Dose conversion from a material dose to effective dose using mesh phantom for retrospective accident dosimetry

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Introduction

- Problems
  - First, the phone dose and the human body dose do not correspond exactly.
  - Second, the position of the mobile phone is not fixed like a dosimeter.

Mobile Phone

The progressions of the mobile phone and the circuit board size
Merits of a mobile phone display glass for numerical dose reconstruction in retrospective dosimetry compare to resistors

- Target Material
  - Bottom Glass: SiO₂ (Silicon dioxide)

- Bottom Glass (target) Size
  : 6.72 x 0.04 x 13.86 (cm³)

- More fast simulation for Monte Carlo Method

[ The mobile phone structure ]
The Voxel Phantom

Voxel-type Reference Computational Phantoms (VRCPs)

Male phantom
(Voxel size: 2.137 × 2.137 × 8 mm³)

Female phantom
(Voxel size: 1.775 × 1.775 × 4.8 mm³)
The Problem of the Voxel Phantom

First, the skin of voxel phantom has many holes incurring significant error in dose estimation for charged particles due to cuboid-shaped voxels.

- This figures are the voxel models of the skin.
- Front view: it looks like human skin is well defined.
- Top view: there are large holes on the surface of the skin.
- There is a problem that large holes are appeared on the surface of the skin.
- This can cause a problem in calculating the dose in some cases.
Second, the size of voxel unit which has about 2 mm for standard ICRP phantom is hard to render small tissues.

- Some of the actual organs consist of the very thin layer.
- For example, when a stomach is constructed by the voxel model, it appears different from the actual stomach.
- The voxel modeling is difficult to express the thin later.
Third, the voxel phantoms are not flexible to modify postures like squatting, sitting and bending.
The Mesh Phantom

MRCPs (Mesh-type Reference Computational Phantoms)

Kim C. H., et al., HUREL, Hanyang University

VRCPs (ICRP Publication 110)

MRCPs (Mesh-type Reference Computational Phantoms)
The Various Postures of the Mesh Phantom

MRCPs (Mesh-type Reference Computational Phantoms)
Phone Location

- The position of the mobile phones is different by individuals.
- Some may put the phone in the pockets, or grasp the phone in the hand.
- Illustration of the phone position (grey rectangles) in the four different locations for various postures
- Four representative phone locations were selected for the chest, hip, thigh, and hand.
- These four phone positions were applied to the standing, kneeling and squatting postures.
Simulation Conditions

- **Simulation**
  - Mesh phantom with Geant4 simulation code
  - Latest mobile phones modeling
  - Target material: display glass (SiO_2)

- **Exposure condition**
  - Phone positions: chest pocket, hip pocket, thigh pocket, hand
  - Exposure geometries: anterior-posterior (AP), posterior-anterior (PA), left-lateral (LLAT) and right-lateral (RLAT), isotropic (ISO) and rotational (ROT)
  - Radiation sources: Ir-192, Cs-137 and Co-60
  - Height/Weight: 176 cm/ 73 kg (MRCPs for adult male)
  - Postures: standing, kneeling and squatting
Simulation Results for Standing Posture

❖ Standing posture

Dose per fluence of mobile phones in different positions (chest, hip, thigh and hand) and human body (converted from the effected dose, pSv cm$^2$) according to the 6 exposure geometries with the standing posture and energies of Ir-192 (a), Cs-137 (b) and Co-60 (c).
Simulation Results for Standing Posture

- **Standing posture**

![Graph](image)

The calculated dose per fluence of the mobile phone in different positions and human body for standing posture for exposures to Ir-192.
Simulation Results for Standing Posture

❖ Standing posture

The calculated dose per fluence of the mobile phone in different positions and human body for standing posture for exposures to Ir-192

❖ For AP exposures

- In the case of the chest location, the phones were directly irradiated without any shielding, so the dose was highly evaluated.
- In the case of the hip location, the dose was the lowest because of the shielding effect.
- The maximum phone dose was 14% higher than the effective dose.
- The minimum phone dose was 65% lower than the effective dose.
Simulation Results for Standing Posture

站立姿势

对于PA暴露

- 在胸腔位置，剂量最低，因为有屏蔽效果。
- 在臀部位置，电话直接照射，没有任何屏蔽，所以剂量评估非常高。
- 最大电话剂量比有效剂量高60%。
- 最小电话剂量比有效剂量低48%。

图(a)显示了站立姿势对Ir-192的不同位置和人体的计算剂量/通量（pGy cm²）。

这个图表展示了站立姿势下移动电话在不同位置和人体的计算剂量/通量，对于Ir-192的暴露。
Simulation Results for Standing Posture

Standing posture

For LLAT exposures
- LLAT is from the left to the right.
- The results are similar depending on the position of the phone. Because almost phones are not shielded by anything.
- The lowest value was the effective dose.
- The maximum phone dose was 22% higher than the effective dose.
- The minimum phone dose was 6% higher than the effective dose.

The calculated dose per fluence of the mobile phone in different positions and human body for standing posture for exposures to Ir-192
Simulation Results for Standing Posture

❖ Standing posture

➢ For RLAT exposures
  • RLAT is from the right to the left.
  • Some of the results are similar depending on the position of the phone. Because almost phones are not shielded by anything.
  • In the case of the hand location, the dose was the lowest because of the shielding effect by the body.
  • The maximum phone dose was 25% higher than the effective dose.
  • The minimum phone dose was 51% lower than the effective dose.

The calculated dose per fluence of the mobile phone in different positions and human body for standing posture for exposures to Ir-192
Simulation Results for Standing Posture

❖ Standing posture

➢ For ISO exposures
  • The direction of the radiation is isotropic.
  • The results are similar depending on the position of the phone. Because almost phones are not shielded by anything.
  • The lowest value was the effective dose.
  • The maximum phone dose was 23% higher than the effective dose.
  • The minimum phone dose was 3% higher than the effective dose.

The calculated dose per fluence of the mobile phone in different positions and human body for standing posture for exposures to Ir-192
Simulation Results for Kneeling Posture

Kneeling posture

Dose per fluence of mobile phones in different positions (chest, hip, thigh and hand) and human body (converted from the effected dose, pSv cm\(^2\)) according to the 6 exposure geometries with the kneeling posture and energies of Ir-192 (a), Cs-137 (b) and Co-60 (c).
Squatting posture

Dose per fluence of mobile phones in different positions (chest, hip, thigh and hand) and human body (converted from the effected dose, pSv cm²) according to the 6 exposure geometries with the squatting posture and energies of Ir-192 (a), Cs-137 (b) and Co-60 (c).
Simulation Results for exposures to Ir-192

- Various postures for exposures to Ir-192

  - There are the doses per fluence of mobile phones in different positions (chest, hip, thigh and hand) and human body (converted from the effected dose, pSv cm²) according to the 6 exposure geometries with the standing, kneeling and squatting posture.

  - This graphs show different results according to the posture.

  - It can be seen that the affection on the mobile phone by the posture is different because of the shielding effect.

  - The results showed that the posture had a significant affect on dose calculations.

  - Especially, in RLAT exposures, the calculated doses have different tendency according to the posture.
Various postures for exposures to Ir-192

- The **maximum** phone dose is the **hip** position and it was **25%** higher than the effective dose.
- The **minimum** phone dose is the **hand** position and it was **51%** lower than the effective dose.

- The **maximum** phone dose is the **thigh (right)** position and it was **57%** higher than the effective dose.
- The **minimum** phone dose is the **chest** position and it was **3%** higher than the effective dose.

- The **maximum** phone dose is the **hand** position and it was **46%** higher than the effective dose.
- The **minimum** phone dose is the **thigh** position and it was **73%** lower than the effective dose.
Conclusion

• As a result, the maximum and minimum exposed dose of human body can be estimated using the numerical method in the present study.

• Moreover the method is analogous in the case of limited information of postures or exposures.

• The calibration factors to convert mean phone dose to effective dose were provided for various radiation exposure situations.

• This study extends the possibility of dose estimation of retrospective dosimetry using the TL/OSL technique of the mobile phone.
Thank You for
Your Attention