

## **LOW DOSE RATE (LDR) Ir-192 WIRE SOURCES FOR BRACHYTHERAPY**

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### **ABSTRACT**

**LOW DOSE RATE (LDR) Ir-192 WIRE SOURCES FOR BRACHYTHERAPY.** This article reviews several aspects of afterloading brachytherapy using low dose rate radioactive sources especially Ir-192 wire sources. The rationale for low dose rate is referred and the advantages of Ir-192 were also considered. The importance of accurate radioactivity calibration is stressed and the radiocalorimetric method is suggested as a new quality control technique. The present status of the low dose rate Ir-192 brachytherapy in Japan is briefly described along with an example of clinical practices in this technique. The status in Indonesia is also quoted by introducing the recent commencement of cooperation between the BATAN and the Hasan Sadikin Hospital, Bandung. As a summary the author appeals the importance of low dose rate brachytherapy using Ir-192 sources which has a potential of development and dissemination with a number of advantageous characteristics for the both production and utilization sectors.

### **ABSTRAK**

**SUMBER KAWAT Ir-192 DOSIS RENDAH UNTUK "BRACHYTHERAPY".** Makalah ini mengemukakan tinjauan beberapa aspek "afterloading brachytherapy" dengan menggunakan sumber Ir-192 (kawat) dosis rendah. Beberapa keunggulan Ir-192 dosis rendah dibandingkan dengan dosis tinggi dibahas pula dalam makalah ini. Ditekankan pula bahwa ketepatan kalibrasi radioaktivitas merupakan hal yang sangat penting, serta disarankan untuk menggunakan metode radiokolorimetri sebagai teknik kendali kualitas yang baru. Status Ir-192 "brachytherapy" dosis rendah di Jepang dan di Indonesia juga dikemukakan serta beberapa contoh aplikasi klinisnya. Sebagai penutup, penulis menyimpulkan bahwa produksi Ir-192 dosis rendah mempunyai potensi besar untuk dapat dikembangkan di BATAN dan karena keunggulannya, penggunaan sumber Ir-192 dosis rendah mempunyai peluang yang besar untuk disebarluaskan sesuai dengan minat beberapa rumah sakit di Indonesia. Langkah awal telah dimulai dengan melakukan kerjasama dengan Bagian Radiologi-Rumah Sakit Hasan Sadikin, Bandung.

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## INTRODUCTION

The cancer therapy is generally divided into three methods, namely surgery, chemotherapy and radiotherapy. The radiotherapy categorized to the treatments by radiopharmaceuticals, teletherapy and brachytherapy. The brachytherapy utilizes the delivery of ionizing radiation using sealed radioisotopes from very close distances to migrant tumours, in contrast to teletherapy or external radiotherapy where radiation is delivered from grater distances. The prefix *brachy* is a term from Greek for 'short range'. The following futures are to be counted as advantages of the brachytherapy; (i) very high dose within a tumour volume, (ii) considerable sparing of surrounding normal tissues and (iii) continuous dose during overall duration of treatment.

A concept of "Quality of Life (QOL)" is a key consideration of cancer management. The most essential point of QOL lies in how sufficiently the looks and functions can be conserved and preserved even after survival from the cancer. In this context, the brachytherapy has potential features of realizing QOL since it can be described as *cancer treatment without surgery*.

The brachytherapy can be classified based on dose rate as LDR (low dose rate) ranging from 0.4 to 2 Gy/hr, MDR (medium dose rate) ranging from 2 to 12 Gy/hr and HDR (high dose rate) over 12 Gy/hr but usually in the region of 150 Gy/hr. In the present article, the introduction of various aspects of LDR brachytherapy sources specifically of Ir-192 wire sources is given, concerning the view point of effectiveness in cancer treatment with simple facilities, easiness in manufacturing and handling and readiness of supply with lower prices.

## RATIONALE FOR LOW DOSE RATE

There is a trend to consider the HDR as an alternative to LDR. It is mainly because logistical reasons including radiation safety since HDR therapy can be applied to several patients a day on an outpatient basis in contrast to LDR. Cost of brachytherapy source itself is far less for the LDR but if an HDR source is applied for more than 20 patients then the source cost becomes equivalent to the LDR. Therefore HDR is of advantage in centers with a large population of cancer patients but needs high technology and high cost instruments both in production and clinical use.

It is expected that LDR brachytherapy will keep its place within the spectrum of cancer treatment modalities. Further, LDR brachytherapy does not necessitate any expensive equipment and facilities either in production or in clinical practices. LDR brachytherapy is characterized by following factors, all of which contribute to its efficacy.

- (1) Good dose distribution (from radioactive sources in or near the tumor).
- (2) Maximize the therapeutic ratio (of tumor control to complications) due to difference of sublethal damage repair between tumor and normal tissues.
- (3) Shorter overall treatment time than conventional external beam radiotherapy, giving full dose within only about one week.

Many researchers studied and evaluated the dose rate effect between LDR and HDR brachytherapy in terms of radiobiology and efficacy in cancer treatment by means of, for example, comparing continuous low dose rate irradiation and fractionated high dose rate irradiation both gave the same total dose [1~8]. All of them came to the results with no distinguishable differences except technical or methodological merits. A Japanese medical team made a comparative study for HDR and LDR brachytherapy of cervical cancer [20] and reported, "In summary, comparable therapeutic results have been obtained in the 300 HDR patients and in the 251 LDR patients because no significant differences between the two groups have been demonstrated for five-year survival rates, incidence of recurrences/metastases and incidence of radiation related complications." (see Fig. 1)

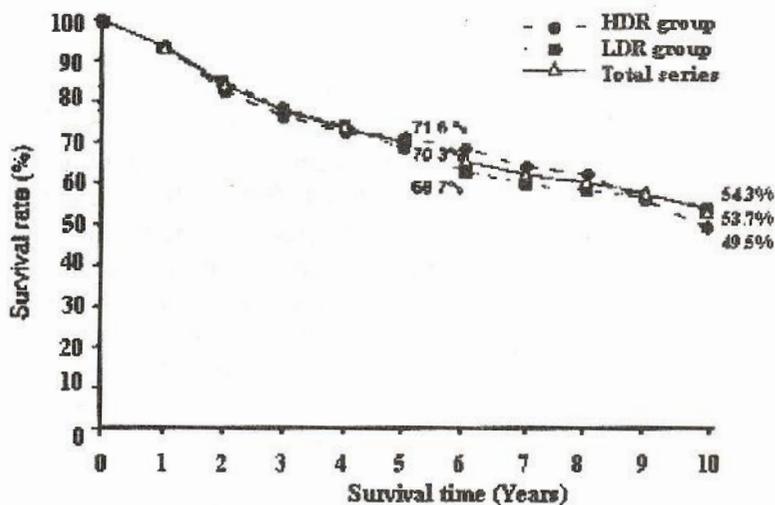


Figure 1. Comparison of therapeutic results between HDR and LDR patients of cervical cancer. (Reproduced from [20])

## **ADVANTAGES OF Ir-192 SOURCE**

Radium was discovered by Marie and Pierre Curie in 1898 and soon applied for cancer treatment as the first brachytherapy method. Radium-226 sources in tubes or needles have been in clinical use until the 1970s. However, the problems of leak of ingrown radon gas and difficulty of disposal of such obsolete sources with extremely long half-life (1600 years) forced many hospitals to substitute the radium to artificial isotopes of iridium-192 and others.

The advantages of radioactive Ir-192 wires for brachytherapy sources are:

- (1) Very thin, flexible wires with max. dia. 0.65 mm give adequate shape to be fit to target area and ease pain of patients,
- (2) Conveniently short half-life of 74 days,
- (3) Low energy of average 0.35 MeV facilitates easy shielding and protection of operational personnel, and
- (4) Afterloading technique ensures better geometry and avoids unnecessary exposure to medical staff.

## **RADIOACTIVITY STANDARDS FOR Ir-192 BRACHYTHERAPY SOURCES**

Establishment of the traceability of radiation and radioactivity measurements for medical sources is of great importance. In radiotherapy, the more radiation dose results better local control of cancer but at the same time the more complication might occur. Therefore optimization of total dose requires accurate quantities of radiation output or radioactivity of the source as much as possible. For the teletherapy, uncertainty of the dose estimation of 5% at the point of exposure is recommended by ICRU [8]. If it is applied to the brachytherapy source, then the initial specification of the source must be carried out with an uncertainty around 2% [12]. Standardization for exposure rate (air kerma rate) calibration was well established [15] but not those for radioactivity calibration, mainly because of error due to self absorption of radiation by metallic source itself. For the routine assay of LDR wire sources, ionization chamber measurement is the most simple and practical way if the standard source of the identical shape as the sources to be measured is available. Japan Atomic Energy Research Institute (JAERI) has developed a radiocalorimetric method for determining absolute radioactivity of various metallic sources without being influenced by self absorption [18,19]. Recently a calorimeter system was installed in the laboratory of Centre for Development of Radioisotopes and Radiopharmaceuticals (P2RR-BATAN) in Serpong. The system is expected to be used for the calibration of ionization chambers for quality control in P2RR.

## STATUS OF LDR Ir-192 BRACHYTHERAPY IN JAPAN

In Japan, various types of LDR Ir-192 brachytherapy wire sources (hairpin, single pin and thin wires of different length as shown in Fig.2) as well as seed and seed assembly are currently being used in about 90 hospitals [2,17]. These sources are all produced and distributed by JAERI [1,7] through the Japan Radioisotope Association (JRIA) to meet whole demand of domestic use. The target materials for hairpins and single pins are supplied by W.C.Heraeus, Germany and those for thin wires and seeds are from Tokuriki Shoten, Japan. After being used in hospitals the obsolete sources are collected and stored by JRIA.

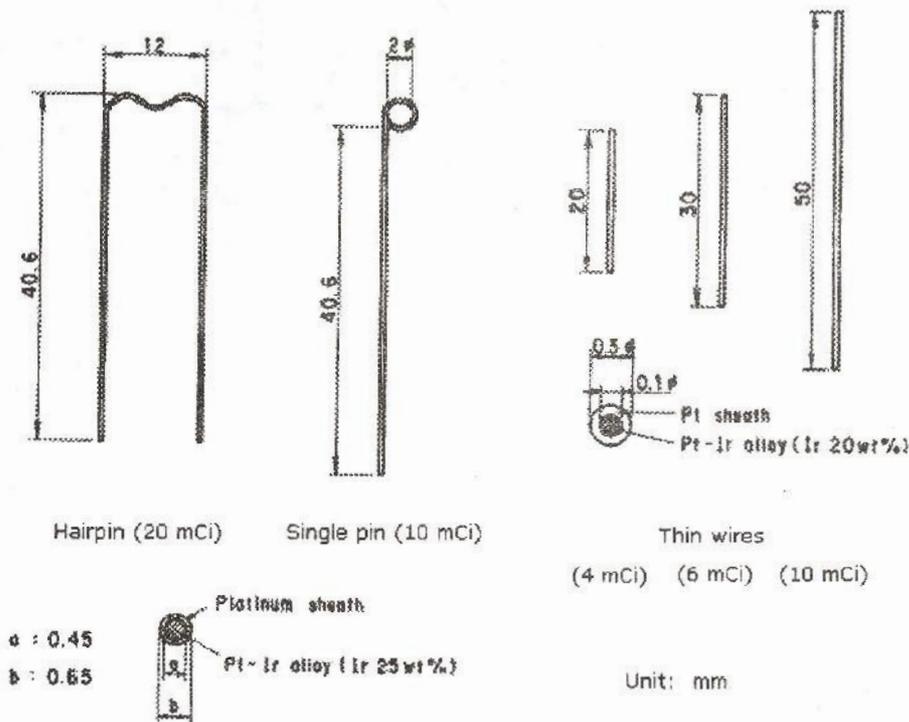
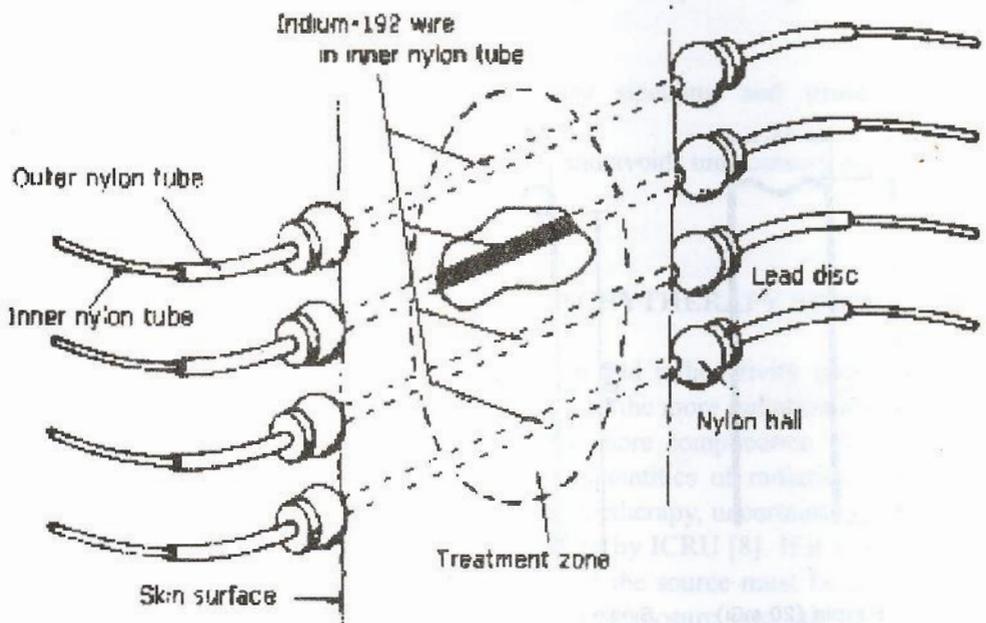


Figure 2. LDR Ir-192 brachytherapy wire sources produced by JAERI.  
 (Reproduced from [1])

The LDR wire sources are fit for not only interstitial brachytherapy for cancers of such as tongue, floor of mouth, rectum, breast, prostate, brain, head and neck but also for lung and gynaecological cancer etc. For the interstitial brachytherapy, plastic tube technique and guide gutter technique are commonly applied. Fig. 3 illustrates the implantation of iridium wires to secure in the target volume. Materials and tools for this technique are shown in Fig. 4. The guide gutter technique utilizing also the manual afterloading principles is rapid and convenient. The gutters are available either double or single for the hairpins or the single pins. Interstitial implantation of a hairpin using the double gutter is illustrated in Fig. 5.



**Figure 3.** Interstitial implantation of Ir-192 thin wire sources by plastic tube technique

## **PRESENT STATUS IN INDONESIA**

Since the first nuclear medicine unit started at Dr. Hasan Sadikin Hospital in Bandung in 1970, 15 facilities of nuclear medicine have been set in hospitals all over the Indonesia and among them 6 hospitals are being engaged in radiotherapy of various types of cancers by 1997 [10]. According to the 1991 statistics, the 10 most frequent tumors treated in Indonesia are, in top down order, uterine cervix, breast, skin, nasopharynx, lymph gland, ovarian, rectum, thyroid, colon and soft tissues. Most of them are possible to be treated by LDR brachytherapy technique.

In 1999, P2RR-BATAN and the Department of Radiotherapy of Dr. Hasan Sadikin Hospital started the cooperation in research and development of LDR brachytherapy including the meeting for introductory talk by the technical coordinator from JAERI and discussion at the hospital, application to the JICA's Group Training Course by two medical doctors from the hospital and trial irradiation of hairpin targets in the reactor MPR-30 and setting up the radiometric calorimeter system for quality control of source production.

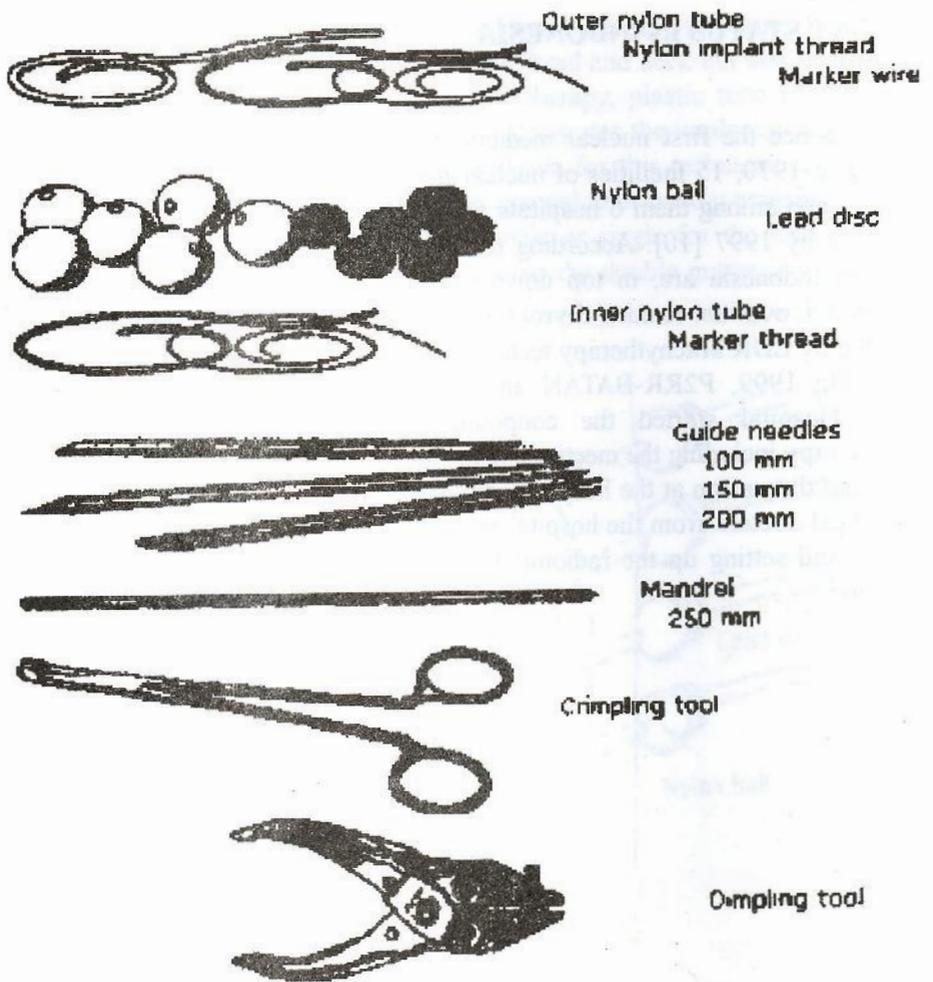
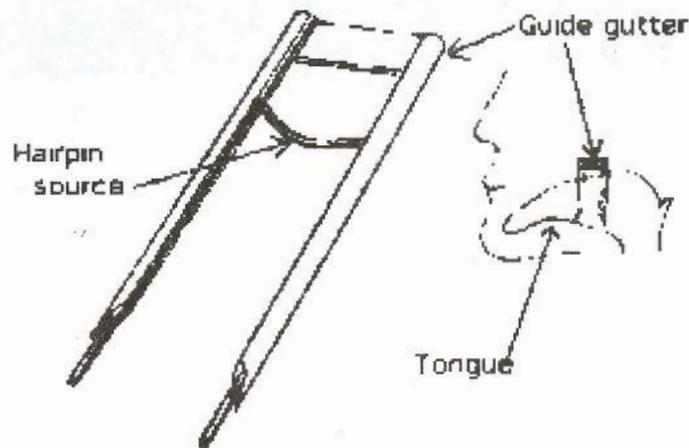


Figure 4. Materials and tools for the plastic tube technique

## PROCEDURES OF CLINICAL USE : IN CASE OF TONGUE CANCER

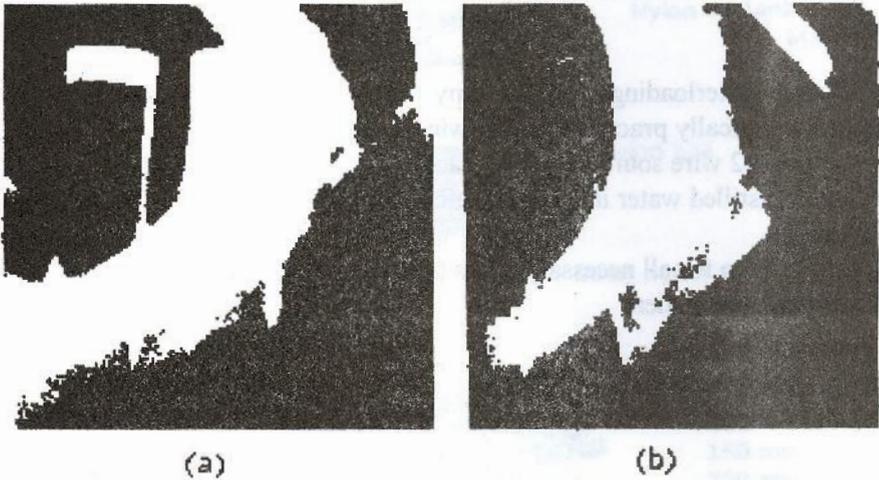
Manual afterloading brachytherapy for tongue cancer by guide gutter technique with hairpins is typically practiced as following procedures.

1. Immerse Ir-192 wire sources in 0.02% hibitane gluconate solution for one hour and wash with distilled water immediate before the implantation. Boiling sterilization must be avoided.
2. Gas sterilization for all necessary items (guide gutters, tools, gloves, threads etc.)
3. Full diagnosis of patient



**Figure 5.** Interstitial implantation of an Ir-192 hairpin source using a double guide gutter in case of tongue cancer treatment by the guide gutter technique

4. Patient taken into operation theatre
5. Surgical asepsis
6. Local anaesthesia (epinephrine added 2% xylocaine, ~10 mL)
7. Guide gutters introduced in and around the lesion (Fig. 6a)
8. Verification X-ray film



**Figure 6.** Verification X-ray images for tongue cancer treatment by guide gutter technique. (a) guide gutters (jawbone is seen), (b) implanted hairpins after removal of gutters. (Reproduced from [12])

9. Afterloaded with iridium-192 sources manually and guide gutters are removed (Fig. 6b)
10. Prescribe tumor dose and time duration based on computerized or manual dosimetry
11. Patient kept in a protected room during the irradiation (typically 4-7 days) with radiation care
12. On completion of irradiation, hairpins are removed
13. Wash hairpins with water and store for next use.

The minimum number of staff for this practice is two, an operator and an assistant. However, for monitoring the whole body condition, blood pressure check and TV monitor observation, another two, a doctor and a nurse, might be adequate to participate [12]. Figure 7 demonstrates an example of the five year survival rate (%) of tongue cancer by interstitial irradiation [15]. The survival rates are shown in accordance with different stages from T1 to T4, the index of disease development, and all cases. Notation "n" is the number of patients.

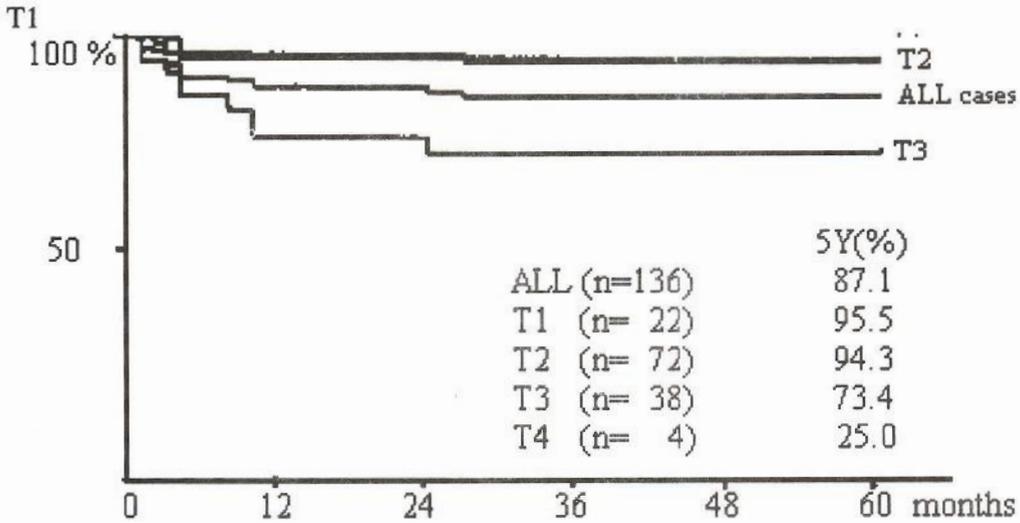


Figure 7. Five year survival rate of tongue cancer by interstitial irradiation. (Reproduced from [12])

## SUMMARY

The low dose rate brachytherapy has a potential of dissemination looking upon a number of advantageous characteristics as follows;

1. Efficacy of cancer treatment is almost identical between LDR and HDR.
2. Expensive sophisticated equipment is not necessary.
3. Heavy duty shielding room with interlock system is not necessary.
4. Price of the LDR source is 17 times lower than the HDR source.
5. Medium power irradiation and simple manufacturing process are enough.
6. Free from severe accident such as disconnection of cable welded to the source.

Development of the production technology for the LDR Ir-192 brachytherapy sources is to be encouraged to follow up the national strategy of science and technology in

Indonesia to contribute as much to the public welfare as possible.

The P2RR-BATAN has enough potential of technology and human resources to be engaged in all steps of production and quality control until distribution to hospitals.

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