MRI Artifacts and Solutions

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Declaration of Conflict of Interest or Relationship
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Type of Artifacts

- K-space Error Artifacts
- Motion and Flow Artifacts
- bSSFP Artifacts
- EPI Artifacts
- ...

K-SPACE ERROR ARTIFACTS

K-space data Overflow

Truncation of k-space Data

Ringing around high contrast objects
Nyquist (N/2) Ghosting

- Different phase shifts in odd and even frequency encoding lines
- Correct by:
  - Gradient calibration and/or eddy current compensation
  - Reference scan (w/o phase encoding or shifting one phase step)
MOTION ARTIFACTS

How to deal with motion?

1. Minimize the amount of motion:
   - Explain the procedure to the patient ahead of time and give feedback during the exam.
   - Ensure comfortable position (e.g. with cushions)
   - Use immobilization devices (e.g. straps, ..., bit bar)
   - Encourage patient cooperation (e.g. Breath-hold)
   - Pharmacological intervention (e.g. Sedation, GA, O2, ...)

2. Suppress signal from moving tissue/organ:
   - Spatial and/or chemical shift selective saturation
   - Use/select appropriate coils
   - Reduced FOV imaging

How to deal with motion? (cont’d)

3. Change / hide of motion artifact
   - Swap phase and frequency directions
   - Use multiple averages
   - Use pseudo random k-space sampling / random view order

4. Monitor and repeat inadequate scans (with adjusted protocols)

Motion Compensation Techniques

1. Motion Detection:
   - Physiological signal: ECG, Pulse, Respiratory Bellow
   - Direct measurement: optical
   - Navigator: 1D, 2D, 3D, Spherical, ...
   - Extract Motion info from acquired data.
   - Comparison of overlapping k-space segments
   - Image registration
   - Combination of the above
Motion Compensation Techniques

2. Correction scheme:
   – Prospective triggering
   – Retrospective gating
   – Sorting data according to the phase of periodical motion (CINE)
   – Reordering of phase encoding steps
   – Update spatial encoding gradients
   – Correct phase error due to motion

Retro Gating with Arrhythmia Rejection

Min. RR | Max. RR
---|---
Target RR

How to deal with motion?

5. Use motion insensitive techniques:
   – Use short essential protocols and scan critical series first.
   – Protocol short scans and/or split a long scan (Use end-expiration for BH consistency)
   – Use faster imaging techniques:
     • Acquire fewer k-space points per image (e.g. parallel imaging)
     • Reduce TR (e.g. GRE, high performance gradient HW, higher BW)
     • Acquire more k-space points per excitation (e.g. SS-EPI, SS-FSE (HASTE), etc.)
   – Motion insensitive k-space sampling (e.g. Radial sampling (PR), Spiral)
   – Flow/motion compensating gradient waveform (e.g. GMN)

Arrhythmia Rejection

Prospectively Triggered blurred by arrhythmias
Retrospectively Triggered with arrhythmias rejection

Segmented versus Single Shot

Segmented DB TSE
8 heartbeats
High spatial resolution
High temporal resolution
Sensitive to arrhythmia and breathing

Single Shot DB HASTE
1 heartbeat
Low spatial resolution
Low temporal resolution
Less sensitive to motion

TSE with MBH versus HASTE

Breath Hold TSE
Free Breathing HASTE
Radial k-space Sampling

- No phase encoding and less sensitive to motion
- Higher spatial and/or temporal resolution
- Isotropic in-plane resolution
- No phase wrap at smaller FOV
- Radial streaks artifact, more pronounced near edge FOV

Higher Resolution with Radial

- Cartesian Real-Time Cine
  - Echo-sharing
  - 50 lines
  - 55 ms frame rate
  - 300mm x 300mm FOV
  - 2.3mm x 6.0mm res

- Radial Real-Time Cine
  - Interleaved Echo-sharing
  - 50 lines
  - 55 ms frame rate
  - 300mm x 300mm FOV
  - 2.3mm x 2.3mm res

Single-shot

- Segmented: Acquired data over several heart beats
- Single-shot: Acquire all k-space data in ONE heart beat i.e. segments = Yres

Real-time Single-Shot

- Acquired temp res about 150ms
- Effective temp res about 75ms
  - With iPA T temp res about 50ms

EKG Trigger

Slice #1

Slice #2

Slice #3

Phase #1 #2 #3 # n
Real-time Single-shot

- Real-time
- Multiple slices
- Free breathing
- Lower resolution

- Can be used non-triggered and non-breath hold with multiple slices.
- Less temporal and spatial resolution than segmented view-shared.

Real-time TrueFISP Example

- 7 short-axis cine slices covering from base to apex of heart, with matrix 70*128.
- After triggering, and all k-space views for each slice were acquired in rapid succession.
- All 7 slices in 14 heartbeats and single breath-hold.

In non-triggered mode, the number of phases define how long the scan will run.

Retrospective Motion Correction

- Spatial pre-saturation pulses prior to entry of the vessel into the slices
- Motion Compensation Gradients
- Cardiac & respiratory gating
- Surface coil localization

Flow Artifact

- Flow Artifact Correction
- BSSFP OFF-RESONANCE ARTIFACTS
**Bright Blood Sequences**

- **SSFP (FLASH)**
- **Balanced SSFP (TrueFISP)**

**Un-spoiled GRE (SSFP)**

- **SSFP-FID:**
  - Echo formed from un-spoiled Mxy of previous TR
- **SSFP-ECHO:**
  - T2 weighted

**Off-resonance Effect**

To Reduce phase accumulation between excitation:
- Improve $B_0$ homogeneity or shift center frequency
- Reduce TR

**bSSFP/TruFi Banding**

- $-100Hz$
- $100Hz$
- $-50Hz$
- Local Shim
- $50Hz$

**CISS – Constructive Interference Steady State**

**EPI ARTIFACTS**
Breast DWI

Artifacts in EPI

Geometric Distortion in EPI

How to reduce Echo SPacing (ESP)

How to reduce echo train length (ETL)

Multi-shot EPI (MS-EPI)
Examples with varying ESP & ETL

Chemical Shift Artifact in EPI

Without Fat Suppression
With Fat Suppression

Other Artifact in EPI

• “Blurring”
  – Due to T2* induced signal modulation in k-space.
  – May not be obvious due to low spatial resolution and other artifacts.

• “Dark Spots”
  – Intra-voxel de-phasing to due to off resonance.
  – Reduce voxel size, i.e. slice thickness.
  – SE-EPI.

What are the artifacts?

Thank You!

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