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Body-Weight Dependent Dose Coefficients for Adults Exposed to Idealized External Photon Fields

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Abstract

In epidemiological investigations of cancer risk from occupational exposure, it is important to obtain organ-specific dose for each cohort member for accurate risk analysis. To date, dose conversion coefficients, which convert physical dose measurement to organ dose, are only available for individuals with reference body size which can differentially bias the estimated organ dose depending on the body mass index of cohort members. In the current study, we calculated the organ dose coefficients applicable to adult males and females with various body weights by using Monte Carlo radiation transport technique combined with a library of body size-dependent hybrid computational phantoms exposed in six idealized irradiation geometries. We adopted the eight adult male phantoms, 175 cm tall with weights of 60, 70, 80, 90, 100, 110, 120, and 130 kg, and the nine adult female phantoms, 165 cm tall with weights of 50, 60, 70, 80, 90, 100, 110, 120, and 130 kg. The radiation transport was simulated using MCNPX 2.7 Monte Carlo code. Phantoms were irradiated by external photon fields in anterior posterior (AP), posterior-anterior (PA), right and left lateral (RLAT, LLAT), rotational (ROT), and isotropic (ISO) geometries. The results showed that the 60 kg adult male phantom shows 1.33-, 1.43-, 1.44-, and 1.52-fold greater dose coefficients for the lungs, heart, stomach, and liver, respectively, than the 120 kg adult male phantom at 0.1 MeV in AP geometry. We derived exponential correlation between organ dose coefficients and body weight to facilitate calculation of organ dose coefficients for a given weight. The comprehensive organ dose coefficients and exponential regression model can be used to estimate more accurate organ dose for individuals of the two genders with various body weights exposed to external photon radiation.

1. Introduction

In epidemiological investigations of cancer risk from occupational exposure, it is important to obtain organ-specific dose for each cohort member for accurate risk analysis [1]. Organ absorbed dose is a fundamental dose quantity defined as the mean energy imparted to matter of mass recommended by the International Commission on Radiation Protection (ICRP) [2,3]. The organ absorbed dose is not directly measurable but can be derived from

measurable quantities such as air kerma or particle fluence by means of dose conversion coefficients. For example, in an organ dose reconstruction study for the United States radiologic technologists (USRT) cohort [4,5], dose measurements from personal dosimeters were obtained from hospitals or literatures (if dosimeter readings were not available) and combined with organ dose conversion coefficients to derive organ absorbed doses.

Dose conversion coefficients are calculated by modeling the radiation field of the exposure event and scoring energy deposition for tissues and organs of interest in a computational human phantom, a representational model of the human anatomy. Solving the radiation transport problem is performed via Monte Carlo methods which are well characterized. Computational human phantoms have rapidly evolved over the past decades. In the 1980's, the first-generation of phantoms, known as stylized phantoms, modeled body and organ contours with mathematical equations [6]. These phantoms lacked anatomical realism but could be easily altered by varying the parameters in the mathematical equations. The next generation of phantoms, known as voxel phantoms, were developed using datasets from tomographic images for improved anatomical realism [7]. However, the voxel phantoms are rigid and cannot be easily manipulated to account for anthropometric variations in the populations. Hybrid (or boundary representation) phantoms, the third and latest generation of phantoms, have been developed that offer the flexibility of the first-generation phantoms but also the anatomic realism of the voxel phantoms [8]. The flexibility of the hybrid phantoms allows for adjusting body contours to develop phantoms with different body morphometry [9,10].

To date, most dose conversion coefficient studies that have been reported for adults have used phantoms with reference body size, those with a standard height and weight, or limited number of size-dependent phantoms [11,12]. The ICRP's initial publications of dose conversion coefficients for the adult male and female used first generation stylized phantoms [13,14]. More recently in 2010, the ICRP published dose conversion coefficients in Publication 116 [15] based on the ICRP reference voxel phantoms, the second-generation phantoms. The purpose of this report was to report dose coefficients for the adult male and female reference voxel phantoms for radiation protection of populations [16]. However, the use of dose conversion coefficients based on the reference size phantoms in the organ dose reconstruction for epidemiological studies can differentially bias the estimated organ dose depending on the body mass index of cohort members. It is reported that organ dose based on the reference size phantoms can over-estimate those of overweight persons and underestimate the values of underweight persons undergoing computed tomography scans [9,17].

In the current study, we calculated the organ dose coefficients applicable to adult males and females with various body weights by using Monte Carlo radiation transport technique combined with a library of body size-dependent hybrid computational phantoms [10] exposed in six idealized irradiation geometries. While other studies have tabulated dose coefficients to phantoms of different body sizes [11,12], we employed more systematic and larger set of body size-dependent computational phantoms in the current study. The results were compared with the values from the ICRP Publication 116 [15], which is based on the reference size voxel phantoms. We also derived exponential correlations between organ dose

coefficients and body weight to facilitate calculation of organ dose coefficients for a given weight.

2. Materials and Methods

2.1. Computational human phantoms

To calculate the body weight-dependent organ dose coefficients, we employed a library of hybrid phantoms with various body weights [10] developed in collaboration between the University of Florida and National Cancer Institute. The hybrid phantom library were derived from 12 pediatric and adult hybrid phantoms with reference body size [18] that were non-uniformly scaled to match body morphometry data from the National Health and Nutrition Examination Survey (NHANES) conducted by the Centers for Disease Control and Prevention (CDC) over the 1999 – 2006. For the current study, we selected a total of 17 phantoms out of the 351 phantoms to cover a range of body mass index for the adult male and females. The eight adult male phantoms are 175 cm tall with weights 60, 70, 80, 90, 100, 110, 120, and 130 kg and the nine adult female phantoms are 165 cm tall with weights ranging from 50, 60, 70, 80, 90, 100, 110, 120, and 130 kg (Figure 1).

2.2. Calculation of dose coefficients

Organ absorbed dose coefficients per unit air kerma (D/K_a) (Gy/Gy) were estimated for a total of 31 organs and tissues: adipose tissue, adrenals, brain, breasts, colon wall, esophagus, extrathoracic region, gallbladder wall, heart wall, kidneys, lens of the eye, liver, lungs, lymph nodes, muscle, oral mucosa, ovaries (female), pancreas, prostate (male), salivary glands, skin, small intestine wall, spleen, stomach wall, testes (male), thymus, thyroid, urinary bladder, uterus (female), and both to the active and shallow marrow. The radiation transport was simulated using the Monte Carlo N-Particle eXtended transport code, MCNPX 2.7 [19]. Phantoms were irradiated by external photon fields in anterior posterior (AP), posterior-anterior (PA), right and left lateral (RLAT, LLAT), rotational (ROT), and isotropic (ISO) geometries which are defined in ICRP Publication 116 [15]. A total of 33 photon energies ranging from 0.01 to 20 MeV were simulated. Dose coefficients were tabulated for each combination of 33 photon energies, six irradiation geometries, and 17 computational phantoms.

A description of the Monte Carlo computation and data processing is shown in Table 1. For organ dose tallies, it was assumed that charged particle equilibrium (CPE) was not applicable as secondary electrons play an important role in organ dose at higher photon energies (> 1 MeV) in particular for small or thin walled organs. Therefore, *F8 tally in MCNPX was used, which is consistent with ICRP 116, as opposed to a kerma approximation tally. Organ dose coefficients were then calculated using the methodology described in the following equations:

$$D(\text{Gy}) = \frac{E(\text{MeV}) \times 1.602 \times 10^{-13} \left(\frac{\text{J}}{\text{MeV}} \right)}{\text{organ Mass (kg)}} \quad (1)$$

$$\text{Dose Coefficient} \left(\frac{\text{Gy}}{\text{Gy}} \right) = \frac{D(\text{Gy})}{K(\text{Gy})} = \frac{D(\text{Gy})}{FKC(p\text{Gy} \times \text{cm}^2) \times \frac{1}{10^6} \left(\frac{\text{Gy}}{p\text{Gy}} \right)} \times A(\text{cm}^2) \quad (2)$$

where FKC is fluence-to-kerma conversion coefficients [15] and A is the area of the photon surface source.

Active and shallow bone marrow coefficients were calculated by scoring fluence (photons/m²) using the F4 tally coupled with dose response functions (DRFs) (mGy m²) [20]. Eighteen bone sites were considered in the marrow dose coefficients including the cranium, mandible, scapulae, clavicles, sternum, ribs, vertebrae, sacrum, femora, tibiae, fibulae, patellae, ankles and feet, humera, radii, ulnae, and hands. The fluence tallies were scored for 33 different energy bins, matching those of the incident photon energies (0.01 to 20 MeV). Organ and bone marrow dose coefficients were calculated with the simulation of 1×10^8 histories using the Biowulf high performance computing system. The results were compared with the data in ICRP Publication 116 [15] calculated for the ICRP reference adult male and female phantoms [16] as well as those from the Japanese adult male phantoms [11].

3. Results

3.1. Body weight-dependent organ dose coefficients

A comprehensive set of organ dose coefficients was established for eight male and nine female phantoms with various weights at the standard heights (175 cm for male and 165 cm for female) in six different irradiation geometries (AP, PA, RLAT, LLAT, ROT, and ISO) and for 33 mono-energies ranging from 0.01 to 20 MeV. The full results are reported in Appendix A1 and A2 for the adult males and females, respectively.

Figure 2 shows dose coefficients (Gy/Gy) in AP irradiation geometry for the (a) lungs, (b) heart, (c) stomach, and (d) liver in the adult male phantoms with the weight of 60, 80, 100, and 120 kg. The 60 kg phantom shows 1.33-, 1.43-, 1.44-, and 1.52-fold greater dose coefficients than the 120 kg phantom at 0.1 MeV. In case of the female phantoms (not shown in figures but tabulated in Appendix A2), the 60 kg adult female phantom shows 1.52-, 1.53-, 1.77-, and 1.78-fold greater dose coefficients in AP geometry for the lungs, heart, stomach, and liver, respectively.

Figure 3 shows the values for the same organs in RLAT geometry and Figure 4 depicts dose coefficients only for the stomach and liver in LLAT geometry for comparison. In the case of 0.1 MeV photon exposure, the stomach of the 60 kg adult male phantom shows 1.55- (RLAT) and 1.38-fold (LLAT) greater dose coefficients than the 120 kg phantom. The liver of the 60 kg phantom shows 1.46- (RLAT) and 1.66-fold (LLAT) greater dose coefficients than the 120 kg phantom.

3.2. Comparison with ICRP 116

Figure 2–4 also include the dose coefficients for the reference adult male voxel phantom available in the ICRP Publication 116 [15] for comparison. Overall, the dose coefficients from the ICRP adult male voxel phantom are between those from the 60 kg and 80 kg phantoms in AP geometry (Figure 2), except for the liver where the ICRP value is slightly smaller than the 80 kg phantom (Figure 2d). In RLAT geometry (Figure 3), ICRP 116 data was greater than the dose coefficients of the 120 kg phantom by up to 180% (liver) at 0.1 MeV. The stomach dose coefficient of ICRP 116 is greater than those of the 120 kg male phantom by up to 170% in LLAT geometry (Figure 4).

We also compared our results (lung dose coefficients in AP geometry for the 60 and 120 kg phantoms) with those calculated for the Japanese adult male voxel phantoms (Figure 5) [11]. The height of the three Japanese adult male phantoms, JM, JM2, and Otoko, are 171, 171, and 170 cm, respectively, and the weight is 65 kg identical for all phantoms. We found the dose coefficients for the Japanese phantoms are close to those of our 60 kg phantom, but significantly greater than those of the 120 kg phantom, which is consistent with the comparison within our phantom series (Figure 2a).

3.3. Exponential relationship between body weight and dose coefficients

For a number of organs, the dose coefficient and body weight exhibited a strongly correlated exponential relationship over a large range of energies, especially in AP irradiation geometry. Therefore, for select organs, we derived a series of regression coefficients to provide body weight-dependent dose coefficients for continuous weight range:

$$\text{Dose Coefficient} \left(\frac{\text{Gy}}{\text{Gy}} \right) = a \times e^{b \times w} \quad (3)$$

where a and b are coefficients for the exponential regression and w is the weight (kg) of an individual whose organ dose coefficients are sought.

A full table of exponential coefficients for the adult male and female phantoms can be found in Appendix B for organs and energy combinations in which the R^2 is consistently above 0.95 over a large range of energies. Table 2 provides sample regression coefficients for the liver and small intestine wall for the adult males and females.

4. Discussion

Overall, as the photoelectric effect subsides, and Compton scattering becomes more prominent at higher photon energies (above 0.01 MeV), dose coefficients rise steadily, reaching cresting around 0.06 to 0.1 MeV as Compton scattering angles reach their maximum. At very high photon energies (above 10 MeV), the dose coefficients plateau and begins to decrease, sometimes rapidly depending on organ size and density, due to the increased secondary electron escape.

In AP irradiation geometry (Figure 2), abdominal organs (stomach and liver) show greater body weight dependency than the organs in the chest region (lungs and heart). This phenomenon was more clearly observed in female phantoms than in males, which may be due to the discrepancy of adipose distribution between males (apple shape) and females (pear shape)[22], which can be observed from Figure 1.

In the case of the stomach, located towards the left side of the body, it appears dose coefficient differences among varying masses are more affected by radiation coming from the right side of the body (RLAT) (Figure 3c) possibly due to greater attenuation levels in the body that are associated with higher mass. This notion is also supported by the dose coefficient data for the liver, located on the right side of the body, when looking at the LLAT irradiation geometry (Figure 4b). The effect of body weight on dose coefficient becomes less pronounced as photon energy increase. At 5 MeV the percent difference between the 60 and 120 kg male phantoms falls to 8.0 and 9.7% for the lungs and stomach wall. This effect is largely due to not only the increase of secondary electrons escaping from the organs and not contributing to dose to the organ but also the increasingly forward scattered electrons and photons and decreasing photoelectric effect.

Although the organ dose coefficients from ICRP Publication 116 agreed well with our results in AP irradiation geometry (Figure 2), we found significant discrepancies for the lateral geometries even between the ICRP adult male (73 kg in weight) and our 80 kg phantom (Figure 3 and 4). It must be noted that the dose differences shown in Figure 2, 3, and 4 came not only from the body size difference but from individual variability in the location and depth of organs between our phantoms and the ICRP adult male voxel phantom. Dose coefficients from our 80 kg phantom showed consistently smaller dose coefficients than the ICRP phantom: 30% and 20% smaller for the liver in RLAT and LLAT geometries at 0.1 MeV, respectively, and 40% and 20% smaller for the stomach wall in RLAT and LLAT geometries at 0.1 MeV, respectively. Some uncertainty caused by individual anatomical variations, especially for lateral exposure geometries, must be expected when our body size-dependent dose coefficients are applied to organ dose reconstruction studies.

We derived exponential regression model between dose coefficients and body weight for adult males and females in AP geometry. The organs with the strongest exponential correlations tended to be in the abdominal region, likely due to the distribution of fat in the body [22] (Figure 1). These organs included the adrenals, colon, kidneys, liver muscle, pancreas, small intestine wall, spleen, stomach, and the active and shallow bone marrows (Appendix B). Other organs whose sizes are relatively unaffected with body-size or were superficial, such as the lens of the eye or thyroid did not exhibit any specific regression correlations.

Our study has a couple of limitations. Because we intended to develop body weight-dependent dose coefficients for occupational exposure of radiologic workers, we only included the adult male and female phantoms. The results cannot be applied to children even in similar irradiation geometries. By assuming that variation of organ dose is mainly driven by weight rather than height, we only included the adult phantoms with various weight but fixed height. As such, until the dose coefficients for the full library of the body size-

dependent phantoms [10] are tabulated, one must rely on using dose coefficient values of similar body mass index based on the phantoms presented in this study. In the application of our dose conversion coefficients or regression equations, only the weight of a subject can be used for dosimetry. Our results are limited to the six idealized irradiation geometries or similar ones. For example, the dose conversion coefficients for AP irradiation geometry may be used for most of radiation workers with potential uncertainty depending on the similarity of actual irradiation geometries to AP. For more accurate dosimetry in irradiation geometries completely different from these idealized ones, detailed Monte Carlo simulations must be conducted. Finally, the potential improvement in accuracy of individualized organ dosimetry and risk analysis in epidemiological studies needs to be carefully evaluated by accounting for other uncertainty factors involved in cohort data such as exposure condition. Epidemiological studies are often prone to several uncertainty factors, which may be greater than those caused by body size.

5. Conclusion

We established organ dose coefficients applicable to adult males and females with various body weights exposed to external photon radiation fields by combining Monte Carlo radiation transport technique with a library of body size-dependent hybrid computational phantoms. We observed significant variation in dose coefficients by body weight and that the reference size phantoms tend to overestimate organ dose received by obese individuals. The exponential regression model derived from the relationship between body weight and organ dose coefficients in AP geometry will be useful in assessing more accurate organ dose where body weight is taken into account. Full data for a dose coefficient for every combination of phantom, organ, irradiation geometry, and photon energy are available in the Appendix along with the regression coefficients. We plan to extend the calculations to include the phantoms with various body heights, other radiation types, and irradiation geometries.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

Lateral views of the adult male phantoms 175 cm tall with weights ranging from 60 to 130 kg (top) and adult female hybrid phantoms 165 cm tall with weights ranging from 50 to 130 kg (bottom)

Figure 2.

Dose coefficients (Gy/Gy) in **AP irradiation geometry** for the (a) lungs, (b) heart, (c) stomach, and (d) liver in the **adult male phantoms** with the weight of 60, 80, 100, and 120 kg. The values from the reference adult male voxel phantom (ICRP Publication 116) are added (solid line) for comparison.

Figure 3.

Dose coefficients (Gy/Gy) in **RLAT irradiation geometry** for the (a) lungs, (b) heart, (c) stomach, and (d) liver in the **adult male phantoms** with the weight of 60, 80, 100, and 120 kg. The values from the reference adult male voxel phantom (ICRP Publication 116) are added (solid line) for comparison.

Figure 4.

Dose coefficients (Gy/Gy) in **LLAT irradiation geometry** for the (a) stomach and (b) liver in the **adult male phantoms** with the weight of 60, 80, 100, and 120 kg. The values from the reference adult male voxel phantom (ICRP Publication 116) are added (solid line) for comparison.

Figure 5.

Comparison of dose coefficients (Gy/Gy) in AP irradiation geometry for the lungs in the adult male phantoms with the weight of 60 and 120 kg (solid lines) with the values obtained for the three Japanese adult male phantoms: JM, JM2, and Otoko.

Table 1.

Details of Monte Carlo radiation transport and data processing

Item	Description	References
Code and version number	MCNPX v2.7.0	Pelowitz [19]
Source description	The source is defined with the SDEF card to produce broad unidirectional beams for mono-energies ranging from 0.01 to 20 MeV.	ICRP 116 [15]
Cross section libraries	ENDF/B-VII	Pelowitz [19]
Transport parameters	Both photons and electrons were transported. The photon physics allowed for the generation of electrons and coherent scattering. The transport cut-off energy for electrons was set at 1 keV (default), after which their energy is locally deposited.	
Variance reduction	No variance reduction was applied in this study.	
Scored quantities	*F8 energy deposition tally – assessment of photon absorbed energy (MeV) to organs F4 volumetric fluence tally – assessment of photon fluence to bone sites	Pelowitz [19]
Number of histories and statistical uncertainty	1×10^8 histories to yield, on average, tallies with relative errors less than 1% for major organs	
Data post-processing	Organ dose coefficients using *F8 (MeV) tallies using MATLAB and Microsoft Excel following the procedures outlined in Chang et al (2017) Bone marrow dose coefficients using F4 (photons/m ²) tallies using MATLAB and Microsoft Excel.	Chang et al.[21] Johnson et al.[20]

Table 2.

Regression coefficients for the liver and small intestine in the adult male and female phantoms at different photon energy bins. The organ and energy combinations with $R^2 > 0.95$ are included.

Photon Energy (MeV)	Adult Male						Adult Female					
	Liver			Small Intestine Wall			Liver			Small Intestine Wall		
	a	b	R ²	a	b	R ²	a	b	R ²	a	b	R ²
0.01												
0.015	5.3060	-0.1184	0.9516				0.0820	-0.0929	0.9508			
0.02	1.3245	-0.0564	0.9759	1.0360	-0.0571	0.9929	0.4612	-0.0584	0.9474	0.9910	-0.0766	0.9589
0.03	1.5307	-0.0258	0.9791	1.5490	-0.0260	0.9945	1.1639	-0.0295	0.9562	1.7978	-0.0383	0.9605
0.04	1.9939	-0.0165	0.9796	2.0536	-0.0166	0.9946	1.7719	-0.0198	0.9580	2.3834	-0.0253	0.9578
0.05	2.3328	-0.0123	0.9779	2.3735	-0.0123	0.9937	2.1799	-0.0153	0.9548	2.7603	-0.0194	0.9546
0.06	2.4390	-0.0099	0.9754	2.4924	-0.0099	0.9924	2.3438	-0.0128	0.9532	2.8824	-0.0161	0.9521
0.07	2.4112	-0.0085	0.9738	2.4750	-0.0086	0.9912	2.3503	-0.0113	0.9518	2.8369	-0.0142	0.9491
0.08	2.3367	-0.0077	0.9723	2.4403	-0.0079	0.9910	2.2969	-0.0104	0.9461	2.7600	-0.0131	0.9480
0.1	2.1396	-0.0068	0.9701	2.2327	-0.0069	0.9901	2.1089	-0.0095	0.9440	2.4925	-0.0118	0.9450
0.15	1.8172	-0.0061	0.9709	1.9223	-0.0063	0.9905	1.8213	-0.0089	0.9435	2.1068	-0.0108	0.9446
0.2	1.6623	-0.0059	0.9728	1.7582	-0.0060	0.9899	1.6733	-0.0086	0.9435	1.9301	-0.0104	0.9442
0.3	1.5084	-0.0055	0.9726	1.5888	-0.0056	0.9916	1.5406	-0.0082	0.9449	1.7373	-0.0096	0.9463
0.4	1.4246	-0.0051	0.9736	1.4909	-0.0052	0.9914	1.4627	-0.0078	0.9476	1.6331	-0.0091	0.9463
0.5	1.3622	-0.0048	0.9740	1.4270	-0.0049	0.9912	1.4139	-0.0074	0.9469	1.5619	-0.0086	0.9485
0.511	1.3621	-0.0048	0.9735	1.4268	-0.0049	0.9917	1.4154	-0.0074	0.9463	1.5557	-0.0085	0.9480
0.6	1.3242	-0.0045	0.9742	1.3813	-0.0046	0.9926	1.3755	-0.0070	0.9468	1.5069	-0.0081	0.9486
0.662	1.3210	-0.0044	0.9741	1.3753	-0.0045	0.9926	1.3703	-0.0068	0.9473	1.4955	-0.0078	0.9518
0.8	1.2790	-0.0042	0.9749	1.3237	-0.0042	0.9931	1.3249	-0.0064	0.9483	1.4380	-0.0073	0.9516
1	1.2457	-0.0038	0.9750	1.2875	-0.0039	0.9931	1.2922	-0.0060	0.9493	1.3850	-0.0067	0.9495
1.117	1.2406	-0.0037	0.9739	1.2732	-0.0037	0.9926	1.2842	-0.0057	0.9488	1.3717	-0.0064	0.9502
1.33	1.2166	-0.0034	0.9745	1.2490	-0.0034	0.9943	1.2554	-0.0053	0.9507	1.3311	-0.0059	0.9488
1.5	1.2007	-0.0033	0.9751	1.2336	-0.0033	0.9935	1.2382	-0.0051	0.9499	1.3111	-0.0057	0.9498
2	1.1774	-0.0029	0.9751	1.2115	-0.0030	0.9916	1.2150	-0.0045	0.9526	1.2671	-0.0050	0.9539
3	1.1508	-0.0024	0.9746	1.1802	-0.0025	0.9928	1.1806	-0.0037	0.9540	1.2202	-0.0041	0.9538
4	1.1335	-0.0021	0.9751	1.1617	-0.0022	0.9892	1.1618	-0.0033	0.9556	1.1936	-0.0036	0.9505
5	1.1232	-0.0019	0.9727	1.1508	-0.0020	0.9942	1.1485	-0.0030	0.9540	1.1754	-0.0032	0.9592
6	1.1074	-0.0018	0.9773	1.1332	-0.0019	0.9891	1.1342	-0.0028	0.9538	1.1501	-0.0029	0.9554
6.129	1.1099	-0.0018	0.9762	1.1393	-0.0019	0.9930	1.1363	-0.0028	0.9565	1.1512	-0.0029	0.9570
8	1.0749	-0.0016	0.9773	1.1059	-0.0017	0.9938	1.1064	-0.0025	0.9500	1.1240	-0.0027	0.9577
10				1.0883	-0.0015	0.9843	1.0924	-0.0024	0.9533	1.1068	-0.0025	0.9666
15										1.0706	-0.0021	0.9522
20												