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ELECTRON DENSITY, CT NUMBERS KERMA VALUES AND DOSE RATE OF SKELETAL MUSCLE RELAXANTS FOR VARIOUS ENERGIES

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Abstract

The Electron density N_e, Kerma values and Dose rate of skeletal muscle relaxants tubocurarine chloride, gallamine triethiodide, pancuronium bromide, suxamethonium bromide and mephenesin for total and coherent, incoherent, photoelectric absorption, pair production in atomic and nuclear field photon interaction have been calculated in the wide region 1keV to 100GeV. The molecular, atomic, electronic cross sections are calculated using mass attenuation coefficient of relaxants obtained by running WinXCOM programme and N_e Kerma values and Dose rate the relaxants have been determined.

Keywords; Electron density, kerma values, Dose rate, relaxants

INTRODUCTION:

Kerma is a measure of energy transferred from radiation to matter and is an acronym for kinetic energy released to matter. It is related to, but not the same as absorbed dose. Kerma measures the amount of energy that is transferred from photons to electrons per unit mass at a certain position. Absorbed dose, on the other hand, measures the energy deposited in a unit mass at a certain position. During the photon interaction transfer and deposition of energy is virtually equal. However, at higher energies, a photon may interact with tissue in one position and create an electron that possesses enough energy to deposit energy at a location away from the interaction point. Hence it plays a huge role in disease management by giving physicians more options, tools, and techniques for detection and treatment

In the present study some skeletal muscle relaxants tubocurarine chloride, gallamine triethiodide, pancuronium bromide, suxamethonium bromide and mephenesin have chosen and its composition is given in the table 1 These agents are used as adjuvant to anesthesia to get the relaxation of skeletal muscle during the corrections of dislocations, surgery, radiotherapy etc… and used as relieving painful muscle spasms because of various musculoskeletal and neuromuscular disorders. By accurate calculation of photon mass attenuation co-efficient, effective atomic number the electron density N_e Kerma values and dose rate above relaxants has been determined, as important in medical diagnostics. Especially calculation of kerma values and dose rates of relaxants is become prime important as it provide the necessary information about relative electron density of relaxants. The contribution of these values will find the application in planning and treatment of the patient in radiotherapy. Hence the above parameters become vital, interesting and exciting field of research for characterization and visualization of matter (biological samples) in medical field.

Table-1
Composition of skeletal muscle relaxants

Skeletal muscle relaxants	Composition
Gallamine triethiodide	H:0.067834 C:0.404167 N:0.047132 O:0.053838 I:0.427030
Mephenesin	H: 0.077441 C: 0.659151 O:0.26340
Pancuronium bromide	H:0.082541 C:0.573763 N:0.038234 O:0.087347 Br: 0.218114
Suxamethonium chloride	H: 0.086249 C: 0.423200 N: 0.070503 O: 0.241598 Cl: 0.178451
Tubocurarine chloride	H:0.067916 C: 0.575857 N: 0.036299 O: 0.228050 Cl: 0.091878

THEORY AND METHODOLOGY:

When electromagnetic radiation passes through matter, their intensity is attenuated according to the exponential law. If a beam of these radiations having an intensity I_0 passes through a thickness x of an absorber, the transmitted intensity I is given as

$$I = I_0 \exp\left(-\mu/\rho\right)x$$

where ρ is the density of the material.

(μ/ρ) is the mass attenuation coefficient & is independent of density of the absorber.

When a beam of photons passes through an absorber, the photons interact with the atoms and are either absorbed (photoelectric effect, pair and triplet production, photo nuclear) or scattered away from the beam (Coherent and incoherent scattering). The intensity of the transmitted beam of photons is the sum of the cross-sections, per atom for all the above processes. Hence the total molecular cross section σ_{mol} is determined from the following equation using the values of mass attenuation coefficient of relaxants using $(\mu/\rho)_{bio}$ obtained by running WinXCOM programme.

$$\sigma_{mol} = \left(\frac{1}{N}\right)\left(\frac{\mu}{\rho}\right)_{bio}\sum_i n_i A_i$$

Where N is Avogadro number, n_i is the number of atoms of i^{th} element and A_i is its atomic weight in a given molecule.

The effective atomic cross section σ_{atm} are determined by

$$\sigma_{atm} = \frac{\left(\mu/\rho\right)_{bio}}{N\sum_i W_i A_i}$$

$$\sigma_{atm} = \frac{1}{N}\sum_i f_i A_i \left(\frac{\mu}{\rho}\right)_i$$

Where f_i is the fractional abundance $(\mu/\rho)_i$ is mass attenuation co-efficient of i^{th} element.

$$\sigma_{atm} = \frac{\sigma_{mol}}{\sum_i n_i}$$

The effective electronic cross section σ_{ele} are determined by

$$\sigma_{ele} = \left(\frac{1}{N}\right)\sum_i \left\{\left(\frac{f_i A_i}{Z_i}\right)\left(\frac{\mu}{\rho}\right)_i\right\}$$

Where, and Z_i is the atomic number of i^{th} element in a molecule respectively.

Then effective atomic number is calculated using

$$Z_{eff} = \frac{\sigma_{atm}}{\sigma_{eie}}$$

The effective electron density is obtained from

$$N_e = \frac{N}{\sum_i n_i A_i} Z_{eff} \sum_i n_i$$

The CT number is estimated from

$$CT = \frac{\left(\mu_m - \mu_w\right)}{\mu_w}$$

RESULTS AND DISCUSSIONS:

The N_e of skeletal muscle relaxants tubocurarine chloride, gallamine triethiodide, pancuronium bromide, suxamethonium bromide and mephenesin are determined in the energy region 1keV-100GeV. It is found that N_e of relaxants vary with energy and composition of them. This variation is shown in the figures1-6 for total and all partial photon interaction (Coherent, Incoherent, Photoelectric absorption, pair production in atomic and nuclear field).

Total photon interaction:

The variation of N_e with photon energy for total photon interactions is as shown in the figure 1 and this variation is because of dominance of different photon interactions with skeletal muscle relaxants. In lower energy region, photo electric interaction dominates, hence N_e varies similar to photo interaction. Except mephenesin, all other relaxants N_e increases and becomes maximum and decreases sharply in the energy region 0.002-025MeV.This variation are due to presence of halogens (Cl, Br and I) in their composition and these elemental cross

sections varies larger in the energy region 0.002-025MeV.The N_e and found to remain constant up to 10MeV which shows that scattering (coherent and Incoherent) processes increases. From 10MeV to100MeV, there is regular increase in the N_e with photon energy. This is due to the increase in incoherent and pair production processes. From 100MeV onwards N_e remains constant which is due to dominance in pair production processes. The N_e values of relaxants vary from the element with lowest Z to the highest Z present in their composition.

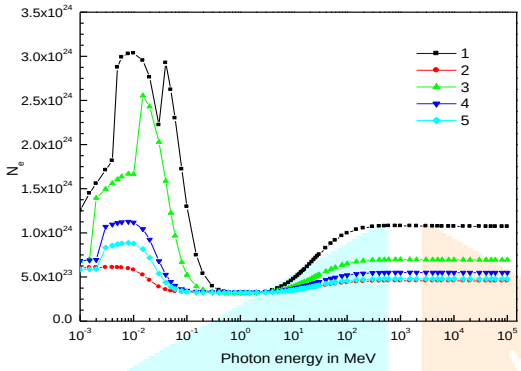

Fig: 1 Variation of N_e with Photon energy E in MeV for total photon interaction (with coherent) (1)Gallamine triethiodide (2) Mephenesin (3) Pancuronium bromide (4) Suxamethonium chloride (5) Tubocurarine chloride

Photo electric absorption:

The variation of N_e with photon energy for photo electric absorption interaction is as shown in the figure 2 and this indicates that N_e increases up to 0.040MeV for all relaxants except for mephenesin which is independent of photon energy. In case of Gallamine triethiodide there is sudden increase in N_e at 0.033169MeV which is the K absorption edge of iodine and it remains constant with photon energy. In Pancuronium bromide sudden increase in Z_{eff} is found at 0.01347MeV which is the K absorption edge of bromine and it remains constant with photon energy. The N_e of Suxamethonium chloride and Tubocurarine chloride increases at 0.002822MeV because chlorine (K absorption edge of Cl is 2.8224keV).Thereafter it becomes constant with increase in photon energy. This is due to the dominance in photoelectric processes in low energy region i.e. less than 1MeV and for the substances of higher atomic number (Z) than for low Z substances.

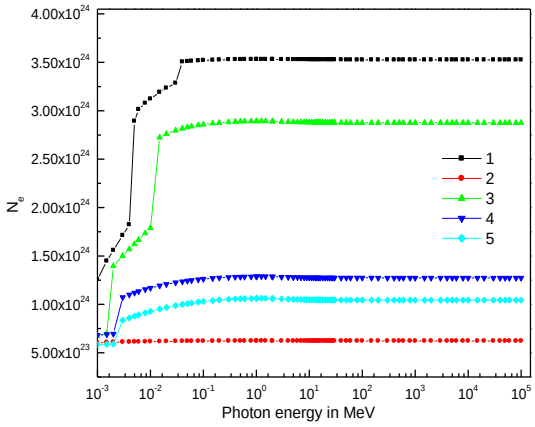

Fig: 2 Variation of N_e with Photon energy E in MeV for photo electric absorption (1)Gallamine triethiodide (2) Mephenesin (3) Pancuronium bromide(4) Suxamethonium chloride (5) Tubocurarine chloride

Incoherent scattering:

The variation of N_e with photon energy for incoherent scattering is as shown in the figure 3 and it indicates that N_e increases from0.001MeV to 0.10MeV shows that it depends on energy. This variation is because of the proportion and the range of atomic numbers of the elements present in relaxants. Above 0.10MeV N_e remains constant and independent of energy for all relaxants.

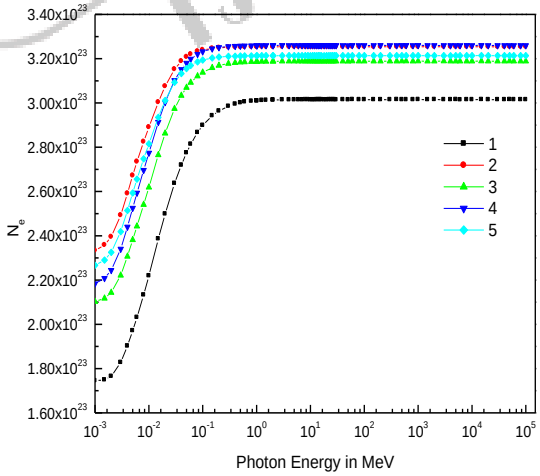

Fig: 3 Variation of N_e with Photon energy E in MeV for incoherent scattering (1)Gallamine triethiodide (2) Mephenesin (3) Pancuronium bromide (4) Suxamethonium chloride (5) Tubocurarine chloride

Coherent scattering:

The variation of N_e with photon energy for coherent scattering is as shown in the figure 4 and it indicates that N_e increases for mephenesin up to 0.03MeV and remains constant. All other relaxants shows increment in N_e from 0.001MeV to 0.40MeV. Thereafter remains constant i.e. independent of energy. The values of N_e for gallamine triethiodide, pancuronium bromide, suxamethonium chloride and tubocurarine chloride have comparatively higher.This is due to the presence of halogens. (42.70% of I in gallamine triethiodide, 21.81% of Br in pancuronium bromide 17.84% of Cl in suxamethonium chloride and 09.87% of Cl in tubocurarine chloride)

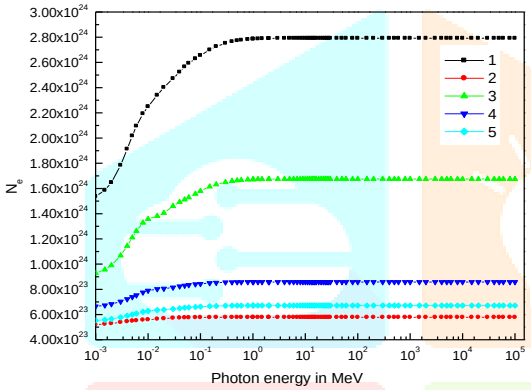

Fig: 4 Variation of N_e with Photon energy E in MeV for coherent scattering
(1) Gallamine triethiodide (2) Mephenesin
(3) Pancuronium bromide(4) Suxamethonium chloride (5) Tubocurarine chloride

Pair production in electric field:

The variation of N_e with photon energy for Pair production in electric field is as shown in the figure 5. It shows that N_e is constant with increase in photon energy from 3MeV to 30MeV i.e. independent of energy. It slightly decreases from 30MeV to 1000MeV and thereafter remains constant for all relaxants. Here also, in case of gallamine triethiodide and pancuronium bromide, N_e values are slightly more compared to the other relaxants. This is due to the large range of atomic number of constituent elements in them.

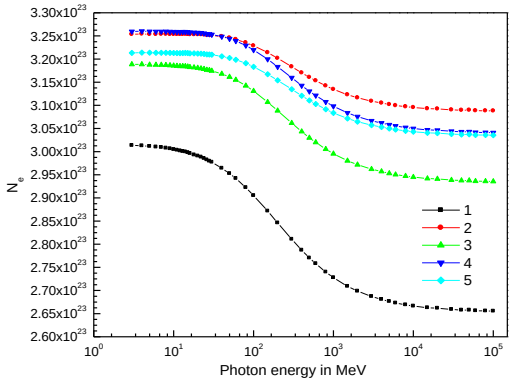

Fig: 5 Variation of N_e with Photon energy E in MeV for pair-production in electric fiel
(1) Gallamine triethiodide (2) Mephenesin
(3) Pancuronium bromide (4) Suxamethonium chloride
(5) Tubocurarine chloride

Pair production in nuclear field:

The variation of N_e with photon energy for Pair production in nuclear field is as shown in the figure 6 and it shows that N_e slightly decreases with increase in photon energy from 1.25MeV onwards and found to remain constant thereafter. This is because of the fact that pair production in nuclear field is Z^2 dependent. In case gallamine triethiodide and pancuronium bromide the variation of Z_{eff} values is more compared to the other relaxants This is due to the large range of atomic number of constituent elements in them.

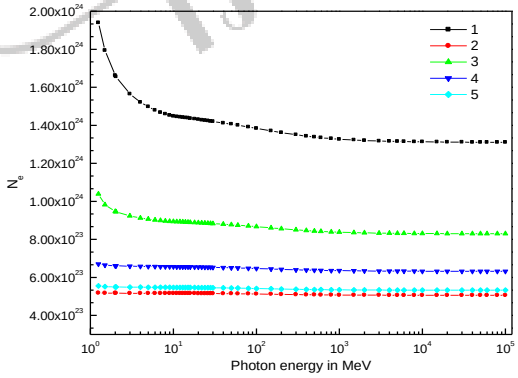

Fig: 6 Variation of N_e with Photon energy E in MeV for pair-production in nuclear field
(1)Gallamine triethiodide (2) Mephenesin
(3) Pancuronium bromie (4) Suxamethonium chloride (5) Tubocurarine chloride

CT numbers of skeletal muscle relaxants

E in MeV	CT* Numbers for Total photon interaction				
	1	2	3	4	5
1.00E-3	0.27	-0.35	-0.42	-0.32	-0.34
2.00E-03	0.68	-0.38	0.61	-0.34	-0.37
5.00E-03	7.73	-0.41	1.03	1.15	0.38
1.00E-02	12.31	-0.41	1.40	1.43	0.53
2.00E-02	12.76	-0.32	13.66	1.29	0.49
1.00E-01	4.42	-0.04	0.64	0.02	-0.02
2.00E-01	0.72	-0.03	0.07	-0.02	-0.04
5.00E-01	0.00	-0.03	-0.04	-0.03	-0.04
1.00E+00	-0.07	-0.03	-0.05	-0.03	-0.04
2.00E+00	-0.07	-0.03	-0.04	-0.03	-0.04
5.00E+00	0.07	-0.04	0.00	-0.02	-0.04
1.00E+01	0.32	-0.06	0.07	0.00	-0.04
2.00E+01	0.66	-0.08	0.17	0.02	-0.04
5.00E+01	1.06	-0.10	0.28	0.05	-0.03
1.00E+02	1.23	-0.12	0.33	0.06	-0.03
2.00E+02	1.30	-0.12	0.35	0.06	-0.03
5.00E+02	1.32	-0.12	0.35	0.06	-0.03
1.00E+03	1.32	-0.12	0.35	0.06	-0.03
2.00E+03	1.32	-0.12	0.35	0.06	-0.03
5.00E+03	1.31	-0.12	0.35	0.06	-0.03
1.00E+04	1.31	-0.12	0.35	0.06	-0.03
2.00E+04	1.31	-0.12	0.35	0.06	-0.03
3.00E+04	1.31	-0.12	0.35	0.06	-0.03
4.00E+04	1.31	-0.12	0.35	0.06	-0.03
5.00E+04	1.31	-0.12	0.35	0.06	-0.03
6.00E+04	1.31	-0.12	0.35	0.06	-0.03
8.00E+04	1.31	-0.12	0.35	0.06	-0.03
1.00E+05	1.31	-0.12	0.35	0.06	-0.03

* Multiplied by 1000

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