Dual energy CT in loosening of revision hip prosthesis: a comparison between MARS and non-MARS images.

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Aims and objectives

The aim of this study was to determine the usefulness of DECT modality in postoperative assessment of revision THA implant loosening, by comparing the efficacy of high-energy monochromatic imaging and low-energy DECT images obtained with and without metal artifact reduction software (MARS).
Methods and materials

Our study included 25 patients (16 women, 9 men), of whom 16 had undergone unilateral primary THA, and 9 had undergone bilateral primary THA (totally 34 primary hip prostheses were implanted). Only 1 of these 25 patients underwent consequent bilateral revision, and 24 underwent unilateral revision THA. Seven prostheses were revised due to stem failure, 10 due to acetabular failure, and in 8 due to failure of both parts. The mean age of patients was 69 years, while mean BMI was 29. Mean time interval between revision surgery and postoperative DECT scan was 23 months (ranged from 13 to 30 months).

Scan acquisition and image reconstruction

All examinations were performed using a fast kilovolt switching dual energy CT scanner (64 channel GE Discovery 750 HD unit). Scanning ranged from anterior superior iliac spines to a point 2 cm below the tip of prosthesis' stem. Other parameters were as follows: detector collimation 0.625mm, pitch 1.3; tube voltage 80/140 kV, tube current 600 mA, field of view 50cm. For each patient 390 to 650 scans were acquired (depending on the length and the size of the prosthesis). Two monochromatic datasets were then generated in post-processing: monochromatic images for a photon energy level of 140 keV without metal artifact reduction (140 keV non-MARS) and monochromatic images for a photon energy level of 75 keV with metal artifact reduction (75 keV MARS).

Image review

Each endoprosthesis was evaluated in bone window (2000/350H.U.), in 140 keV non-MARS and 75 keV MARS datasets for signs of loosening by two radiologists with ten and four years' experience in musculoskeletal imaging. Implant loosening was assessed by measuring the thickness of a low density strip between the implant and the bone. For this purpose a three-point scoring system for each area of the prosthesis was established:

- 3 pts - absence of loosening in the evaluated area;
- 2 pts - thickness of low density strip from 1 to 2 mm (incomplete adhesion);
- 1 pt - thickness of low density strip over 2 mm (loosening suspicion);

Loosening of the stem was evaluated independently for three different segments (distal, middle and proximal), loosening of an acetabular component was also evaluated in three zones independently: the central part, marginal part, and in the area around the screws.
To summarize: 6 different segments were evaluated, each rated 1 to 3 points - on the basis of this we propose an eighteen-point radiological grading system in which the highest attainable score was 18 pts, and the lowest was 6 pts. Based on this score, images were assigned into three groups: no loosening (17-18 pts), incomplete adhesion (15-16 pts), loosening suspicion (<15 pts) [Tab.1]. On the day of CT scan, each patient underwent clinical examination performed by an orthopaedic surgeon with 15 years of experience, during this examination function of the hip joint was evaluated with the Harris Hip Score (HHS) [11].

<table>
<thead>
<tr>
<th>Radiological appearance</th>
<th>Radiological score</th>
<th>140 keV Non-MARS</th>
<th>75 keV MARS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No. of prostheses</td>
<td>Mean HHS (range)</td>
</tr>
<tr>
<td>No loosening</td>
<td>17-18 points</td>
<td>16</td>
<td>67 (35-97)</td>
</tr>
<tr>
<td>Incomplete adhesion</td>
<td>15-16 points</td>
<td>14</td>
<td>65 (40-97)</td>
</tr>
<tr>
<td>Loosening suspicion</td>
<td>&lt;15 points</td>
<td>4</td>
<td>42 (28-67)</td>
</tr>
</tbody>
</table>

**Tab. 1.** Result of imaging analysis of prosthesis in comparison to HHS for the non-MARS group and MARS group. MARS - metal artifact reduction software, HHS - Harris Hip Score.
Results

The mean radiological score for loosening in the non-MARS group was 16.2, and was statistically significantly lower than in the MARS group (17.0, p<0.001). Three out of 4 prostheses rated as "loosening suspicion" in the non-MARS group, were classified in the MARS group as "incomplete adhesion", and one prosthesis rated "loosening suspicion" in 140 keV non-MARS (scoring only 14 out of 18 pts) was classified as "no-loosening" in 75 keV MARS examination [Tab.1]. Discrepancy analysis between MARS and non-MARS groups has shown that the 7 prostheses which were rated as "incompletely adjacent" in the non-MARS group - were included in a group of 24 prostheses rated as "no-loosening" in the MARS group. Interobserver agreement was found to be 0.80, which is interpreted as a good agreement between the two radiologists.

Radiological prosthesis loosening evaluation in 140 keV non-MARS images correlated to an HHS score with rho=0.43, p=0.03 while there was no statistical correlation between 75 keV MARS images and HHS, rho=0.15, p=0.47.

In the linear regression analysis between 140 keV non-MARS images and HHS score was statistically significant, coefficient $a$ was 0.03 and adjusted R-squared, 0.19; p=0.03 (Fig. 1) while in MARs images the correlation was not statistically significant, p=0.51; coefficient $a$, 0.01 and adjusted R-squared, 0.02 (Fig.2).

In our study in 140 keV non-MARS images shape distortion artifacts weren't found in any of 34 prostheses (Fig. 4), while in 75 keV MARS these artifacts were noticed in 22 of 34 prostheses (Fig 3).
Fig. 1: The diagram showing a statistically significant positive correlation between radiological score and clinical examination findings [HHS] in 140keV non-MARS group (p=0.03)

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Fig. 2: The diagram showing no statistically significant correlation between radiological score and clinical examination findings [HHS] in the 75keV MARS group (p=0.51)

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**Fig. 3:** Fig. 3a. 60 year-old male patient clinically with loosening HHS=43. Coronal MARS reconstruction image reveals shape distortion and ground-glass blurring area around screws and margin of the Burch-Schneider acetabular cage.

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**Fig. 4:** Fig. 3b. The same patient, coronal reconstruction non-MARS image. There is no blurring and shape distortion and fracture of the upper screw and small zone of loosening could be demonstrated.

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Conclusion

In our opinion this observation leads to the conclusion that the correct approach for revision THA DECT imaging should include the application of at least two datasets:

- **high-energy monochromatic reconstructions without MARS** - to evaluate bone, hardware and bone-implant interface (loosening) and

- **low-energy monochromatic reconstructions with MARS** - which should be used in assessment of soft tissues of the thigh and pelvis.

These two DECT datasets are complementary and should be evaluated inseparably to prevent omission of relevant clinical information (Fig. 3,4).
Fig. 3: Fig. 3a. 60 year-old male patient clinically with loosening HHS=43. Coronal MARS reconstruction image reveals shape distortion and ground-glass blurring area around screws and margin of the Burch-Schneider acetabular cage.
**Fig. 4:** Fig. 3b. The same patient, coronal reconstruction non-MARS image. There is no blurring and shape distortion and fracture of the upper screw and small zone of loosening could be demonstrated.

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