

Impression of effective doses of MSK examinations in a topclinical teaching hospital

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Background/introduction

The importance of radiation safety and the awareness of the radiation burden to the population due to medical imaging has been emphasized by the 2013/59/Euratom directive of the European Union and the subsequent adoption of this directive into national law of the member states since the 6th of February 2018 [1]. In the Netherlands, the NVvR (Nederlandse Vereniging voor Radiologie i.e. Dutch Society for Radiology) has created a committee Technology and the NVKF (Nederlandse Vereniging voor Klinische Fysica i.e. Dutch Society for Clinical Physics) has been collaborating closely with the Health Inspectorate clarifying and implementing the 2013/59/Euratom directive into daily practice.

Currently, 13 national Dutch DRLs (Diagnostic Reference Levels) are available [2]. Only one of these DRLs is related to musculoskeletal diagnostic examinations, i.e. X-pelvis AP ($300 \mu\text{Gy}\cdot\text{m}^2$). Therefore, the purpose of this study was to calculate effective doses of musculoskeletal diagnostic imaging examinations from the available data in our hospital for musculoskeletal diagnostic examinations.

Description of activity and work performed

All available DICOM-RDSR (Digital Imaging and Communication in Medicine - Radiation Dose Structured Report) for musculoskeletal diagnostic imaging examinations were retrospectively identified.

DICOM-RDSR were available from 4 digital X-ray machines and 3 CT-scanners [Table 1]. From 2 DXA-scanners (Dual X-ray Absorptiometry) dose information was manually extracted from the DICOM-images and for Scintigraphy systems dose calculations were based on administered activity [Table 1].

Only musculoskeletal examinations performed in the adult population (i.e. equal or older than 18 years) were included if a minimum of 20 patients per acquisition protocol and machine were available. A minimum number of 20 patients was chosen as the national Dutch DRLs are also calculated based on groups of at least 20 patients each.

Included examinations were performed between June 2013 and November 2018 for CT scans, and between April 2018 and Oktober 2018 for conventional radiography and DXA studies.

DAP (Dose Area Product) in $\mu\text{Gy}\cdot\text{m}^2$ per radiographic acquisition protocol was converted to ED (Effective Dose) in μSv based on the effective dose per unit DAP conform ICRP Publication 103 tissue factors [3,4]. Calculated ED are presented as mean +/- standard deviation [Table 2]. In case no conversion factors were known, ED values were left blank.

DLP (Dose-Length Product) in $\text{mGy}\cdot\text{cm}$ per CT acquisition protocol was converted to ED in mSv based on mean DLP/ED conversion coefficients[-6]. Calculated ED are presented as mean +/- standard deviation [Table 3].

DAP (Dose Area Product) in $\mu\text{Gy}\cdot\text{m}^2$ per DXA acquisition protocol was converted to ED (Effective Dose) in μSv similar to the conversion for conventional radiographic acquisitions. [3]. Calculated ED are presented as mean +/- standard deviation [Table 4].

For bone scintigraphy 600 MBq of Technetium-99m hydroxymethylenediphosphonate was injected intravenously. The injected dose in MBq was converted to ED in mSv conform ICRP 128 [7]. Resulting in an ED for adults with normal bone uptake of 2,94 mSv and an ED for adults with high bone uptake of 2,58 mSv.

Images for this section:

| Equipmentlist | | | | |
|---------------|--------------|------------------|---------------------------|--------------|
| Modality type | Modality | Department | Type/Model | Manufacturer |
| CT | CT AS ER | Emergency room | Somatom Definition AS | Siemens |
| CT | CT AS RAD | Radiology | Somatom Definition AS | Siemens |
| CT | CT Flash RAD | Radiology | Somatom Definistion Flash | Siemens |
| CR | TRAUMA 01 | Emergency room | Fluorospot Compact FD | Siemens |
| CR | TRAUMA 02 | Emergency room | Fluorospot Compact FD | Siemens |
| CR | X-ray ER | Emergency room | Fluorospot Compact FD | Siemens |
| CR | X-ray 4 RAD | Radiology | Fluorospot Compact FD | Siemens |
| DXA | Discovery A | Nuclear medicine | Discovery A | Hologic |
| DXA | Horizon A | Nuclear medicine | Horizon A | Hologic |

Table 1: Equipment

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| Dose Area Product (DAP) and Effective Dose (ED) of conventional radiography per protocol, orientation and modality | | | | | |
|--|-------------|-------------|-----------------|---------------------------------------|-----------------------|
| Protocol | Orientation | Modality | Number of scans | DAP ($\mu\text{Gy}\cdot\text{m}^2$) | ED (μSv) |
| Pelvis AP | T | X-ray ER | 162 | 78.59162.60 | 102.17155.38 |
| | T | TRAUMA 01 | 252 | 102.90167.48 | 133.77187.72 |
| | T | TRAUMA 02 | 427 | 84.33165.02 | 109.63158.53 |
| | T | X-ray 4 RAD | 120 | 109.07145.59 | 141.801189.26 |
| Dens AP | W | X-ray 4 RAD | 835 | 254.791194.50 | 331.231252.85 |
| | W | X-ray 4 RAD | 236 | 7.5113.70 | |
| Hands 3/4 | X | X-ray 4 RAD | 308 | 3.3510.78 | |
| Hands PA | X | X-ray 4 RAD | 314 | 3.2910.83 | |
| Knees | W | X-ray 4 RAD | 95 | 17.7719.38 | 0.6010.32 |
| Feet AP | X | X-ray 4 RAD | 234 | 3.3710.91 | 0.1110.03 |
| Feet Standing AP | X | X-ray 4 RAD | 42 | 4.1410.99 | 0.1310.03 |
| Shoulder AP | W | X-ray ER | 246 | 18.1111.34 | 11.5917.26 |
| | W | X-ray 4 RAD | 600 | 16.57113.88 | 10.6018.89 |
| | T | TRAUMA 02 | 67 | 39.85125.50 | 25.50116.32 |
| Shoulder Y-view | X | X-ray ER | 61 | 14.3316.81 | 9.1714.36 |
| | W | X-ray ER | 288 | 21.81116.53 | 10.0317.60 |
| | W | X-ray 4 RAD | 549 | 19.85119.06 | 9.1318.77 |
| | T | TRAUMA 02 | 51 | 49.10111.30 | 22.58114.40 |
| Wrist PA | X | X-ray ER | 67 | 14.4815.81 | 6.6612.67 |
| | X | X-ray 4 RAD | 423 | 1.0410.42 | |
| | X | TRAUMA 02 | 41 | 1.2010.45 | |
| Wrist LAT | X | X-ray 4 RAD | 349 | 1.0910.53 | |
| | X | X-ray ER | 531 | 0.8810.31 | |
| | X | TRAUMA 02 | 54 | 1.0210.37 | |
| Foot AP | X | X-ray 4 RAD | 443 | 0.8510.36 | |
| | X | X-ray ER | 338 | 1.6810.48 | 0.0510.02 |
| | X | X-ray 4 RAD | 390 | 1.8110.68 | 0.0610.02 |
| Foot 3/4 | X | X-ray ER | 342 | 1.9110.59 | 0.0610.02 |
| | X | X-ray 4 RAD | 679 | 2.0610.57 | 0.0710.02 |
| Finger LAT | X | X-ray ER | 160 | 0.2510.11 | |
| Finger PA | X | X-ray 4 RAD | 83 | 0.2610.15 | |
| | X | X-ray ER | 117 | 0.2910.13 | |
| Hip AX | X | X-ray 4 RAD | 68 | 0.2910.12 | |
| | X | X-ray ER | 130 | 50.10123.76 | 65.13130.89 |
| | X | TRAUMA 01 | 149 | 51.39127.88 | 66.81136.25 |
| | X | TRAUMA 02 | 316 | 55.35132.87 | 71.96142.73 |
| Clavicle AP | X | X-ray ER | 733 | 47.76132.21 | 62.09141.88 |
| | W | X-ray ER | 45 | 10.6318.85 | 6.8115.66 |
| | W | X-ray 4 RAD | 45 | 7.5314.11 | 4.8212.63 |
| Clavicle caud-cran | W | X-ray ER | 79 | 4.6511.41 | 2.1410.65 |
| | W | X-ray 4 RAD | 58 | 3.8511.15 | 1.7710.53 |
| Ankle AP | X | X-ray ER | 411 | 2.1010.71 | |
| | X | TRAUMA 02 | 67 | 2.6811.12 | |
| | X | X-ray 4 RAD | 469 | 2.2110.72 | |
| Ankle Lat | X | X-ray ER | 394 | 2.5110.81 | |
| | X | TRAUMA 02 | 70 | 3.5011.52 | |
| | X | X-ray 4 RAD | 452 | 2.7110.74 | |
| Hand PA | X | X-ray ER | 444 | 1.3610.69 | |
| | X | X-ray 4 RAD | 265 | 1.5910.68 | |
| Hand 3/4 | X | X-ray ER | 416 | 1.3910.61 | |
| | X | X-ray 4 RAD | 259 | 1.5710.60 | |
| Radiushead | X | X-ray ER | 49 | 1.5210.64 | |
| Lower arm LAT | X | X-ray ER | 46 | 3.3111.90 | |
| | X | X-ray 4 RAD | 32 | 3.0411.04 | |
| Lower arm AP | X | X-ray ER | 49 | 2.9610.98 | |
| | X | X-ray 4 RAD | 31 | 2.9510.70 | |
| Knee AP | X | X-ray ER | 65 | 9.3413.84 | 0.3210.13 |
| | W | X-ray 4 RAD | 724 | 9.4219.80 | 0.3210.13 |
| | T | X-ray ER | 127 | 11.2616.90 | 0.3910.23 |
| | T | TRAUMA 02 | 43 | 13.8118.19 | 0.4710.28 |
| | T | X-ray 4 RAD | 102 | 9.9217.19 | 0.3410.24 |
| Knee LAT | X | X-ray ER | 91 | 10.8913.61 | 0.3710.12 |
| | X | TRAUMA 02 | 48 | 12.6913.63 | 0.4310.12 |
| | T | X-ray ER | 128 | 7.6113.98 | 0.2610.14 |
| | T | X-ray 4 RAD | 1071 | 6.3615.50 | 0.2210.12 |
| Lower leg AP | X | X-ray ER | 68 | 5.4311.72 | |
| | X | TRAUMA 02 | 48 | 7.0312.60 | |
| | X | X-ray 4 RAD | 91 | 5.9311.78 | |
| Lower leg LAT | X | X-ray ER | 87 | 6.9713.97 | |
| | X | TRAUMA 02 | 47 | 7.8012.57 | |
| | X | X-ray 4 RAD | 105 | 6.4211.86 | |
| Upper arm AP | W | X-ray ER | 55 | 7.8412.05 | |
| | W | X-ray 4 RAD | 45 | 8.1211.83 | |
| Upper arm LAT | W | X-ray ER | 41 | 7.9212.31 | |
| | W | X-ray 4 RAD | 45 | 8.6812.75 | |
| Foot Standing AP | X | X-ray 4 RAD | 369 | 2.0710.66 | 0.0710.02 |
| Foot Standing LAT | W | X-ray 4 RAD | 357 | 5.4811.24 | 0.1810.04 |
| Elbow AP | X | X-ray ER | 161 | 2.0710.61 | |
| | X | X-ray 4 RAD | 153 | 2.0310.71 | |
| Elbow LAT | X | X-ray ER | 132 | 2.3110.68 | |
| | X | X-ray 4 RAD | 140 | 2.3810.95 | |
| Upper leg AP (met Knee) | T | X-ray 4 RAD | 63 | 15.8018.56 | 5.6913.08 |
| Shoulder AP (Endo) | W | X-ray 4 RAD | 206 | 6.5516.59 | 4.1914.21 |
| Shoulder AP (Exo) | W | X-ray 4 RAD | 194 | 5.7414.24 | 3.6812.71 |
| Patella AX | X | X-ray 4 RAD | 131 | 1.5210.61 | |
| Hand LAT | X | X-ray ER | 55 | 1.4311.03 | |
| Wrist 3/4 | X | X-ray ER | 56 | 0.9410.60 | |

Table 2: Dose Area Product (DAP) and Effective Dose (ED) of conventional radiography

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Dose Length Product (DLP) and Effective Dose (ED) of CT and protocol per modality

| Protocol | Modality | Number of | | |
|------------------|--------------|-----------|------------------|-------------|
| | | scans | DLP (mGy.cm) | ED (mSv) |
| Pelvis | CT AS RAD | 415 | 254.71± 218.16 | 3.34± 2.86 |
| | CT AS ER | 359 | 297.71± 167.01 | 3.90± 2.19 |
| | CT Flash RAD | 253 | 382.69± 229.55 | 5.01± 3.01 |
| Hip Dual Energy | CT Flash RAD | 204 | 788.96± 316.77 | 9.35± 3.75 |
| Hips Dual Energy | CT Flash RAD | 260 | 1,047.06± 398.23 | 12.41± 4.72 |
| Elbow | CT AS RAD | 27 | 164.24± 136.48 | |
| | CT AS ER | 33 | 126.18± 95.15 | |
| | CT Flash RAD | 149 | 156.14± 143.44 | |
| Ankle | CT AS RAD | 55 | 146.60± 27.34 | 0.03± 0.01 |
| | CT AS ER | 52 | 167.70± 50.89 | 0.03± 0.01 |
| | CT Flash RAD | 171 | 210.38± 213.01 | 0.04± 0.04 |
| Hand | CT AS RAD | 137 | 103.16± 31.07 | |
| | CT Flash RAD | 20 | 196.01± 165.21 | |
| Knee | CT AS RAD | 73 | 125.38± 32.25 | 0.05± 0.01 |
| | CT AS ER | 93 | 143.57± 84.46 | 0.06± 0.03 |
| | CT Flash RAD | 165 | 174.23± 190.49 | 0.07± 0.08 |
| Wrist | CT AS RAD | 141 | 99.79± 24.19 | |
| | CT AS ER | 76 | 89.57± 16.95 | |
| | CT Flash RAD | 293 | 131.06± 91.53 | |
| Shoulder | CT AS RAD | 326 | 214.86± 151.10 | |
| | CT AS ER | 148 | 323.78± 158.64 | |
| | CT Flash RAD | 292 | 316.14± 150.26 | |
| Foot | CT AS RAD | 39 | 88.03± 27.93 | |

Table 3: Dose Length Product (DLP) and Effective Dose (ED) of CT

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Dose Area Product (DAP) of Bone Densitometry (X-Ray) per protocol and modality

| Protocol | Modality | Number of scans | DAP ($\mu\text{Gy}\cdot\text{m}^2$) | ED (μSv) |
|----------|-------------|-----------------|---------------------------------------|-----------------------|
| Arm | Horizon A | 23 | 0.54±0.38 | |
| Hip | Discovery A | 29 | 3.13±2.24 | 4.07±0.29 |
| | Horizon A | 28 | 1.36±3.74 | 1.77±0.49 |

Table 4: Dose Area Product (DAP) and Effective Dose (ED) of Bone Densitometry

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Conclusion and recommendations

Currently, only one of the national Dutch DRLs is referring to a musculoskeletal imaging examination, i.e. X-pelvis AP ($300 \mu\text{Gy}\cdot\text{m}^2$). The average DAP of X-pelvis AP performed in our hospital ranged from 79 to $109 \mu\text{Gy}\cdot\text{m}^2$ and stayed well below this limit.

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