Eastern Journal of Medicine 4 (2): 73-76, 1999.

The use of pure lead instead of lipowitz alloy in radiotherapy applications and a newly-developed mold apparatus

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Objective The protection of vital-critical organs inside the radiated area during radiotherapy applications is very important. For this purpose, cerroband protection blocks are commonly used. During casting of the Lipowitz alloy its inhalation has a toxic effect, and its radiation transmission compared to pure lead is greater. As a result, the thickness of protection blocks decreases. More importantly it is costly. In this study, pure lead, a newly developed mold aparatus were medically tested.

Method The blocking samples were chosen from 70mmx 110mmx 110mm dimensions of the commercially pure Lipowitz metal and pure lead. The fusion of the Lipowitz metal and pure lead has been done in a crucible produced from stainless stell, the heat of which can be controlled by a thermo-couple. The blocking samples were radiated after placing them in such a way that it would cover the whole field on the plexiglass trays containing 100mmx100mm target area and photon rays of 10 MV and 25 MV of the Lineer Accelerator magavoltage apparatus. The radiation transmission measurements were done using 0.6cc ion chamber, PTW Unidos Dosymeter and solid water phantom.

Results The measurements taken using 10 MV photon ray showed that the field protected by pure lead had the least radiation transmission, and it was accepted to have 27.3% less transmission compared to the field protected by cerroband alloy. The measurements taken using 25 MV photon ray showed that the field protected by pure lead had 38.4 % less transmission compared to the field where a Lipowitz metal block is used, so it was proved that the pure lead blocks have the least radiation transmission.

Conclusion It has been shown that the fact that pure lead, both the treatment cost and the radiation transmission of which is less, can be preffered instead of bismuth, which are too expensive, in this study.

Key words Radiotherapy,Shielding, Pure Lead, Lipowitz Alloy, Mold Apparatus.

Introduction

The protection of vital-critical organs inside the irradiated area during radiotherapy applications is very important. The dose received by anatomical structures which are apparently shielded by blocks during a course of megavoltage radiotherapy may not be negligible (1). For this reasons, cerroband protection blocks are widely used. The chemical composition of this alloy, known also as Lipowitz's metal, consists of 50% bismuth, 26.9% lead, 13.3% tin and 10% cadmium. Determination of airborne concentrations of lead, cadmium, bismuth, and tin were made above vessels containing a "fusible" lead alloy (70° C melting point) commonly used for construction of radiotherapy blocks. Fume concentrations were analysied by atomic absorption spectrophotometry after the collectıon on a membrane filter. The samples were obtained for alloy at temperatures of 93.3°C, 204.4° C, and 582.2° C. In all instances, concentrations were much lower than the applicable occupational limits for continuous exposure (2).

A cadmium free fusible lead alloy with low melting point which is suitable for custom radiotherapy shielding blocks is described. The alloy, referred as Alloy-203 here, differs in composition from the more common cerroband (Lipowitz's metal by being cadmium free) alloy, having a slightly higher lead content and a 185.2°C melting temperature of 185.2°C (3).

Accepted for publication: 15 April 1999

Bismuth alloys with low melting temperature that contain about 20% to 25% lead and 10% cadmium are commonly used in radiotherapy to construct shielding blocks. Since 1980, five studies have addressed the questions concerning potential metal toxicity, safe shop practices, measurement of airborne vapors and metal particuls, and the results of biological testing of stuff manufacturing secondary field shaping blocks. In February, 1990, the Occupational Safety and Health Administration (OSHA), proposed new occupational air concentration safety standards for cadmium and cadmium compounds (4).

In a previous study, the shielding-block fabrication areas of three hospitals were surveyed to assess inhalation exposure to lead, cadmium, bismuth, and tin fumes, as well as styrene and methyl chloride vapors. Area and personal breathing zone samples were collected for various steps in the block fabrication process. The data suggests that the materials and procedures investigated do not present an inhalation hazard to employees who construct shielding blocks (5).

In this study, besides the advantage of less radiation transmission of pure lead, a newly developed mold aparatus were medically tested. Pure lead, both the treatment cost and the radiation transmission of which are less, can be preffered instead of Cerroband alloy.

Material and Method

The blocking samples were chosen from the commercially available Lipowitz metal by being cadmium free (50% bismuth, 32% lead, 18% tin ,without cadmium) and pure lead (100% lead) having dimensiones of 70mm x 110mm x 110mm. The chemical composition of the Lipowitz metal was determined by wet analysis, and the composition of pure lead by the x-ray spectrophometer (Table I).

Table I.The chemical components of samples

Name	Composition(%)		
	Pb	Sn	Bi
Cerroband Alloy	31.8	18.2	Remaining
Pure Lead	99.9	-	-

The fusion of the Lipowitz metal and pure lead were performed in a crucible (stainless) stell, the heat of which can be controlled by a thermo-couple. The scheme of the fusion crucible and the casting-mold are shown in Figure 1.

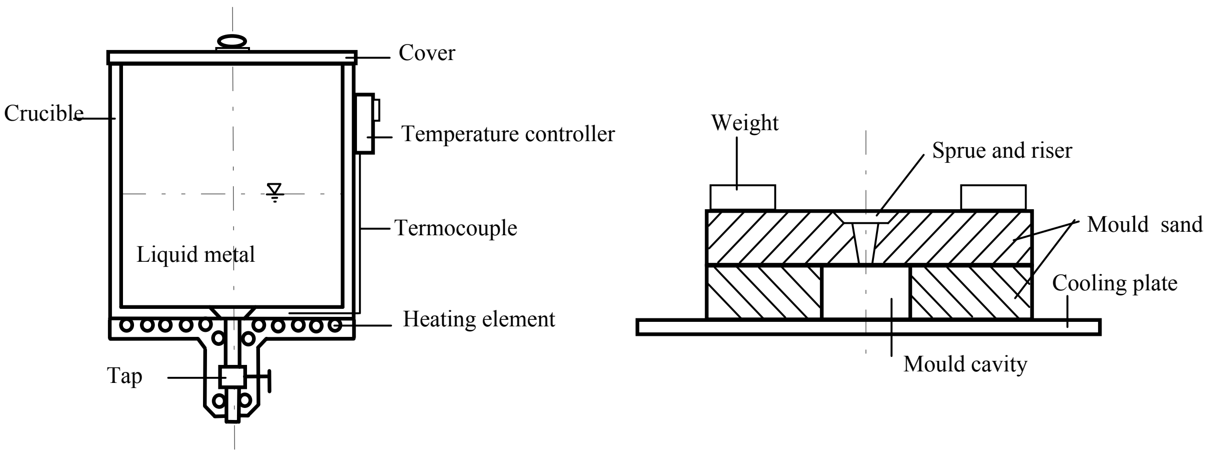

Figure 1. The scheme of the fusion crucible and the casting-mold apparatus.

In order to produce the samples, a strafor mold having 70mm x 110mm x 110mm dimensions was built in a hot-wire apparatus (i.e. an apparatus for cutting polystrene foam). Lipowitz alloy melted at 80 °C was poured into the mold cavity and solidified. Pure lead was solidified at 350 °C by putting casting sand into the strafor piece cut in the same diameter and dimensions within the container with the HEPA(High Efficiency Particulate Absorbtion) filter. The blocking samples were radiated by photon rays of 10 MV and 25 MV of lineer accelerattor magavoltage apparatus after placing them on the plexiglass trays containing 100mmx100mm target area, Moreover, (a radiation was done to) an open(unprotected) field having the same energy levels and dimensions was irradiated. The radiation transmission measurements were performed using 0.6cc ion chamber, PTW Unidos Dosemeter and solid water phantom.

Cerabond alloy and pure lead were melted in a stainless steel crucible. The temperature of the crucible was controlled by a temperature controller with thermocouple. Models were prepared from hard foam polystyrene material by hot-wire device to form the mold cavity in the sand. Then, surface of the polystyrene models were coated with silicon spray to disjoin models and sand. Coated models were put into cooling plate produced from copper material. Surrounding of the models were filled by specially prepared mold sand and this sand was pressed by hand and pressing hand tool. Mold cavity was formed by removing the models from compressed sand. Sprue and riser were formed on the mold cavity pouring the liquid metal to prevent the metal shrinkage during solidification. Dead weight were put onto sand mold. Liquid metal was poured into mold cavity for solidificatıon in the mold. After the solidification and cooling the metal, specimen were removed from the sand mold, and then riser and sprue were cut by the saw.

Discussion

Cerroband protection blocks are widely used in radiotherapy. The most important advantage of this alloy is the low fusion temperature of about 70 °C which enables casting at medical centers. On the other hand, the low fusion temperature for pure lead is 327 °C and it can be produced by casting it into special molds made from polystrene strafor. However, it has been shown that, as far as radiation transmission is concerned, at megavoltage radiations, pure lead of 6 cm is equal to lipowitz alloy of 7.5cm. Adding bismuth, tin and cadmium to pure lead decreases the fusion temperature (2,3,6,7). The bigger radiation transmission of the Lipowitz alloy compared to pure lead, the toxic effect as a result of inhalation during casting of the cerroband alloy, the increase of thickness which decreases the practical use of the protecting blocks and its the ten fold cost are the disadvantages.

Cadmium has been extracted from the content of cerroband alloy because of its toxic effect[3]. In lead poisoning, along with the lead concentration in the air of the work place, the exposure time and frequency are also important. Despite the advantage of radiation transmission to solve the problem of not using pure lead in medical practice, in this study, a new mold apparatus developed in order to provide less exposure to toxic substances,was used.

The present study suggests that instead of the Lipowitz metal alloy containing Bismuth, that is too expensive, pure lead, both the treatment cost and radiation transmission of which are less, can be preferred. As a result, pure lead with low radiation transmission and less cost compared to cerroband alloy can be suitable for protect block applications. Furthermore, the problem of high fusion temperature of pure lead can be solved by this newly-developed mold aparatus, and the toxic inhalation risk for the staff can be reduced to minimum possible level.

Results

The output values for 10 MV and 25 MV found using PTW Unidos Dosemeter system at a depth of 10 cm at 25 °C and under pressure of 990 mbar, 0.6cc ion Chamber at 100 cm SSD in solid phantom, are shown in table II.

Table II. The radiation transmission of open field and protected field.

Energy	Open Field (%)	The Protected Field by Lipowitz's Metal(%)	The Protected Field by Pure Lead(%)
10MV	0.714	0.030	0.022
25MV	0.760	0.026	0.016

The measurements by using 10 MV photon ray showed that the field protected by pure lead had the least radiation transmission. (27.3% less transmission compared to the field protected by cerroband alloy). The measurements by using 25 MV photon ray revealed that the field protected by pure lead had 38.4 % less transmission compared to the field where a Lipowitz metal block was used.These findings prove that the pure lead blocks have the least radiation transmission.

The radiation transmissions of open(unprotected) fields and protected fields are shown in Figure 2 and 3.

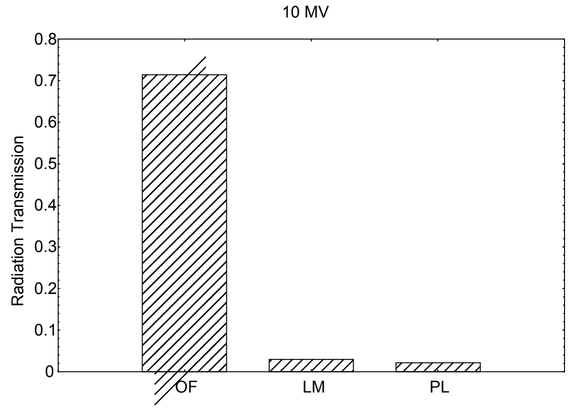

Figure.2: The radiation transmission of open field and protected field by using 10MV (OF:open field, LM:lipowitz's metal, PL:pure lead).

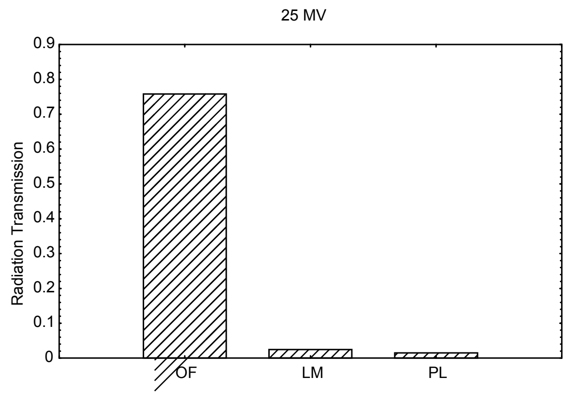

Figure 3. The radiation transmission of open field and protected field by using 25MV (OF:open field, LM:lipowitz's metal, PL:pure lead)

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