Iterative Reconstruction in CT

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Disclosure

- GENERAL ELECTRIC HEALTHCARE
- MEDICAL ADVISORY BOARD
MDCT / FBP

- HIGH PITCH HELICAL
- THIN IMAGE THICKNESS
- LARGE VOLUME COVERAGE
- CONE BEAM GEOMETRY
- HIGH RADIATION DOSE
Filtered Back Projection

**RAPID COMPUTATION**

- PROJECTION DATA
  - CALIBRATED
  - FILTERED
  - WEIGHTED
  - BACKPROJECTED

**CLOSED FORM SOLUTION**
Filtered Back Projection

LIMITATIONS

- NOISE SENSITIVITY
- ARTIFACT SUPPRESSION
  - BEAM HARDENING
  - HELICAL
  - STREAK
Adaptive Statistical Iterative Reconstruction: ASIR
Alternative to FBP

- MODELS NOISE PROPERTIES IN SCANNED OBJECT
  - NOISE REDUCTION SCALED TO DESIRED LEVEL OF IMAGE QUALITY
  - 50% IMPLEMENTATION TARGETED TO PRODUCE EQUIVALENT IMAGE NOISE AT HALF THE RADIATION DOSE
HEPATIC CIRRHOSIS
PORTAL HYPERTENSION

VCT
ASIR 40
750 HD
# ATTENUATION VALUES AND ASIR

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MULTIFOCAL SOLID VARIANT PANCREATIC SEROUS CYSTADENOMA

VCT

750 HD

ASIR 50
23 yrs old with Crohn’s Disease. Baseline and FU CT exam

40% ASIR

55% Dose Reduction

Radiation Dose – 11.6 mSv

Radiation Dose – 5.1 mSv
**Flow Velocity**

**TRANSIT TIME CALCULATION**

- 2 MINI BOLUS INJECTIONS
- TIME TO PEAK
  - PROXIMAL DESC AORTA
  - EXTERNAL ILIAC ARTERY
- \( \text{DISTANCE (CM)} / \text{TIME (S)} \)
THORACO ABDOMINAL AORTIC DISSECTION
M50 Chest pain on exertion
BMI 28
100 kV, 325 mA
HR 60-63 bpm
ASIR 40%
DLP 54mGy/cm
Dose: 0.9mSv*
Dose: 0.75 mSv**

Jonathan Leipsic, MD St Paul Vancouver Canada

Obtained by EUR-16262 EN, using a chest factor of 0.017DLP*
Obtained by ICRP using a chest factor of 0.014DLP**
M50 Chest pain on exertion
BMI 28
100 kV, 325 mA
HR 60-63 bpm
ASIR 40%
DLP 71mGy/cm
Dose: 1.2mSv*
Dose: 0.99 mSv**

Obtained by EUR-16262 EN, using a chest factor of 0.017DLP*
Obtained by ICRP using a chest factor of 0.014DLP**

Jonathan Leipsic, MD St Paul Vancouver Canada
F70 Abnormal ECG pre-surgery
100 kV, 275mA
HR 53 bpm
ASIR 40%
DLP 35 mGy/cm
Dose: 0.59mSv*
Dose: 0.49mSv**
Noise Reduction

- **ASIR**
  - MODELLING NOISE PROPERTIES IN SCANNED OBJECT

- **MBIR**
  - MODELS SYSTEM OPTICS AND OBJECT NOISE
  - PROBABILITY OF FURTHER IMAGE QUALITY IMPROVEMENTS AND DOSE REDUCTION
FBP Assumptions

• POINT SOURCE RADIATION
• PENCIL BEAM
• DETECTOR PHOTON INTERACTION CENTER OF CELL
Model-based Iterative Reconstruction

PROCESS (1)

- SYNTHESIS OF FORWARD PROJECTIONS
- ACCURATE DESCRIPTION OF FINITE ELEMENTS OF THE CT SYSTEM DURING DATA ACQUISITION
  - FOCAL SPOT DIMENSION
  - IMAGE VOXEL (ACCOUNTING FOR DIFFERENT PHOTON PATH LENGTHS)
  - DETECTOR SHAPE / SIZE (MODELLED BY RESPONSE FUNCTION)
Conventional (FBP) vs. Model-based Iterative Reconstruction (MBIR)

- Point Focal Spot vs. Real Focal Spot
- Point Detector vs. Real Detector
- Point Voxel vs. Cubic Voxel
- Pencil Beam vs. Broad Beam
- Perfect Sample vs. Statistical Model
- Line Integral vs. Physics Model
- Simple Calculation vs. Complex Computation

Simplicity vs. Image Quality
Model-based Reconstruction

x-ray tube

subject

x-rays

detector

reconstructed image

mathematical focal spot

mathematical rays

projection
Model-based Iterative Reconstruction

*PROCESS (2)*

- FORWARD PROJECTION AND ACTUAL MEASUREMENT DATA ARE REPEATEDLY COMPARED AND THE RECONSTRUCTED IMAGE VOXELS ARE CONTINUOUSLY ADJUSTED
- PHOTON STATISTICS ARE ESTIMATED AND THE RECONSTRUCTED OBJECT IS MODELED DURING THE ITERATION
In model-based reconstruction, we try to minimize the difference between our measurements and our synthesized measurements:
Model-based Iterative Reconstruction

**INITIAL CLINICAL EVALUATION**

- 29 EXAMINATIONS
  - 17 (ABDOMEN/PELVIS, 1 WITH CONTRAST)
  - 9 (ABDOMEN, 1 WITH CONTRAST)
  - 3 (CHEST, 1 WITH CONTRAST)
- EACH EXAM WAS RECONSTRUCTED WITH FILTERED BACK PROJECTION FBP
- MODEL-BASED ITERATIVE RECONSTRUCTION MBIR
Image Quality Interpretation

-2.5 -1.5 -0.5 0.5 1.5 2.5 3.5 4.5 5.5


Reformat Image Quality


Pleasing Image Quality

Reading Acceptability

Artifacts

Anat. Structures/Boundaries

Noise Uniformity

Spatial Res. Uniformity

Low Contr. Detail

High Contr. Detail

Noise Suppression

Ax

Sag

Cor

General

Reformat Image Quality

Spatial Resolution

Noise Suppression

High Contr. Detail

Low Contr. Detail

Spatial Res. Uniformity

Noise Uniformity

Artifacts

Anat. Structures/Boundaries

Pleasing Image Quality

Reading Acceptability

Image Quality Interpretation
Noise Comparison

![Bar chart showing noise comparison in different body parts (Liver, Spleen, etc.) with FBP and IR methods. The chart indicates noise levels in HU (Hounsfield Units).]
Model-based Iterative Reconstruction

**ADVANTAGES ~ FBP**

- **SAME RADIATION DOSE**
  - NOISE REDUCTION AND IMPROVED IMAGE QUALITY
- **LOWER RADIATION DOSE**
  - EQUIVALENT IMAGE QUALITY
Model-based Iterative Reconstruction

**DISADVANTAGES ~ FBP**

- COMPUTATIONALLY INTENSE
  - 2 PHASE DEVELOPMENT
  - *PARTIAL APPLICATION (ASIR)*
    - MODEL NOISE PROPERTIES
  - *COMPLETE APPLICATION (MBIR)*
    - INCLUDE NOISE PROPERTIES AND SYSTEM OPTICS