CO7-1 A Trial Experiment for Establishment of Material Data Base for Low Activation Design Method by Neutron Activation Analysis with KUR

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INTRODUCTION: Concrete is very useful material for all of aspects for construction, including infrastructure, office building, and facilities. In addition, concrete for radiation shield is also commonly used in nuclear power plants and radiation related facilities, because of inexpensively, durability, and flexibility. However, once those facilities start to operation, the concrete for the shield are affected by the radiation ray from the operating radiation source in the facilities and activated. For the above situation, low activation concrete [1]-[4] is the one of the way to solve the problem. Especially, boron neutron capture therapy (BNCT) should be effective facilities to apply the low activation concrete, because accelerator based BNCTs, including Cyclotron-based BNCT Epi-thermal Neutron Source (C-BENS) [5], have been developed by several groups in the world right now. Compared to irradiation facilities for X-ray and charged-particle radiation therapy, the neutron yield is much higher at BNCT facility. Thus, the activation of concrete, which is a main structure material of the irradiation facility, becomes an issue from the viewpoints of radiation exposure of medical workers, and the decommissioning of the facility. One of the objects for this research is intended to perform the characteristic estimation of the materials for activation reduction and to confirm its usability at BNCT facility. In 2016, characteristic estimation of a neutron shielding material covering concrete wall surfaces was performed by using an Am-Be neutron source in the same manner in 2014 and 2015 [6], [7], because Kyoto University Reactor (KUR) was not operated. After the re-operation of KUR, we restarted to make the data base for low activation concrete.

METHODS: More than 3000 of raw material for low activation concrete and ordinary concrete were gathered from all over the Japan and oversea, including hundreds of raw materials newly corrected during the period of KUR shut down. Several tens of the materials were chosen among the material stock library shown Fig.1. These materials were crushed to certain size (typically under 1mm or less), and were packed for 0.1 to 0.3 g with special treatment for the irradiation in KUR Pn-2 facility. After the irradiation with 5 to 60 minutes and with the certain cooling period, these samples were measured by Ge detector one by one. The quantity of the target elements, which were selected by former investigations as Co, Cs, Sc, Fe, and Eu [1]- [4], in each sample were estimated by the comparison of the standard material in the same package for the irradiation.

CONCLUSION: A trial experiment for establishment of material data base for low activation design method by neutron activation analysis with KUR has been conducted from 2017. More than several tens of raw materials were irradiated in KUR and were waited to estimate the target elemets, which are important for activation in the concrete sheild. These new data enable to support exisiting data base and introduce the effective low activation sheilding design for the BNCT facility as well as other radiation related facilities.

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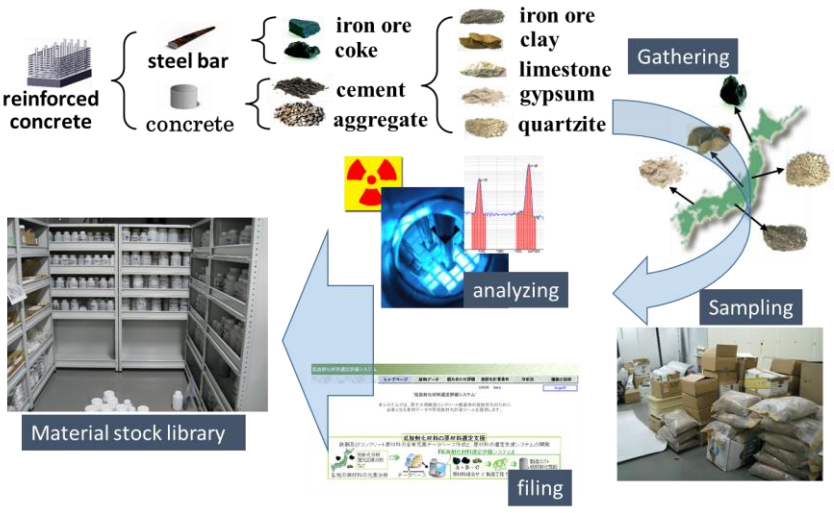

Fig. 1. Data based materials and stock library for low activation concrete.

CO7-2 The Feasiblity Study of Eu:LiCaF Neutron Detector for an Accelerator-based BNCT

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INTRODUCTION: The stability of neutron flux intensity at an accelerator-based BNCT facility is relatively worse than that at a reactor-based one. Therefore, it is necessary to measure the neutron flux precisely in real-time to optimize the patient's exposure dose for the accelerator-based BNCT. However, the neutron flux is so intense (about 10^9(n/cm^2/s)) that the real-time measurement has not been realized yet. Hence we tried to measure the neutron flux with a small detector using a Eu:LiCaF scintillator [1] on the tip of optical fibers, as shown Fig.1. We have carried out some experiments to check the followability and the linearity of the detector to the reactor power at KUR.

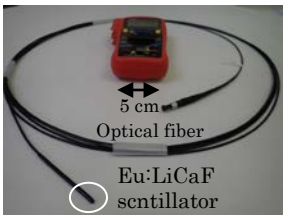

Fig. 1 Detector coupled with the optical fiber.

EXPERIMENTS: The experiments were performed at the KUR-SLY where the maximum neutron flux of about 10^{12}(n/cm^2/s) is available at the bottom when the reactor power is 1MW [2]. Figure 2 shows the experimental set-up for the measurement. The optical output from the Eu:LiCaF scintillator through the optical fibers was properly converted to an electric signal and counted with the counting units. Prior to the measurement, the detector was put into the plastic bottle and loaded to the bottom of the KUR-SLY by two threads. Figure 3 shows the loading of the detector into the KUR-SLY. The measurement was carried out during the power-up of the reactor.

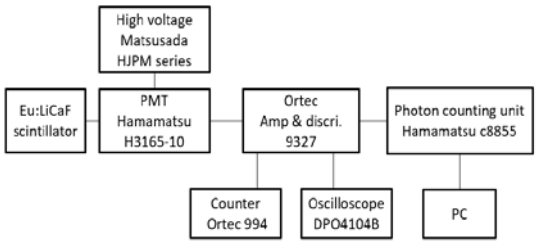

Fig. 2 Experimental setup.

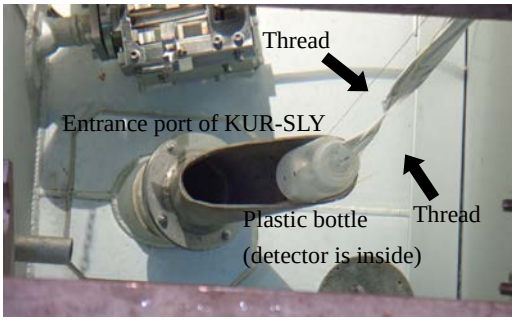

Fig. 3 Loading of the detector into the KUR-SLY.

RESULTS: Figure 4 shows the measured counting rate of the detector during the power up from 20 W to 1 kW. Also shown is a reactor power, where the both counting rate and reactor power were normalized at the average of the maximum values. As the followability to the reactor power from 20 W to 1 kW, the counting rate agrees with the reactor power. Figure 5 shows the counting rate as a function of the reactor power. We can see the good linearity of the counting rate to the reactor power.

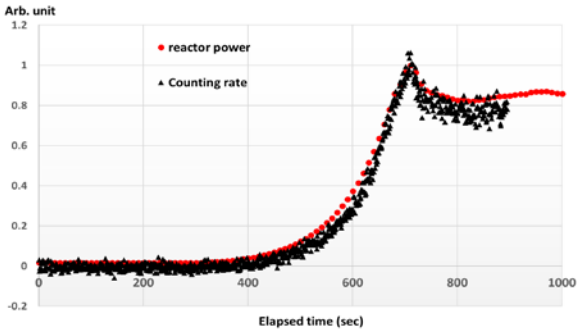

Fig. 4 Detector counting rate and reactor power

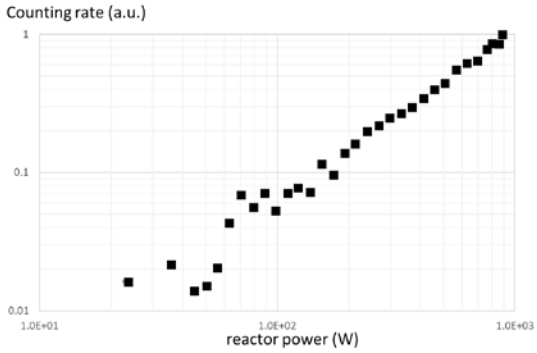

Fig. 5 Counting rate as a function of reactor power

CONCLUSIONS: A small detector using a Eu:LiCaF scintillator has been tested at the KUR-SLY experimental port. The counting rate from the detector has a good linearity and followability to the reactor power from 20 W to 1kW. Based on the results, we are planning to conduct another experiment at the KUR-SLY with a modified experimental setup.

In addition, we will investigate the influence of Cerenkov radiation of which wavelength spreads from 400 nm to 750 nm. Since the scintillation peak of the Eu:LiCaF is about 370 nm, the influence of the Cerenkov radiation should be estimated.

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CO7-3 Development of *closo*-Dodecaborate-Conjugated Serum Albumins as Novel Boron Delivery Carriers to Tumor for BNCT

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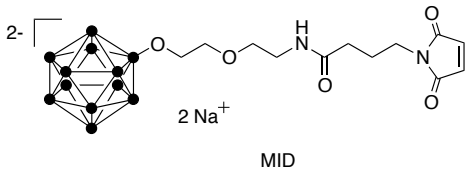
INTRODUCTION: Boron neutron capture therapy (BNCT) has been attracting growing interest as one of the minimally invasive cancer therapies. The accelerator-based BNCT is now undergoing phase II clinical study for the treatment of brain tumor and head and neck cancer patients using L-BPA in Japan.
We focused on a serum albumin as a nano biocarrier. Albumin is known to accumulate in malignant and inflamed tissues due to enhanced permeability and retention (EPR) effect. We developed maleimide-functionalized *closo*-dodecaborate (MID; Figure 1) for conjugation to bovine serum albumin (BSA).[1] In this paper, we examined confirmation of BSA-MID conjugation by western blot analysis and SEM image analysis.

EXPERIMENTS:
Conjugation of MID to BSA and Western blot analysis
BSA (0.1 mM) was reacted with MID (1.0 mM) to BSA in PBS (50 μL) at ambient temperature for 1h. The mixture was subjected to SDS-polyacrylamide gel electrophoresis (PAGE), transferred to polyvinyliden difluoride (PVDF) membrane (GE Healthcare, Buckinghamshire, UK), and immunoblotted with anti-MID antibody.
E-SEM analysis of MID-albumin conjugates
The morphology of MID-albumin conjugates was measured by FE-SEM (Hitachi SEM S-5500, Tokyo, Japan) at an accelerating voltage of 5,0 kV. Dried MID-albumin conjugates were placed on double-side carbon tape and then sputter-coated with gold-palladium in an argon atmosphere using a Hummer I sputter coater (Anatech Ltd. St. Alexandria, VA, USA).

RESULTS: The conjugation reactions of MID to BSA were carried out in PBS buffer (pH 7.4) at room temperature for 1 h and the resulting MID-albumin conjugates were detected by Western blot analysis using anti-MID antibody. MID was conjugated to BSA not only at SH free Cys residue but also at an amino group of Lys residue. In general, common maleimide compounds do not react with a nucleophilic amino group of Lys residue that is protonated under physiological conditions (pH 7.4). In the case of MID, MID contains negatively charged boron cluster in the molecule associated with sodium counter cations. In the local environment in proteins, the protonated amino group of Lys is probably deprotonated with the negatively charged boron cluster to induce the nucleophilicity. Therefore, the Michael reaction proceeded between the amino group of Lys residue and the maleimide moiety of MID.[2,3]



MID

Fig. 1. Structures of maleimide-functionalized *closo*-dodecaborate (MID)

Nanoparticles albumin-bound technology using high-pressure homogenizers has been used to make albumin nanoparticles of 100–200 nm. In particular, Abraxane® was reported to form albumin-paclitaxel nanoparticles with a mean particle size of 130 nm. In the current study, a self-assembly method was used to make BSA-MID nanoparticles. As shown in Figure 3, albumin-MID conjugates were found to be almost spherical with size distribution from 36 to 52 nm in diameter by field-emission scanning electron microscopy (FE-SEM) analysis.

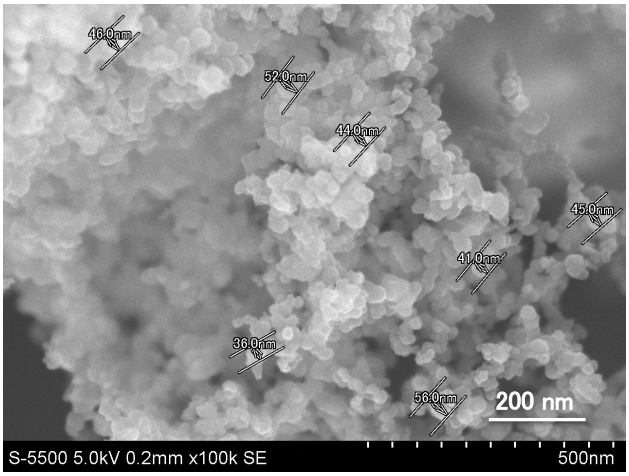


Fig. 2. FE-SEM images of albumin-MID conjugates.

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CO7-4

In vivo Biodistribution Study of new Boron-containing Compound BN2017 for BNCT

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INTRODUCTION: The principle of cancer cell destruction in boron neutron capture therapy (BNCT) is due to the nuclear reaction between ^{10}B and thermal neutrons to release alpha-particles (^{4}He) and lithium-7 ions (^{7}Li) after delivery of ^{10}B atoms to cancer cells selectively. The ^{4}He kills cells in the range of 10 μm from the site of ^{4}He generation, so the BNCT is prospective as low invasive cancer therapy.

Many clinical studies has been performed using *p*-boronophenylalanine (^{10}BPA) and sodium borocaptate (^{10}BSH) as neutron capture agents. These boron compounds show superior selective tumour accumulation property, but low tumour retentivity, so administration several hours before the radiation and persistent administration are necessary for effective BNCT. We already had reported that boron cluster conjugated polymer which had tumour selectivity and retentivity showed the anti-tumour effects by BNCT in tumour bearing mice [1].

In this study, we synthesized the novel derivative of boron cluster conjugated polymer, and evaluated the anti-tumour effects by BNCT.

EXPERIMENTS: We prepared the tumour bearing mice model after injection of CT26 mouse colorectal cancer cells (3 x 10^6 cells) into the right femoral region subcutis of the female Balb/c mice. Nine days after tu-mour inoculation, boron cluster conjugated polymer BN2017 (17.1 mg[^{10}B]/kg) as tested compound, fructose chelate of ^{10}BPA 300 mg/kg (14.4 mg[^{10}B]/kg), or ^{10}BSH 100 mg/kg (57 mg[^{10}B]/kg) as a positive control was dissolved in saline and administrated by tail vein injec-tion under anesthesia in CT26 mouse tumour bearing models (each group n=3).

To evaluate the selective accumulating tendency of boron compound, we measured ^{10}B concentration in tumour, normal liver tissue, kidney tissue, or blood after 2 hours injection in the group of ^{10}BPA and ^{10}BSH, or after 2 and 24 hours injection in the group of BN2017. We firstly treated ashing. Briefly, the twenty to fifty mg weighted tissues except the blood after freeze crushing, and 0.1mL of blood were heated at one hour by 50℃, followed at two hour by 90℃, in each 60% nitric acid water solution. After filtration of insoluble matter, we diluted ashing samples to 20 times with ion exchanged water and assayed quantity of ^{10}B atoms using ICP-MS.

RESULTS: As shown in Figure 1, it was suggested that the BN2017 has high tumor retentivity, because the intratumoral boron concentration increased, and blood boron concentration decreased in the manner of time course until 24 hours in the BN2017 administrated group.

Concerning to the comparison of the boron concentration in ^{10}BPA or ^{10}BSH group 2 hours after injection, and in BN2017 group 24 hours after injection, the intratumoral boron concentration of the BN2017 group was higher than the groups of ^{10}BPA or ^{10}BSH administrated, and it exceeded 50 ppm. The boron concentrationratio in tumor / blood (T/B) between ^{10}BPA or ^{10}BSH and BN2017 was equivalent, but hopefully, it is expected that the T/B ratios in BN2017 group increase 24 hours after administration by the changes of concentration in Fig. 1.

Therefore, it is expected that BN2017 can be a novel practical boron compound characterized with selective accumulation activity, intratumoral retentivity, and high T/B ratio by administrating on an appropriate timing.

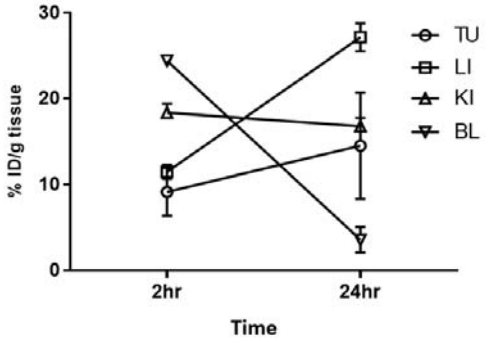

Fig. 1. Tissue distribution profiles of BN2017 (n =3, 17.1 mg[^{10}B]/kg). (TU: tumor, LI: liver, KI: kidney, BL: blood)

Table 1. Boron level (ppm) in each tissue of tumor-bearing mice after injecting BPA, BSH and BN2017.

	Boron level (ppm)		
	BPA (2 hr after i.v. administration)	**BSH** (2 hr after i.v. administration)	**BN2017** (24 hr after i.v. administration)
Tumor	13.2	13.3	55.4
Liver	4.4	35.5	102
Kidney	10.4	25.4	63.2
Blood	4.3	29.6	13.7
Tumor/blood ratio	3.1	0.45	4.0

REFERENCE:

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CO7-5 Severe Adversed Effects after BNCT

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INTRODUCTION: Advanced head and neck carcinoma (AHNC) and recurrent head and neck cancer (RHNC) are often radio-/chemo-resistant and show extensive growth, requiring a wide resection including surrounding normal tissues. To avoid severe impairment of head and neck structures, it is necessary to explore new treatment for AHNC. Mishima first proposed employing BNCT for malignant melanomas utilizing the specific melanin synthesis activity of melanoma cells[1)]. Kato et al.[2)] began BNCT using both BSH and BPA for recurrent parotid gland carcinoma for the first time and reported excellent preliminary results. On the basis of the encouraging results of their pioneering clinical trial, our many years' experience with melanoma BNCT and the trend toward emphasizing the quality of life after treatment, we also began treating our patients with BNCT using BPA alone[3)4)].

BPA is known as a renally excreted drugs and have been reported no toxicity before. Sometimes the inflammation of the urinary bladder is occurred after undergoing BNCT, cause of BPA forming crystals damaging urinary mucosa. Therefore, hydration after BNCT is recommended as soon as possible.

This report is a summary of severe adverse effect that developed acute renal failure after BNCT in 2017.

EXPERIMENTS: Two RHNC patients developed acute renal failure after BNCT. One is nasal cancer and the other is oropharynx cancer, they have no medical history of renal dysfunction. The last medical examination including blood tests was one week before BNCT date and they were conformed no abnormality in renal function such as serum creatinine (Scr) <1.0 mg/dL and estimate glomerular filtration rate (eGFR) >65. The day of BNCT, physical conditions of patients seemed no change from the one presented in the last examination. BPA was dripped administered to the patients according to schedule, and BNCT was undergoing without difficulties. After starting neutron irradiation, the blood boron level at second period was announced and found that the level is higher than one at second period that never expected usually. Although blood boron level at the end of BNCT is less than one at second period in general, in these cases, the opposite result was shown.

In the following day of BNCT, patients were developing anuria, and blood test showed higher Scr (>4.0 mg/dL) and lower eGFR (<20) than before treatment. A computed tomographic scanning (CT) of patients' abdomen was taken immediately and found many small high absorption range in kidney (Fig. 1). The further examination determined that small lesions deposit on renal calyx are crystals of BPA, and patients turned to acute renal failure. The cause of acute renal failure was not only postrenal failure by BPA crystals but also based on appearance of prerenal failure such as severe dehydration which was induced by tumor preventing oral intake or molecular targeted drugs associated diarrhea. Patients were rehydrated by an intravenous drip and used diuretic drugs, for four to five days later, levels of Scr and eGFR were improved to normal range. Hemodialysis for salvation was considered at first but never went at this time.

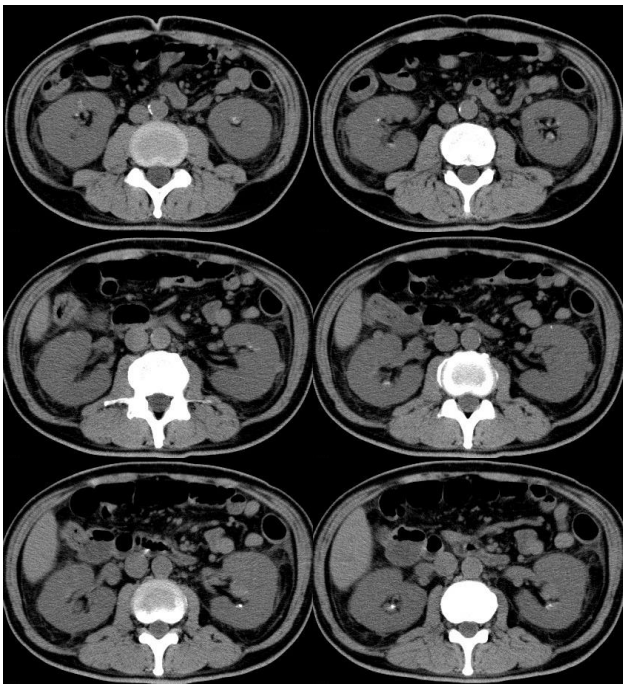

Figure 1. Crystals of BPA depositing kidney.

RESULTS: Patients with poor oral intake have possibility of complicating an acute renal failure after BNCT. To hydrate adequately before/after BNCT will help to prevent severe renal dysfunction from patients.

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[3] T.Aihara, *et al.* First clinical case of boron neutron capture therapy for head and neck malignancies utilizing 18F-BPA PET. Head and Neck **28** (2006) p850-855.

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CO7-6 Boron Neutron Capture Therapy Combined with Early Successive Bevacizumab Treatments for Recurrent Malignant

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INTRODUCTION: Recurrent malignant gliomas (RMGs) are difficult to control, and no standard protocol has been established for their treatment. At our institute, we have often treated RMGs using a form of tu-mor-selective particle radiation called boron neutron capture therapy (BNCT). However, despite the cell-selectivity of BNCT, brain radiation necrosis (BRN) may develop and cause severe neurological complica-tions and sometimes death. This is partly due to the full-dose X-ray treatments usually given earlier in the treatment course. To overcome BRN following BNCT, recent studies have used bevacizumab (BV). We herein used extended BV treatment beginning just after reac-tor-based BNCT to confer protection against or amelio-rate BRN, and evaluated; the feasibility, efficacy, and BRN control of this combination treatment.

MATERIALS and METHODS: Two cohorts were in-cluded in this study. The first cohort was treated with BNCT between June 2013 and May 2014, followed by successive BV treatments. The second cohort was treated with BNCT between August 2017 and December 2017, followed by successive BV treatments. The first cohort is composed of 7 patients with RMGs (4 grade 4 and 3 grade 3 cases). The second cohort was composed of 6 patients with RMGs (5 grade 4 and 1 grade 3 cases). They were followed-up to April 2018. The Kyoto Uni-versity Reactor did not work between these 2 cohorts due to renovation.

RESULTS: Median overall survival (OS) and progres-sion-free survival (PFS) after combination treatment were 15.1 and 5.4 months, respectively in the 1st cohort. Me-dian OS and PFS in the second cohort was not reached. The OS data was compared with the class of recursive portioning analysis (RPA) for RMG as advocated by Carson et al. in a 2007 article in the Journal of Clinical Oncology[1]. RPA classification is the stratified progno-sis grouping as shown in Fig. 1. In the 1st cohort, in one case, uncontrollable brain edema occurred and ultimately led to death after BV was interrupted due to meningitis. In 2 other cases, symptomatic aggravation of BRN oc-curred after interruption of BV treatment. No BRN was observed during the observation period in the other cases. CTCAE grade 2 and 3 proteinuria occurred in two cases and necessitated the interruption of BV treatments. In the second cohort, no apparent BRN and adverse event oc-curred. Totally 11 cases' OS in both cohorts were com-pared using JCO's RPA classification. Nine out of 11 cases showed longer OS in comparison with correspond-ing JCO's RPA classes (Table 1). Representative MR images of Case 7 were shown in Fig. 2 and 3.

CONCLUSION: BNCT followed by BV treatments well-prevented or well-controlled BRN with prolonged OS and acceptable incidence of adverse events in our patients with RMG.

Fig. 1 RPA in JCO (Carson *et al.* in a 2007 article in the Journal of Clinical Oncology[1].)

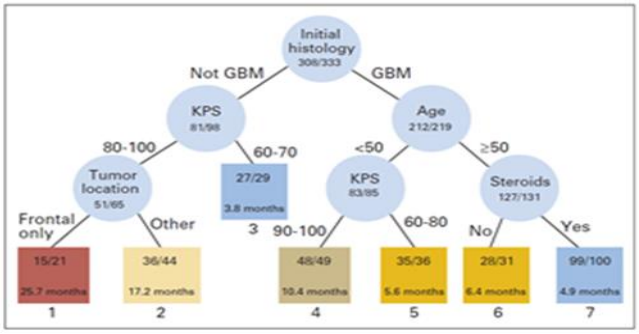

Fig. 2 Case 7 periodic change of MRI

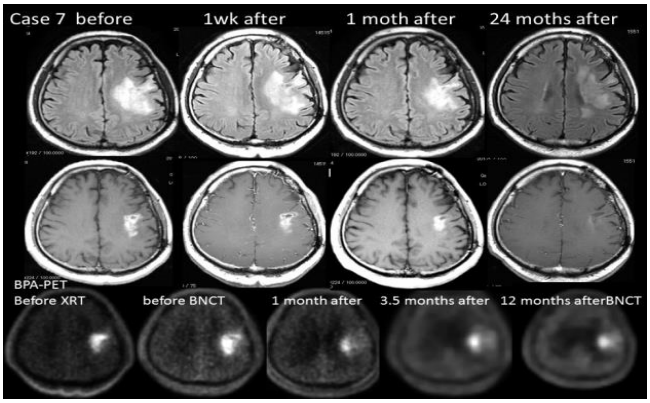

Fig. 3 Worsening of brain radiation necrosis in Case 7 After discontinuation of BV

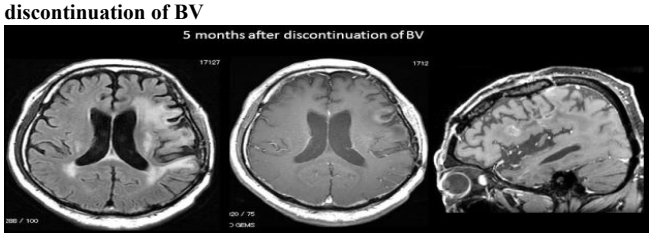

Table 1

	WHO grade	RPA*1	mOSin JCO*2	OS*3	PFS*4	AE*5
Cohort 1						
case 1	4	7	4.9	15.1	3.1	PU*6 grade1
case 2	4	3	3.8	7.5	5.4	–
case 3	3	2	17.2	38	19.5	PU grade2
case 4	3	1	25.7	57(alive)	NP*7	PU grade1
case 5	4	7	4.9	11	5	–
case 6	4	7	4.9	4.4	NA*8	meningitis
case 7	3	3	3.8	47(alive)	47	PU grade3
cohort 2						
case 8	3	3	3.8	8(alive)	4.7	PU grade3
case 9	4	7'*9	4.9	8(alive)	N8	
case 10	4	7'	4.9	6(alive)	3.7	
case 11	4	5	5.6	6(alive)	NP	
case 12	4	5	5.6	55	3	
case 13	4	7'	4.9	6(alive)	NP	

*1RPA :recarsive partioning anaiysis
*2mOSinJCO :median overall survival in J Clin Oncol[1]
*3OS :overall survival from BNCT
*4PFS :progression free survival asessed by RANO criteria
*5AE :adrerse event
*6PU :protein uria
*7NP :no progression
*8NA :not applicable
*9 7' RPA 7': recurrence after BV treatment

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[1] Carson KA *et al., J Clin Oncol* **25** (2007) 2601-2606.

29129

CO7-7 Research on Pretreatment or Concomitant Drug to Augment Therapetutic Effect of BPA-BNCT

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Research Reactor Institute, Kyoto University

Introduction

We have reported that high dose of L-phenylalanine preloading reduce the uptake of L-4-dihydroxy-borylphenylalanine (L-BPA) in the brain relative to the tumor leading to the increase of BPA accumulation ratio of tumor to brain. The aim of this study is to search another pretreatment drug to reduce L-BPA uptake in the normal organs especially in the dose-constraint organ in BPA-BNCT.

In this study, the measurement of boron concentration in the tumor and normal tissues is essential component. The boron concentrations in the tissues are measured by prompt gamma ray spectroscopy (PGA) and inductively coupled plasma atomic emission spectroscopy (ICP-AES). In the both methods, the sample volume to measure the boron concentration is greater than 300-500 mg. To get the blood greater than 500 mg, the mice should be sacrificed. To monitor the change of the boron concentration in the blood after the administration of boron compound at one mouse, it is important to measure the boron concentration in the blood less than 1 to 10 mg.

We developed a new device to measure the boron concentration in the blood less than 1 mg. In this report, we present preliminary results of the experiments using the new device.

Materials and methods

New device

We have developed a device which has eight well (<10 μl) with upper side made by CR-39 film on the plate. CR 39 film is a particle track detector.

Experimental protocols

The aim of the preliminary experiment is to optimize the irradiation condition for the standard curve to measure the boron concentration. Boron-containing standard solutions of 20, 40, 60 and 80 ppm were applied into 8 wells at the volume less than 10μl on the four devices, separately. The devices were irradiated with thermal neutron beam in two conditions of 1.1×10^{12} n ・ cm^{-2} and 2.2×10^{12} n・ cm^{-2}, respectively. After irradiation, the devices was etched by a 6N NaOH solution for 1 h at 65°C. The etched pits were observed by a microscope with a magnification of 40 times. The number of pits was countered automatically using the software installed in the analyzing system of the microscope. The average of pit number was calculated after the smallest and the largest pit numbers were excluded.

Results

Figures 1 and 2 show the images of CR-39 films irradiated with 20 ppm boron standard solution for 15 min and 60 ppm boron standard solution for 30 min. Visually, the density of pit was increased in proportion to boron concentration and irradiation time (neutron intensity).

Fig.1 Images of CR-39 films irradiated with 20-ppm boron standard solution

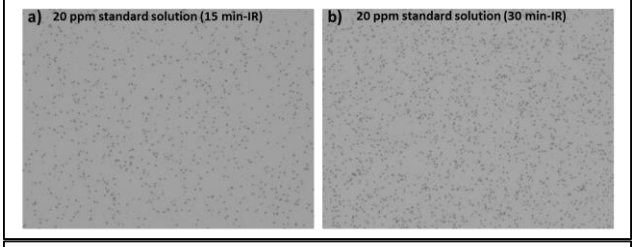
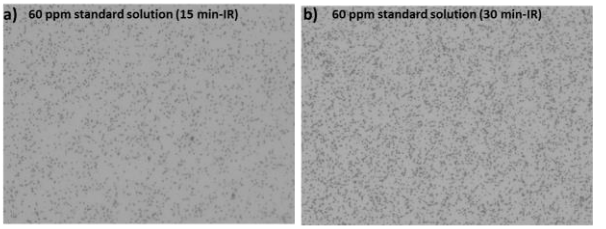
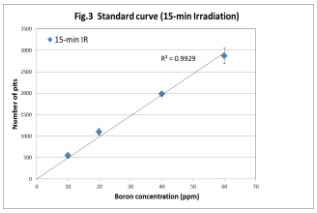
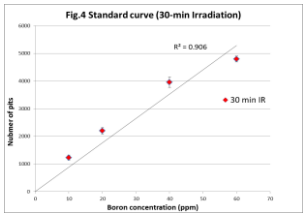


Fig.2 Images of CR-39 films irradiated with 60-ppm boron standard solution



Figures 3 and 4 show the standard curve yielded by two irradiation conditions (15-min and 30-min irradiation). The curve obtained by 15-min irradiation show a remarkable agreement with linear approximation (r^2=0.9929). The curve obtained by 30-min irradiation shows poor agreement with linear approximation compared with that by 15-min irradiation (r^2=0.906) due to overlaps of pits by combination of 60-ppm solution and intensity of 2.2×10^{12} thermal neutron fluence.





We will repeat the experiments to optimize the irradiation condition and use this new device for measurement of boron concentrations in small sample size less than 1-10 mg.

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CO7-8

The Effect of Boron Neutron Capture Therapy (BNCT) on Normal Tissues or Organs in Mice

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Introduction

Boron neutron capture therapy (BNCT) has been applied mainly for the treatment of locally recurrent malignant brain tumors or head and neck cancers in the irradiated region. The outcomes of the clinical BNCT studies on BNCT for both tumors have been reported to be promising in some studies.

Clinical trials using accelerator-based (AB)-BNCT system are currently in progress. Since the AB-BNCT system is much compact compared with a research reactor, the system can be installed in the existing medical institutes. The AB-BNCT system in the hospital is available to more patients suffering from malignant tumors compared with the BNCT system using research reactor. Lung cancer, breast cancer and hepatic tumors including hepatocellular carcinoma and multiple metastatic tumors are more common than malignant brain tumors and head and neck tumors.

In this study, for BNCT to apply more common cancer such as lung cancer, breast cancer and hepatic tumors, the effect of BNCT irradiation on normal organs including lung and liver was investigated. These normal tissues are irradiated in the treatment of lung cancer, breast cancer and hepatic tumors with BNCT. Kyoto University Research Reactor (KUR) reworked at the end of August following the long period of operation stopping. Therefore, the research on the effect of BNCT on the normal lung is still ongoing and that on the normal liver just stared. The preliminary results of the study on normal lung not liver were reported.

Materials and methods

Experimental animals

Twelve- to thirteen-week-old female C3H/He mice were used for this study. All procedures for animal experiments were carried out in accordance with the regulations of Kyoto University Research Reactor Institute regarding animal care and handling.

Experimental protocols

In this study, the radiobiological effectiveness of high linear energy transfer (LET) irradiation by $^{10}B(n,\alpha)^{7}Li$ reaction on normal lung tissues is investigated in comparison to that of X-ray.

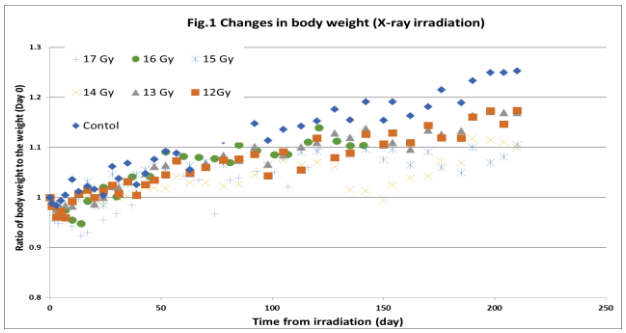
Three types of irradiation carried out in this study ware as follows, X-ray irradiation, thermal neutron beam irradiation and BNCT-irradiation using p-boronophenylalanine –fructose complex (BPA-F). In each irradiation, the whole lung was irradiated with shielding other part of the body. In X-ray-irradiation, anesthetized mice were confined in 1mmPB box with 25x20 mm-sized window. The whole thoracic put within the window was irradiated with 150keV X-ray at 1.16 Gy min^{-1}. In thermal neutron beam irradiation, mice was held within a specially designed acrytic cage at the flux of 3.73E+10 $cm^{-2}\cdot min^{-1}$. LiF tiles (50-mm thick) were used to shield parts of the body other than the chest. In BNCT-irradiation, BPA-F was subcutaneously injected in each mouse at the dose of 500 mg/kg. Irradiation was started at two hours after the injection of BPA-F. Eight- to nine mice were used for each data point.

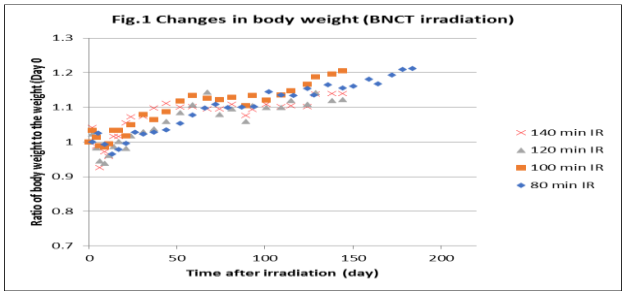
At two or three days' intervals during two months from the irradiation and weekly intervals after two months, the mice were weighted and carefully observed.

Results

In X-ray treatment, mice were irradiated with a single dose (12 to 17 Gy). In BNCT treatment, mice were sorted in four groups (80, 100, 120 and 140 min-duration groups). Thermal neutron beam irradiation had not been carried our due to less allocation of the experiment.

Figures1 and 2 shows the changes in body weight after irradiation in the X-ray irradiation group and BNCT irradiation group.





One or two mice died at 3 to 6 months after irradiation in 15,16, and 17 Gy X-ray irradiation groups. Survival time in the each treatment group will be analyzed.