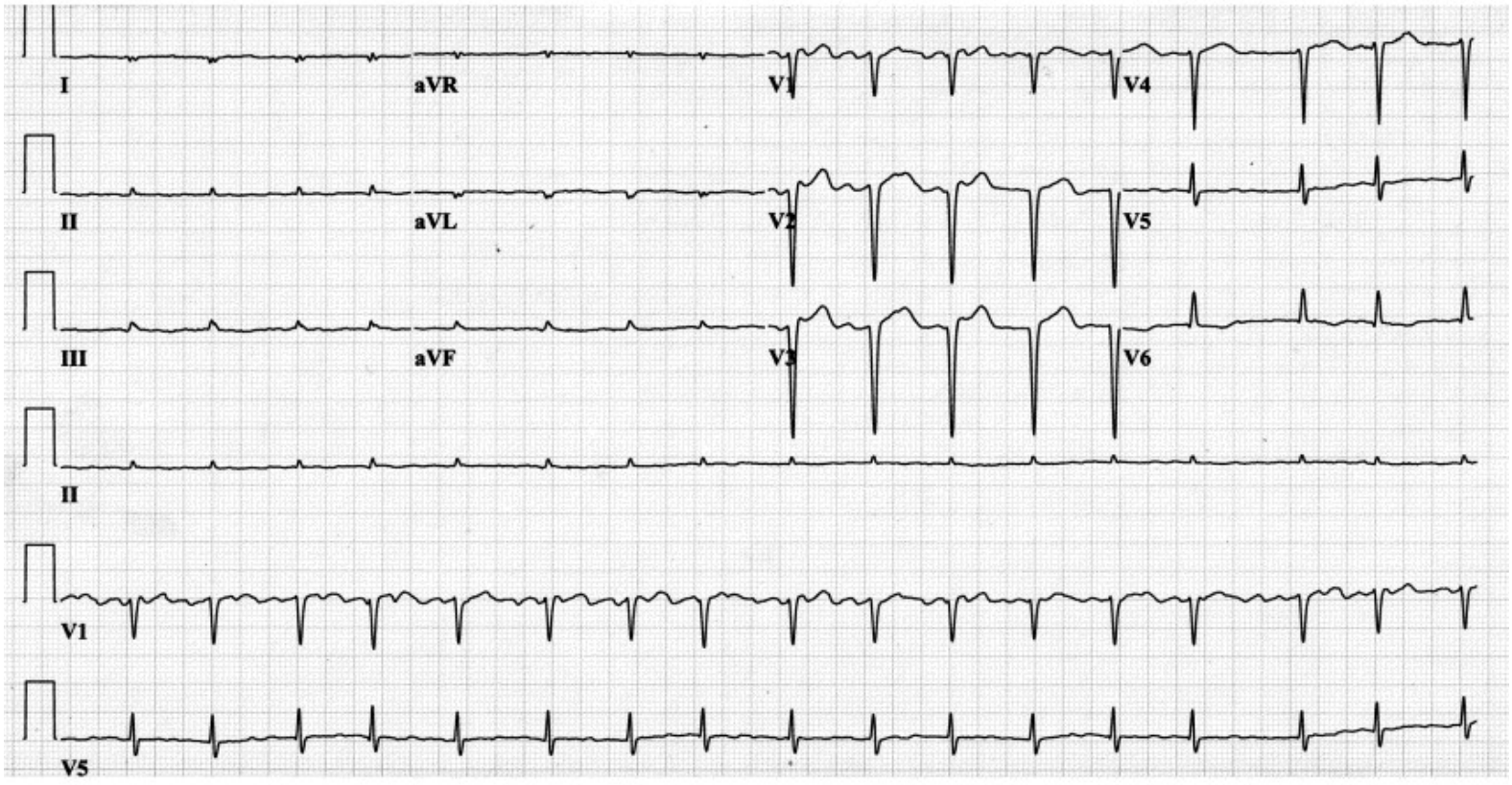
Merlini *NEJM* 2003

CARDIAC PATHOPHYSIOLOGY

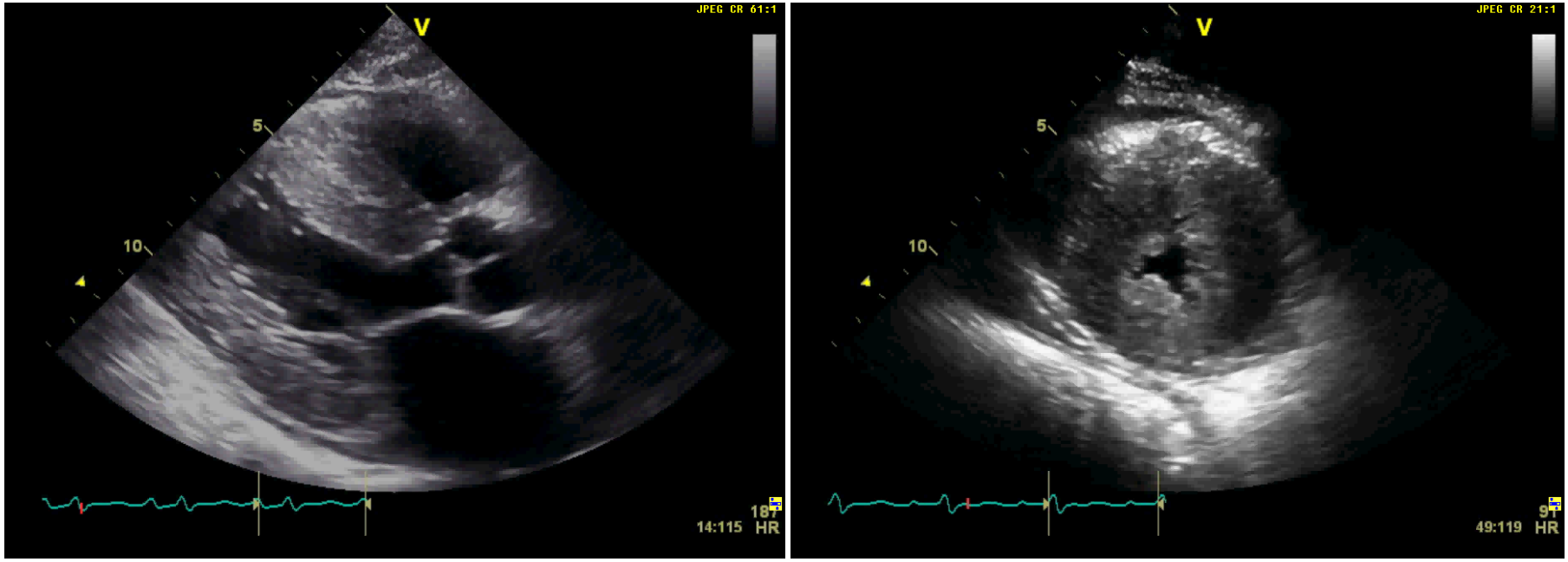
- Amyloid infiltration results in progressive ventricular wall thickening and impairment of ventricular relaxation
- Restrictive filling - Very high intra-cardiac pressures
- Frequently with preservation of global measures of systolic function in early stages of disease

Merlini *NEJM* 2002

LOW-VOLTAGE, INFARCT PATTERN ECG



CLASSIC ECHO FINDINGS IN AMYLOIDOSIS



Challenge: By this stage of disease – treatment options are limited

BOSTON MEDICAL CENTER
EXCEPTIONAL CARE. WITHOUT EXCEPTION.

BU School of Medicine

WHEN TO CONSIDER CARDIAC AMYLOIDOSIS

Challenge – signs and symptoms of heart failure are common and amyloid heart disease relatively rare

1. Increased echocardiographic wall thickness and low voltage ECG
2. Advanced diastolic dysfunction without hypertension
3. Severely increased (>15-16 mm) wall thickness
4. Patient > 60 years (African American in particular) with advanced diastolic heart failure

Diagnosis requires histologic identification of amyloid

OTHER AMYLOIDOSIS PRESENTATION SCENARIOS

- NSTEMI/chest pain presentation
  - Normal coronary angiography due to infiltration or peri-vascular amyloidosis in small myocardial vessels
- Stroke/thromboembolism due to impaired atrial mechanical activity and in situ LA thrombosis
  - More common in AL
  - Highest risk - restrictive filling and concurrent AF
- Syncope due to autonomic dysfunction, tachy or brady-arrythmia

Tso *Amyloid* 2011: Feng *Circulation* 2007 and 2009

OVERVIEW OF CARDIAC AMYLOIDOSIS

- Nomenclature and epidemiology
- Clinical presentation
- Diagnosis
- Prognosis/Treatment

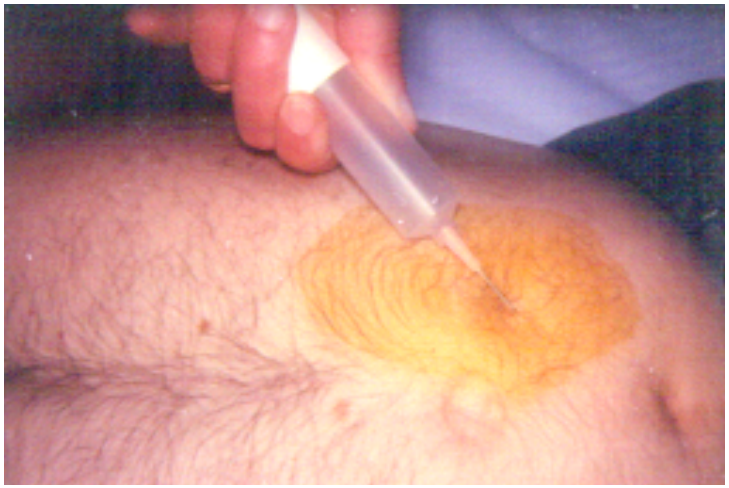
NON-INVASIVE CARDIAC DIAGNOSIS

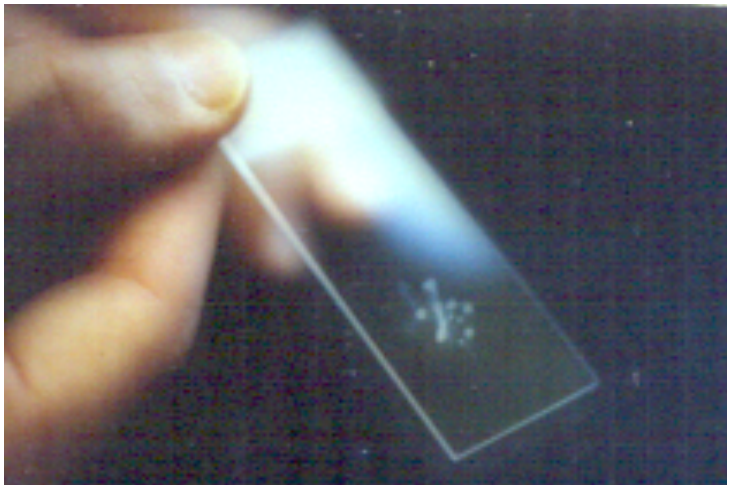
While systemic amyloidosis requires a tissue diagnosis, cardiac amyloidosis can be diagnosed with extra-cardiac tissue biopsy and consistent non-invasive testing

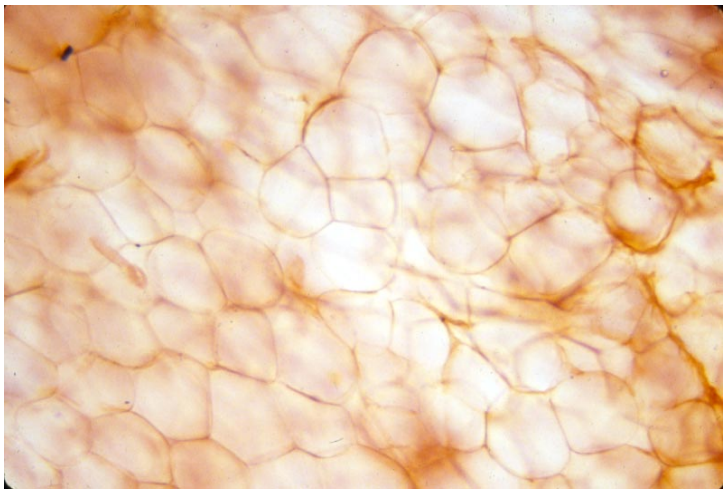
- **Abdominal fat aspirate**

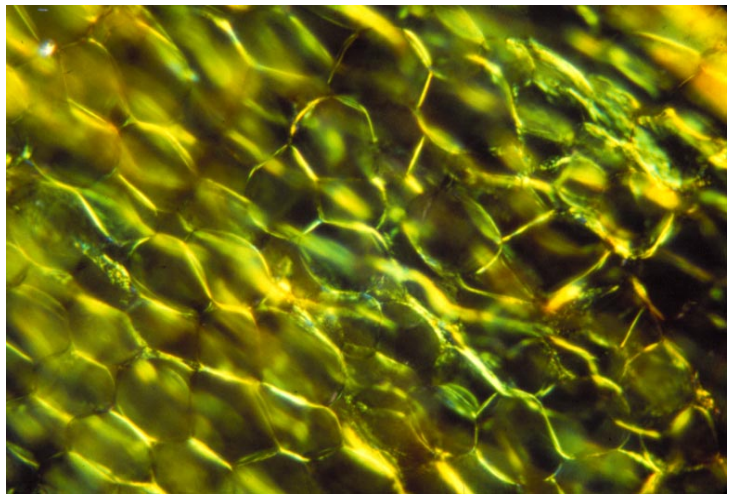
- Echocardiography
- ECG
- Serum biomarkers (BNP and troponins)
- Cardiac MR

ABDOMINAL FAT ASPIRATION AND CONGO RED STAINING









SUMMARY OF ECHO FEATURES: ADVANCED DISEASE

- Restrictive cardiomyopathy with profound abnormalities of diastolic function
  - Systolic dysfunction (LVEF) late manifestation so diastolic assessment is critical
- Classic textbook teaching
  - biventricular thickening in a small chambered ventricle
  - valvular thickening, “granular sparkling” myocardium
  - Atrial enlargement
  - Pericardial effusion/evidence of elevated filling pressures

Cohen Harrison’s Principles of Internal Medicine 13ed

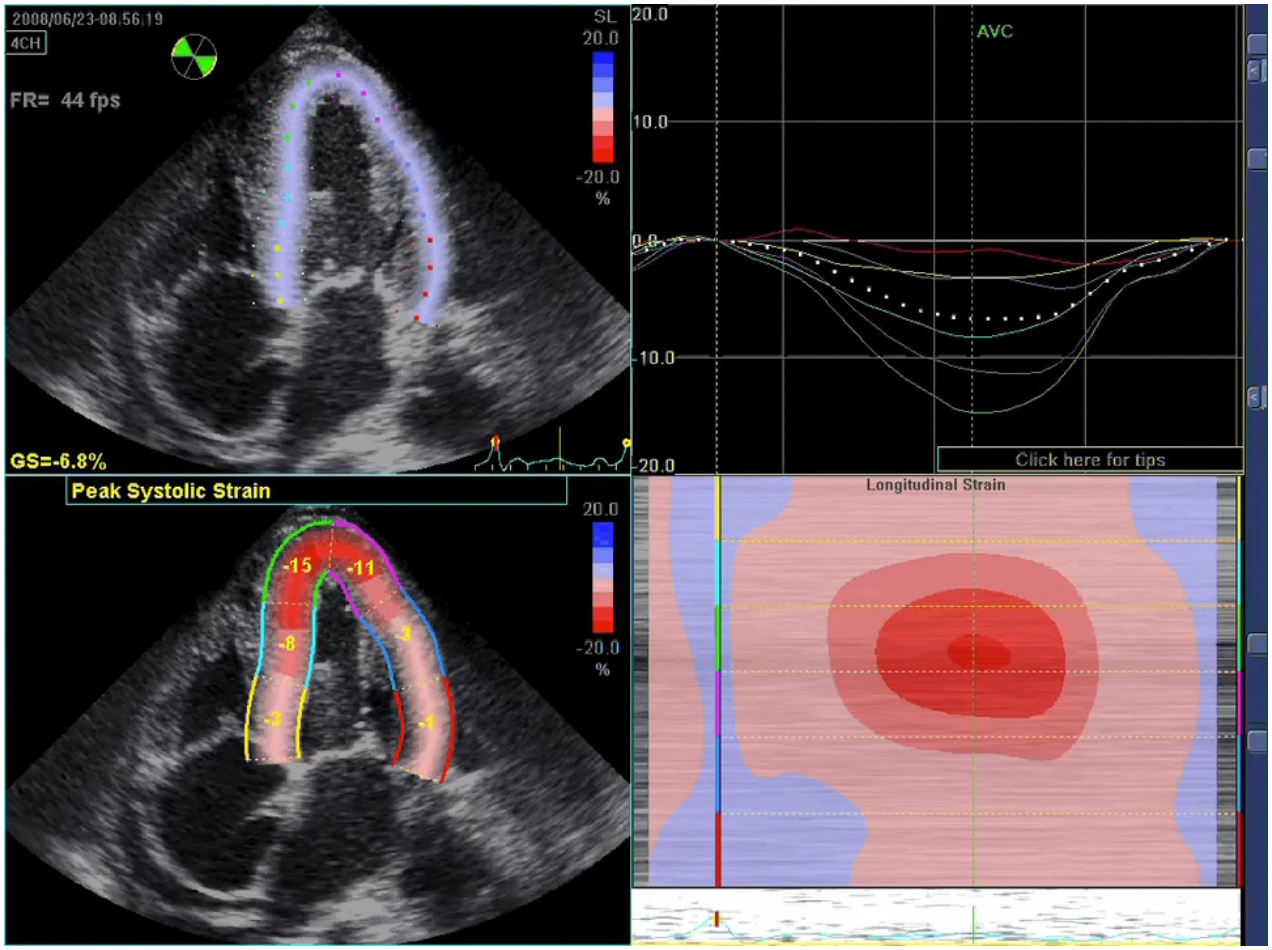
FEATURES OF AMYLOID HEART DISEASE

Table 2. Baseline Instrumental Characteristics: ECG, Echocardiography, and Hemodynamic Evaluation (Bologna Center Only)

	AL	ATTRm	ATTRwt	*P*
Echocardiography				
Diastolic interventricular septum thickness (mm)	15.8±2.8*	16.6±3.8‡	19.7±4.1	<0.0001
Diastolic LV posterior wall thickness (mm)	14.6±2.9*	15.4±3‡	17.9±3.8	<0.0001
Mean LV wall thickness (mm)	15.1±2.7*	16±3.2‡	18.8±3.8	<0.0001
Left atrial diameter (mm)	46.4±7.3†	43.1±7.7‡	49.5±6.6	0.002
LV ejection fraction (%)	52.5±13.1†	58±13‡	44.2±15.4	<0.0001
LV ejection fraction <40%, n (%)	34 (22)	5 (8)‡	6 (40)	0.009
LV end-diastolic diameter, mm	43.9±6.9	45.5±6.8	46.6±7.5	0.149
LV end-systolic diameter, mm (n)	29.9±6.3* (145)	31.2±8.2‡	36.3±8.5	0.003
E-wave deceleration time, ms (n)	160.9±48.3† (89)	182.8±61.4 (55)	168.2±20.8 (15)	0.049
Restrictive filling pattern, n (%)	82/150 (55)	22/59 (37)	4/14 (29)	0.024
Pericardial effusion, n (%)	100 (64)	36 (59)	12 (80)	0.32
LV mass among men, g (n)	338.8±105.5* (84)	391.6±149.9‡ (40)	512.9±161.9 (14)	<0.0001
LV mass among women, g (n)	290.8±96.3 (45)	137.6±42 (11)	281 (1)	NA
Interatrial septum thickness, mm (n)	8.7±2.4 (45)	8.7±2.3 (35)	9.1±1.1(15)	0.814
Atrioventricular valve thickening, n (%)	31/66 (47)	36/54 (67)	7/14 (50)	0.08
Voltage/mass ratio (n)	0.9±0.5*† (151)	1.1±0.5‡ (60)	1.97±0.5 (15)	<0.0001

Rapezzi *Circulation* 2009

ECHOCARDIOGRAPHY – LONGITUDINAL SYSTOLIC STRAIN

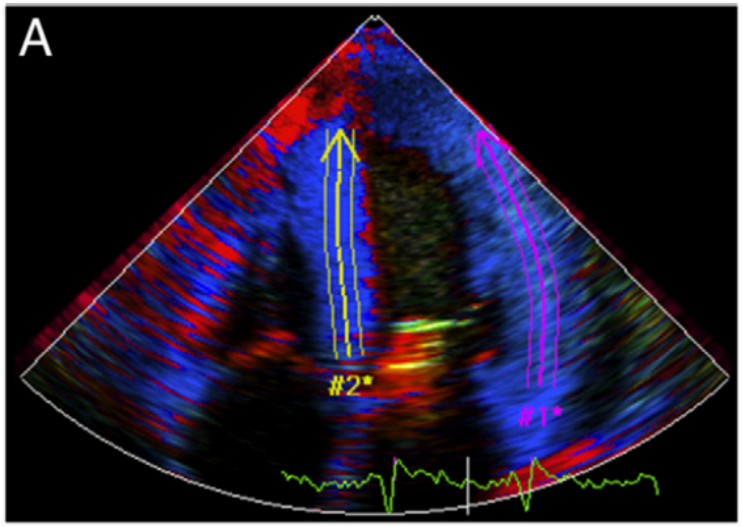


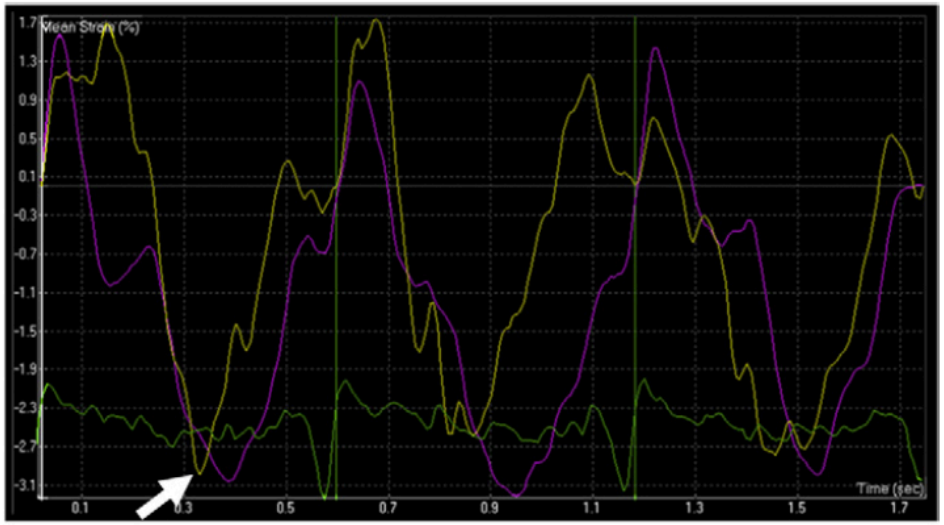
BOSTON MEDICAL CENTER
EXCEPTIONAL CARE. WITHOUT EXCEPTION.

BU School of Medicine

DIAGNOSIS: ECHO LONGITUDINAL STRAIN

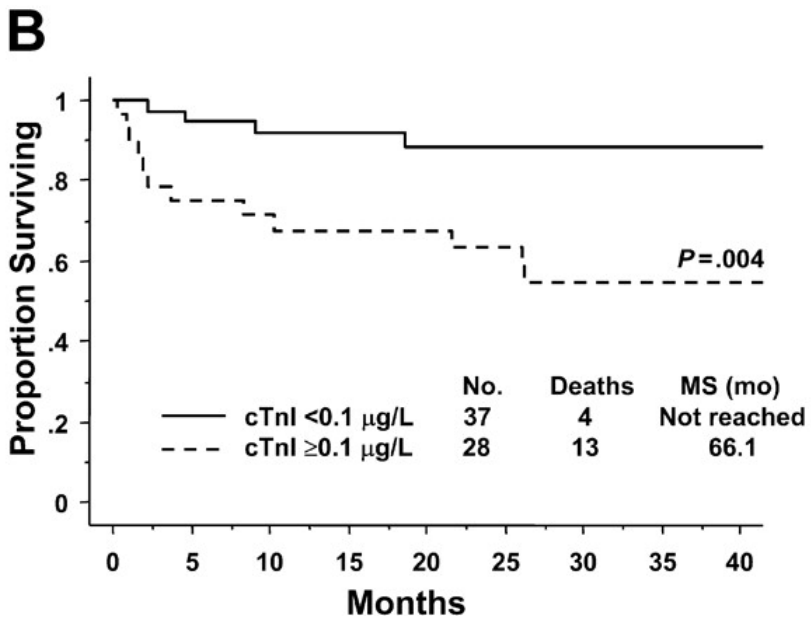
- Observational cohort n = 206 with AL cardiac amyloidosis
- Mean strain of approximately -11% identified survivors (particularly true in preserved LVEF)

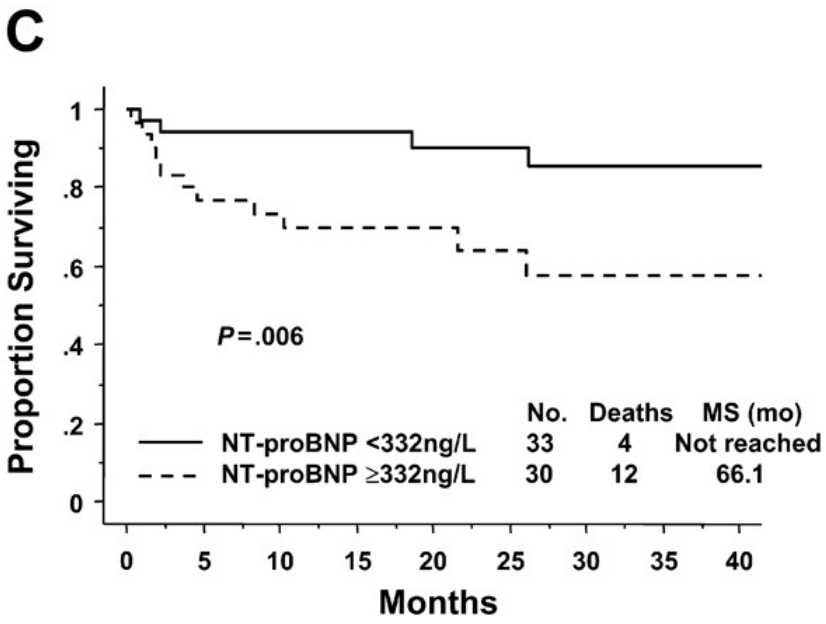




Buss *J Am Coll Cardiol* 2012

BNP/TROPONIN STRATIFY RISK

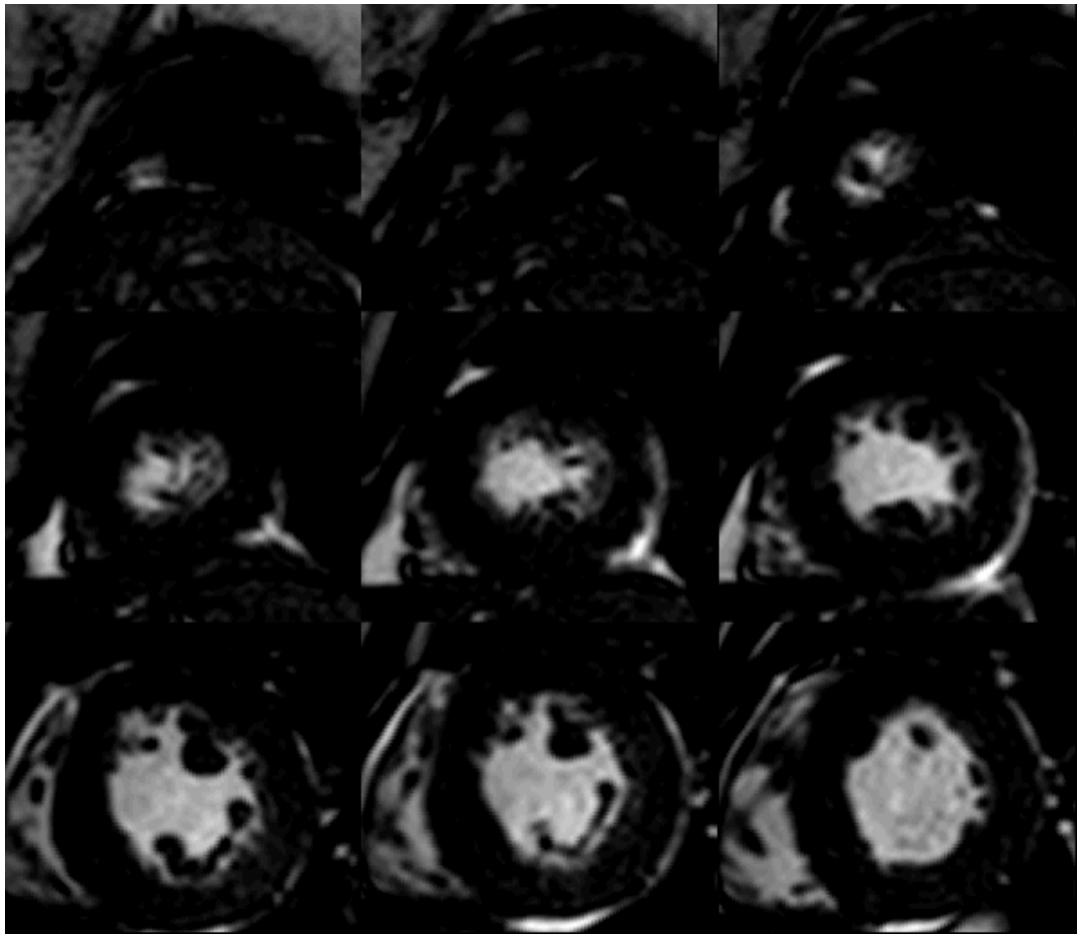




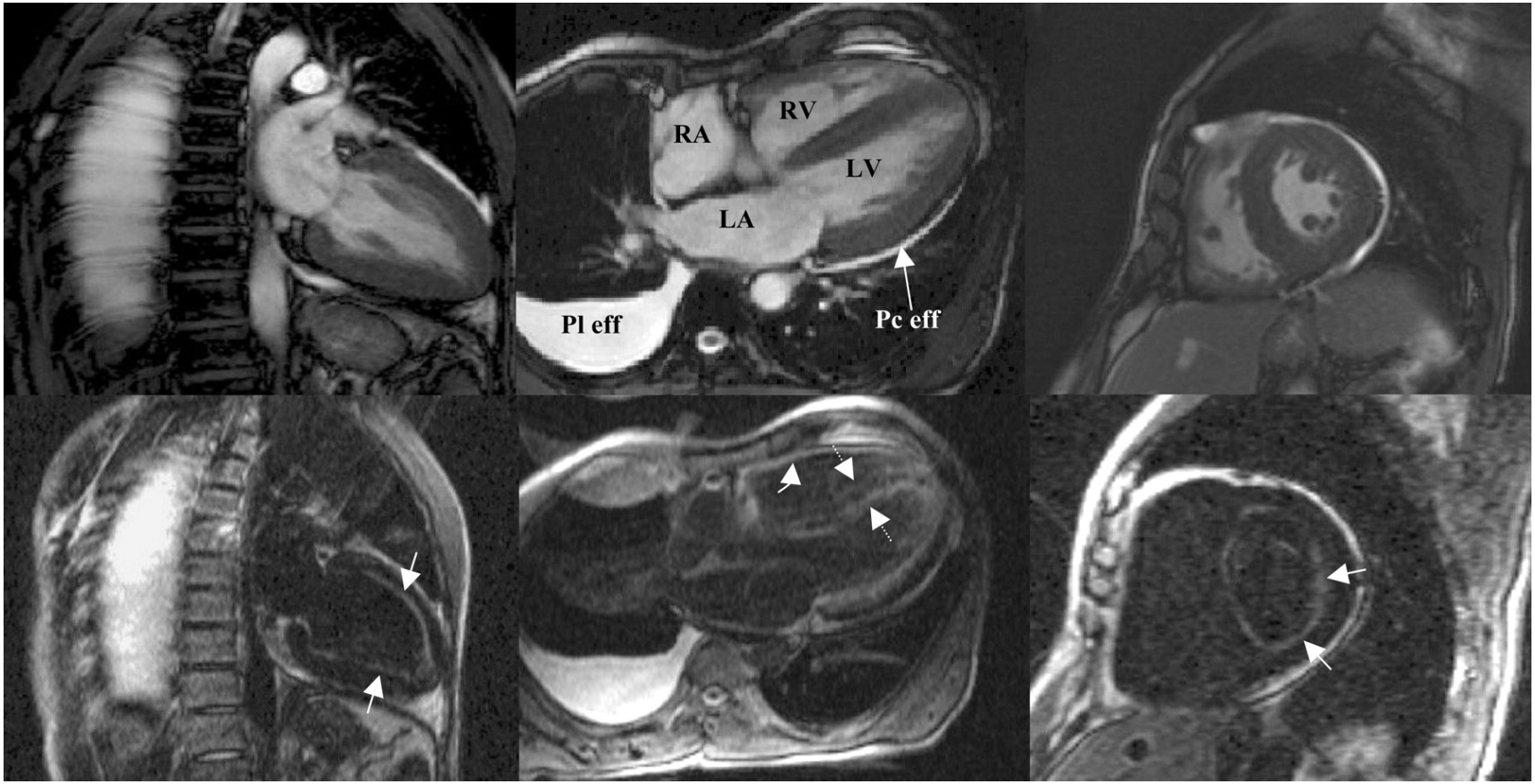
Clinical pearl: In patients with known AL disease, BNP < 100 virtually excludes clinically significant cardiac involvement

Dispenzieri *Blood* 2004

CARDIAC MR



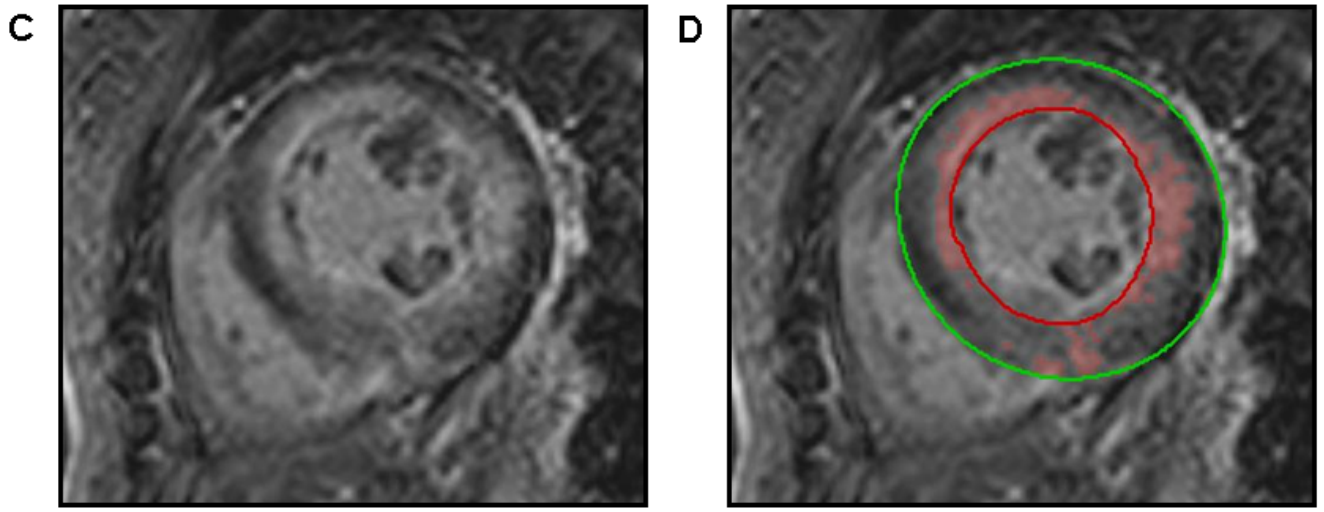
LGE CMR IN AMYLOIDOSIS



Maceira *Circulation* 2005

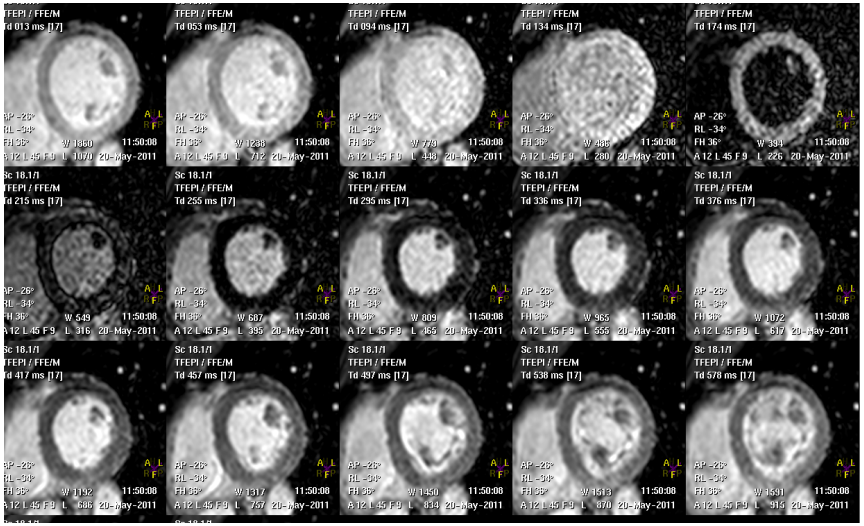
CARDIAC MR – HIGHLY SENSITIVE AND SPECIFIC FOR CARDIAC AMYLOIDOSIS

Reference	Sensitivity	Specificity	PPV	NPV
Vogelsberg et al., JACC 2008	80%	94%	92%	85%
Ruberg et al. Am J Cardiol 2009	86%	86%	95%	67%
Austin et al., JACC CVI 2009	88%	90%	88%	90%
Average	85%	90%	92%	81%

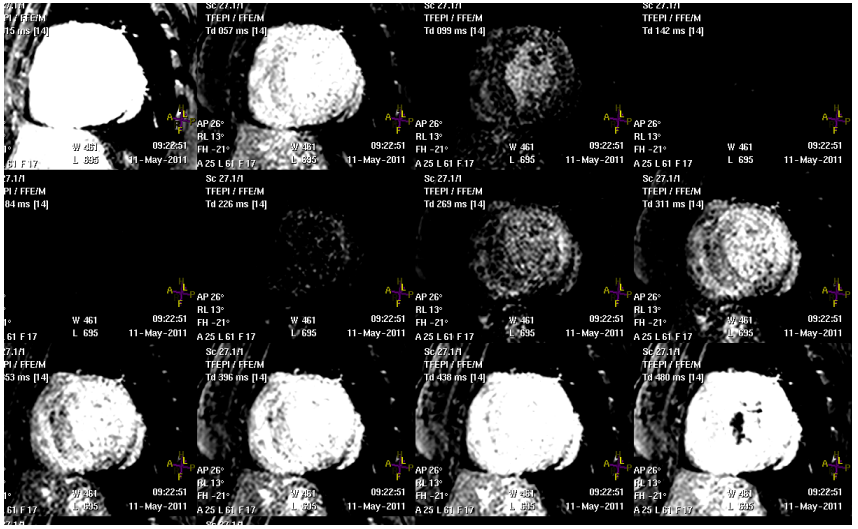


Ruberg *Am J Cardiol* 2009

CARDIAC MR - DIFFUSE ENHANCEMENT



Normal

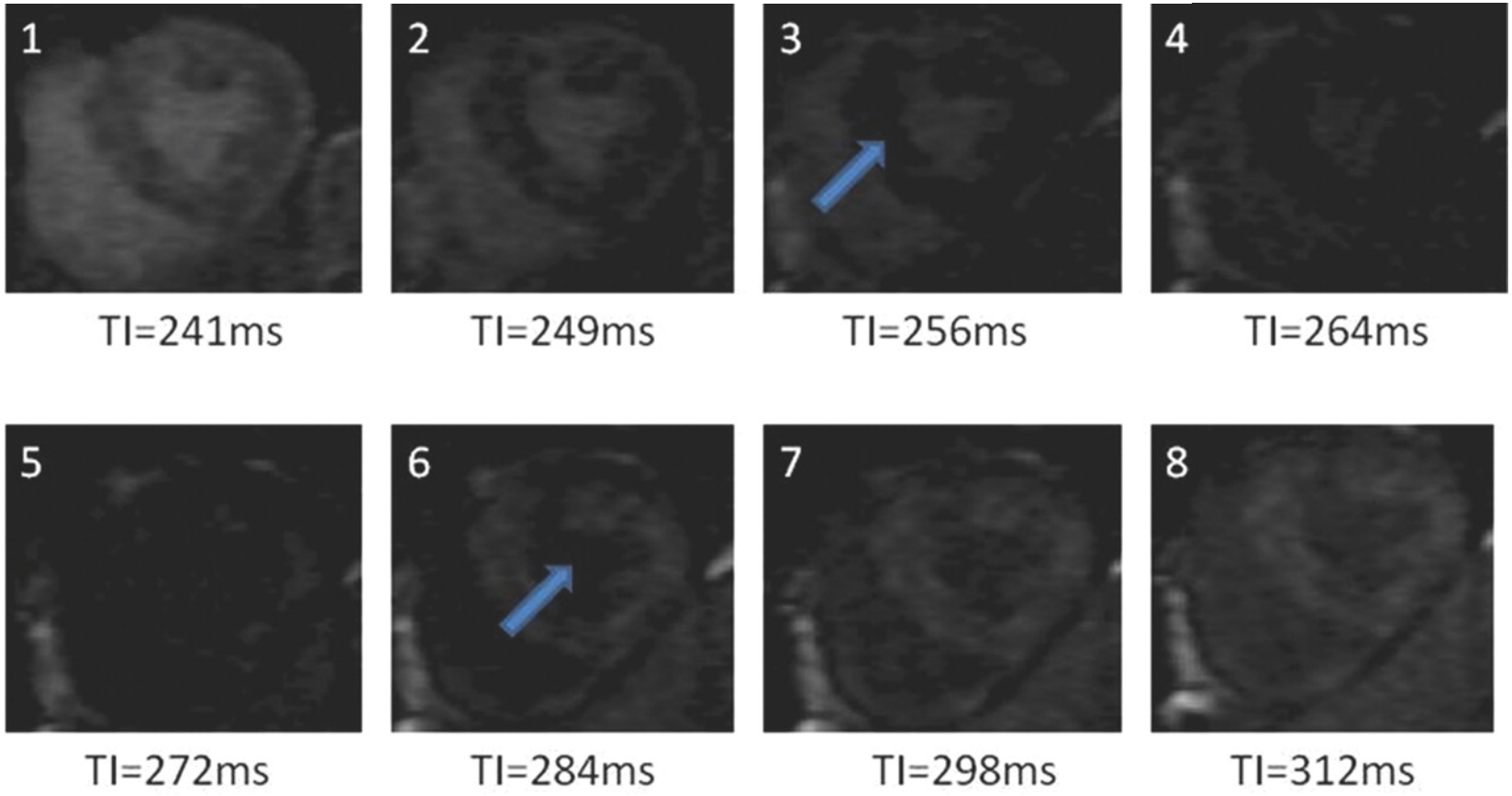


Cardiac Amyloidosis

- Normal – Blood and myocardial T1 are sufficiently different to pass through null point at different times
- Amyloidosis – Blood and myocardial T1 similar and thus pass through null point at similar time

Updates in Cardiac Amyloidosis: A Review

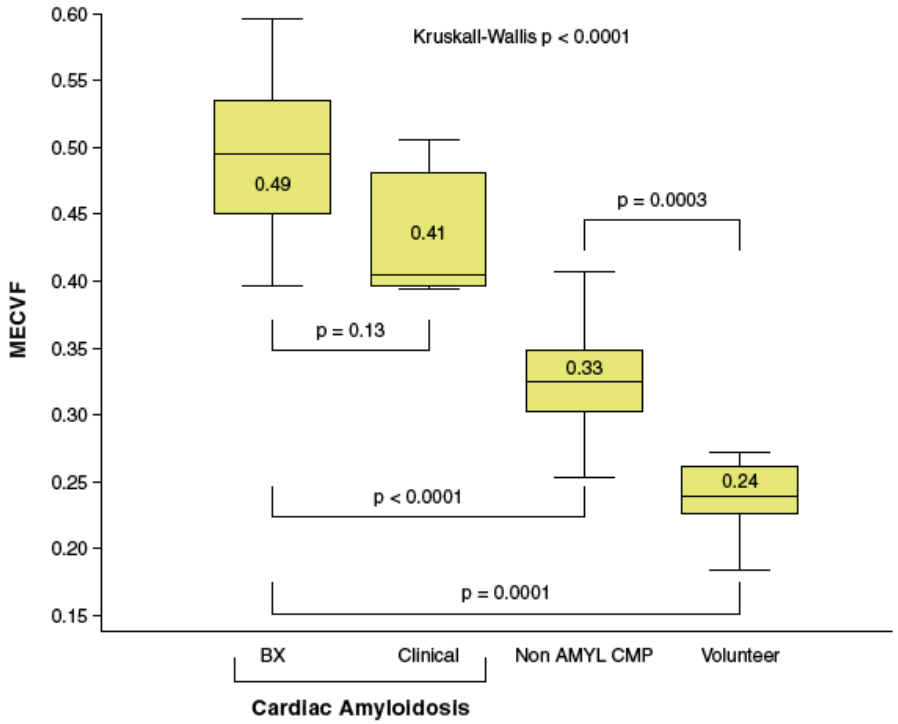
Sanjay M. Banypersad, MRCP; James C. Moon, MD, MRCP; Carol Whelan, MD, MRCP; Philip N. Hawkins, PhD, FMedSci; Ashutosh D. Wechalekar, DM, MRCP, FRCPath



Banypersad et al., JAHA 2012

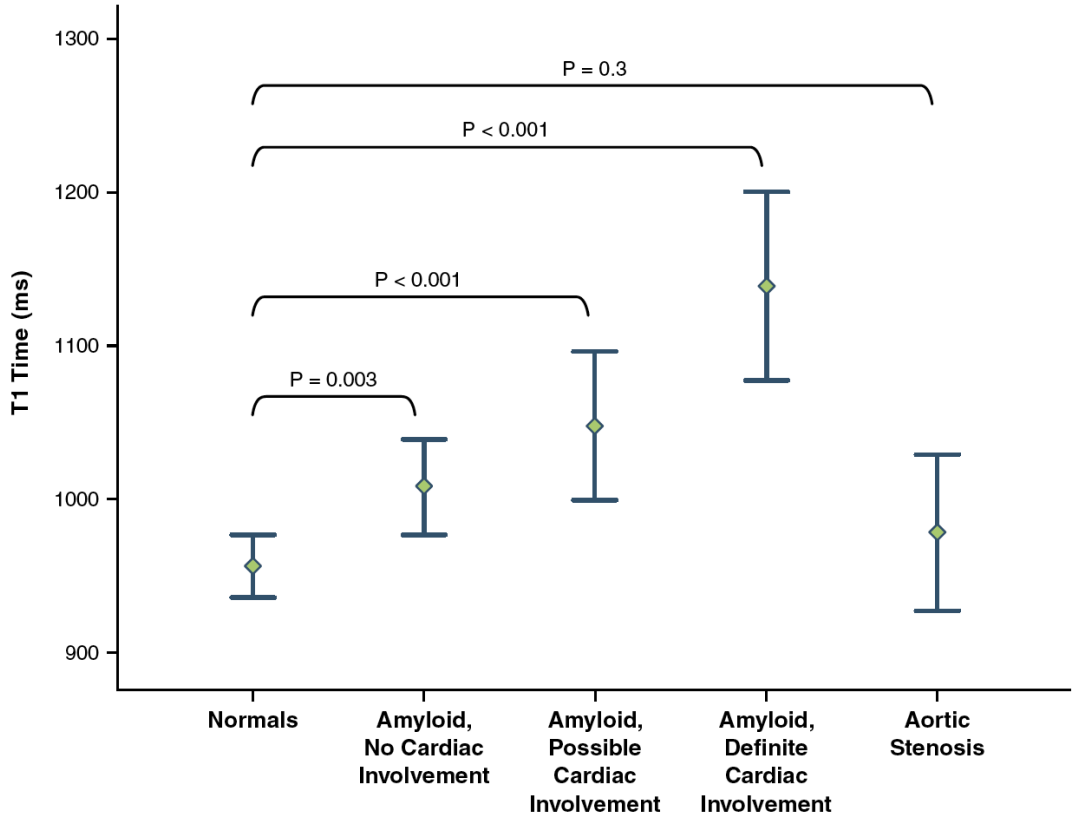
CMR AND EXTRACELLULAR VOLUME FRACTION (ECF)

- ECF higher in cardiac amyloidosis vs. non-amyloid restrictive cardiomyopathy



Kwong *JACC Img* 2012

NON-CONTRAST T1 MAPPING



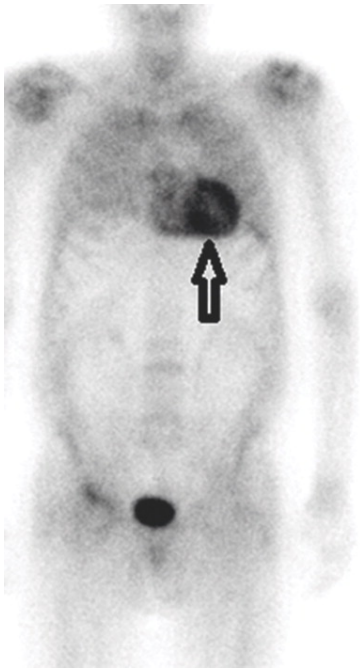
Karamitsos, iJACC 2013

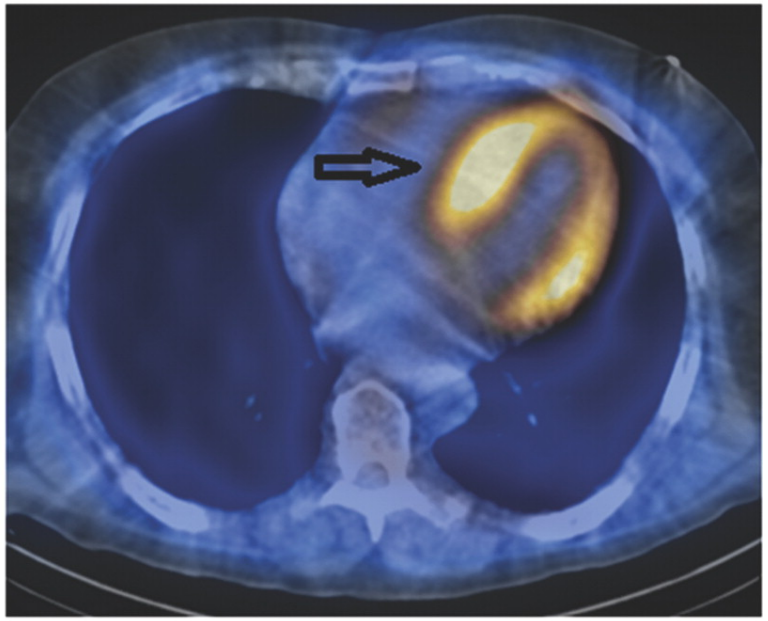
BOSTON MEDICAL CENTER
EXCEPTIONAL CARE. WITHOUT EXCEPTION.

BU School of Medicine

DIAGNOSIS: NUCLEAR IMAGING

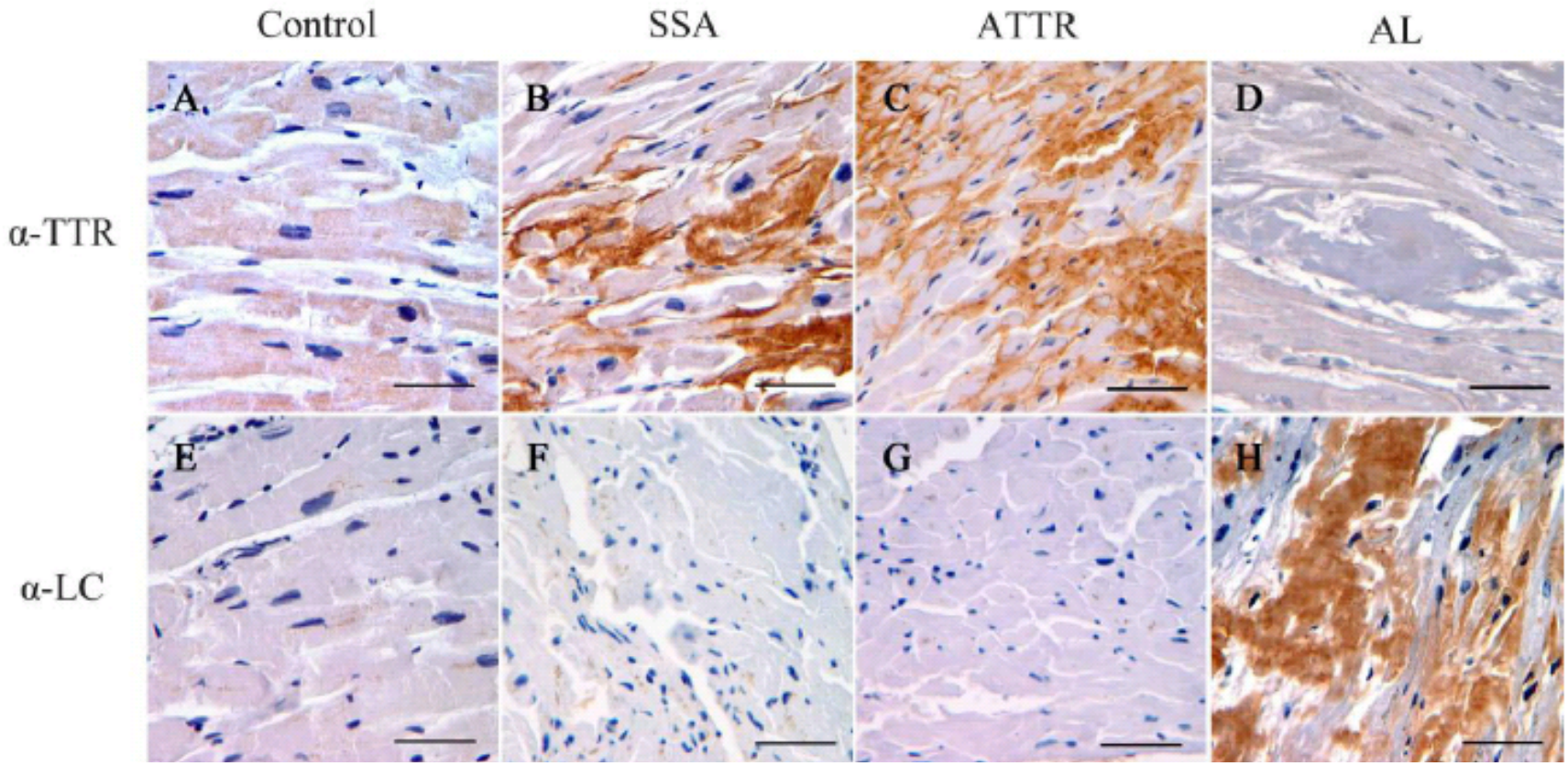
- Tc-99m Bone avid compounds
  - Pyrophosphate (PYP) and DPD – latter not available in US
  - May preferentially identify TTR cardiac amyloidosis vs. AL disease





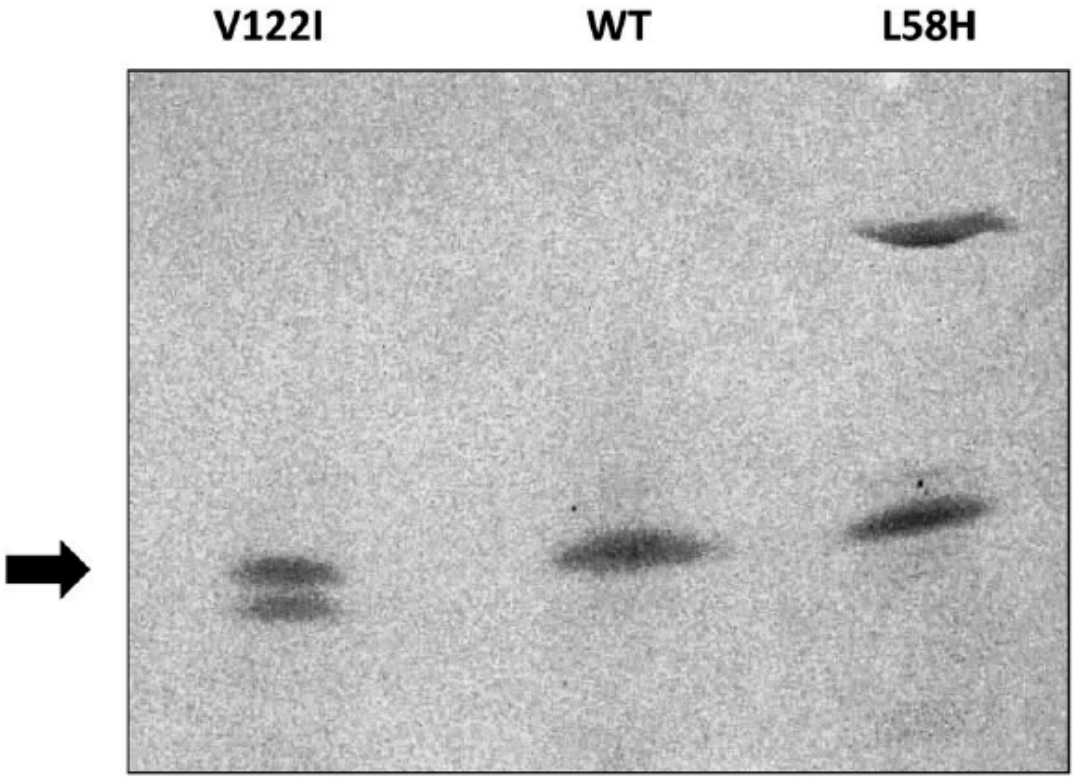
Rapezzi *Eur J Nuc Med Mol Imag* 2011: *JACC Img* 2011: Banypersad et al., JAHA 2012

IMMUNOHISTOCHEMISTRY



Greene, *Am J Pathol*. 2011

SERUM TEST FOR TTR: ISOELECTRIC FOCUSING (IEF) AND PCR



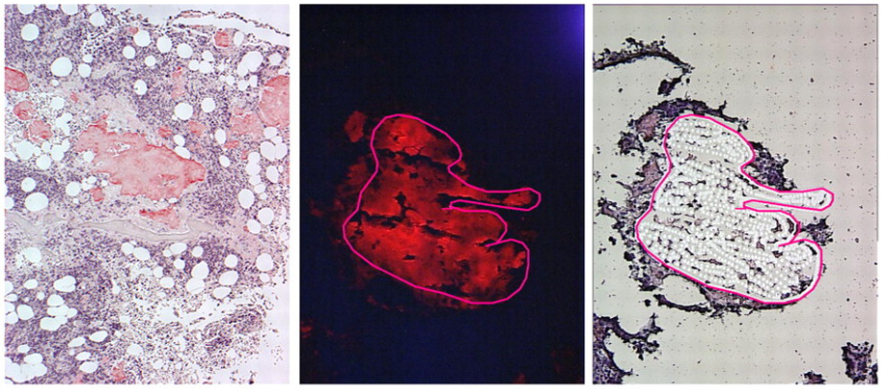
Ruberg *Circulation* 2012

BOSTON MEDICAL CENTER
EXCEPTIONAL CARE. WITHOUT EXCEPTION.

BU School of Medicine

LIQUID CHROMATOGRAPHY TANDEM MASS SPECTROMETRY (LC/MS)

A



B

#	Accession	MW	Control	1	2	3	4
1	ALBU_HUMAN	69 kDa		100% (36)	100% (35)	100% (36)	100% (35)
2	APOE_HUMAN	36 kDa		100% (19)	100% (17)	100% (18)	100% (17)
3	VTNC_HUMAN	54 kDa		100% (13)	100% (13)	100% (17)	100% (14)
4	KAC_HUMAN	12 kDa		100% (7)	100% (8)	100% (7)	100% (8)
5	APOA4_HUMAN	45 kDa		100% (15)	100% (19)	100% (17)	100% (13)
6	SAMP_HUMAN	25 kDa		100% (8)	100% (9)	100% (9)	100% (9)
7	C4BP_HUMAN	67 kDa		100% (11)	100% (10)	100% (12)	100% (10)
8	HBB_HUMAN	16 kDa		100% (4)	100% (8)	100% (9)	100% (7)
9	CLUS_HUMAN	52 kDa		100% (10)	100% (7)	100% (8)	100% (8)
10	CO6A3_HUMAN	344 kDa		100% (6)	100% (13)	100% (17)	100% (10)
11	APOA1_HUMAN	31 kDa		100% (7)	100% (5)	100% (9)	100% (7)
12	CO9_HUMAN	63 kDa		100% (5)	100% (5)	100% (5)	100% (7)
13	TRFE_HUMAN	77 kDa		100% (7)	100% (6)	100% (9)	100% (4)
14	HBA_HUMAN	15 kDa			100% (4)	100% (4)	100% (4)
15	CO3_HUMAN	187 kDa		100% (3)	100% (4)	100% (8)	100% (5)

MAYO CLINIC
Mayo Medical Laboratories

C

Protein	Sample	Probability	Unique Peptides	Unique Spectra	Total spectra	% Coverage
Ig kappa chain C region -	Sample 1	100%	7	10	53	80%
Ig kappa chain C region -	Sample 2	100%	8	11	53	67%
Ig kappa chain C region -	Sample 3	100%	7	11	58	67%
Ig kappa chain C region -	Sample 4	100%	8	12	61	80%

Vrana *Blood 2009*

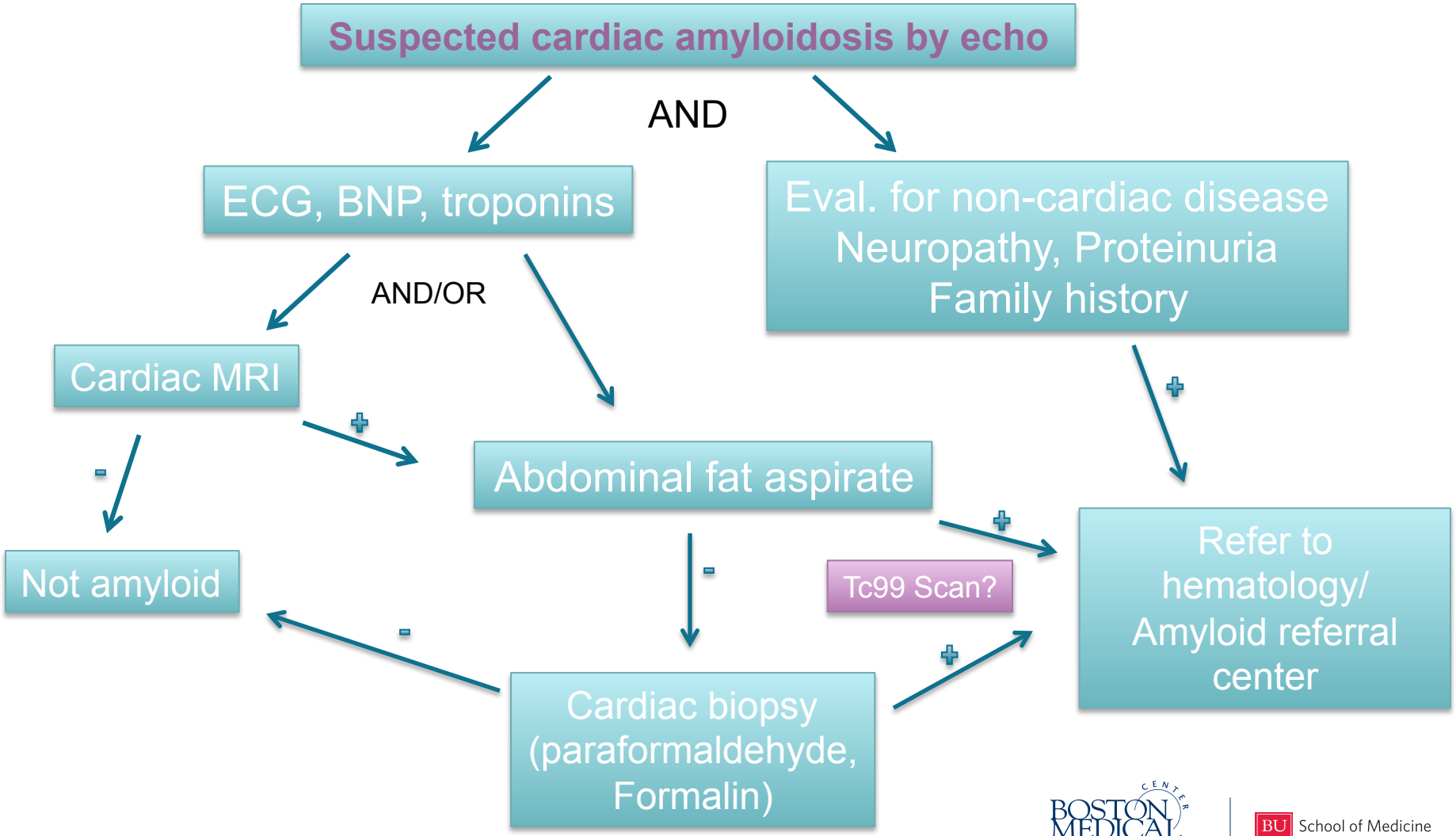
BOSTON MEDICAL CENTER
EXCEPTIONAL CARE. WITHOUT EXCEPTION.

BU School of Medicine

DIAGNOSIS OF CARDIAC AMYLOIDOSIS IN THREE (EASY) STEPS

1. Recognition of Cardiac Amyloid Disease
   - Biomarkers, Echocardiography, Cardiac MR, Nuclear imaging
2. Identification of amyloid deposits using Congo red staining and polarized microscopy
   - Abdominal Fat Aspirate (high sensitivity in AL, low in SSA)
   - Endomyocardial biopsy
   - Other tissue biopsy (kidney, bone marrow, gastrointestinal, etc.)
3. Typing of Precursor Protein (AL, TTR, AA)
   - Exclusion of AL (bone marrow biopsy, serum immunofixation electrophoresis (SIFE), serum/urine free light chains)
   - Tissue biopsy - Immunologic techniques, mass spectrometry
   - Serum testing - Genetics (TTR disease)
   - Proteomics

DIAGNOSTIC APPROACH FOR SUSPECTED CARDIAC AMYLOIDOSIS



BOSTON MEDICAL CENTER
EXCEPTIONAL CARE. WITHOUT EXCEPTION.

BU School of Medicine

OVERVIEW OF PRESENTATION

- Nomenclature and epidemiology
- Clinical presentation
- Diagnosis
- Prognosis/Treatment

TREATMENT: SYMPTOMS OF HF

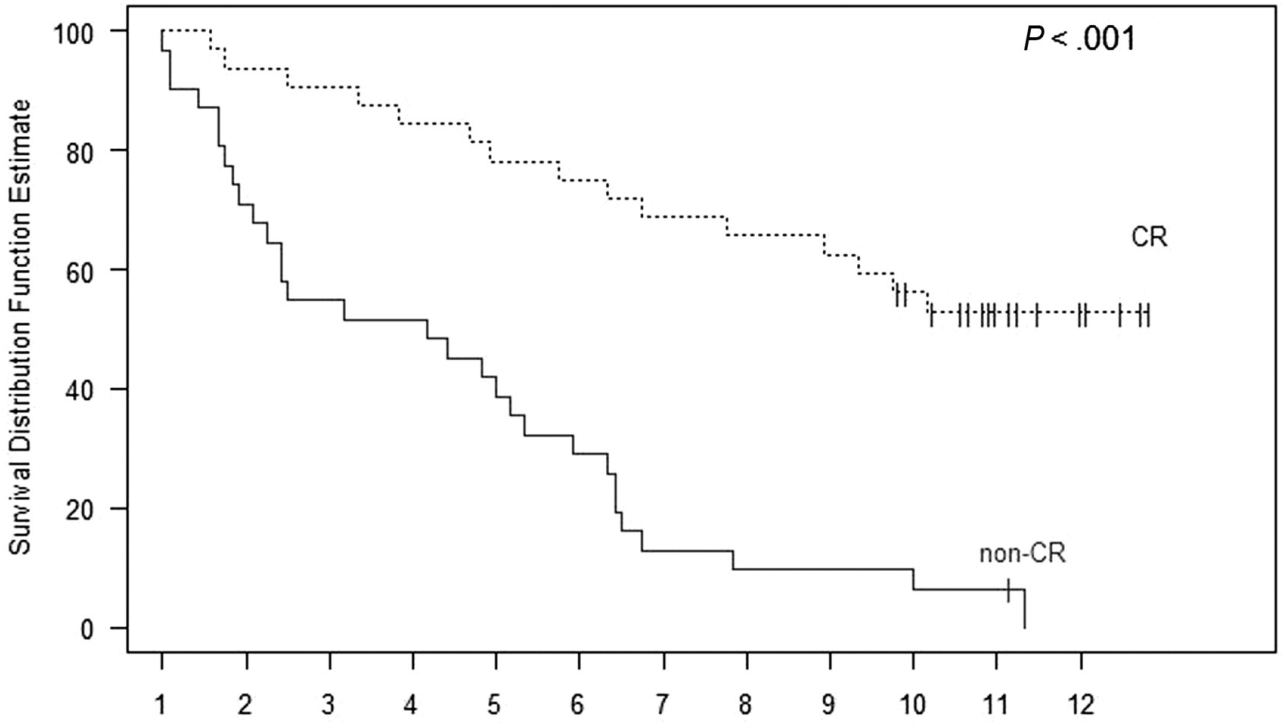
- Volume control – diuretic therapy
- Standard heart failure therapies do not apply
  - Fixed stroke volume due to restriction
  - Tachycardia - intolerant to high dose beta blockers/ calcium channel blockers
  - Dig toxicity predisposition - AVOID
- BP support for autonomic neuropathy
  - Midodrine (Proamatine)

TREATMENT: AL DISEASE

- All derive from myeloma
- High dose intravenous melphalan with autologous stem cell transplantation (HDM/SCT)
  - Advantage – rapid reduction in light chains, arguably most durable response
  - 50% with cardiac involvement
  - 40% complete hematologic response induction
  - Subject selection is critical to success
- IV Bortezomib (Velcade) and derivatives
- Oral lenalidomide (Revlimid) and derivatives
- Oral melphalan/dexamethasone

Skinner *Ann Int Med* 2004: Cibeira Blood 2011

LONG TERM SURVIVAL IN AL FOLLOWING STEM CELL TRANSPLANTATION



CR – complete hematologic response

Patients, n												
CR:	32	30	29	27	25	24	22	21	20	16	9	5
non-CR:	31	22	17	16	13	9	4	3	3	3	2	0

Sanchorawala *Blood* 2007

AL: CARDIAC TRANSPLANTATION

- Do not meet inclusion criteria for HDM/SCT but younger and with typically isolated cardiac involvement
- Orthotopic heart transplantation (OHT) followed by stem cell transplantation (SCT)
- Overall data suggests that survival for these patients is similar to non-amyloid OHT recipients
  - 60% 7-year survival, most often amyloid does not recur in allograft

Gilmore *Blood* 2006: Lacy *J Heart Lung Txp* 2008: Dey *Transplantation* 2010

PROGNOSIS: TTR AMYLOIDOSIS

- TTR mutant
  - Variable - depends upon age of onset and mutation
  - 98% alive at 2 years
- Senile systemic
  - Slow progression, median survival with CHF 75 months, many over age 70 at diagnosis

Dubrey *Heart* 1997: Ng *Arch Int Med* 2005

PROGNOSIS: TTR DUE TO V122I

- Mutation seen in 4% African Americans
  - 1 million African Americans with mutation
  - Approximately 100,000 over age 65y at risk
- Increased risk of CHF in cohort studies
- Median survival is 24-27 months following diagnosis
  - Prospective multi-center TRACS (Transthyretin Amyloidosis Cardiac Study)

Jacobson *NEJM* 1997: Buxbaum *AHJ* 2010: Connors *AHJ* 2009: Ruberg *AHJ* 2012

TREATMENT: TTR DISEASE

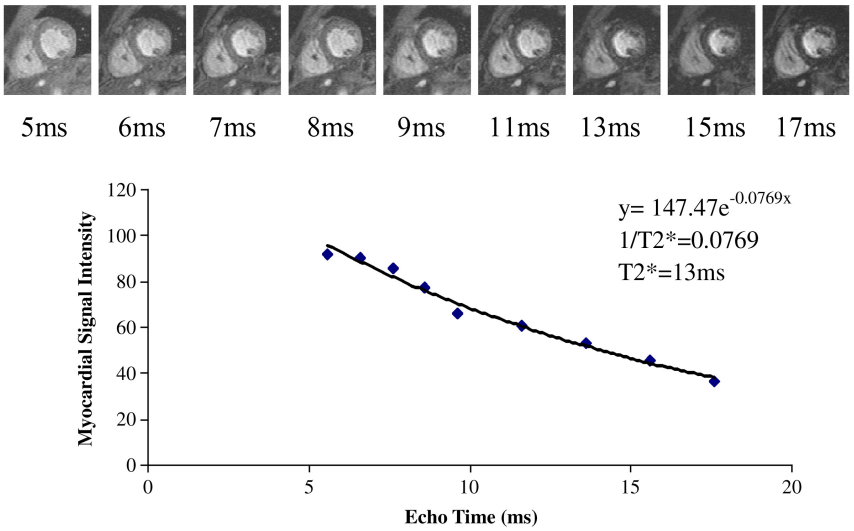
- Cardiac and/or liver transplantation
  - Timing of transplantation (before cardiomyopathy)
  - In liver txp alone, reported progression of cardiac amyloid despite normal TTR produced by liver
- Inhibitors of protein misfolding (diflunisal, tafamidis)
  - Diflunisal (Dolobid) - generic
  - Tafamidis (Vyndaquel) – Pfizer (not FDA approved)
- Inhibitors of TTR expression
  - RNAi (Alnylam, Cambridge, MA)
    - Cohelo, NEJM 2013
  - Antisense ODN (Isis, Carlsbad, CA)

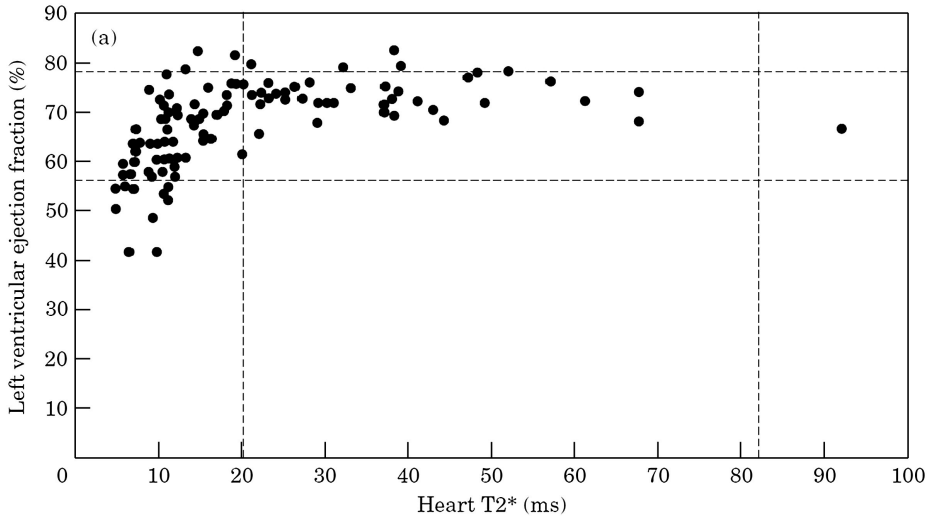
OTHER INFILTRATIVE CARDOPMYOPATHY

- Iron Overload/Hemochromatosis
- Cardiac Sarcoidosis

IRON OVERLOAD CARDIOMYOPATHY

- Iron shortens myocardial T2-star (T2*)
  - Normal = 50 - 60 ms with < 20 ms considered abnormal
  - Change in T2* associated with LVEF improvement with chelation therapy





Anderson Eur Heart J 2001: Tanner Circulation 2007: Anderson Prog Cardiovasc Disease 2011

BOSTON MEDICAL CENTER
EXCEPTIONAL CARE. WITHOUT EXCEPTION.

BU School of Medicine

CMR AND IRON OVERLOAD

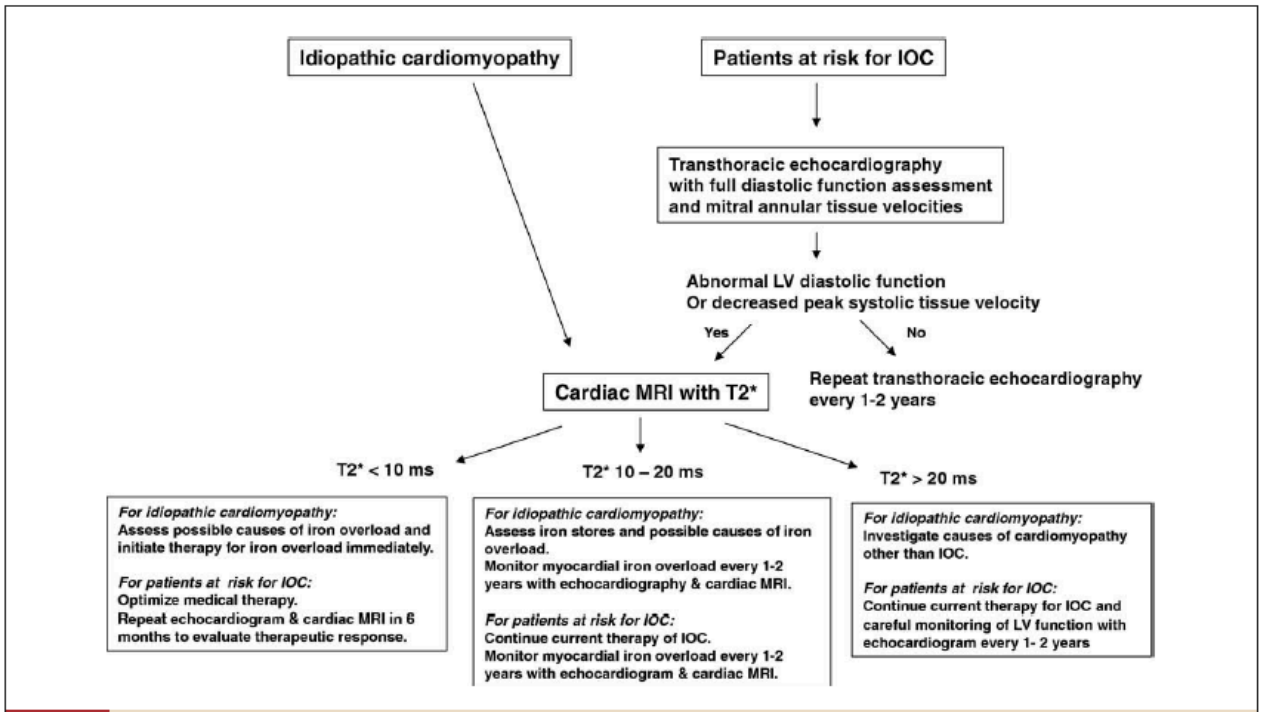


Figure 3 Our Proposed Clinical Pathway to Evaluate Patients With Idiopathic Cardiomyopathy or Those at Risk for Iron Overload

IOC = iron overload cardiomyopathy; LV = left ventricle; MRI = magnetic resonance imaging.

Gujja JACC 2010

CARDIAC SARCOIDOSIS?

- Diagnosis – Identify regions of LGE that represent granulomatous inflammation, thus increase detection
  - LGE in approximately 25-30%, JMH criteria 10-20%
- Prognosis – LGE presence associated with increased risk of mortality

Smedema, *JACC* 2005: Patel, *Circulation* 2009

CLASSICAL DEFINITION OF CARDIAC SARCOIDOSIS

† Modified Guidelines for the Diagnosis of Cardiac Sarcoid based on JMH Criteria, 1993

Clinical diagnosis group: in patients with histologic diagnosis of extra-cardiac sarcoidosis, cardiac sarcoidosis is suspected when 'A' and at least one from 'B' to 'D' is present and other etiologies such as coronary artery disease have been excluded.

A. Complete RBBB, left axis deviation, AV block, VT, NSVT, PVC (>grade 2 of Lown's classification),or pathological Q or ST-T change on resting or ambulatory ECG.

B. Abnormal wall motion, regional wall thinning, or dilation of the left ventricle on echocardiographic studies.

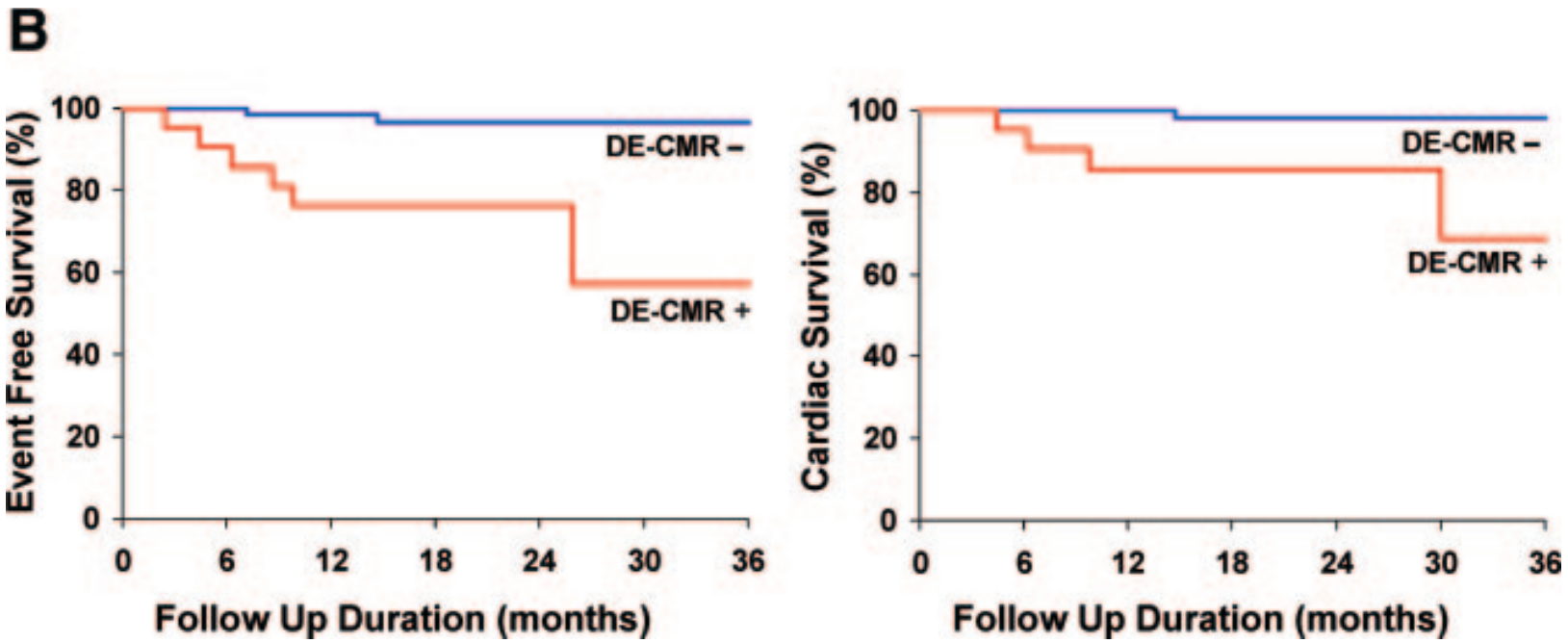
C. Perfusion defect by thallium-myocardial scintigraphy or abnormal accumulation on 67Ga-citrate or 99m Tc-PYP myocardial scintigraphy.

D. Abnormal intracardiac pressure, low cardiac output, or abnormal wall motion or depressed ejection fraction of the left ventricle on cardiac catheterization.

AV= atrioventricular; RBBB= right bundle branch block; NSVT= nonsustained ventricular tachycardia; PVC= premature ventricular contraction; VT= ventricular tachycardia. Modified from Hiraga et al.[8]

Hiraga, Japan Ministry Health Welfare 1993

LGE CMR IN SARCOIDOSIS



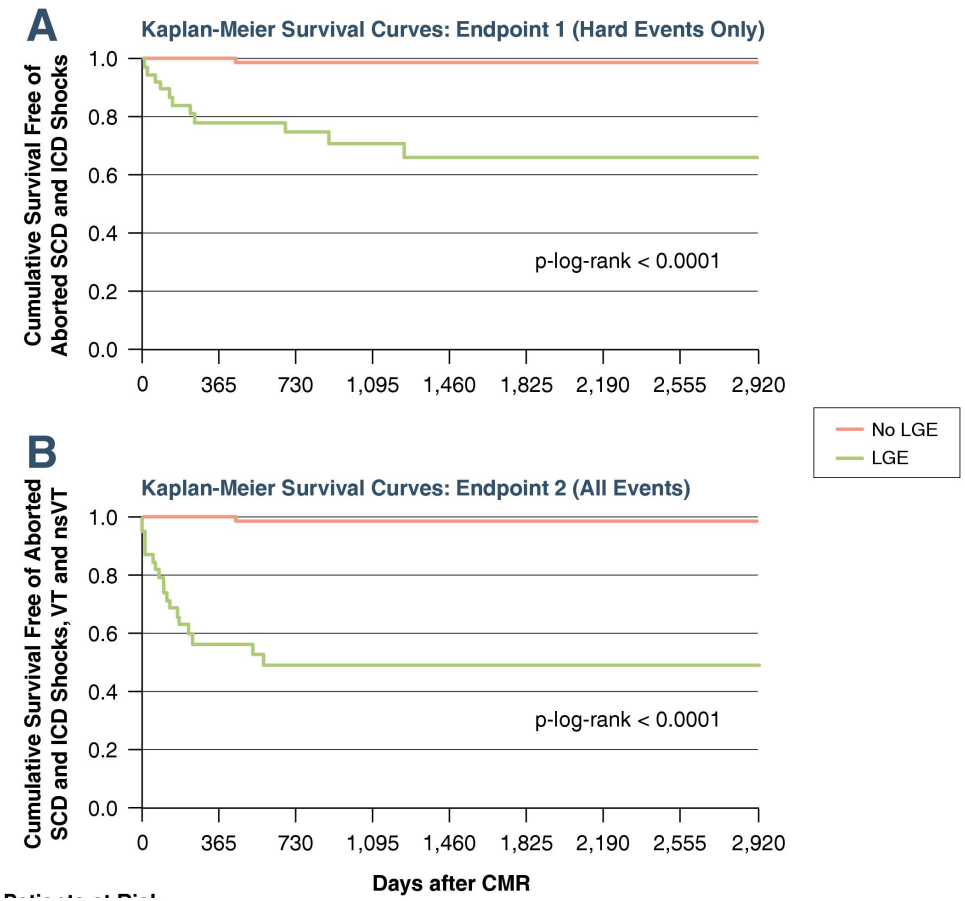
Patel Circulation 2009

BOSTON MEDICAL CENTER
EXCEPTIONAL CARE. WITHOUT EXCEPTION.

BU School of Medicine

LGE CMR IN SARCOIDOSIS

- 155 patients with systemic sarcoidosis, 2.6 year followup
- LGE in 26%, HR of 32 for death or arrythmia (virtually no events in no LGE group)

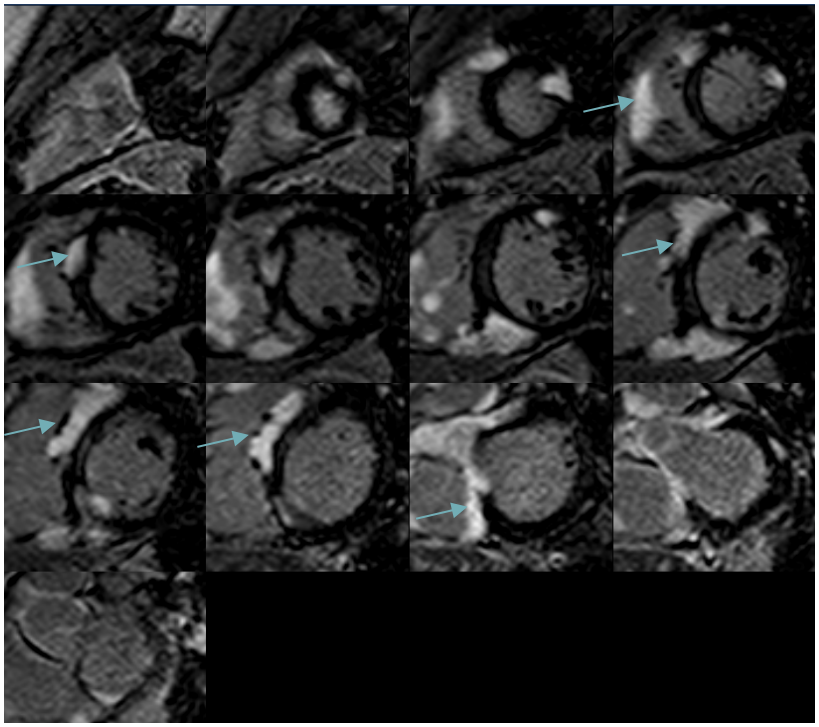


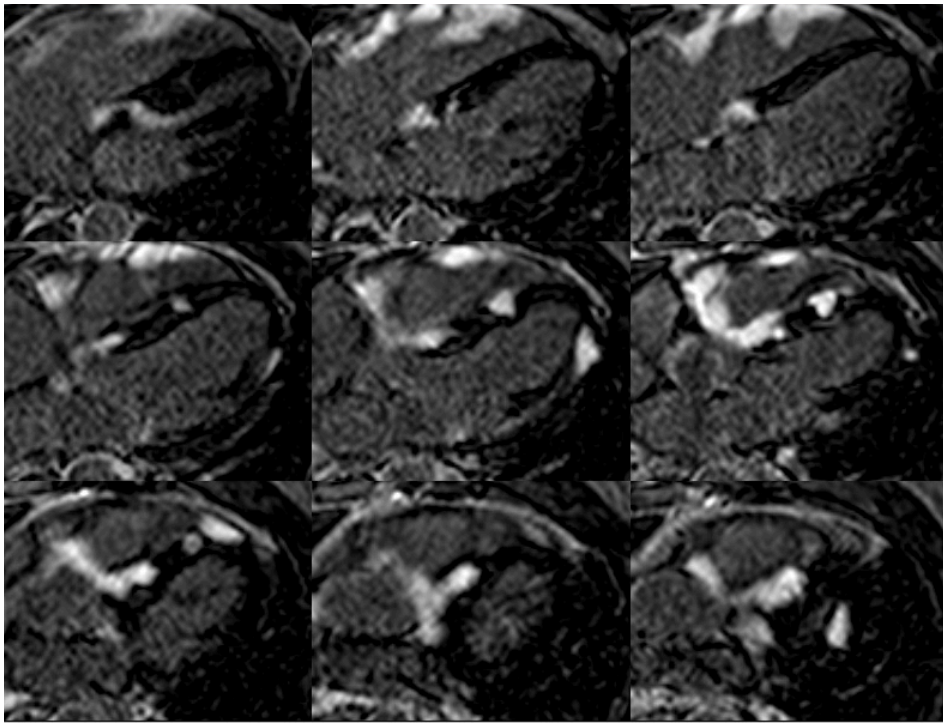
Greulich JACC Img 2013

BOSTON MEDICAL CENTER
EXCEPTIONAL CARE. WITHOUT EXCEPTION.

BU School of Medicine

CARDIAC SARCOIDOSIS – LGE





CONCLUSIONS

- Infiltrative CM – amyloidosis, sarcoidosis, iron overload
- Diagnosis can be made by various non-invasive tests, but CMR figures prominently in algorithm
- In iron overload, low T2* associated with poorer outcomes
- In sarcoidosis, LGE associated with poorer outcomes
- Amyloidosis is more complicated
  - CMR has high sens/spec for diagnosis
  - Prognosis varies by type, as do treatments

AMYLOIDOSIS CENTER
BOSTON UNIVERSITY SCHOOL OF MEDICINE

BOSTON MEDICAL CENTER
EXCEPTIONAL CARE. WITHOUT EXCEPTION.

BU School of Medicine