PRODUCTION OF ^{153}SM-LABELLED MICROPARTICLES AND DOSIMETRIC STUDIES FOR POTENTIAL APPLICATION IN LIVER RADIOEMBOLIZATION

N.A.A. Hashikin[1], B.J.J. Abdullah[2], C.H. Yeong[3], K.H. Ng[2], L.Y. Chung[4].

[1] School of Physics, Universiti Sains Malaysia, Penang, Malaysia.
[2] Department of Biomedical Imaging, Faculty of Medicine, University of Malaya, Kuala Lumpur, Malaysia.
[3] School of Medicine, Faculty of Health & Medical Science, Taylor's University, Selangor, Malaysia.
[4] Department of Pharmacy, Faculty of Medicine, University of Malaya, Kuala Lumpur, Malaysia.

Abstract— **Yttrium-90 (^{90}Y)-microspheres have been increasingly used for transarterial radioembolization (TARE) of hepatocellular carcinoma (HCC). ^{90}Y (a pure beta emitter) does not show sufficient post-procedural imaging capability. Samarium-153 (^{153}Sm) may serve as a better alternative, due to its promising theranostic (therapy and diagnostic) characteristics. This thesis explored the production of ^{153}Sm-microparticles and dosimetric studies for its application in TARE of HCC.**

A pilot study was performed to determine the suitable microparticle (diameter: 20 – 40 µm) to be labelled with ^{153}Sm. Two commercially available ion-exchange resins; Fractogel® EMD SO_3^- and Amberlite® IR-120H$^+$, each was labelled with 1 g of Samarium Chloride ($^{152}SmCl_3$) in six different formulations and sent for neutron activation in the TRIGA PUSPATI research reactor. Radionuclide purity of these microparticles were tested via gamma spectrometry, and the optimum formulation for each microparticle was determined following a 48 h radiolabelling efficiency study in distilled water and human blood plasma (Fig 1). Amberlite® IR-120H$^+$ was chosen, as it possesses excellent (99.9 %) radiolabelling efficiency and did not produced any radionuclide impurity following neutron activation.

Physicochemical properties of the chosen microparticle (Fig 2) before and after neutron activation was further investigated. Fourier Transform Infrared (FTIR) spectroscopy showed its unaffected functional group throughout the preparation processes. Energy Dispersive X-ray (EDX) spectroscopy confirmed the absence of radionuclide impurity. The microparticles possess irregular surface with increased fragments (< 10 µm) following neutron activation, as seen via a Field Emission Scanning Electron Microscope (FESEM) (Fig 3). The measured particle density was 2.5 g.cm^{-3} with specific radioactivity of 54 Bq per microparticle, and settling velocity of 0.03 cm.s^{-1}.

Monte Carlo (MC) simulations were done using the Geometry and Tracking 4 (Geant4) software toolkit, to study the dosimetric accuracy of the routinely used Medical Internal Radiation Dose (MIRD) based partition model (PM) for TARE with ^{90}Y-microspheres. It was found that PM markedly underestimated the normal liver dose by up to – 78 % (Fig 4), due to exclusion of cross-fire irradiation between the tumour and normal liver tissue. The model also overestimated both tumour and lung dose by up to 8 and 12 %, respectively (Fig 5). These data can be used to recognise the cases with large dosimetric inaccuracy when PM is being used. Also, a corrected formula for lung dose was suggested for future used.

Dosimetric assessment for TARE with ^{153}Sm-microparticles was performed using similar MC method. Various treatment scenarios were simulated by targeting 120 Gy to the tumour. The ^{153}Sm-microparticles were able to deliver comparable tumour dose with normal liver and lung dose close to that of ^{90}Y-microspheres, and other organ doses far below 1 Gy.

Finally, the simulations were repeated with other potential radionuclides; Holmium-166 (^{166}Ho), Lutetium-177 (^{177}Lu) and Rhenium-188 (^{188}Re), and the doses were compared with ^{90}Y and ^{153}Sm.

^{153}Sm-microparticles showed great potential as alternative to ^{90}Y with advantage of post-procedure imaging. It possesses ideal characteristics including; stable for neutron activation, excellent radiolabelling efficiency, absence of radionuclide impurities, stable in suspension, low production cost, and ability to deliver comparable tumour dose, without exceeding the organ dose limit. However, improvements should be made to its physical structure for better intraarterial delivery to the tumour.

Keywords— ***Samarium-153, Yttrium-90, Microspheres, Radioembolization, Hepatocellular Carcinoma, Geant4 Monte Carlo Simulation.***

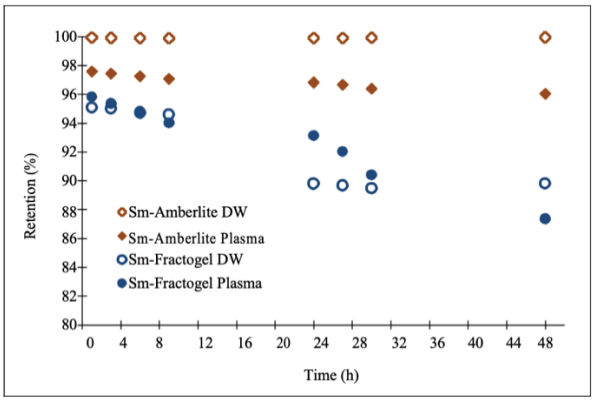

Fig. 1 Percentage retention of ^{153}Sm in both resins suspended in distilled water (DW) and blood plasma over 48 h.

(a) (b)

Fig. 2 The Amberlite resin (a) beads (620 – 830 µm) and (b) powder (20 – 40 µm) following size reduction.

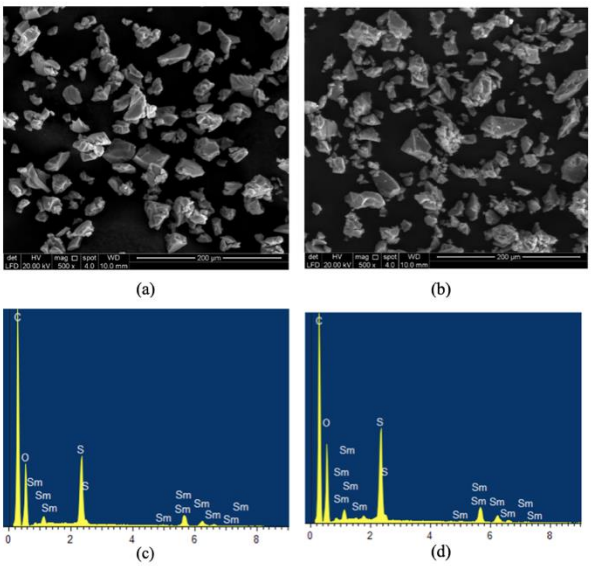

Fig. 3 The FESEM images of the Sm-Amberlite microparticles, (a) before and (b) after 6 h neutron activation with their corresponding EDX spectra (c) and (d), respectively.

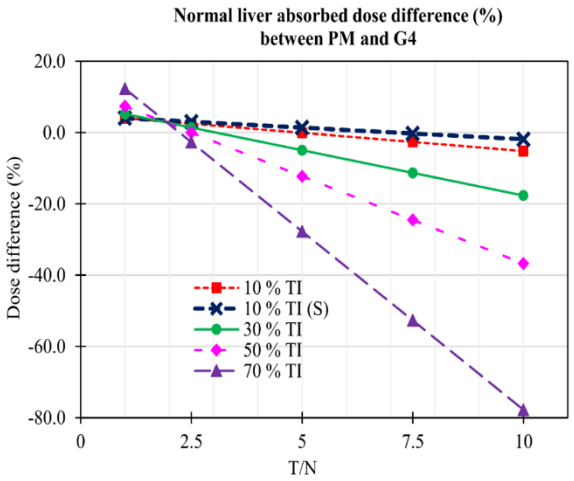

Fig. 4 Normal liver absorbed dose difference (%) between the partition model (PM) and Geant4 (G4) for various tumour involvements (TI) (including 10 % sphere (S)) and tumour-to-normal liver uptake ratio (T/N), normalised to PM, with ^{90}Y-microspheres.

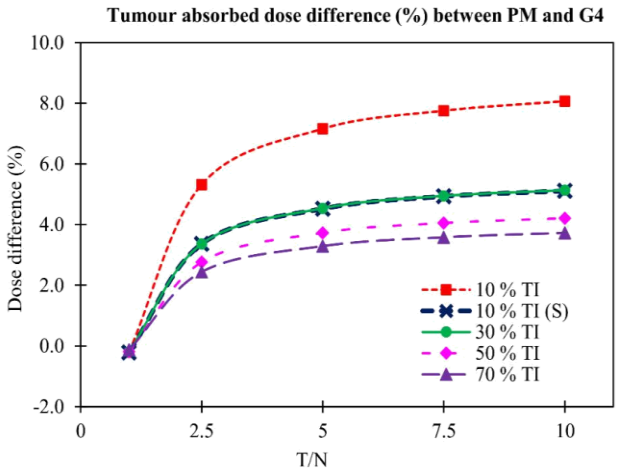

Fig. 5 Tumour absorbed dose difference (%) between the partition model (PM) and Geant4 (G4) for various tumour involvements (TI) (including 10 % sphere (S)) and tumour-to-normal liver uptake ratio (T/N), normalised to PM, with ^{90}Y-microspheres.

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Contacts of the corresponding author:

Author: N.A.A. Hashikin
Institute: Universiti Sains Malaysia
City: Penang
Country: Malaysia
Email: hashikin@usm.my