Cardiac MRI measurement of right ventricular strain using feature tracking in a model of embolic pulmonary hypertension

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Background

- Pulmonary embolism (PE) common pathologic process
- Right heart function following PE prognostic indicator of patient morbidity.

Large segmental right pulmonary embolism on MRA chest.
Imaging of Right Ventricle

**Echocardiography**
- RV functional evaluation limited by morphology and poor acoustic windows
- Speckle tracking used to measure cardiac strain on ultrasound
- Cardiac strain shown to be early and cardiac load independent indicator of function

**MRI**
- Excellent characterization of global and focal right ventricular function
- Novel technique of feature tracking allows for retrospective evaluation of strain within the right ventricle.

CMRI measurement of RV strain in embolic PH

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Purpose

Evaluate changes in right ventricular (RV) strain using a tissue-tracking algorithm in acute and chronic models of embolic pulmonary hypertension.
Methods: Canine Model

• 11 canines received cardiac MRI (cMRI) and right heart catheterization (RHC) preceding pulmonary microbead (150-500 μm)

• cMRI and RHC performed in 6 dogs immediately post embolization

• cMRI and RHC performed in 4 dogs following chronic embolization.

• One chronic canine excluded after failure to develop pulmonary hypertension
Methods: Image Acquisition

• Axial cine balanced steady state free procession cardiac MRI was performed through the right ventricle before and after embolization

• 3.0T scanner (MR 750, GE Healthcare, Waukesha, WI)
Methods: Strain analysis

• Baseline and post embolization radial and longitudinal strain and strain rates measured using tissue tracking algorithm (cmr42, Circle Cardiovascular Imaging, Inc. Calgary, Canada)

• RV free wall was subdivided into apical, mid and base segments for analysis

Radial (left) and longitudinal (right) strain maps in post embolization canine heart with three evaluated segments indicated as regions of interest (ROI).
Results

Example of radial and longitudinal strain rate and % both pre and post embolization
Summary of both radial and longitudinal strain and strain rates in AEPH and CEPH models with p values from paired, two tail t-test.
Results

Scatter plot of change in cardiac strain values versus change in mPAP in chronic embolic pulmonary hypertension models.
Results

Scatter plot of change in cardiac strain values versus change in mPAP in acute embolic pulmonary hypertension models.
Results: Segmental Strain

Acute embolic pulmonary hypertension

• Statistically significant decreased strain rate in apical segment (p<0.05)

Chronic embolic pulmonary hypertension

• Statistically significant change in radial and longitudinal apical segment strain rates.
• Statistically significant change in radial strain rate and % change in the mid segment.
Discussion

• Changes in cardiac strain were identified in both acute and chronic models of embolic pulmonary hypertension.

• Acute embolic model demonstrated significant change in radial and longitudinal strain rate without significant change in global strain.

• Chronic embolic model demonstrated significant change in all global parameters including radial and longitudinal strain rate and global strain values.
Discussion

• Results were variable at the segmental level with incidences of statistically significant change in both the acute and chronic models involving the apical and mid segments.

• Changes in cardiac strain did not correlate well with changes in main pulmonary artery pressure on right heart catheterization.
Discussion

- Strain on echocardiography has been studied in the setting of pulmonary embolism
  - Global and free wall right heart strain both associated with 30 mortality (p<0.05)
- Little research has been conducted on right heart strain in the setting of pulmonary embolism
- CMR longitudinal strain (SENC) shown to be correlated with RV ejection fraction in setting of pulmonary hypertension
  - R= 0.81
  - p<0.0001

Longitudinal strain % versus CMR RVEF %

Freed, B et al. Echocardiography. 2014


a Global Right Ventricular Strain (RVLS) and b free wall RVLS categorized as mild, moderate and severe among survivors and non-survivors in a cohort of patients with acute pulmonary embolism
Discussion

• CMRI has multiple methods of assessing strain which may differ in efficacy and acquisition time.
  – Tagged myocardium
    • Gold standard
    • Increased time of acquisition
    • Harmonic phase (HARP) improved post processing
  – Velocity encoding
    • Dynamic measurement of tissues through phase encoding
    • More sensitive to motion but not susceptible to T1 fading.
  – Strain encoding
    • Stimulated echoes using magnitude images in through plane dimension
  – Displacement encoding (DENSE)
    • Stimulated echoes with myocardial displacement encoded in phase image
  – Tissue tracking
    • Allows retrospective analysis decreasing total patient scan time
Limitations

• Small sample size may limit detection of small changes in strain
  – Such small changes may have limited clinical relevance

• Canine model
  – Changes in right ventricular morphology may limit tissue tracking algorithm
  – Possible difference in cardiac response to embolic event may limit extrapolation to human model
Conclusion

Cardiac strain is a viable metric for right ventricular function following acute and chronic pulmonary embolic events.
Future Directions

• Further study of cardiac strain in a human population
  – Validation of tissue tracking software
  – Establish normative values for given strain technique
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References


