

# Role of CMR in Valvular Regurgitation: When Is It Indicated?

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## 40 year old woman with murmur.

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### ASE GUIDELINES AND STANDARDS

## Recommendations for Noninvasive Evaluation of Native Valvular Regurgitation

A Report from the American Society of Echocardiography  
Developed in Collaboration with the Society for Cardiovascular  
Magnetic Resonance

William A. Zoghbi, MD, FASE (Chair), David Adams, RCS, RDCS, FASE, Robert O. Bonow, MD, Maurice Enriquez-Sarano, MD, Elyse Foster, MD, FASE, Paul A. Grayburn, MD, FASE, Rebecca T. Hahn, MD, FASE, Yuchi Han, MD, MMSc, Judy Hang, MD, FASE, Roberto M. Lang, MD, FASE, Stephen H. Little, MD, FASE, Dipan J. Shah, MD, MMSc, Stanton Sherman, MD, FASE, Paladinesh Thavendranathan, MD, MSc, FASE, James D. Thomas, MD, FASE, and Neil J. Weissman, MD, FASE, *Houston and Dallas, Texas; Durham, North Carolina; Chicago, Illinois; Rochester, Minnesota; San Francisco, California; New York, New York; Philadelphia, Pennsylvania; Boston, Massachusetts; Toronto, Ontario, Canada; and Washington, DC*

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## Chronic Mitral Regurgitation by Doppler Echocardiography

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Zoghbi et al, JASE 2017

## Sequences Needed:

### CMR For Valve Assessment

Cine-CMR

Phase Contrast CMR

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## Quantification of LV Stroke Volume:

**Volume = Area x Thickness**

LV EDV = 41 ml  
LV ESV = 0 ml  
Stroke Volume = 41 ml

**EF = (EDV-ESV)/EDV = 100%**  
**LVEF = (206-102)/206 = 50%**

Shah, Curr Opin Cardiol 2012, 27:485-491

Pathyama PM. Radiology 1993;187:261-8.  
Sarmela RC. Am Heart J 1990;119:1367-73.  
Stratemeier EJ. Radiology 1986;158:775-7.

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Rehr RB. Radiology 1985;156:717-9

CMR volumetry validated:

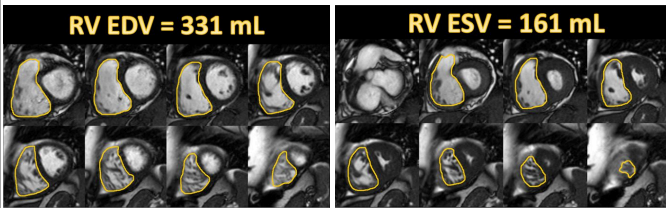
- Animals
- In vitro
- In vivo
- Ex vivo

Superior to ECHO

- Highly accurate
- Highly reproducible
- Low intra-observer variability
- Low inter-observer variability
- LVEF: 2-7%
- Low inter-study variability

Accurate and reproducible volumes  
No geometric assumptions

## Quantification of RV Stroke Volume:

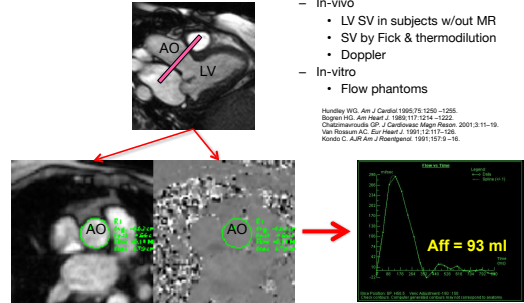


**RV Stroke Volume = RVEDV (331) - RVESV (161) = 170 mL**

Zhan et al. Journal American College of Cardiology, 2020.

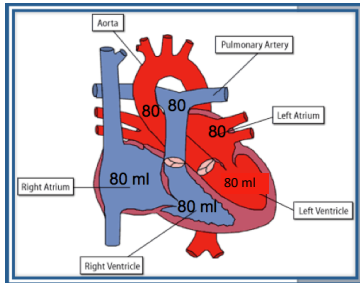
## Accuracy of CMR Derived Flow & Stroke Volume (SV) Measurements

- Strong correlation
  - In-vivo
    - LV SV in subjects w/out MR
    - SV by Fick & thermodilution
    - Doppler
  - In-vitro
    - Flow phantoms



Handley WG. Am J Cardiol 1990;75:1250-1255.  
Bogren HG. Am Heart J 1986;117:214-222.  
Chakravarthy S. J Cardiovasc Med Res 2001;3:11-19.  
Van Rossum AC. Eur Heart J 1991;12:1175-126.  
Korico C. AJR Am J Roentgenol. 1991;157:9-16.

## Conservation of Mass Principle



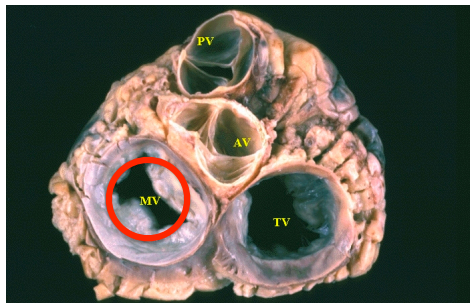
**LVSV = RVSV = AO Flow = PA Flow**

## OUTLINE:

- ♦ What are the goals of CMR in valve assessment ?
  - Severity of lesion
  - Mechanism of lesion
  - Consequences of lesion
- ♦ How does CMR compare to Echo
- ♦ When to use CMR for valve assessment

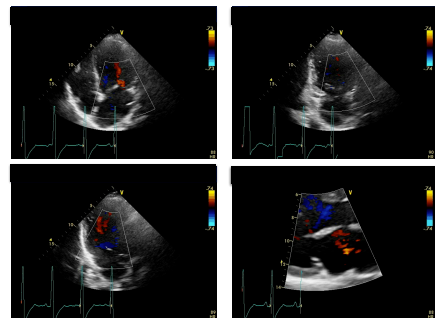


## OUTLINE:



[www.med.uottawa.ca](http://www.med.uottawa.ca)

## 40 year old woman referred for evaluation of murmur.



### Quantification of Mitral Regurgitation Severity:

**End-Diastole** HOUSTON Methodist DEBAKEY HEART & VASCULAR CENTER

Mitral Reg Vol = LV stroke volume – Aortic forward volume  
 $Z = X - Y$

**End-Systole**

This technique is not affected by:

1. Presence of changing degrees of MR during systole.
2. Eccentric jets
3. Mobile mitral regurgitant jets.

LVSV X ml

### 40 year old woman referred for evaluation of mitral regurgitation noted on echo.

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### MR Regurgitant Volume & Fraction

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MR Regurgitant Volume = LV Stroke Vol – Systolic Aortic Forward Flow

LVSV 176 ml

Aff = 93 ml

Mitral Reg Vol = LV SV – Aortic FF = 176 – 93 = 83 ml

Regurgitant Fraction (%) = MR regurg vol / MV Flow = 83/176 = 47%

### OUTLINE:

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- How does CMR assess valve regurgitation ?
  - Severity of lesion
  - Mechanism of lesion
  - Consequences of lesion
- How does CMR compare to Echo for regurgitation assessment
- When to use CMR for valve regurgitation

HOW? WHAT? WHO? WHEN? WHERE? WHY?

### Mechanism of MR:

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Bileaflet Prolapse

Posterior leaflet prolapse

### Mechanism of MR:

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Prolapse

Flail

CMR is inferior to TEE in depicting torn chordae.

		Sensitivity	Specificity	Accuracy
AML	TEE (n=36)	75	96	92
	MRI (n=35)	71	96	91
PML	TEE (n=36)	86	93	89
	MRI (n=35)	86	100	91

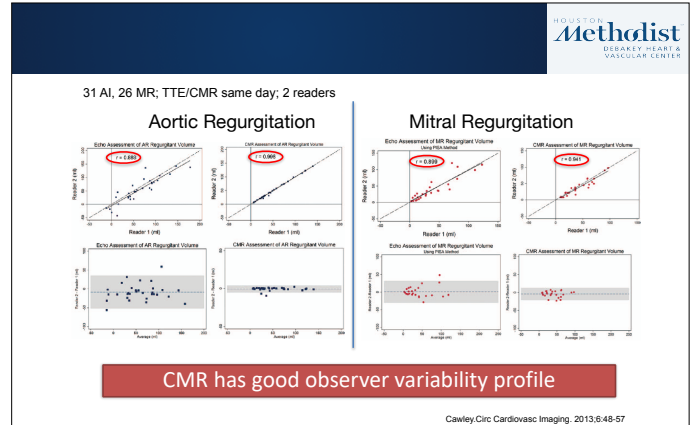
Stork A.Eur Radiol (2007) 17: 3189-3198

# OUTLINE:

- How does CMR assess valve regurgitation ?
  - Severity of lesion
  - Mechanism of lesion
  - Consequences of lesion



- How does CMR compare to Echo for regurgitation assessment
- When to use CMR for valve regurgitation



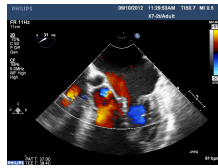
## Circulation

- 258 asymptomatic patients
- Moderate or Severe MR by Echo
- LVEF > 60%

### ORIGINAL RESEARCH ARTICLE

**Prognostic Implications of Magnetic Resonance–Derived Quantification in Asymptomatic Patients With Organic Mitral Regurgitation**  
 Comparison With Doppler Echocardiography–Derived Integrative Approach

- Concordant Grading of Severity: 76%
- Discordance: 24%
  - Late Systolic Jet
  - Multiple Jets
  - Eccentric Jets



Pericak, et al. Circulation. 2018;137:1349–1360

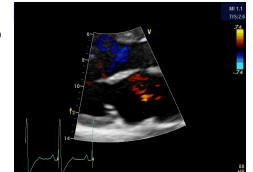
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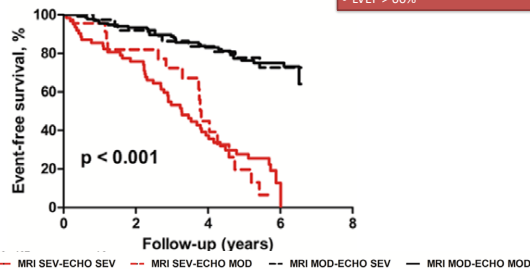
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  - Multiple Jets
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Pericak, et al. Circulation. 2018;137:1349–1360

### C All cause mortality and indication for MV surgery

- 258 asymptomatic patients
- Moderate or Severe MR by Echo
- LVEF > 60%



Pericak, et al. Circulation. 2018;137:1349–1360

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1 B-NR

3. In patients with primary MR, CMR is indicated to assess LV and RV volumes and function and may help with assessing MR severity when there is a discrepancy between the findings on clinical assessment and echocardiography (6–9).

Otto et al, JACC 2020.



## OUTLINE:

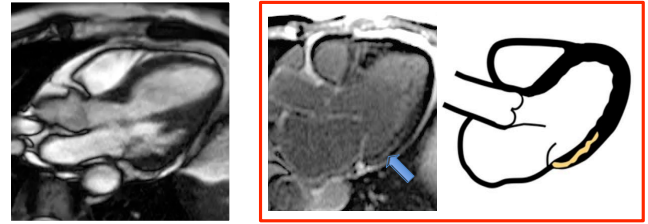
### How does CMR assess valve regurgitation ?

- Severity of lesion
- Mechanism of lesion
- Consequences of lesion
  - ◆ LV Enlargement
  - ◆ LV Dysfunction
  - ◆ LA Enlargement
  - ◆ Myocardial Fibrosis



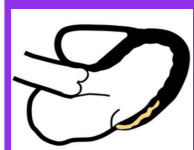
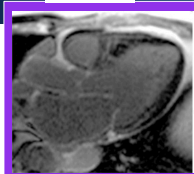
## Consequences: Regional Fibrosis in MVP

LGE → fibrosis

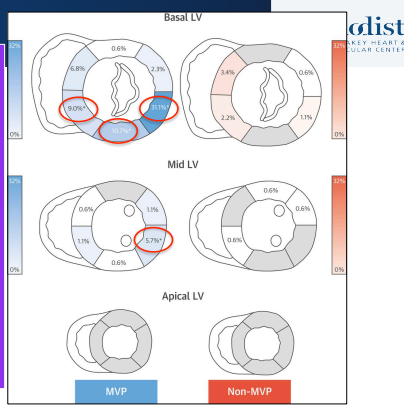


Danal Kitkungvan et al. JACC 2018;72:823-834

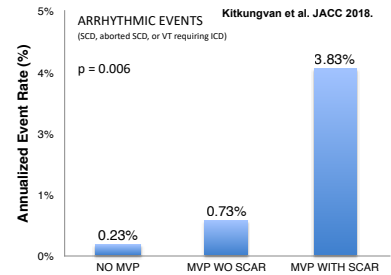
## Midwall



Danal Kitkungvan et al. JACC 2018;72:823-834



## ARRHYTHMIC EVENTS AND MVP:



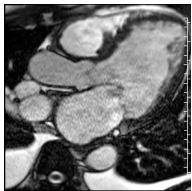
PATIENTS WITH MVP AND REPLACEMENT FIBROSIS HAD THE HIGHEST RATE OF ARRHYTHMIC EVENTS



## TYPES OF MITRAL REGURGITATION

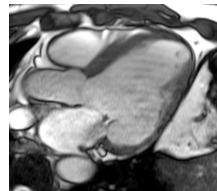
### Mitral Regurgitation

#### Primary MR



Anatomic abnormality of the mitral valve

#### Secondary MR



Abnormality of the myocardium NOT valve

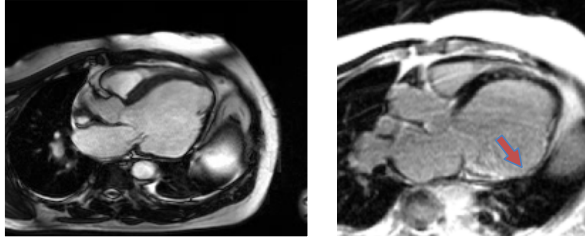
### Recommendations for Diagnosis of Secondary MR

Referenced studies that support the recommendations are summarized in Online Data Supplement 3L.

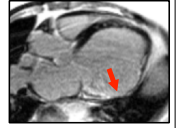
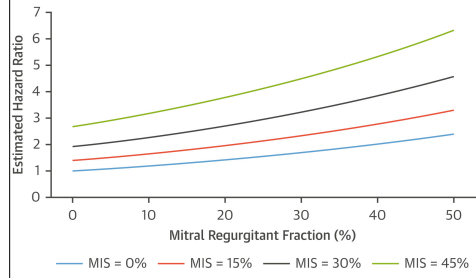
COR	LOE	RECOMMENDATIONS
1	B-NR	1. In patients with chronic secondary MR (Stages B to D), TTE is useful to establish the etiology and to assess the extent of regional and global LV remodeling and systolic dysfunction, severity of MR, and magnitude of pulmonary hypertension. (1,2)
1	C-ED	2. In patients with chronic secondary MR (Stages B to D), noninvasive imaging (stress nuclear/PET, CMR, or stress echocardiography), coronary CT angiography, or coronary arteriography is useful to establish etiology of MR and to assess myocardial viability.

# Secondary MR

## POSTERIOR LEAFLET TETHERING FROM INFEROLATERAL WALL INFARCTION



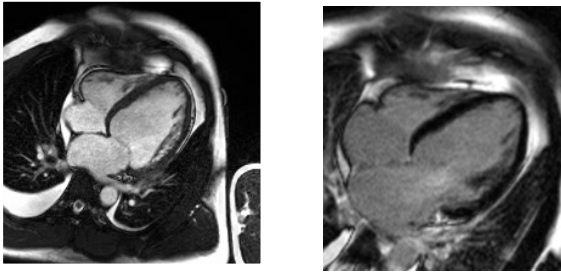
# Prognosis in Ischemic Secondary MR Is Influenced by MRF and Infarct Size



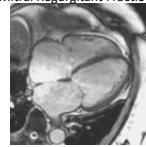
Cavalcante et al. JACC Cardiovascular Imaging 2019

# Secondary MR

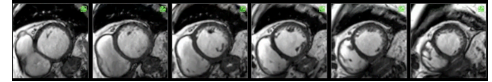
## NONISCHEMIC SECONDARY MR



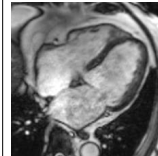
Mitral Regurgitant Fraction 41%



LVEF 22%



LVEF 51%



Mitral Regurgitant Fraction 10%

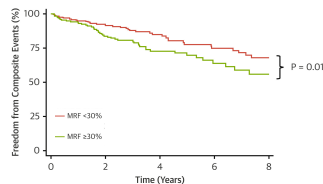
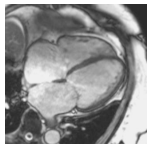
# Secondary MR: Ischemic and Nonischemic

JACC Cardiovascular Imaging  
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PUBLISHED BY ELSEVIER

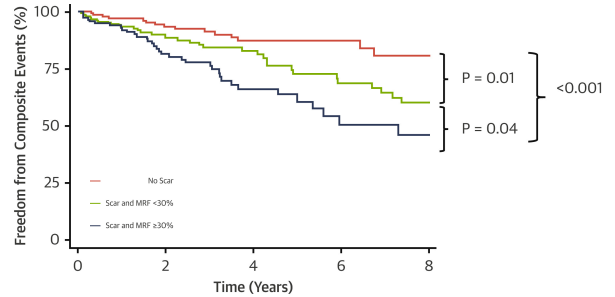
## CLINICAL RESEARCH Impact of Myocardial Scar on Prognostic Implication of Secondary Mitral Regurgitation in Heart Failure

Bhagwanti Tyagi, MD, PhD<sup>1,2</sup>; Deep Datta, MD<sup>1,2</sup>; Pooja Thakur, MD<sup>1,2</sup>; Manish Mehta, MD<sup>1,2</sup>; Stephen H. Litwin, MD<sup>1,2</sup>; Michael Bruckner, MD<sup>1,2</sup>; William English, MD<sup>1,2</sup>; Neal Kishore, MD<sup>1,2</sup>; Stefan J. Shah, MD<sup>1,2</sup>

Tayal et al, JACC Imaging 2021

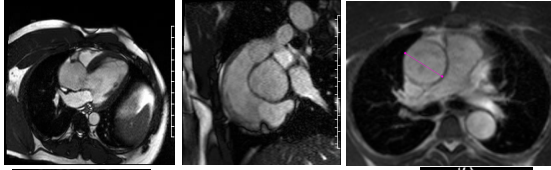


# Patients with Secondary MR and no Scar had better prognosis



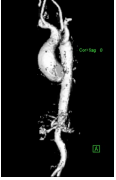
Tayal et al, JACC Imaging 2021

## Bicuspid AI



**39 yr old with SOB:**

- Bicuspid aortic valve with severe AI (RV 80 ml, RF 50%)
- Dilated LV
- Normal LV and RV EF
- Severely dilated aortic root (5.3 cm at the sinus)
- Moderately dilated ascending aorta (5.2 cm)



## Recommendations for Diagnostic Testing of Chronic AR

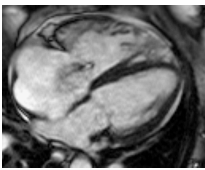
Referenced studies that support the recommendations are summarized in [Online Data Supplement 14](#).

COR	LOE	RECOMMENDATIONS
1	B-NR	3. In patients with moderate or severe AR and suboptimal TTE images or a discrepancy between clinical and TTE findings, TEE, CMR, or cardiac catheterization is indicated for the <u>assessment of LV systolic function, systolic and diastolic volumes, aortic size, and AR severity (20-25)</u> .

Otto et al, JACC 2020.

## Natural History of Functional Tricuspid Regurgitation Quantified by Cardiovascular Magnetic Resonance

547 patients with functional TR  
Median FU 2.6 years



**RV EDV = 331 mL**

**RV ESV = 161 mL**

**PA Flow = 109 mL**

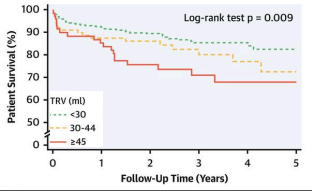
**TR 45%**

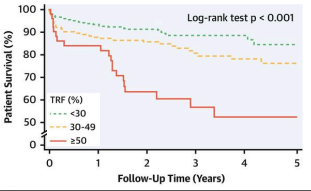
**RV SV 170 mL**

Zhan et al, Journal American College of Cardiology, 2020.

## Tricuspid Regurgitation:

TR quantified by CMR is independently associated with mortality even after adjusting for clinical and imaging covariates including RVEF, MR severity, and PA pressures





Zhan, Y. et al. J Am Coll Cardiol. 2020;76(11):1289-301.

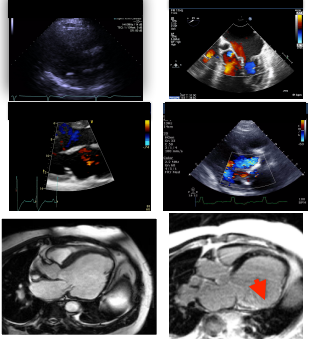
## Evaluation of Patients With Known or Suspected VHD

Reason	Test	Indication
Initial evaluation: All patients with known or suspected valve disease	TTE*	Establishes chamber size and function, valve morphology and severity, and effect on pulmonary and systemic circulation
History and physical	TEE	Establishes symptom severity, comorbidity, valve disease presence and severity, and presence of HF
Further diagnostic testing: Information required for equivalent symptom status, discrepancy between examination and echocardiogram, further definition of valve disease, or assessing response of the ventricles and pulmonary circulation to load and to exercise	ECG	Establishes rhythm, LV function, and presence or absence of hypertrophy
	Chest x-ray	Important for the symptomatic patient; establishes heart size and presence or absence of pulmonary vascular congestion, intrinsic lung disease, and calcification of aortic and pericardium
	TEE	Provides high-quality assessment of mitral and aortic valve, ensuring definition of mitral regurgitation and possible associated abnormalities (eg, intracardiac thrombus, LA thrombus)
	CMR	Provides assessment of LV volumes and function, valve severity, and aortic disease
	PET CT	Aids in determination of active infection or inflammation
	Stress testing	Gives an objective measure of exercise capacity
	Catheterization	Provides measurement of intracardiac and pulmonary pressures, valve severity, and hemodynamic response to exercise and drugs
Further risk stratification: Information on future risk of the valve disease, which is important for determination of timing of intervention	Biomarkers	Provides indirect assessment of filling pressures and myocardial damage
	TTE strain	Helps assess mitral myocardial performance
	CMR	Assesses fibrosis by gadolinium enhancement
	Stress testing	Provides prognostic markers
	Procedural risk	Quantified by STS (Surgical Risk of Mortality) and TAVI scores
	Frisley score	Provides assessment of risk of procedure and chance of recovery of quality of life

Otto et al, JACC 2020.

## Conclusion:

- Technically difficult TTE
- Discordance between Hx, PE, 2D, Doppler findings
- Eccentric Regurgitant Jets
- Non-holosystolic Regurgitant Jets
- Multiple Regurgitant Jets (i.e. MR and AR)
- Determine the consequences of the valve lesion
  - Quantification of LV volumes
  - Quantification of LVEF
  - Assessment of myocardial viability/scar




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# Houston Methodist CV Imaging Team

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