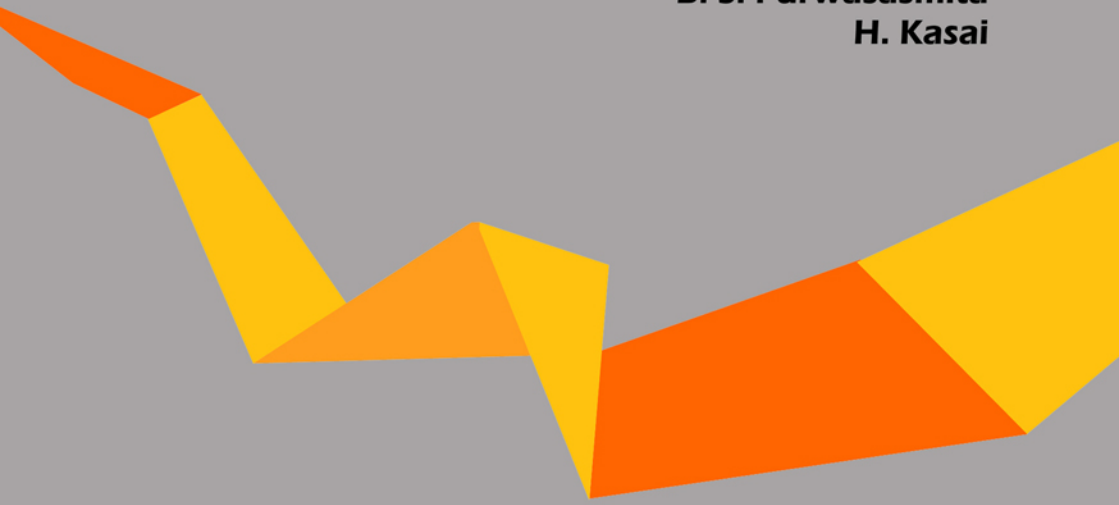
Vol. 2 No.1 | 2015 | ISSN : 2356-3303

Research and Development on Nanotechnology in Indonesia

Editors :
H. K. Dipojono
B. S. Purwasasmita
H. Kasai



CENTER FOR ADVANCED SCIENCES
Jln. Ganesha No. 10 Bandung 40132
http://nrcn.itb.ac.id/
nrcn@cphys.fi.itb.ac.id

ISSN : 2356-3303

Research and Development on Nanotechnology in Indonesia

Vol.2, No.1, 2015

Selected papers from
Symposium Nanotechnology & Biotechnology ITB
November 2014

Editors :
H. K. Dipojono, B. S. Purwasasmita, H. Kasai

Center for Advanced Sciences
INSTITUT TEKNOLOGI BANDUNG

KATA PENGANTAR

Assalamu'alaikum wr. wb

Perkembangan sains dan teknologi dalam skala berdimensi nano, membawa dampak perubahan yang besar dalam industri dan kehidupan sehari-hari, kemajuan teknologi material ini tentunya harus dapat di tangkap dan di implementasikan di Indonesia agar dapat bersaing dengan produk dari luar negeri. Kekayaan alam dan kekayaan hayati Indonesia yang banyak ini haruslah dapat dimanfaatkan untuk kepentingan bangsa Indonesia seutuhnya. Keberadaan lembaga penelitian menjadi salah satu upaya peningkatan kualitas produk material berbasis sumberdaya Indonesia ini,

Kebutuhan akan ajang tukar informasi dan pertemuan karya ilmiah para peneliti di Indonesia dalam bidang nanosains dan nanoteknologi, perlu diwadahi melalui publikasi ilmiah yang dapat menjadi cermin kemajuan pencapaian karya anak bangsa dalam bidangnya. Untuk itu *Research and Development on Nanotechnology in Indonesia* (RDNI) diterbitkan, yang direncanakan akan terbit rutin tiap tahun. Sesuai dengan agenda kegiatan *workshop*, seminar atau *symposium* dalam bidang nanosains dan nanoteknologi.

Institut Teknologi Bandung, sebagai salah satu penghela bidang sains dan teknologi di Indonesia sudah seyogyanya memainkan peranan penting dalam teknologi ini. Sesuai dengan rencana akademik ITB 2010 – 2015 serta bantuan dana JICA untuk pengembangan ITB, yang mana salah satu tujuannya adalah pengembangan nanoteknologi dalam bentuk kegiatan riset dan akademik. Penelitian dalam bidang *Nano science* dan nanoteknologi di ITB telah dimulai sejak sekitar tahun 2000, dan di lakukan secara terpisah-pisah di beberapa fakultas, misalnya FMIPA, FTI, SF dan SITH. Keterbatasan anggaran dan peralatan mengakibatkan sulitnya pertumbuhan riset dalam bidang ini, sedangkan upaya untuk mengintegrasikan riset dalam bentuk kerjasama riset antar fakultas perlu difasilitasi.

Symposium Nanotechnology dan Biotechnology yang telah diselenggarakan di tahun 2014 ini adalah kegiatan pengembangan pusat riset bidang nanoteknologi yang terangkum dalam agenda kegiatan pengembangan *Center for Advances Sciences (CAS)* pada Proyek Pengembangan ITB (III) dengan bantuan dana dari JICA. Makalah-makalah terpilih dari aktivitas workshop tersebut menjadi bahan utama dalam RDNI volume 2.

Besar harapan kami melalui RDNI ini, kerjasama riset dalam bidang nanosains dan nanoteknologi akan lebih memacu pertumbuhan riset antar instansi sehingga pemanfaatan hasil-hasil riset dapat lebih cepat terasa untuk masyarakat.

Wassalam.

EDITORS

Prof. Ir. Hermawan Kresno Dipojono, MSEE. Ph.D. (ITB)

Prof. Dr. Bambang Sunendar Purwasasmita, M.Eng. (ITB)

Prof. Hideaki Kasai, Ph.D. (Osaka University)

Research and Development on Nanotechnology in Indonesia

Vol .2, No.1, 2015

***Center for Advanced Sciences* – CAS**
Jln. Ganesa No.10 Bandung
http://nrcn.itb.ac.id/

ISSN 2356-3303
9 772356 330001

DAFTAR ISI

Symposium Nanotechnology & Biotechnology ITB 2014

Date : 12 -14 November 2014
Venue : Institut Teknologi Bandung, Indonesia
Auditorium IPTEKS, East Campus Center

Organized by :

Center for Advanced Sciences (CAS)
http://nrcn.itb.ac.id/

Institut Teknologi Bandung (ITB)
Jln. Ganesa No.10 Bandung

STEERING COMMITTEE

Dr. Aditianto Ramelan
Dr. Sony Suhandono
Dr. Suprijadi

ORGANIZING COMMITTEE

Dr. Triati Dewi Kencana Wungu (Chairman)
Dr. Heni Rachmawati
Dr. Ferry Iskandar
Dr. Veinardi Suendo
Dr. Brian Yuliarto
Dr. Mohammad Kemal Agusta

Symposium & Workshop
Nanotechnology & Biotechnology
***Computational Material Design* (CMD)& Bio-Informatika**
12 – 14 Nopember 2014

Rabu, 12 Nopember 2014
Auditorium *Campus Center* Timur

08.00 – 08.30	Registrasi Peserta
08.30 – 09.00	Pembukaan Wakil Rektor Bidang Riset dan Inovasi (WRRI) ITB Sambutan Kepala UIP Pengembangan ITB (III) - JICA Moderator : Dr. Freddy Haryanto
09.00 – 09.30	Keynote speaker: **Prof. Dr. rer. nat. Gerhard Glatting - Heidelberg University, German** *Molecular Radiotherapy using physiologically based pharmacokinetic (PBPK) modeling*
09.30 – 09.45	***Photo Session & Coffee Break***
09.45 – 10.15	Keynote speaker: **Prof. Dr. Bambang Sunendar Purwasasmita, M.Eng - ITB** "Membangun Kerangka Riset Nano Kolaboratif Berbasis Agenda Riset Nasional"
10.15 – 10.45	Invited Speaker: **Leenawaty Limantara, Ph.D– Ma Chung University** *"Chlorophylls And Carotenoids In Foods, Healths, and Future Energy Sectors: an Outlook For Nanotechnology Applications"*
10.45 – 11.00	**Dr. Veinardi Suendo, S.Si., M.Eng** "Fabrikasi DSSC (Dye Sensitized Solar Cell) Berbasis Elektrolit Padat Polianilina"
11.00 – 11.15	**Dr.rer.nat. Freddy Haryanto** "Kajian In-vitro eksperimen dan simulasi Monte Carlo pada sel dalam Karakterisasi Gadolinium sebagai agen kontras"
11.15 – 11.30	**Nurul Ikhsan** *"Study on Electronic and Magnetic Properties of xMnO3 by Density Functional Theory with Hubbard Correction Approximation"*

11. 30 – 11.45	**Nur Rahmah Hidayati, M.Sc** "*Effect of Deviation in Image Quantification for Internal Dosimetry Assessment in Radionuclide Therapy"*
11.45 – 12.00	**Raafqi Ranasasmita, M.Biomed** *"Halal Production of Mycelle-Encapsulated Calcitrol as Nanotechnology-Based Product"*
12.00 – 13.00	***ISHOMA***
13.00 – 13.30	Keynote speaker: **Dr. Ir. Usman Pasarai, M.Eng - LEMIGAS** "Peptida untuk Surfactant EOR"
13.30- 14.00	Keynote speaker: **Prof. Yoshitada Morikawa - Osaka University**
14.00 – 14.15	**Utami Wulandari Rachmadi, S. Farm** *"Self- Nanoemulsion Containing Combination of Curcumin and Silymarin : Formulation and Characterization"*
14.15 – 14.30	**Dr. Heni Rachmawati** **"**Pengembangan Formula dan Karakterisasi In Vitro Tablet Multipartikulat Lepas Lambat di Kolon Mengandung Fraksi Bioaktif dari Cacing Tanah (Lumbricusrubellus)"
14.30 – 14.45	**Dr. Rachmat Mauludin, MSi, Apt** "Pemanfaatan bahan alam sebagai antioksidan yang diformulasikan dalam bentuk nanoemulsi"
14.45 – 15.15	***Coffee Break***
15.15 – 15.30	**Brian Yuliarto, Ph.D** "Pengembangan Material Komposit Multiwalled Carbon Nanotubes dan Zinc Oxide Berstruktur Nano untuk Aplikasi Sensor Gas Methane"
15.30 – 15.45	**Ir. Sutrisno, M.Si** "Sintesis, Karakterisasi dan Fungsionalisasi Bio-Nano Filler dari Abu Pembakaran Limbah Kayu pada Boiler Industri Kayu Lapis untuk Menurunkan Emisi Formaldehida Produk Bio-Komposit"
15.45 – 16.00	**Dr. rer. nat. Rino Rakhmata Mukti** *"Synthesis of Zeolite Catalyst at Low Temperature in a Non-Hydrothermal Method"*
16.00 – 16.15	**Nina Siti Aminah, M.Si** "Fabrikasi Nanopatterned Sensing Layer Berbasis Polimer Hibrid Untuk Pengawasan Pencemaran Lingkungan"
16.15 – 16.30	**Dr. Fenny M. Dwivany**

	"Studi Efek Nanopartikel Kitosan Terhadap Proses Pematangan Buah untuk Aplikasi Pasca Panen Buah Pisang Raja Bulu"
16.30 – 16.45	**Sony Suhandono, Ph.D** "Karakterisasi Kandidat Nano-Vaksin VLP (Virus Like Particle) HPV-16 Rekombinan**"**
16.45 – 17.00	**Oktira Roka Aji** "A New Whole Cell Biocatalyst To Degrade Poly-Ethylene Terephthalate (Pet)"
17.00 – 17.15	**Rahmat Azhari Kemal** *"Preliminary Study of Isolation of Sucrose 1-Fructosyltransferase Gene from Dahlia (Dahlia sp.) using Degenerate Primer"*

Kamis, 13 Nopember 2014
Auditorium *Campus Center* Timur

08.00 – 08.30	Registrasi
08.30 – 08.45	**Annistia Rahmadian Ulfah** *"Virus Like Particles (VPLs) Production in Plant Transient System"*
08.45 – 09.00	**Sparisoma Viridi** Simulasi Deposisi Berdasrkan Penumbuhan Butiran Menggunakan Dinamika Molekular
09.00 – 09.15	**Agil Nawa Irawan Putro, ST** *"Application of Fe3+-Doped Tio2/Sno2nanoparticles for Bacterial Disinfectant and as Inhibitor of The Fruit Ripeningrate"*
09.15 – 09.30	**Adi Surya Pradipta** *"Influence of Starch and Chitosan on Silica Nanorod Formation for Hydrophobic Textiles Application"*
09.30 – 10.00	**Dr. Mohammad Kemal Agusta – FTI ITB**
10.00 -10.15	**Photo session – Coffee break**
10.15 – 10.45	**Prof. Hiroshi Nakanishi –Osaka University**
10.45 – 11.15	**Dr. Florian Stieler** "*Modern Radiation Treatment Techniques"*
11.15 – 11.30	**Hayyu Widiatma Sakya, S.T** *"Synthesis of Sio2nanosphere and Nanoporous As Filler In Tire Rubber From Na2sio3 And Chitosan Coupling Agent"*
11.30 – 11.45	**Danang Crysnanto** *"Encapsulation dsRNA GIH (Gonad Inhibiting Hormone) Using Chitosan Nanoparticle With Several Physiochemical Optization"*
11.45 – 12.00	**Nuke Ayu Febryana, S.Si** *"Study Characterization of Aflatoxin-Whole Cell Biosensor Based on Co-transformed Escherichia coli BL21 (DE3) with pKCYP and pSOSGFP"*
12.00 – 12.15	**Sri Indah Ihsani, ST** *"Encapsulation of Fe3o4 Superparamagnetic Nanoparticles Using Chitosan and Alginate, Impregnated With Mangosteen and Modification of Fe3o4 Morphology Using Chitosan and Starch"*
12.15– 13.00	***Penutupan & ISHOMA***

Kamis, 13 Nopember 2014	
Workshop Computational Material Design	
Lab. Komputer, Gedung TP. Rahmat, Lt.4	
13.30 – 15.00	*Hands on Computational Material Design – CMD (Quantum Espresso)*
15.00 –15.15	***Coffee Break***
15.15 – 17.00	*Hands on NANIWA*
Workshop Biotechnology	
Lab. Komputer, Gedung TP. Rahmat, Lt.4	
13.30 – 15.00	*Hands on* Bioinformatika
15.00 –15.15	***Coffee Break***
15.15 – 17.00	*Hands on* Bioinformatika

Jum'at, 14 Nopember 2014	
Workshop CMD	
Lab. Komputer, Gedung TP. Rahmat, Lt.4	
08.30 – 09.00	Registrasi peserta Workshop CMD
09.00 – 11.00	*Studi Kasus CMD (Quantum Espresso / NANIWA)*

Effect of Deviation in Image Quantification for Internal Dosimetry Assessment in Radionuclide Therapy

Nur Rahmah Hidayati[1)], Deni Hardiansyah[2)],Gerhard Glatting[2)]
1) Pusat Teknologi Keselamatan dan Metrologi Radiasi– Badan Tenaga Nuklir Nasional, Indonesia
2) Medical Radiation Physics/Radiation Protection, Medical Faculty Mannheim of Heidelberg University, Germany

** e-mail: inn98@batan.go.id*

Received : 14 January 2015
Accepted : 16 February 2015

ABSTRACT

There is a raising interest regarding internal dosimetry assessment for radionuclide therapy. One focus of interest lies on the importance of patient specific dosimetry for the efficacy of therapy, which needs a step of imaging quantification from gamma camera scans for a particular time interval. The quantification must be conducted according to Pamphlet No. 16 from Medical Internal Radiation Dosimetry Committee (MIRD) with a conjugate view method to determine the time-integrated activity coefficients (TIACs), which are necessary for absorbed dose prediction in the patients. The region of interest (ROI) in a gamma camera image reflects the accumulated activity of radionuclides in the respective organ. Hence, it is important to define the region of interest for target and source organs to find the amount of cumulated activity in each organ. The objective of this study is to observe the effect of deviation in the drawing process of organ ROI on the TIACs. Five patients with neuroendocrine tumors (NET) were intravenously injected with ^{111}In-labelled DTPAOC (Octreoscan^{TM}) as bolus for (120 ± 48) MBq. Patients were scanned using a dual head gamma camera (ECAM; Siemens, Erlangen, Germany) for a series of whole-body scans. As a result, a pair of anterior and posterior image has been acquired at 0.6, 4, 24, 48 and 72 h post injection to observe the cumulated activities in particular organs. ROIs were defined using the ULMDOS software for treatment planning in internal radionuclide therapy. In this study, kidneys, liver and spleen were investigated. The process of ROI drawing for each patient has been repeated with decreased and increased ROIs and an approximate deviation of 5 %, 10 % and 15 % of the defined optimal ROI. Linear regression was used to quantify the dependence of the TIACs on the ROI size. The relation between the relative size of the ROI and the

corresponding relative change of the time-integrated activity coefficients can be approximated by a linear relationship. Linear regression yielded for the slope s and the y-intercept y_0 of the organs the following values: kidneys: s = (0.61 ± 0.05), y_0 = (0.37 ± 0.05), liver: s = (0.58 ± 0.10), y_0 = (0.44 ± 0.10), and spleen: s = (0.51 ± 0.04), y_0 = (0.49 ± 0.04). To conclude, the step of drawing ROIs is a crucial step in the process of calculation of time-integrated activity coefficients. Hence, the enlargement and reduction of a ROI will affect the obtained TIAC. In general, the relative error in the TIACs is in the same order of magnitude as the errors in the organ ROI drawing process.

***Keywords**: patient specific dosimetry, gamma camera, image quantification, ULMDOS software*

INTRODUCTION

Radionuclide therapy has been acknowledged as a loco regional treatment for killing cancer cells in which radiation energy has been delivered selectively to diseased cells or tissues, while minimizing the damage on surrounding normal tissues. Moreover, radionuclide therapy has been proved as therapy with revolutionary approach, especially for the cancer type which is inoperable[1].

With regard to internal dosimetry assessment for patients in the nuclear medicine department, the importance of patient specific dosimetryhas been stressed for achieving the efficacy of therapy[2-4]. As initial step, an imaging quantification from gamma camera scans in a particular timing scale should be done as a treatment planning study prior the therapy[4].

The latest studies have reported that performing patient specific dosimetry assessment prior radionuclide therapy will reduce the damage to the organ at risks and maximize the drug delivery to the target tissues[2, 3, 5, 6]. There are few ways to perform patient specific dosimetry using either a simple planar gamma camera, or advanced imaging equipments such as SPECT/CT or PET/CT, and a computational tool such as Monte Carlo code[7-10].

Patient specific dosimetry is developed by a conventional internal dosimetry method. One of available and the most favorable is a method from Medical Internal Radiation Dosimetry (MIRD) Committee in United States Nuclear Medicine community, which has been reported in the MIRD pamphlet no. 16[9]. The MIRD 16 method suggests the use of a series of whole body scan from a gamma camera with anterior and posterior images. Calibration and attenuation correction must be considered as additional factors.

ULMDOS is a software for facilitating internal dosimetry studies for radionuclide therapy based on the MIRD pamphlet 16 method[11]. The ULMDOS evaluates a pair of anterior and posterior images from gamma camera scans and will produce time-integrated activity coefficients (TIACs) as the output. These outputs are needed in further calculation steps, especially when software such as OLINDA/EXM[12] will be used for predicting the organ doses .

In ULMDOS the delineation of source and target organ region of interest (ROI) is performed, which reflects the accumulated activity of radionuclides in the organs. Since in the determination of accumulated activity by using image quantification method, need a precise delineation of target organ, hence the objective of this study is to observe the effect of error in the drawing process of target organ ROI on the TIACs.

MATERIAL AND METHODS

To perform image quantification for patient specific dosimetry, patients need to be scanned in a series of gamma camera acquisitions. The acquired images have been subjected to investigate the response of radiopharmaceutical administration on either cancer cells or relevant organs. The responses which have been presented in the images can be quantified as cumulated activity of radiopharmaceutical by drawing the region of interest for relevant organs. Figure 1 shows the sample of display menu in ULMDOS which represent the number of cumulated activity in the organs.

In this study, five patients with neuron endocrine tumors (NETs) were intravenously injected with ^{11}In-labelled DTPAOC (Octreoscan^{TM}) as bolus for (120 ± 48) MBq. Patients were scanned using a dual head gamma camera (ECAM; Siemens, Erlangen, Germany) for a series of whole body scans. As a result, a pair of anterior and posterior images has been acquired at 0.6, 4, 24, 48 and 72 h post injection to observe the cumulated activities in particular organs. ROIs were defined using ULMDOS software for treatment planning in internal radionuclide therapy. In this study, kidneys, liver and spleen have been investigated as these organs have been considered as organ at risk in peptide receptor radionuclide therapy (PRRT). The process of ROI drawing for each patient has been repeated with decreased and increased ROIs at± 5 %, 10 % and 15 % of the defined true ROI based on the pixel number.

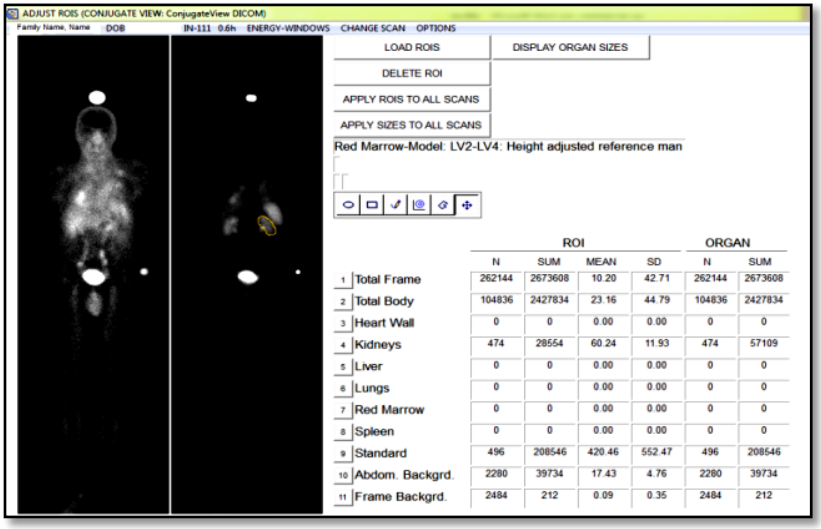


Figure 1.Display menu in ULMDOS for creating ROIs on the organs.

After ROIs have been adjusted in each scan, the fitting process could be started. An example of fitting process is displayed in Figure 2. From the PLOT&FIT menu, it can be seen how the accumulation and washout process occurred in the organs. The fit functions consist of the sum of exponential functions. The number of parameters can be reduced by constraining some prefactors of the exponentials or setting the biological half-life to infinity. Moreover, a fit function which is linked to the process can be chosen by investigating the trend of data. For example, “organ1” function has been chosen for the fitting model in kidneys. This is because the data of kidneys has a similar trend with three exponential functions.

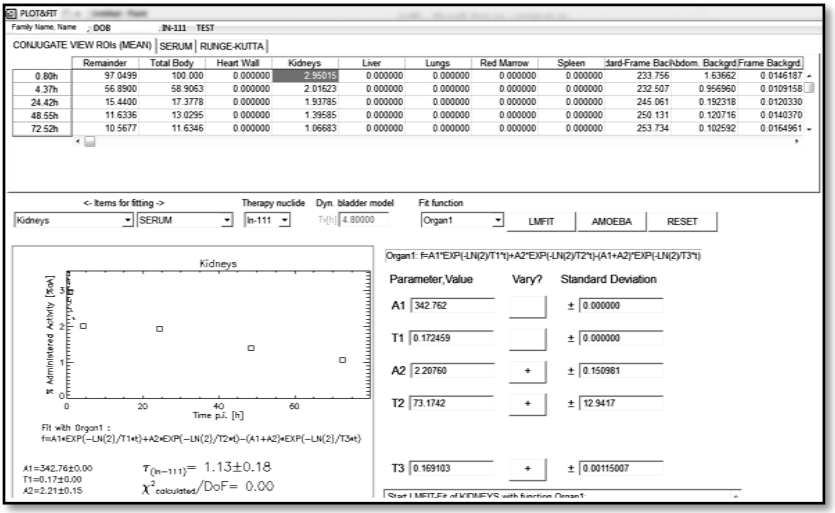


Figure 2.PLOT&FIT menu - ULMDOS software

RESULTS AND DISCUSSION

As the result of investigation, the effect of relative size of the ROI and the corresponding relative change of the time-integrated activity coefficients has shown a linear relationship, for example, with 5% ROI deviation, it has been produced approximately 5% error in TIACs.A linear regression with the slope s and the y-intercept y_0 of the organs on the following values, such as : kidneys: s = (0.61 ± 0.05), y_0 = (0.37 ± 0.05), liver: s = (0.58 ± 0.10), y_0 = (0.44 ± 0.10), and spleen: s = (0.51 ± 0.04), y_0 = (0.49 ± 0.04). These relationships are presented in Figures 3, 4, and 5 for kidneys, liver and spleen, respectively.

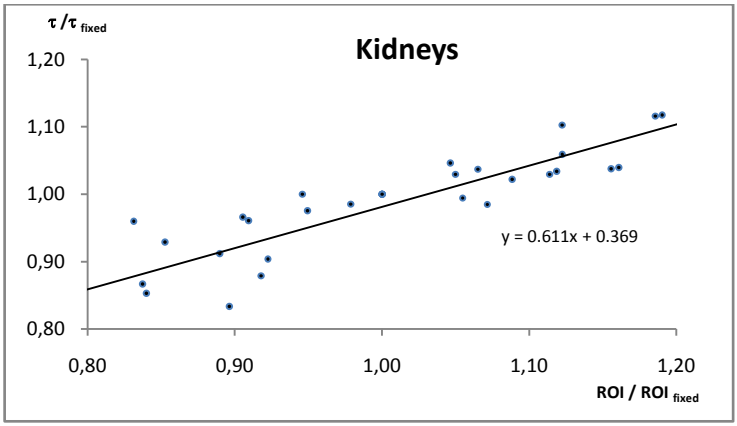


Figure 3.The relationship between relative size of the ROI and the corresponding relative change of the TIAC (τ) forkidneys.

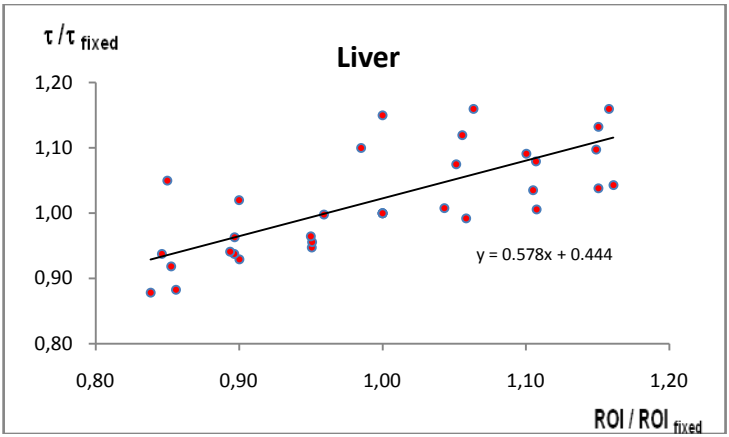


Figure 4.The relationship between relative size of the ROI and the corresponding relative change of the TIAC (τ) for liver.

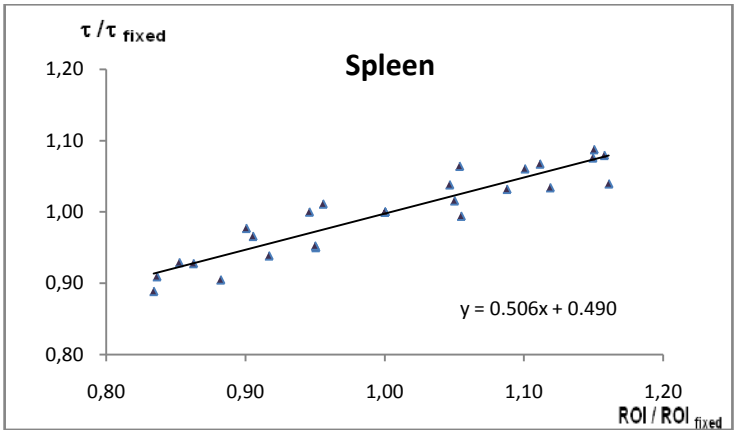


Figure 5.The relationship between relative size of the ROI and the corresponding relative change of the TIAC (τ) for spleen.

From the plot analysis, when the ROIs have been set to be decreased and increased, the effect onTIACs will be either larger or smaller respectively. For example, 10% smaller or larger error will produce the similar error at 5 % error of TIAC in spleen, while in kidneys and liver, the relationship is on the contrary, for example the smaller ROI in kidneys produce larger error in TIAC, but the larger ROI in kidneys produces the smaller error of TIAC.

During the ROI drawing process, there were a few challenges in defining ROI for the livers in some patients since it seems that they have metastases in the liver. As a result a relationship which is less accurate can be seen in Figure 3. This is one of the particular problems in image quantification using planar images from gamma camera, for example a similar problem exists in the area where organs overlap, which can reduce the accuracy of ROI definition. To solve the problem, some correction need to be performed, for example the metastasis area needs to be subtracted from the total gross of ROI, but in this study, the correction has not been done, and the metastasis has been disregarded. It has been suggested[2] that this correction will not be necessary for image quantification for PET images, since it represents a three dimensional volume. Moreover, a calibrated PET image can also be used to eliminate the effect of overlapping organs.

CONCLUSION

The step of drawing ROIs is a crucial step in the process of calculation of time-integrated activity coefficients. Hence, the enlargement and reduction of a ROI will affect the obtained time-integrated activity coefficient. In general, the relative error in the TIACs is in the same order of magnitude as the errors in the organ ROI drawing process.

ACKNOWLEDGMENT

The first author gratefully acknowledges a grant by The Non-Degree Program for Research Innovation in Science and Technology Project (RISET-Pro) for the financial support to visit Medical Faculty Mannheim of Heidelberg University, Germany. We also are grateful for a DIKTI Scholarship which is awarded to the second author for his PhD study. Both grant and Scholarship are funded by the Ministry for Research, Technology and Higher Education, Republic Indonesia.

REFERENCES

[1] M. Sathekge, "Targeted Radionuclide Therapy, Continuing Medical Education," *31*, vol. 8, pp. 289-294, 2013.

[2] M. B, "Nuclear Medicine radiation Dosimetry – advanced Theoretical Principles," pp. 455-457, 2010.

[3] M. Lyra, N. Lagopati, P. Charalambatou, and I. Vamvakas, "Patient-specific dosimetry in radionuclide therapy," *Radiat Prot Dosimetry*, vol. 147, pp. 258-63, 2011.

[4] S. R. Thomas, "Options for radionuclide therapy: from fixed activity to patient-specific treatment planning," *Cancer Biother Radiopharm*, vol. 17, pp. 71-82, 2002.

[5] M. Cremonesi, M. Ferrari, L. Bodei, G. Tosi, and G. Paganelli, "Dosimetry in Peptide radionuclide receptor therapy: a review," *J Nucl Med*, vol. 47, pp. 1467-75, 2006.

[6] E. J. Rolleman, M. Melis, R. Valkema, O. C. Boerman, E. P. Krenning, and M. de Jong, "Kidney protection during peptide receptor radionuclide therapy with somatostatin analogues," *Eur J Nucl Med Mol Imaging*, vol. 37, pp. 1018-31, 2010.

[7] T. Das and M. R. Pillai, "Options to meet the future global demand of radionuclides for radionuclide therapy," *Nucl Med Biol*, vol. 40, pp. 23-32, 2013.

[8] Z. Fan, "Theranostic nano medicine for cancer detection and treatment," *Journal of Food and Drug Analysis*, vol. 22, pp. 3-17, 2014.

[9] G. Glatting and M. Lassmann, "Nuclear medicine dosimetry: quantitative imaging and dose calculations," *Z Med Phys*, vol. 21, pp. 246-7, 2011.

[10] E. B. Silberstein, "Radioiodine: The Classic Theranostic Agent, Seminars in Nuclear Medicine," vol. 42, pp. 164-170, 2012.

[11] G. Glatting, M. Landmann, T. Kull, A. Wunderlich, N. M. Blumstein, A. K. Buck, *et al.*, "Internal radionuclide therapy: the ULMDOS software for treatment planning," *Med Phys*, vol. 32, pp. 2399-405, 2005.

[12] M. G. Stabin, R. B. Sparks, and E. Crowe, "OLINDA/EXM: the second-generation personal computer software for internal dose assessment in nuclear medicine," *J Nucl Med*, vol. 46, pp. 1023-7, 2005.