Metal Artifact Reduction - CT Techniques

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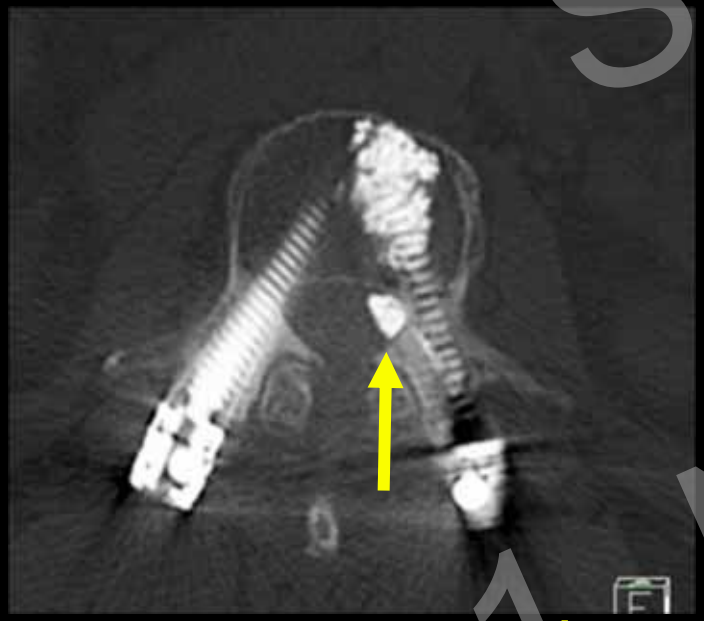
EXPERTISE IN MOTION

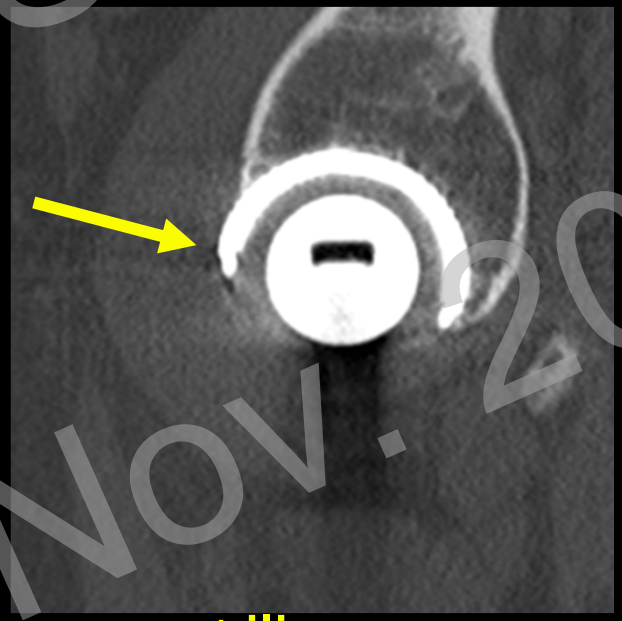
Postoperative CT – Metal Implants

CT is accurate for assessment of hardware integrity, wear, fractures, heterotopic….

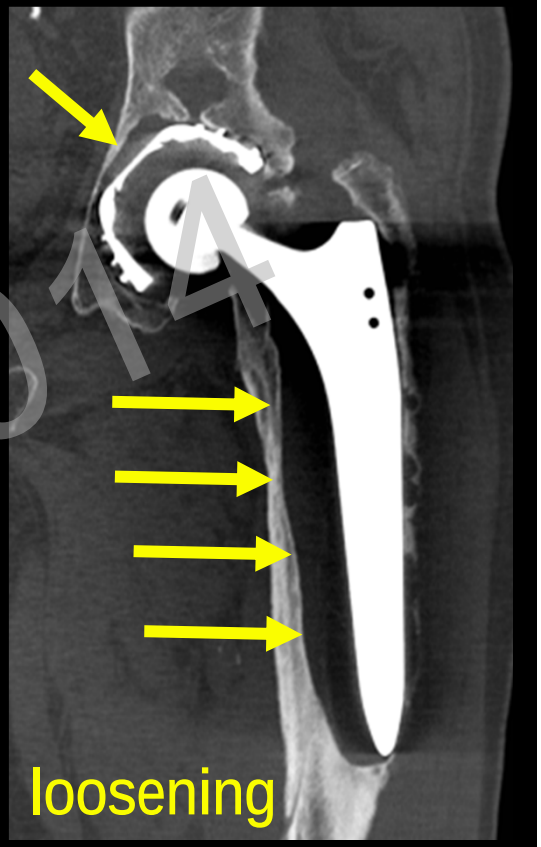
➔ **<u>Metal Implants degrade CT images</u>**



cement extrusion
next to nerve root



ant iliopsoas
Impingement

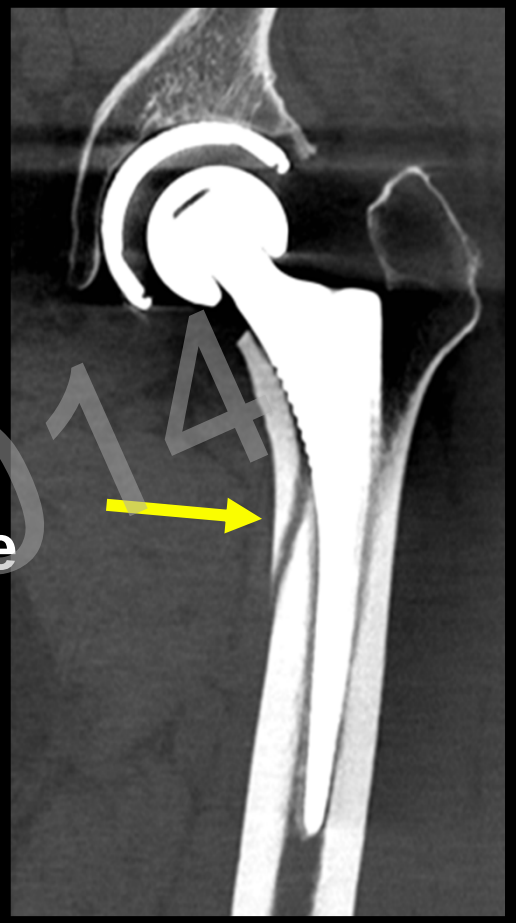


loosening

Outline: Metal Artifact Reduction

- **Basic Principles**
- **Iterative Reconstruction versus**

  Filtered Back Projections
- **specific Metal Artifact Reduction Software**
- **Edge Effects**
- **Dual-Energy Computed Tomography**



Periprosthetic Fx

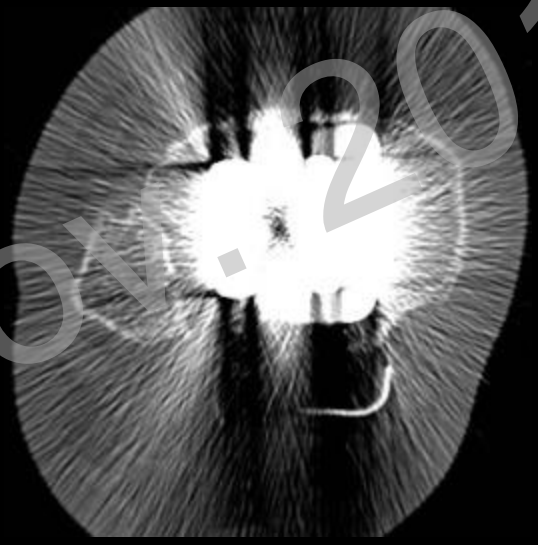
Metal-induced Artifacts

Metal Implants degrade CT images due to two main Artifact Components

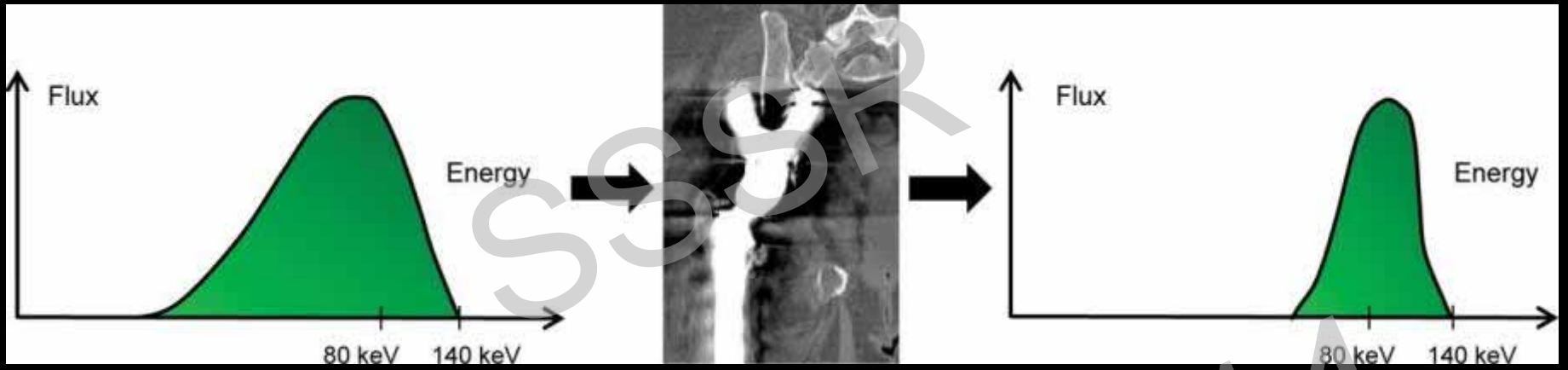
- photon starvation due to absorption of x-ray photons => image noise
- beam hardening due to absorption of low-energy photons => dark streaks

Additional Metal Artifact Components

- scattering, partial volume and edge gradient effects



Beam-Hardening Artifact



Pessis et al. Virtual Monochromatic Spectral…. RadioGraphics 2013

- lower-energy photons are absorbed more rapidly than higher-energy photons
- the detected x-ray beam contains the higher-energy portion of the spectrum, resulting in dark streaks next to metal structures

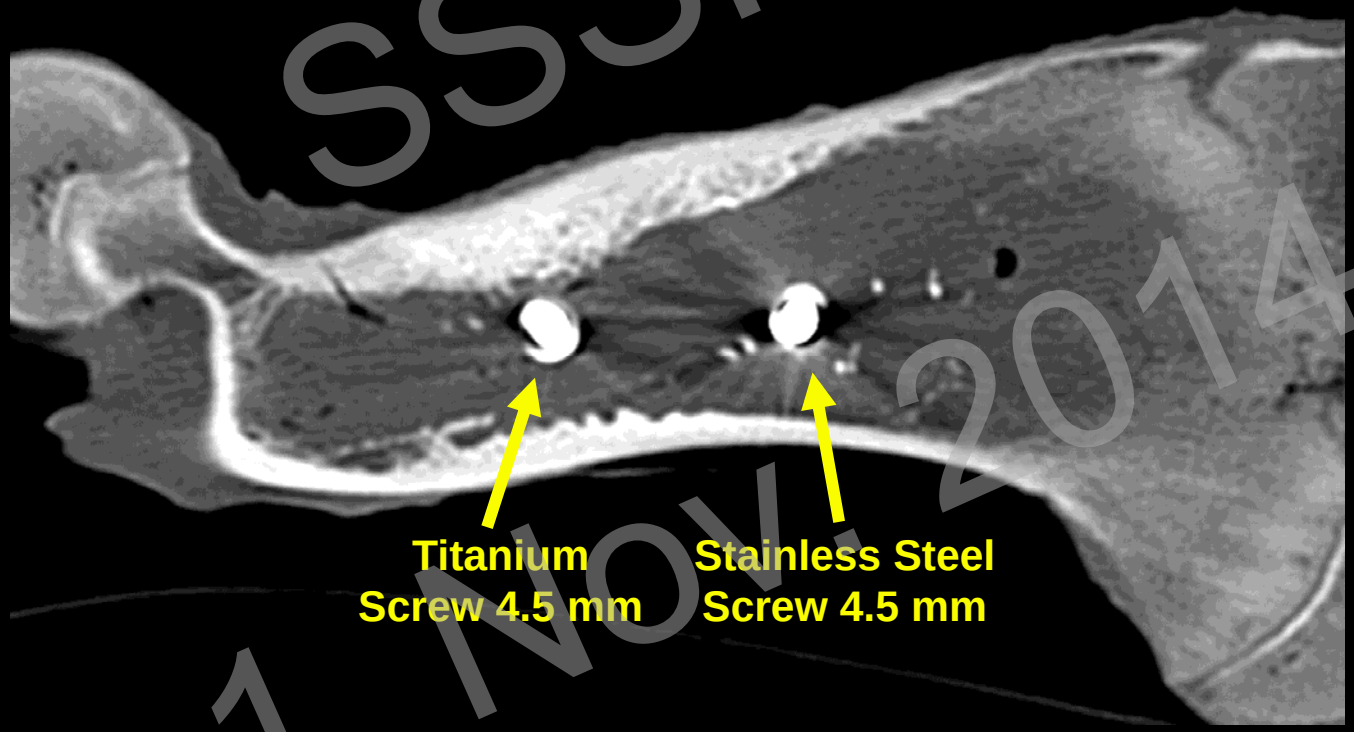
Basic Principles-Metal Artifact Reduction

Basic Principles

Hardware Composition

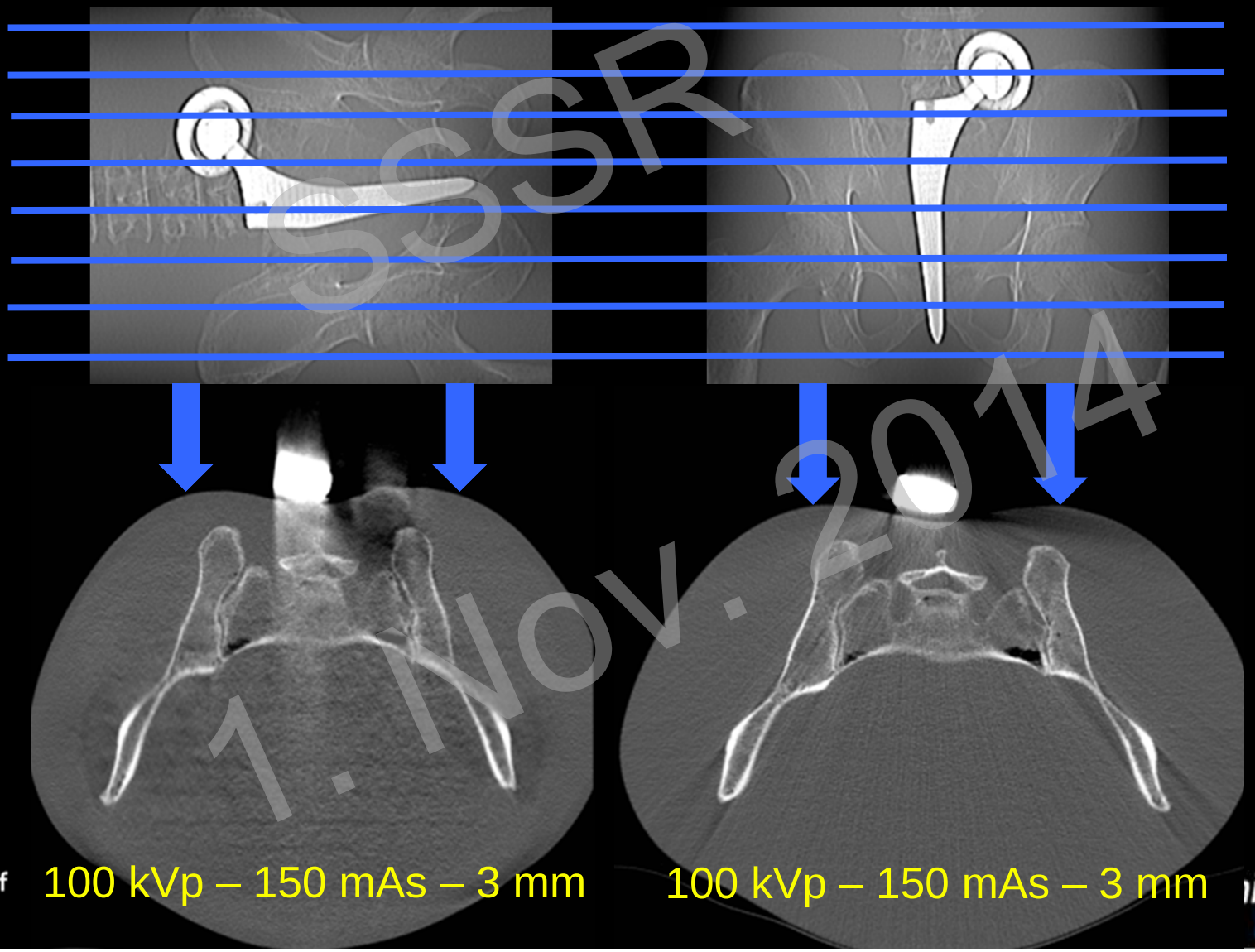
Metal-induced Artifacts: Titanium < Cobalt-Chrome < Stainless-Steel

➔ related to Mass Attenuation Coefficient

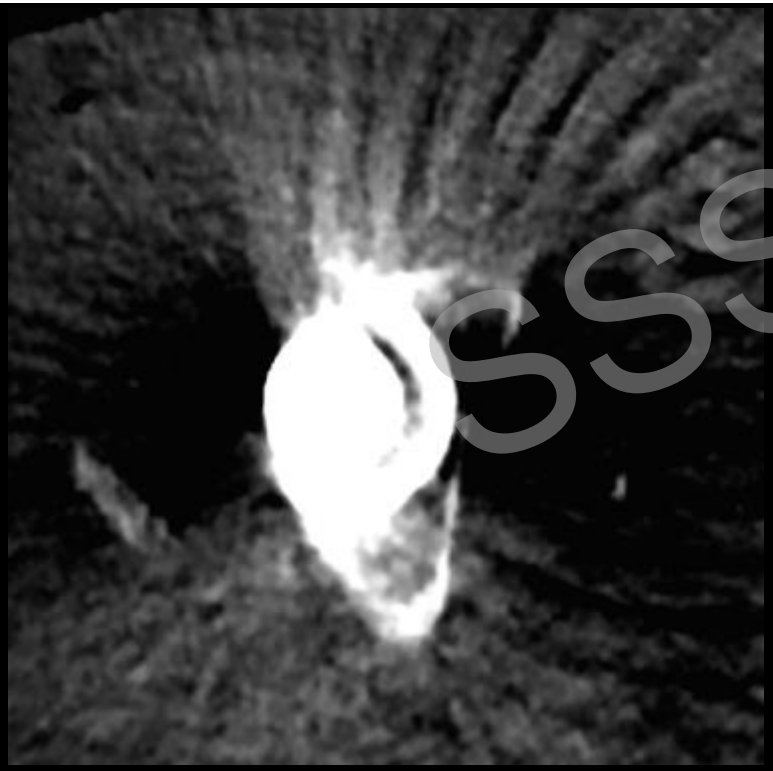


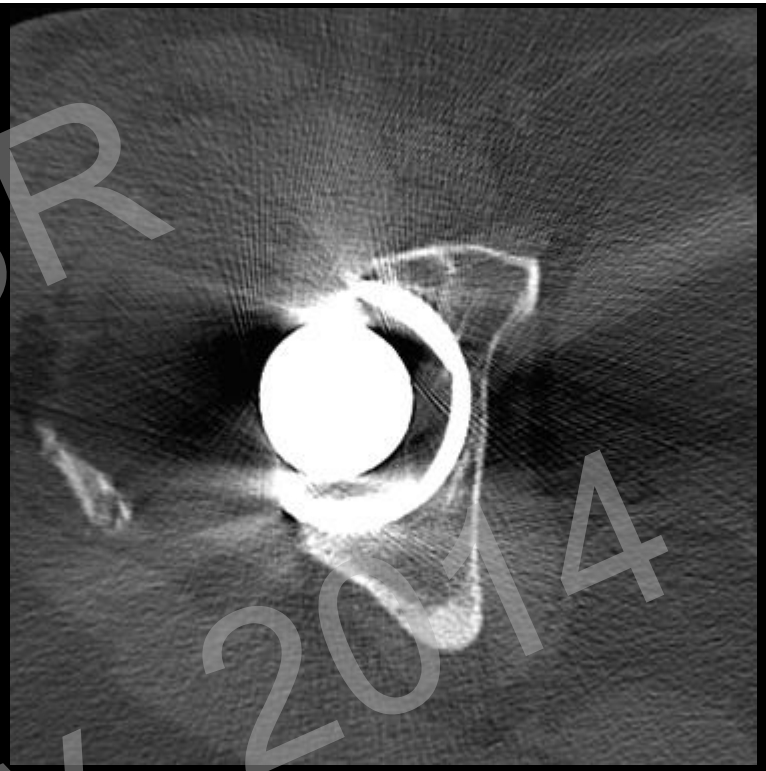
Patient Positioning

➔X-ray beam should traverse smallest possible cross-sectional area of implant



Effect of Tube Voltage & Current





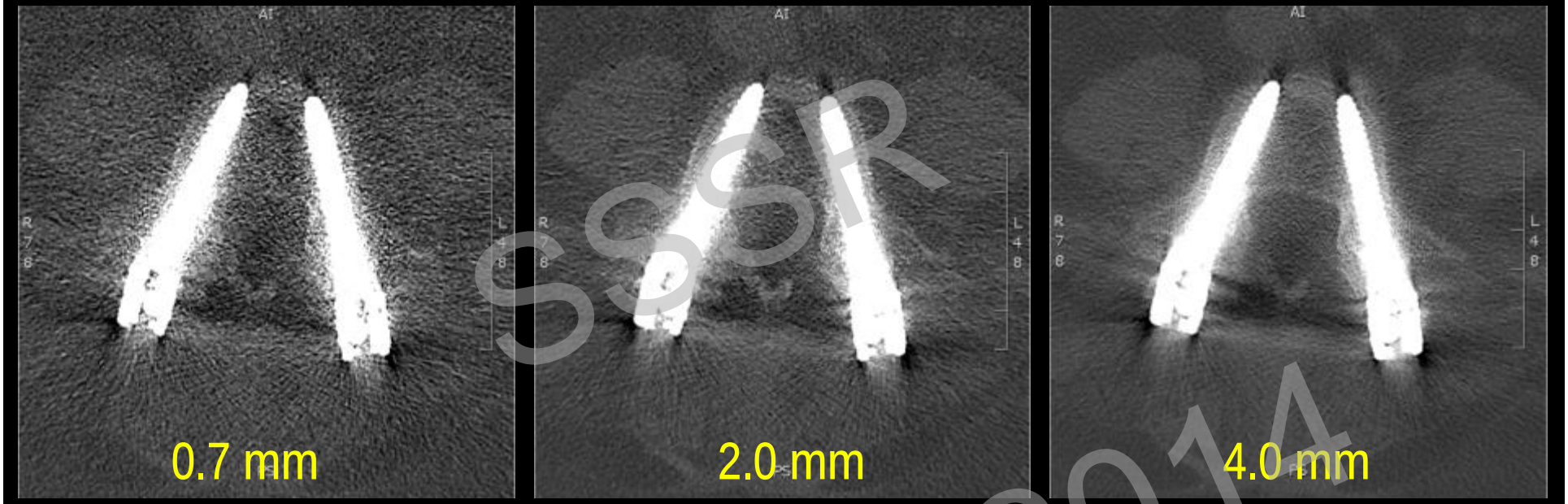
80 kVp – 15 mAs

140 kVp – 350 mAs

Radiation Exposure: 185 x higher

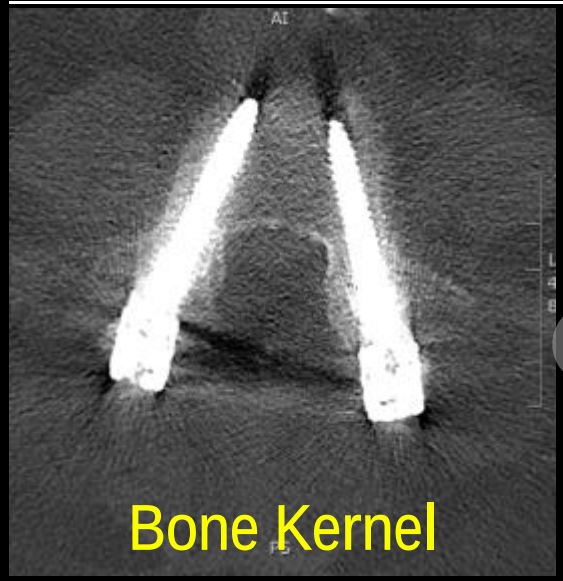
Hip Arthroplasty work-up at Balgrist: 140 kVp, 350 mAs

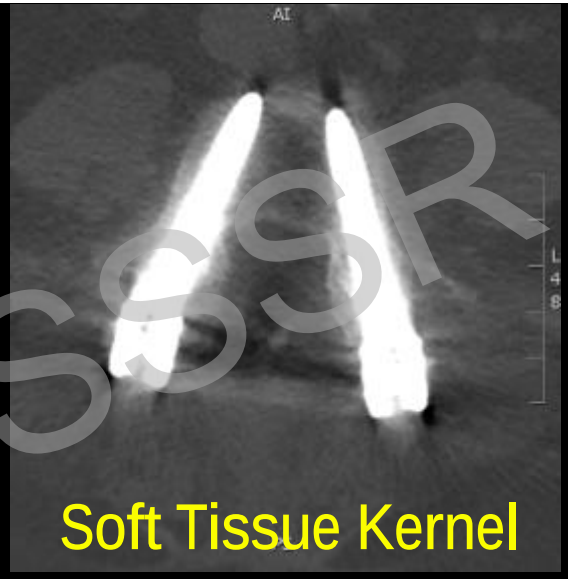
Section Thickness

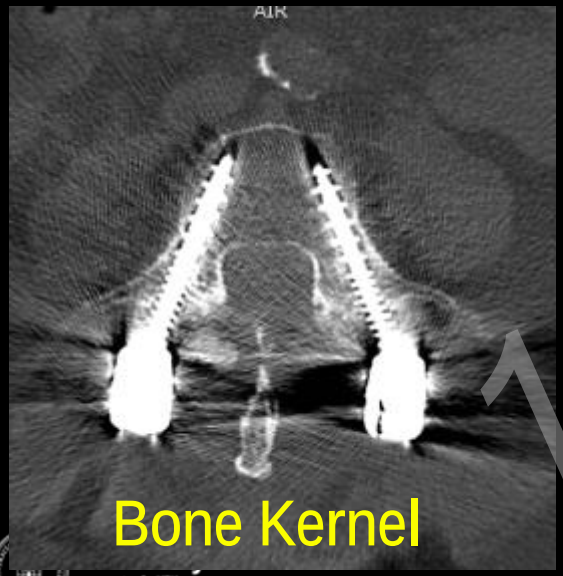


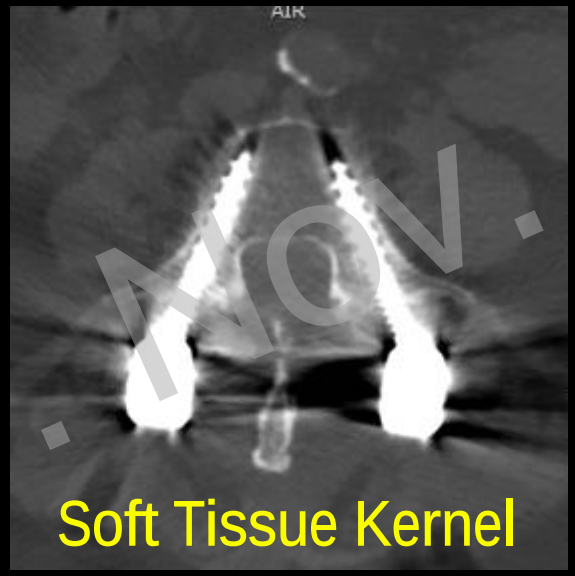
- partial volume artifacts can best be avoided by acquiring thin sections
- thicker sections during image reconstruction reduces image noise and decreases metal-related artifacts

Critical Role: Kernel-Selection



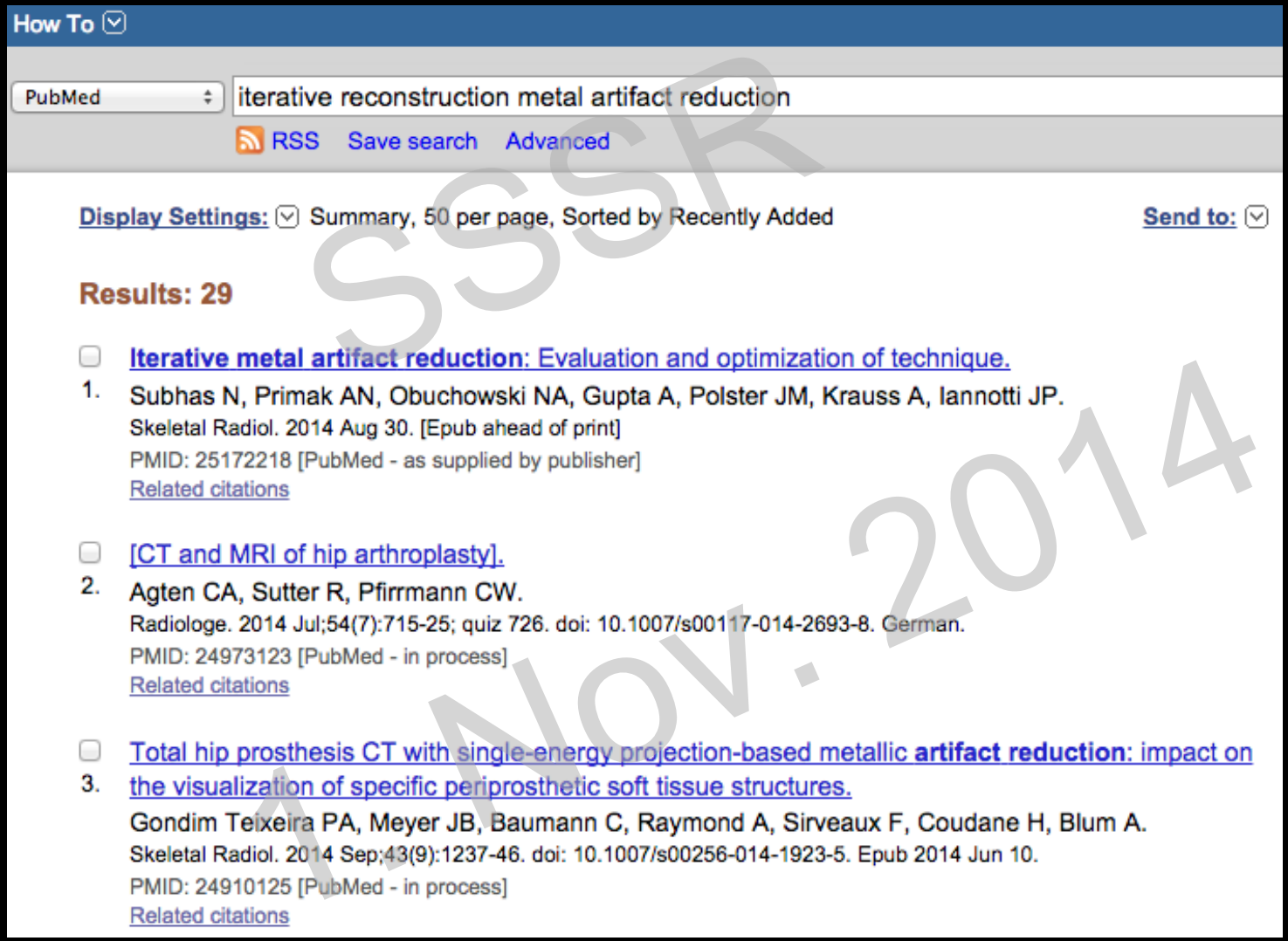






➔ standard or smooth reconstruction filter is preferred compared to edge-enhancing algorithms

Iterative Reconstruction



How To

PubMed | iterative reconstruction metal artifact reduction

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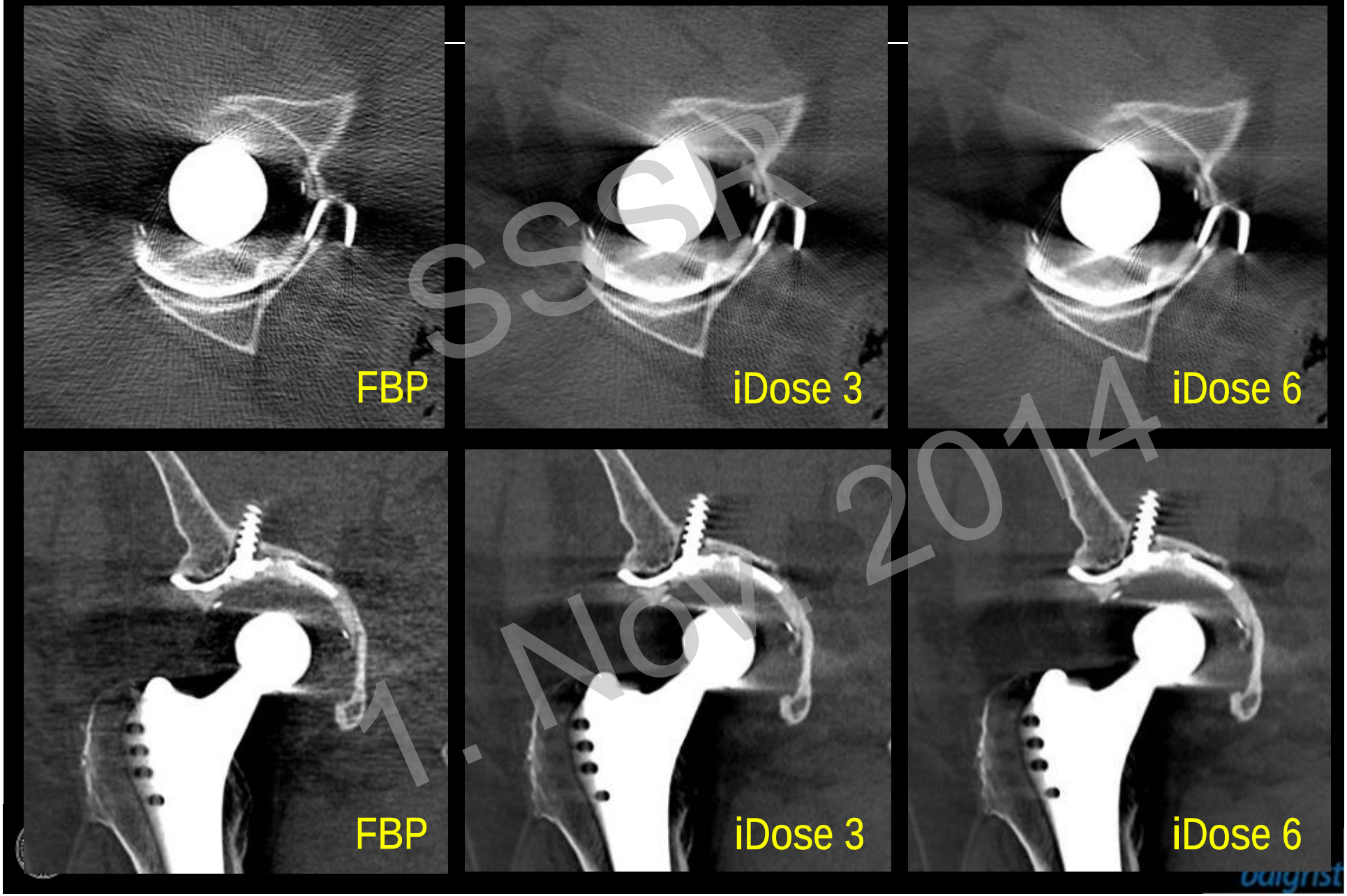
1. **Iterative metal artifact reduction**: Evaluation and optimization of technique.
Subhas N, Primak AN, Obuchowski NA, Gupta A, Polster JM, Krauss A, Iannotti JP.
Skeletal Radiol. 2014 Aug 30. [Epub ahead of print]
PMID: 25172218 [PubMed - as supplied by publisher]
Related citations

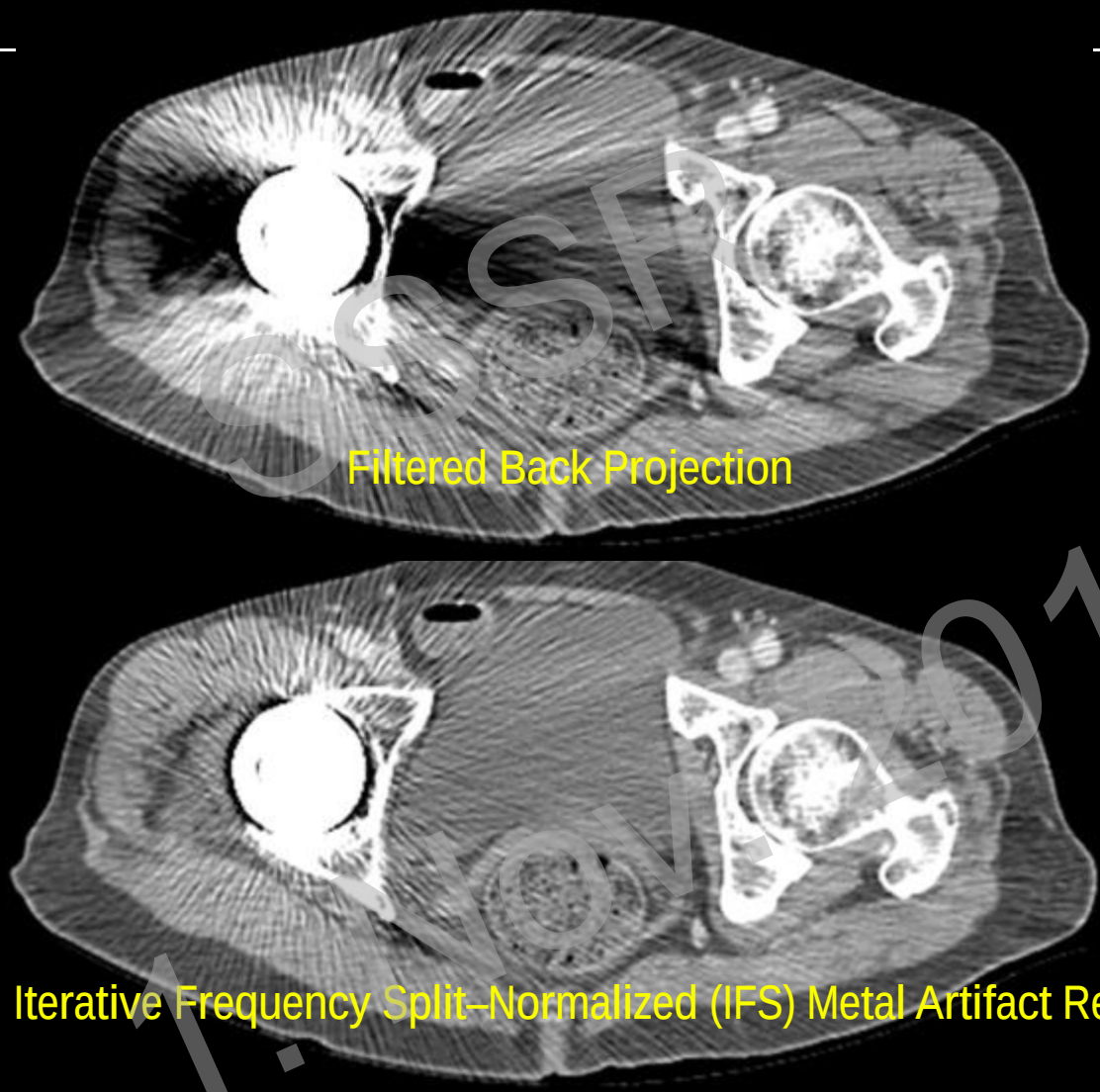
2. [CT and MRI of hip arthroplasty].
Agten CA, Sutter R, Pfirrmann CW.
Radiologe. 2014 Jul;54(7):715-25; quiz 726. doi: 10.1007/s00117-014-2693-8. German.
PMID: 24973123 [PubMed - in process]
Related citations

3. Total hip prosthesis CT with single-energy projection-based metallic **artifact reduction**: impact on the visualization of specific periprosthetic soft tissue structures.
Gondim Teixeira PA, Meyer JB, Baumann C, Raymond A, Sirveaux F, Coudane H, Blum A.
Skeletal Radiol. 2014 Sep;43(9):1237-46. doi: 10.1007/s00256-014-1923-5. Epub 2014 Jun 10.
PMID: 24910125 [PubMed - in process]
Related citations

Iterative Reconstruction



Summary - Iterative Reconstruction



Iterative reconstruction has a high potential to reduce metal artifacts

Morsbach et al. Reduction of Metal artifacts from … Radiology 2013

Specific Metal Artifact Reduction Software (MAR)

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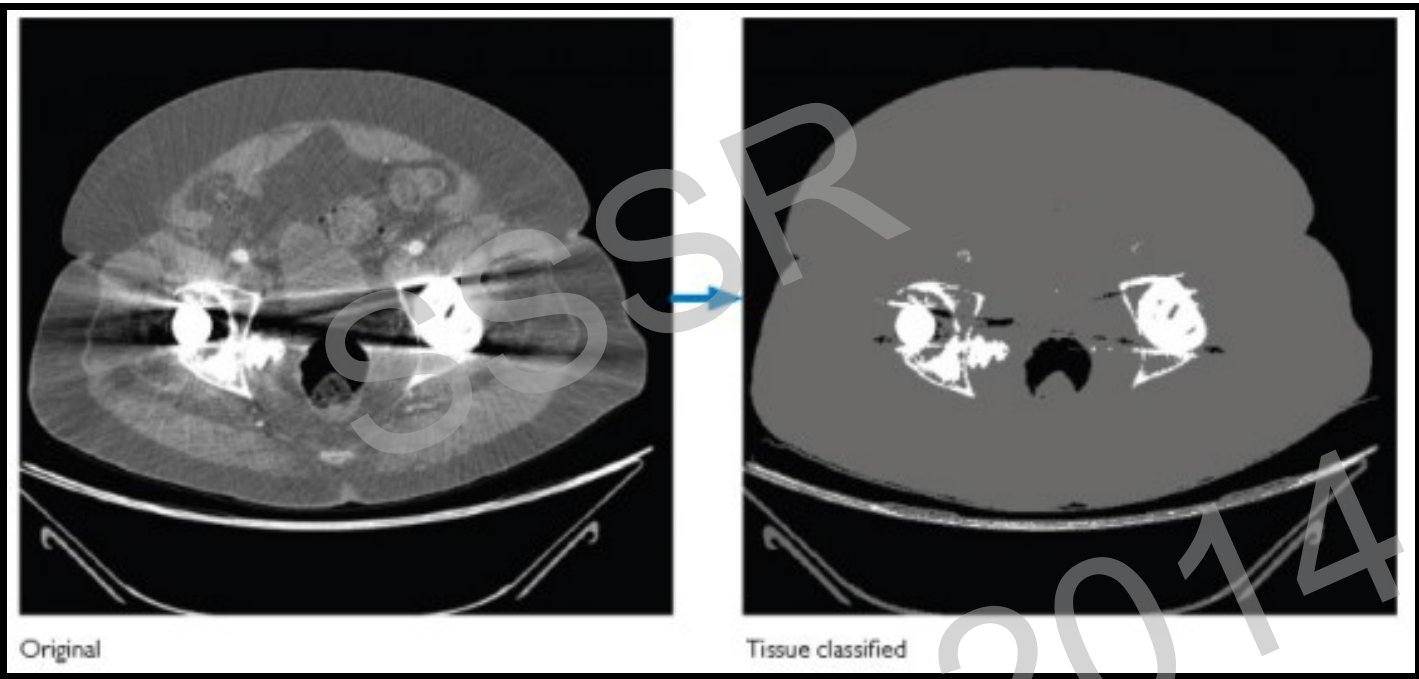
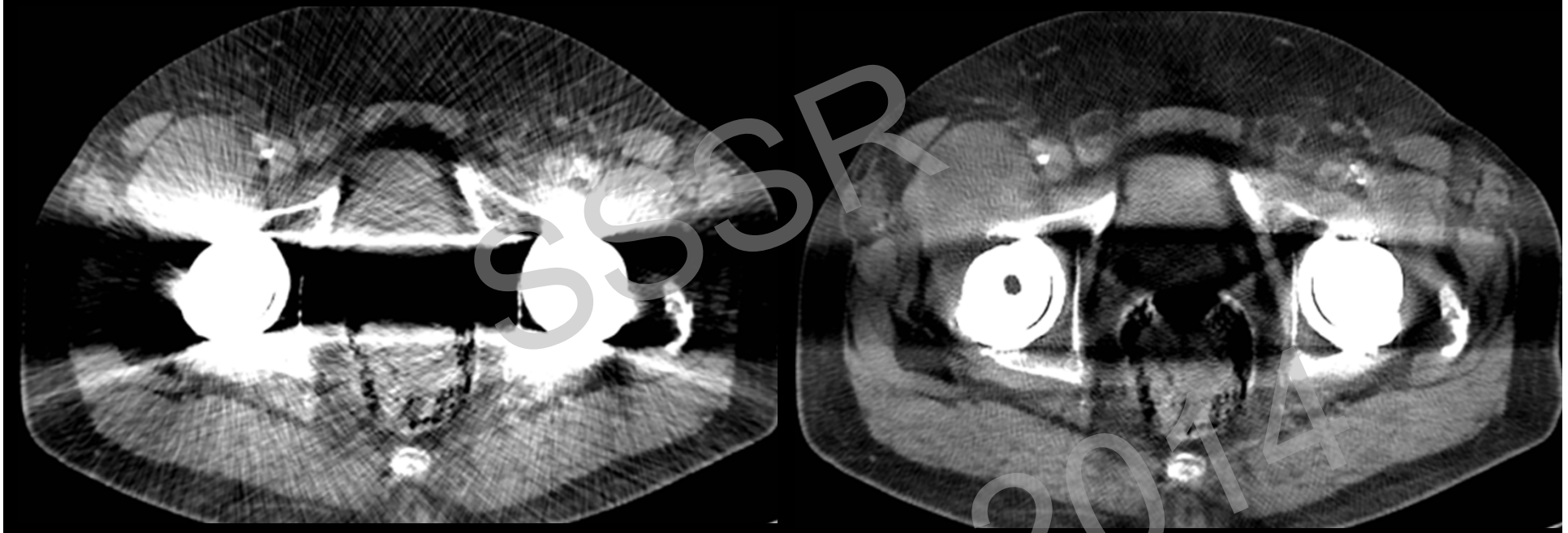


<u>O-MAR (Orthopedic Metal Artifact Reduction, Philips):</u>

- first step is to create a metal only image - all pixels set to zero except for those pixels categorized as metal
- repetitive loop where the output correction image is subtracted from the original input image

Specific Metal Artifact Reduction Software (O-MAR)



FBP **O-MAR**

MAR software is valuable for soft tissue: improvement of anatomical visualization e.g. intrapelvic anatomy and lymphadenopathy

University of Zurich

Li H et al. Clinical evaluation of a commercial orthopedic metal artifact reduction tool for CT simulations in radiation therapy Med Phys. 2012

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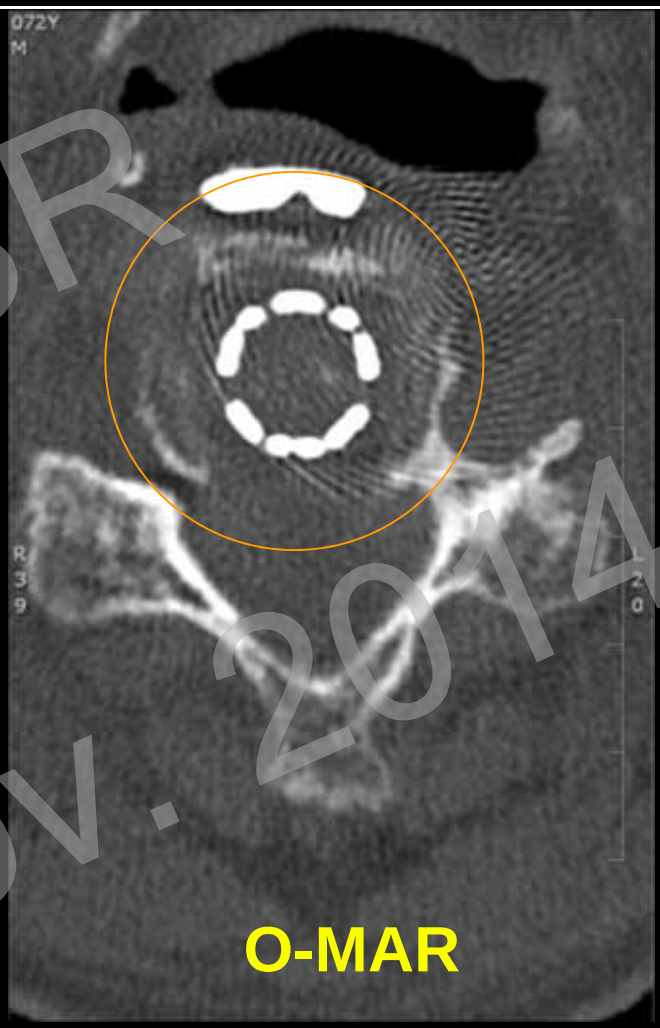
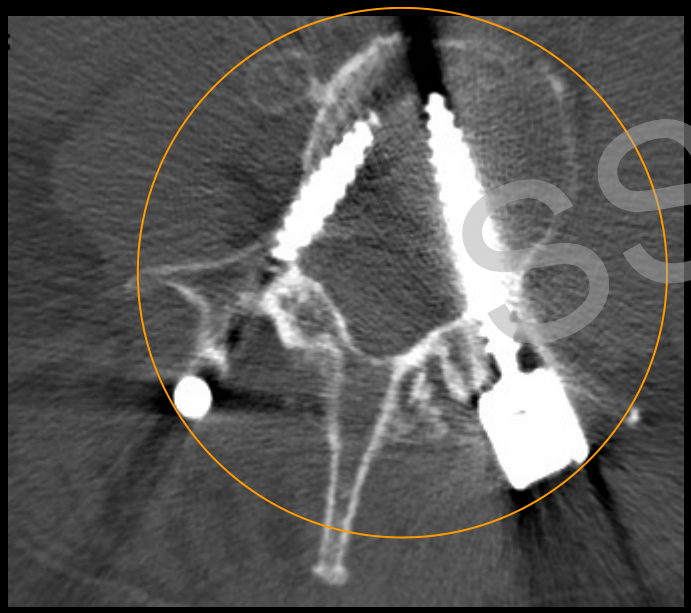
Metal Artifact Reduction Software Must Be Used with Caution

Standard

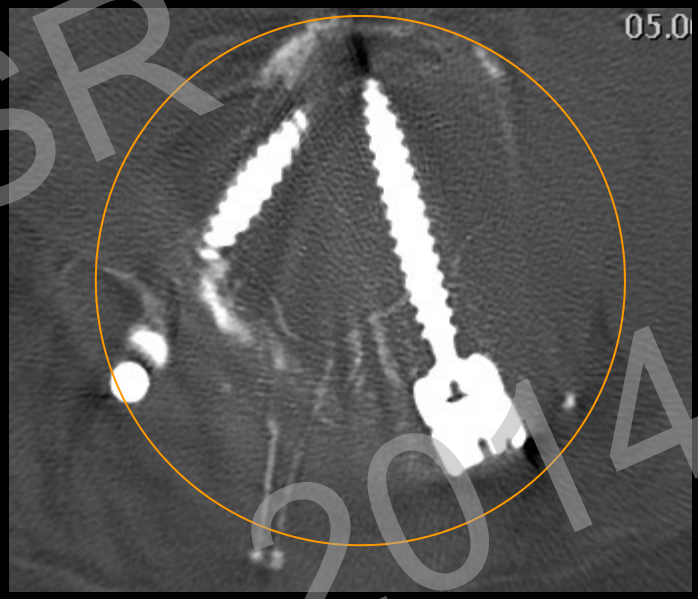


O-MAR

Metal Artifact Reduction Software Should Be Used with Caution



Standard



O-MAR

- O-MAR does not improve visualization of metal-to-bone interface
- O-MAR reduces metal artifacts in soft tissue

University of Zurich[UZH]

Li H et al. Clinical evaluation of a commercial orthopedic metal artifact reduction tool for CT simulations in radiation therapy Med Phys. 2012

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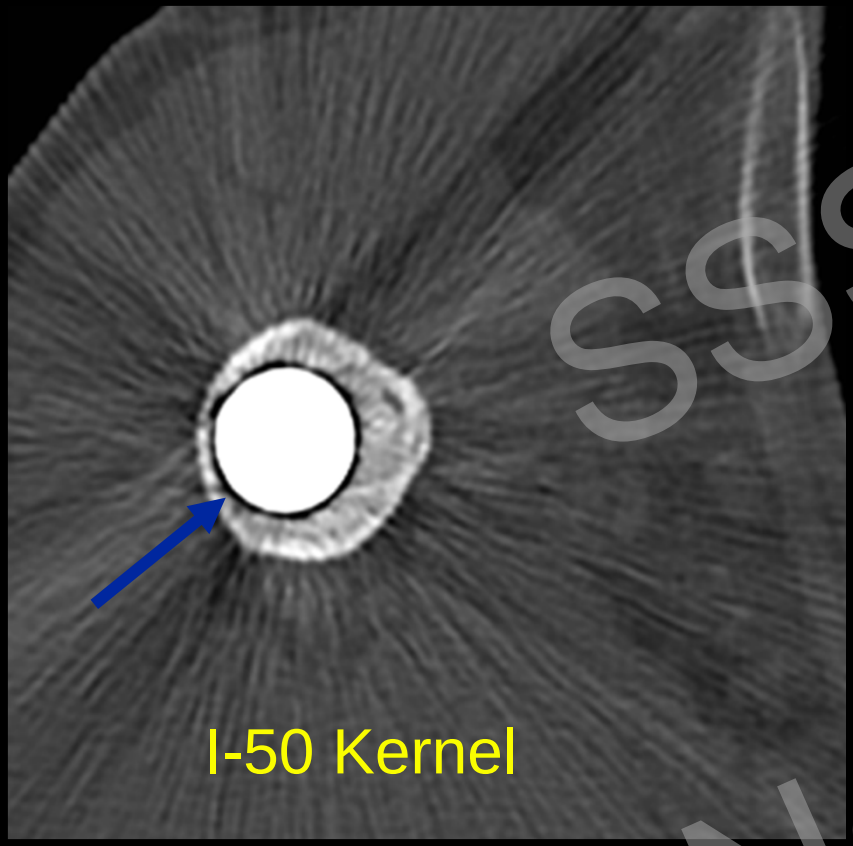
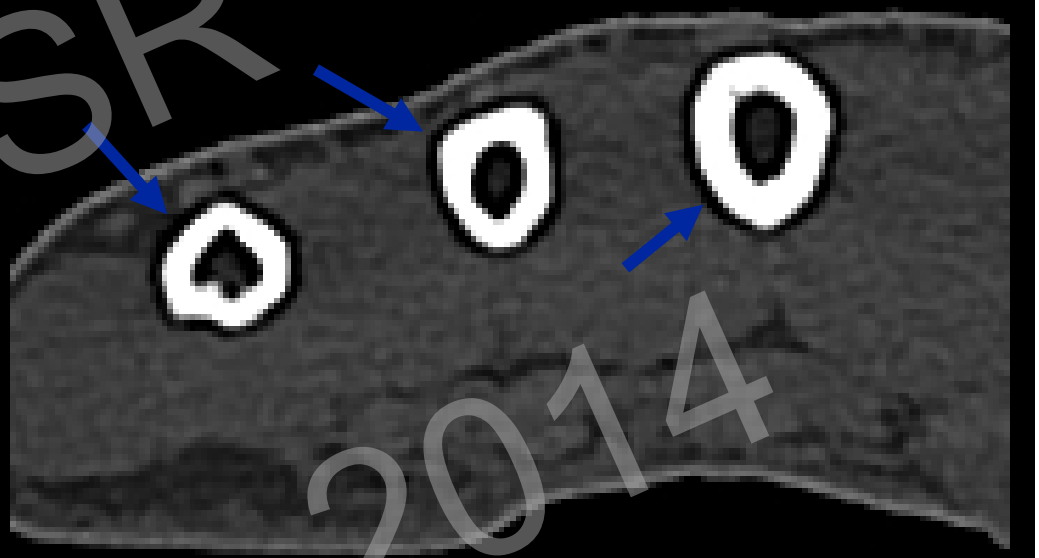
Edge Effects



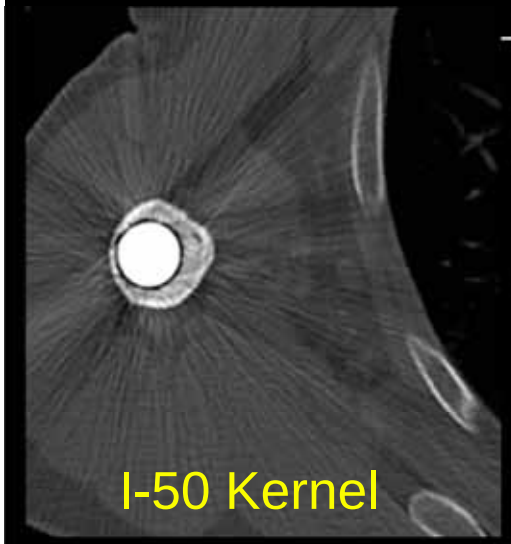
I-50 Kernel



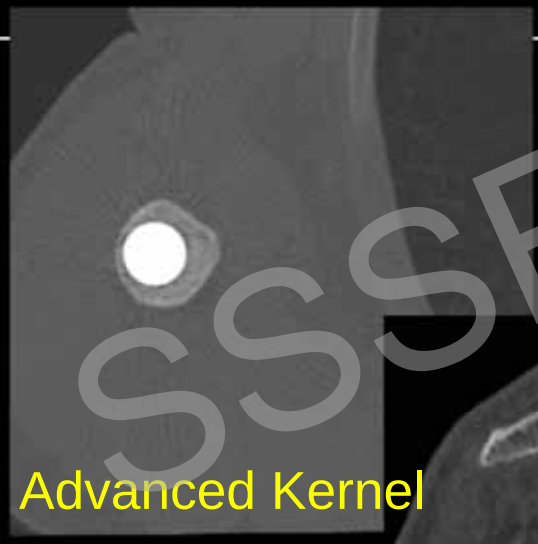
I-50 Kernel

Edge effects: artifacts due to sharp changes in x-ray attenuation

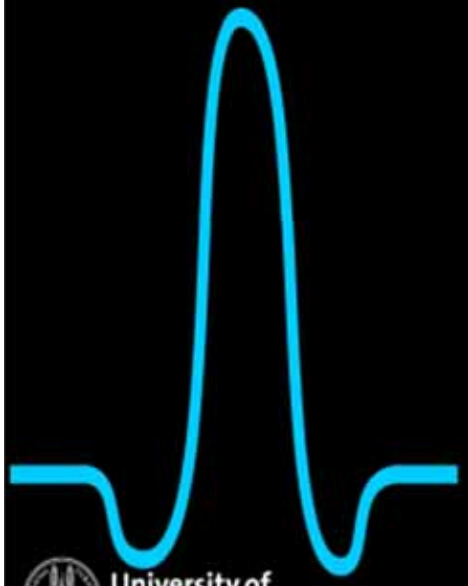
Edge Effects – Kernel Optimiziation



I-50 Kernel



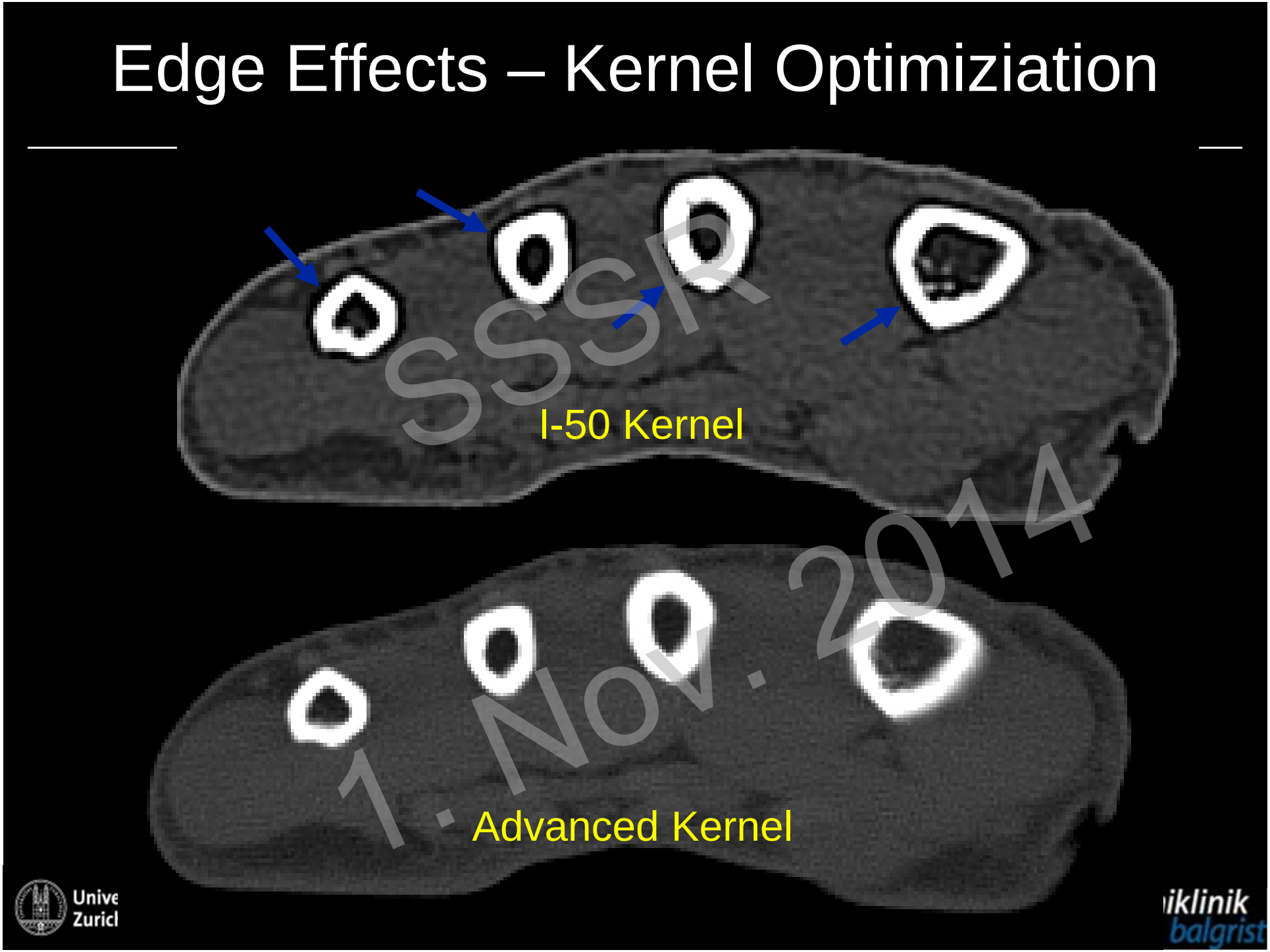
Advanced Kernel



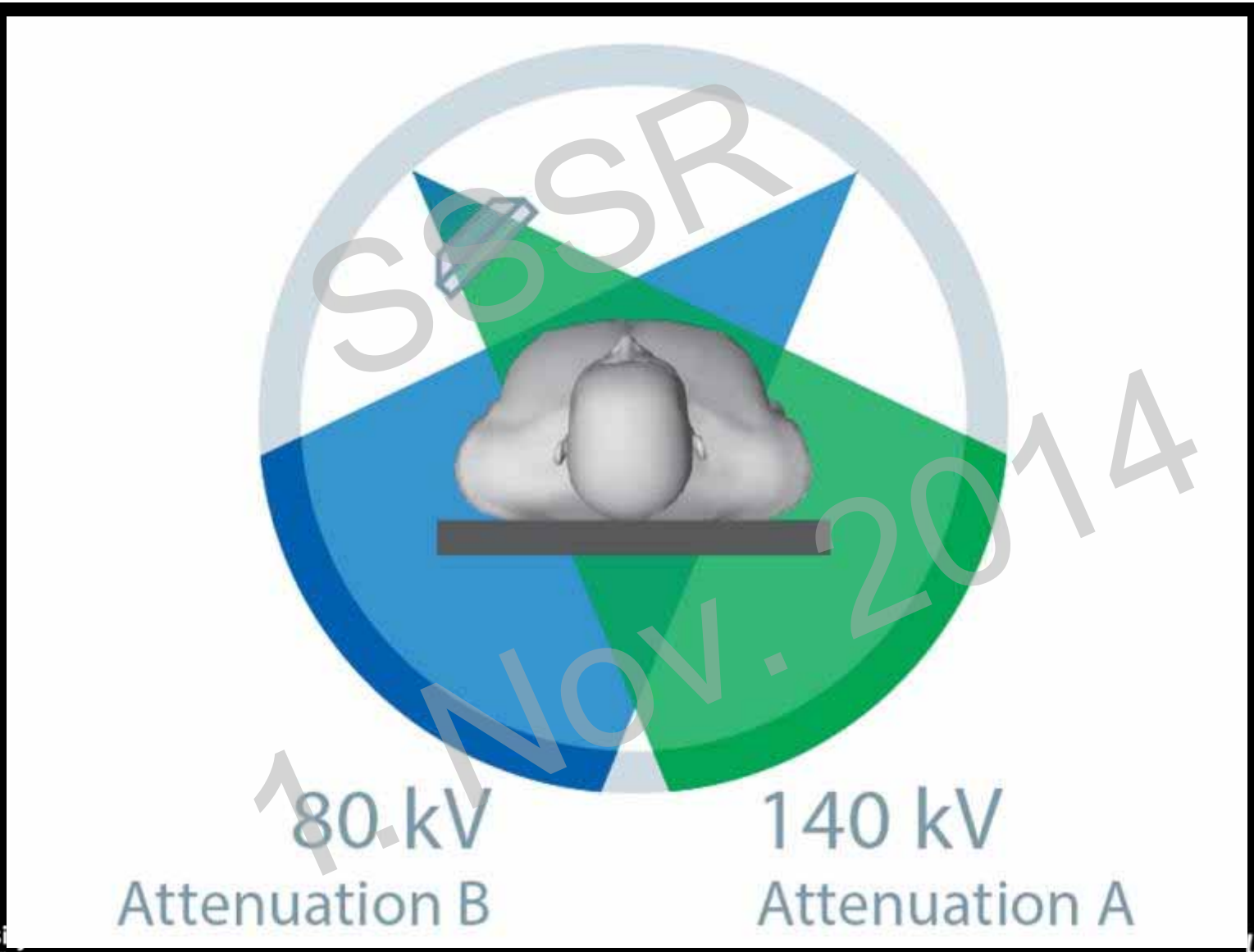
I-50 Kernel

Advanced Kerne

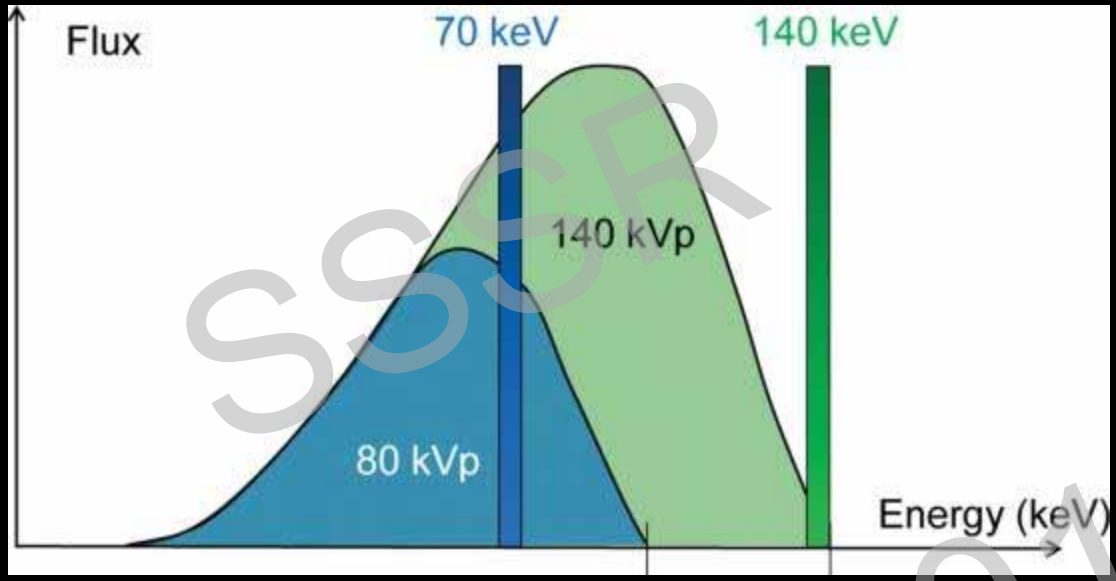
Edge Effects – Kernel Optimiziation



Dual Energy – CT



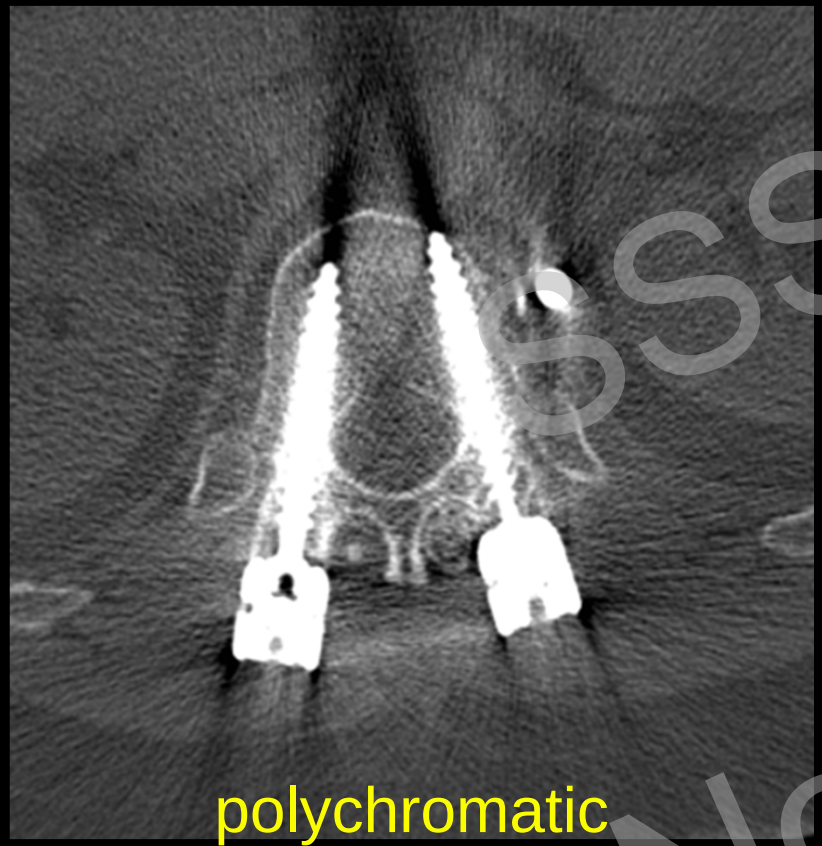
Virtual Monochromatic Spectral Imaging versus Polychromatic Spectral Imaging



- x-ray tube: polychromatic x-ray beam ➔ photons with a range of energies, maximum energy expressed as kilovolt peak
- monochromatic = monoenergetic => virtual CT image reconstruction of x-ray photons at a single energy level

➔ Reduction of Beam-Hardening Effect

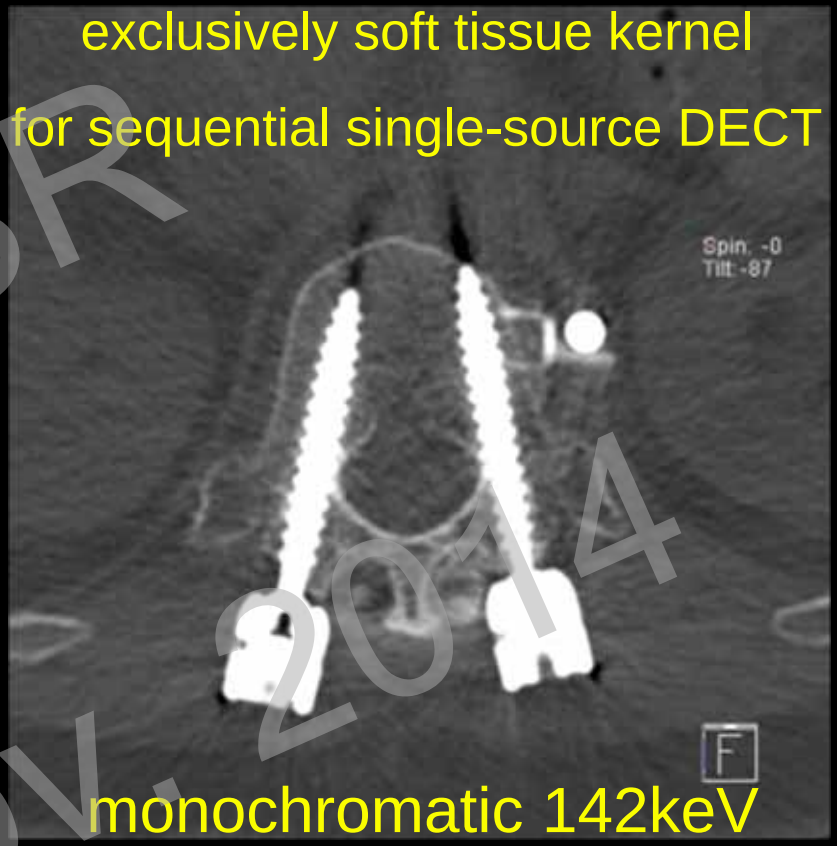
Dual Energy CT



polychromatic

exclusively soft tissue kernel

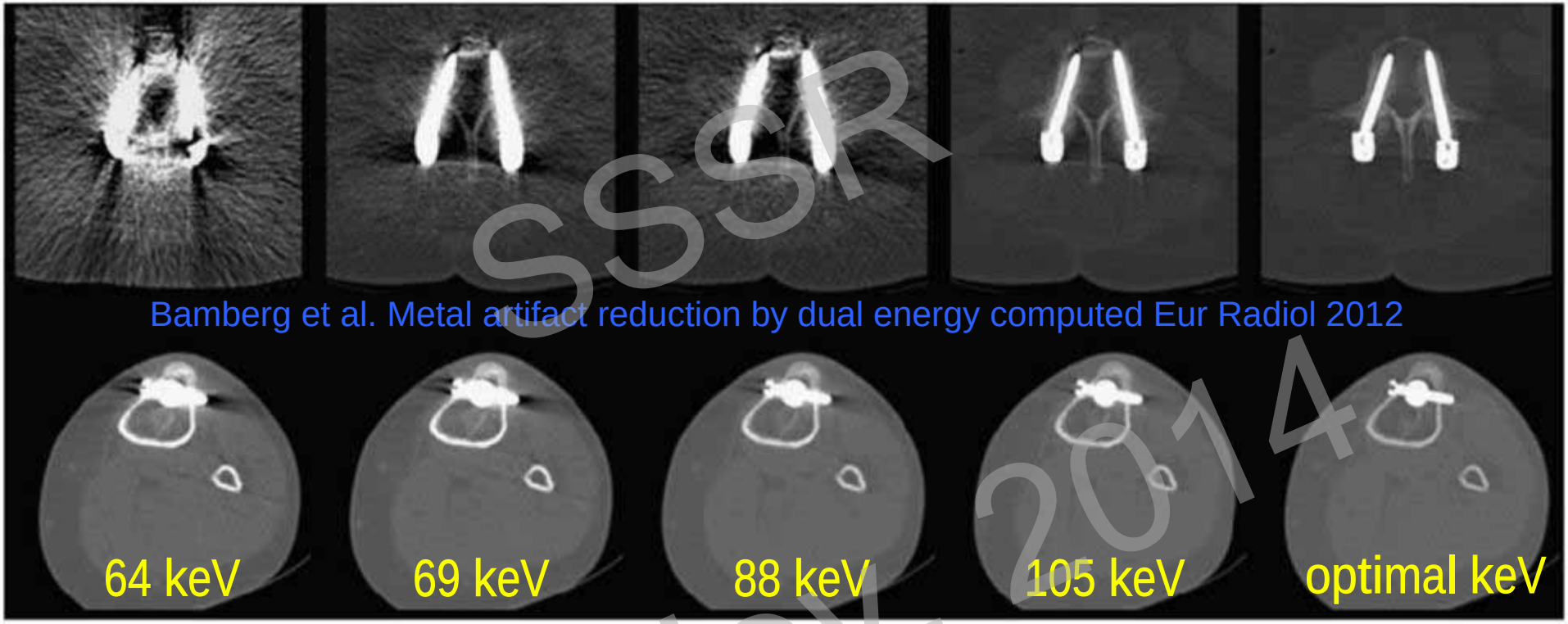
for sequential single-source DECT



monochromatic 142keV

Dual-energy CT allows an efficient reduction of metal artifacts using high-energy monochromatic extrapolation

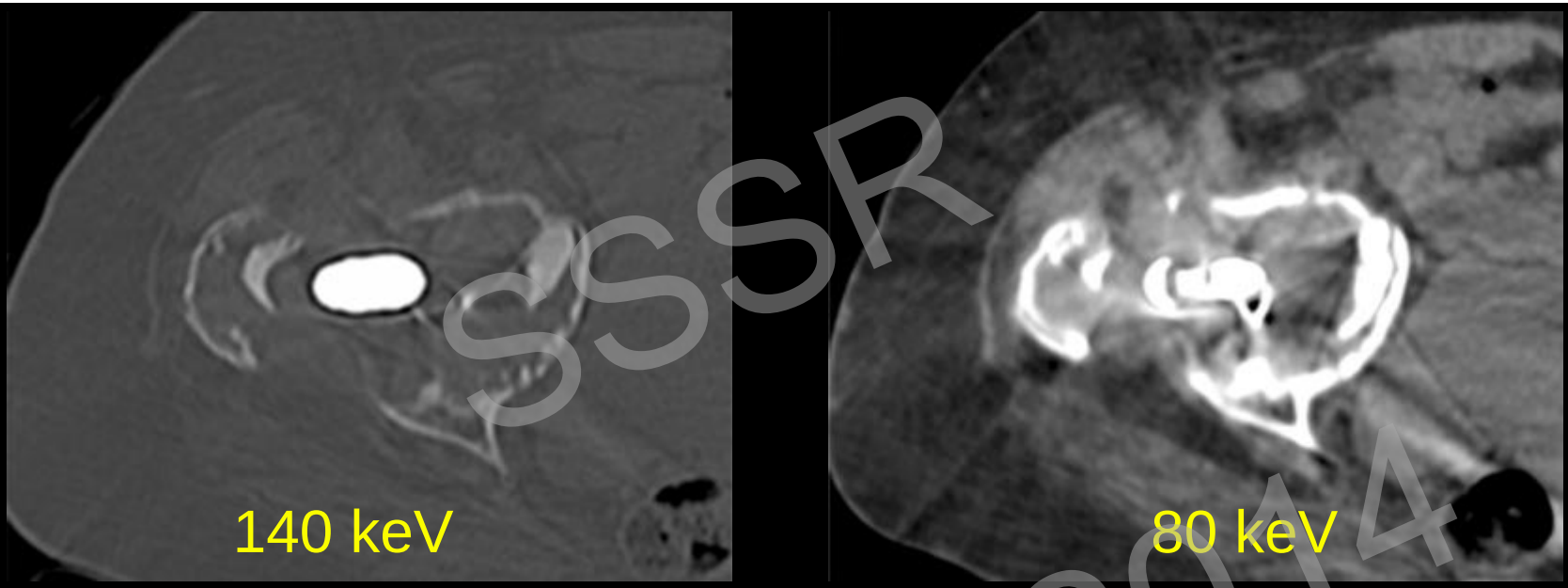
Dual Energy



119.5 ± 13.5 keV

Improve visualization of metal-to-bone interface ➔ higher energy

Dual Energy



Pessis et al. Virtual Monochromatic … RadioGraphics 2013

Improve visualization of metal-to-bone interface ➔ higher monochrom. energy

Improve visualization of soft tissue ➔ lower monochromatic energy levels
(↑contrast & ↓noise)

Summary Dual Energy

dual-energy CT techniques can reduce metal artifact due to beam-hardening reduction

radiation exposure similar to standard polychromatic protocol

financial investment and maintenance cost ➔ DECT scanners are not widely available, restricted application

Conclusion

- Protocol should be tailored
- Consider first basic principles to reduce Metal Artifacts
- Commercially available specific MAR algorithm are appropriate for soft tissue, not metal-to-bone interface
- Dual-energy CT can reduce metal related artifacts

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Thank You
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