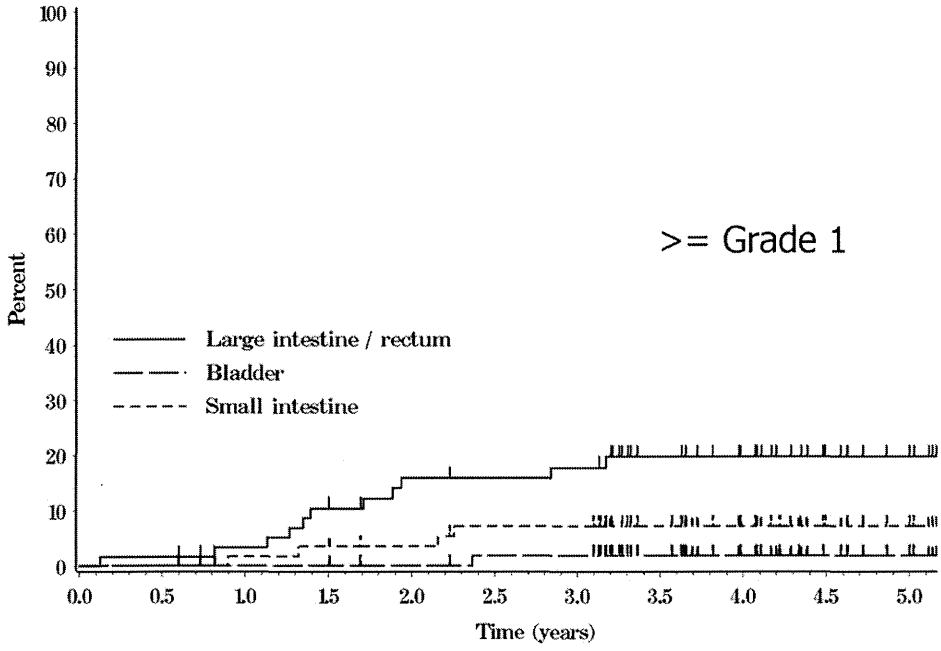

Fig. 4. Late complications (Grade ≥1) are shown for patients treated with definitive radiotherapy using HDR-ICBT with a low cumulative dose schedule (BED 62 Gy_{10} at point A).

even if such a low dose is not effective in treating bulky tumors.

In our study, acute and late toxicities were also evaluated prospectively. We assessed the incidence and grade of acute toxicities among our study patients as acceptable. Regarding late toxicities, no patient suffered severe gastrointestinal or genitourinary complications (Grade ≥3). We would consider this outcome to be a positive consequence of the low cumulative doses delivered to the central pelvis.

One potential limitation to our study was that the application of a MB might have introduced some degree of uncertainty with respect to the EBRT dose to the cervical tumor (38). This uncertainty resulted from the difficulty in confirming that the MB completely covered the cervix in every patient during every EBRT fraction in this study. Recently, onboard CT images have now become routinely available in clinical practice. Daily confirmation with this imaging device is feasible to confirm that an MB completely covers the cervical lesion.

CONCLUSIONS

In conclusion, the results of our study suggest that definitive radiotherapy consisting of whole-pelvis EBRT of 20 Gy/10 fractions, pelvic EBRT with an MB of 30 Gy/15 fractions, and HDR-ICBT of 24 Gy/4 fractions at point A (BED 62 Gy_{10}) is an effective and safe treatment for stage I and II cervical cancer patients with small (<4-cm) tumor diameter. Recently, the value of dose-volume histogram parameters for predicting local control in MR image-guided BT has been investigated for treating cervical cancer (39, 40). A future prospective study with the novel image-guided BT method using appropriate dose-volume histogram parameters is encouraged to confirm the findings of the present study in the near future.

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Source strength assay of iodine-125 seeds sealed within sterile packaging

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Early-stage prostate cancer is widely treated by iodine-125 (I-125) seed implantation. While quality assurance methods are in place to assure consistency in I-125 seed source strength, current methods involve the breaking of the sterilization package, raising issues concerning sterility and time limitations. The purpose of this study was to develop a method of characterizing the total source strength of I-125 seeds within a cartridge that has been sealed within a sterilization package and to evaluate the probability of detecting an out-of-calibration seed (aberrant seed). We defined a protocol to determine the ability of a well-type ionization chamber to detect aberrant I-125 seeds within a cartridge sealed in the sterilization package. A novel jig for a well-type ionization chamber was designed to accommodate the sterilization package. One seed was chosen randomly from two cartridges containing five or 15 seeds (0.544 U source strength) and was exchanged with aberrant seeds of six different source strengths. The source strength was measured at each position within the cartridge. The results indicated that the response of the well chamber was sensitive to changes in the aberrant seed position within the cartridge and the source strength of the aberrant seed. The correlation coefficient between single seed and batch assay results was high (0.998). A novel jig and a measurement method using a well ionization chamber were developed, which allowed for a batch assay characterization of the total source strength of I-125 seeds within a cartridge sealed within sterilization package. This method is simple, time-saving, and offers greater practical application.

PACS number: D6.20.Dk

Key words: batch assay, I-125 seeds, permanent implant brachytherapy, prostate cancer, sterile convenience pack

I. INTRODUCTION

Iodine-125 (I-125) permanent implant brachytherapy is a widely used modality in the treatment of prostate cancer.[1-5] Between 2003, when prostate brachytherapy was first introduced as a form of treatment in Japan, and 2010, a total of 15,427 patients were treated at 107 Japanese institutions.[6] The OncoSeed model 6711 (General Electric Healthcare, Barrington, IL) is the

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type of therapeutic I-125 seed used by most Japanese institutions and is delivered in a sterile convenient blister pack (SCBP). Currently used only in Japan, this form of SCBP, which contains a preloaded five-seed or 15-seed cartridge, was jointly developed by two companies (General Electric Healthcare and Nihon Medi-Physics, Tokyo, Japan) as an improvement on the conventional sterile convenient Tyvek pack (SCTP) (DuPont, Wilmington, DE) with respect to prevention of seed loss from the cartridge and damage to the sterilization package.

The American Association of Physicists in Medicine (AAPM) Task Group 64 recommended that institutional medical physicists perform seed calibration on at least 10% of the seeds in all shipments to satisfy the need for an independent assay of a random sample.[7]

However, there are several downsides to the evaluation of individual seeds. It is extremely time-consuming, involves exposing hospital personnel to frequent doses of radiation, and poses a challenge regarding the resterilization procedure. To meet these challenges, several batch assay methods have been developed, among which the two main approaches are the source holder approach and the cartridge approach. In the source holder approach, several seeds are removed from the cartridge and loaded in a source holder to allow the measurement of their source strength, typically using a well ionization chamber.[8-10] This method can assess the source strength of various seeds with one measurement, but the operators must return the seeds to the cartridge after the assay. The cartridge approach can assess the source strength using an imaging plate or a well ionization chamber, with the seeds still in the cartridge.[11-12] Although the cartridge approach can effectively assess the source strength while preserving sterilization, it requires the sterile inserts to be deployed in the operating room relatively close to the time of implant and, hence, poses the risk of seeds being lost and inserts being contaminated. These disadvantages have encouraged the development of a new method of characterizing the total actual source strength of I-125 seeds within a cartridge sealed in an SCBP and of evaluating the probability of detecting aberrant seeds. The purpose of this study was to develop a method that achieves these goals in a time-efficient manner without encountering the disadvantages of the other methods of measurement currently in use.

II. MATERIALS AND METHODS

A. Dosimetry methods and materials

A well ionization chamber (Capintec Inc., Ramsey, NJ; CRC-15BT Dose Calibrator) calibration standard for the OncoSeed model 6711 was obtained from the Japan Radioisotope Association (calibration uncertainty was 6.0% k = 2). The common single-seed assay was used to confirm the manufacturer's claims that the source strength among seeds varied by less than 5% (Table 1). Figure 1(a) shows the appearance of SCBP. The front of the SCBP is covered with plastic and

TABLE 1. Differences between the nominal value and actual value for each air-kerma strength.

Air-kerma Strength (U)			*Difference Between Nominal Value and Measurements Value (%)*
	Measurement Value		
Nominal Value	*Mean (Range)*	*SD*	*Mean (Range)*
0.544	0.543 (0.522–0.556)	0.009	-0.20 (-4.05–2.25)
0.460	0.461 (0.450–0.467)	0.005	0.14 (-2.26–1.60)
0.434	0.435 (0.420–0.450)	0.008	0.16 (-3.14–3.59)
0.395	0.401 (0.391–0.413)	0.005	1.60 (-0.97–4.49)
0.367	0.377 (0.366–0.385)	0.005	2.73 (-0.33–4.85)
0.336	0.336 (0.326–0.347)	0.006	0.23 (-2.57–3.50)
0.310	0.313 (0.304–0.323)	0.005	1.44 (-1.77–4.40)
0.285	0.285 (0.281–0.295)	0.003	-0.03 (-1.52–3.38)

Abbreviations: SD = standard deviation.

the back becomes the water-repellent machined cardboard. A batch assay method was performed using a novel jig, developed by the authors, to stabilize and hold the SCBP (Fig. 1(b)). The jig was made of transparent acrylic material and constructed with a depth adjuster. It was designed in such a manner that the seed cartridge was centered in the well ionization chamber. The top cover of the jig was therefore designed to have a double structure so that the jig would fit firmly into the well ionization chamber.

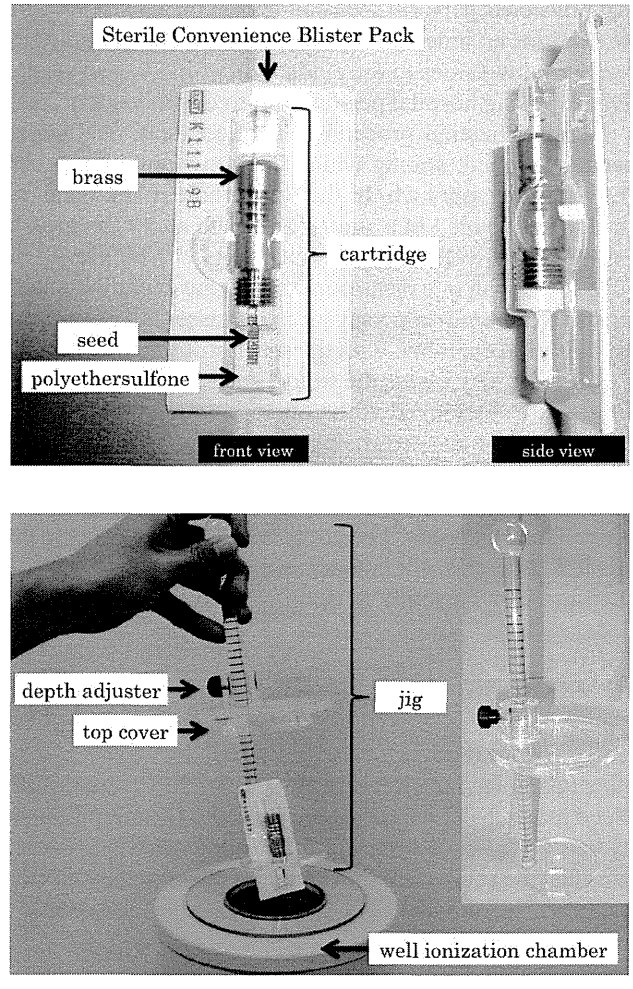

FIG. 1. Photographs showing (a) the front and side of the SCBP and (b) the novel jig specifically developed for use in this study.

B. Optimization protocol for the well-type ionization chamber

Two basic experiments were performed before evaluating the batch assay. The first was designed to determine the optimal measurement depth of the batch assay because certain well chambers are known to exhibit a depth-dependent response.[13] The second experiment established that the measured source strength was linearly dependent on the number of seeds.

In this study, the shielded cartridge often used to reduce the radiation exposure of the operator was used. The shielded cartridge was made of brass, while the upper and the lower parts of the cartridge were made of polyethersulfone. Therefore, the response of the well chamber was potentially influenced by the presence of the brass in close proximity to the seeds.

C. Position of the sample within the chamber

Two cartridges, one containing five seeds and the other containing 15 seeds within the SCBP, were set on the jig. The SCBP was set to a nominal depth of 0 cm, so that the top of the SCBP was touching the top cover of the jig. It was then lowered 7 cm in 0.5 cm increments, with a measurement acquired at each increment. The process was repeated three times.

D. Rate of diminution ratio within the cartridge

The 17 seeds, with a source strength of 0.434 U, were loaded in a cartridge and numbered in increasing order such that the seed at the bottom of the cartridge was labeled No. 1. The cartridge was then repackaged in the SCBP and attached to the jig in preparation for measurement using the well ionization chamber. A series of measurements was performed by reducing the number of seeds in the cartridge one by one. The measurement was repeated three times and before each repetition, the seeds in the cartridge were rearranged randomly.

E. Correlation between single-seed and batch assays

To determine whether the batch assay on an intact SCBP reproduced the standard single-seed assay, we calculated the correlation factor between the source strength of five-seed and 15-seed cartridges with single seeds. Eight different source strength seeds (source strength: 0.544, 0.460, 0.434, 0.395, 0.367, 0.336, 0.310, and 0.285 U) were evaluated to determine the correlation between the single-seed and batch assays, with the correlation for the five-seed and 15-seed cartridges being evaluated separately. The result of the single-seed assay was determined from the mean value of 15 seeds measured three times, while that of the batch assay was determined from the mean value of one batch measured three times. In the batch assay, after measurement of a 15-seed cartridge, ten seeds were pushed out from the cartridge, a five-seed cartridge was measured, and the seeds were exchanged and arranged randomly for every measurement.

F. Detection sensitivity of aberrant I-125 seeds

To investigate the impact of inclusion of an aberrant seed in the SCBP, one seed was chosen at random from two cartridges containing five or 15 seeds and exchanged. A seed with source strength of 0.544 U was used as the reference seed, and six seeds with different source strengths (source strength: 0.395 (73% of the 0.544 U), 0.367 (68%), 0.336 (62%), 0.310 (57%), 0.285 (52%), and 0 (0%) U) were used as the aberrant seeds. The position of each aberrant seed was interchanged at every possible position within the cartridge, and the source strength was measured at each position. The change in position of the aberrant seed was achieved by refilling the top of a cartridge seed pushed out from under a cartridge. Similarly, one seed was randomly selected from the reference seeds for measurement of its source strength when the position was changed.

G. Clinical application of the batch assay

To evaluate the clinical relevance of the proposed methodology, the batch assay method was used for source strength measurements at our facility. Measurements of 15 cartridges containing five seeds and 69 cartridges containing 15 seeds were made on a weekly basis on the same day. In our facility, the nominal manufacturer's source strength of 0.460 U is always used.

III. RESULTS

A. Impact of cartridge position on measured source strength

Figure 2 shows the changes in measured source strength as a function of depth normalized to a depth of 0 cm. The well chamber displayed sensitivity to the axial position in the signal output for a given source. Although no significant change from the source strength measurement at 0 cm was found at a depth of 2.5 cm, the measured source strength consistently decreased at depths beyond 2.5 cm, until it reached 84.3% and 85.7% of the original source strength at a depth of 7 cm in the five-seed and 15-seed cartridges, respectively. Based on this result, measurements were performed at a depth of 2 cm. The mean difference in measured source strength at 2 cm depth, as determined by the evaluation of three measurements, was found to be 0.6% (range: 0.2% to 1.0%) in the five-seed cartridge and 0.3% (range: 0% to 0.7%) in the 15-seed cartridge.

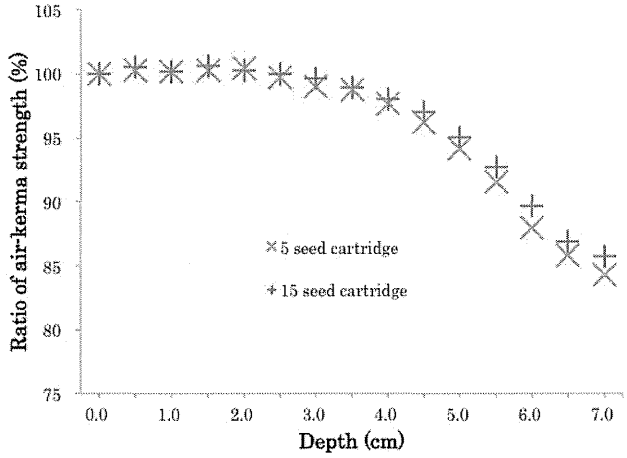

FIG. 2. Change in measured source strength with change in depth in the well ionization chamber. The data were normalized with reference to the measured level at a depth of 0 cm. The limit of the top cover of the jig, to which the SCBP could be mounted without interference, was calculated to be a depth of 0 cm.

B. Impact of seed number on cartridge measured source strength

The reproducibility of measurements for each seed was found to be 1.1% (range: 0.1% to 3.8%). The reproducibility of measurements in the five-seed cartridge and in the 15-seed cartridge was found to be 1.2% and 0.2%, respectively. Analysis of the correlation between the number of seeds and the mean source strength yielded a correlation coefficient of 0.999 for a third-order polynomial fit (Fig. 3). Despite this strong correlation, the rate of increase in source strength varied according to the source position in the cartridge (Fig. 4). The average (and standard deviation) of the increase in measured source strength in seeds No. 1 and No. 17 were 0.345 U ± 0.010 and 0.144 U ± 0.012, respectively.

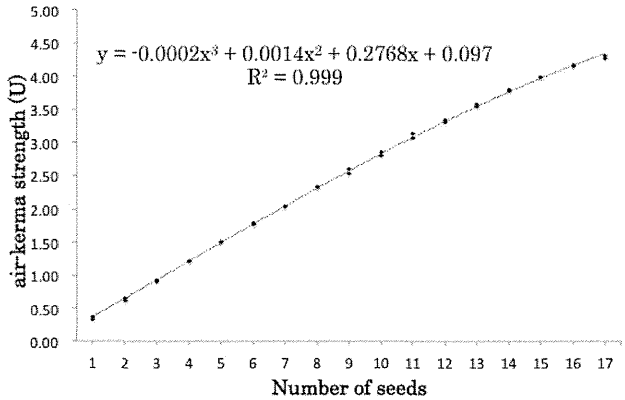

FIG. 3. Change in measured source strength with an increase in the number of seeds.

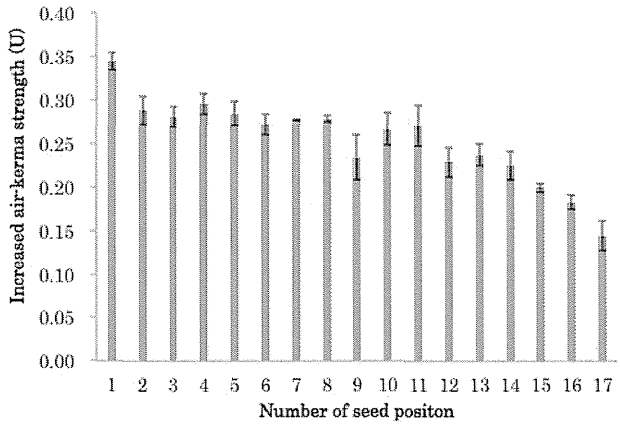

FIG. 4. The increase in mean measured source strength with the addition of each seed. The positions of the seeds were numbered such that the seed at the bottom of the cartridge was labeled No. 1.

C. Correlation coefficients for single-seed and batch assays

The measured source strength for various single seeds is plotted in Fig. 5. A correlation coefficient of 0.998 was determined between the batch and single-seed assay results for both the five-seed and 15-seed cartridges. The mean difference between the predicted source strength of the batch assay, as calculated using the regression formula, and the measured source strength of the five-seed cartridge was found to be 0% (range: -0.1% to 1.6%). In contrast, the 15-seed cartridge was found to be 0% (range: -2.6% to 1.5%).

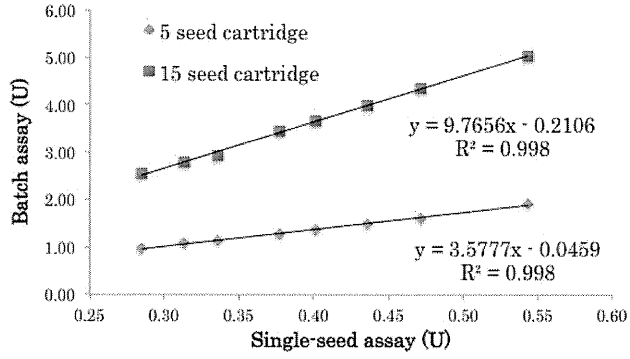

FIG. 5. Plot showing the source strength as determined by single-seed and batch assay for various seeds. Eight different source strength seeds (source strength: 0.539, 0.457, 0.429, 0.391, 0.364, 0.333, 0.306, and 0.282 U) were used.

D. Impact of an aberrant seed on the batch assay

Figure 6 shows the change in source strength when one seed was replaced with an aberrant seed. The mean differences between the theoretical source strength and the mean measured source strength of the five-seed and 15-seed cartridges were found to be -1.2% (range: -0.7% to 1.8%) and -0.3% (range: 0% to 0.6%), respectively. Figures 6(a) and 6(b) show the change in the source strength measured with a change in the position of an aberrant seed; the response of the well chamber was found to be sensitive to the position of the aberrant seed when using the batch assay method. The asymmetry in the 15-seed cartridge results may be due to the fact that the top of the cartridge is covered with brass and the bottom with polyethersulfone. Figures 6(c) and 6(d) change the x-axis of the data of 6(a) and 6(b) into the relative air-kerma strength of the aberrant seed. The 60% quintile range and the range of data are displayed, and the cross marker shows the theoretical source strength.

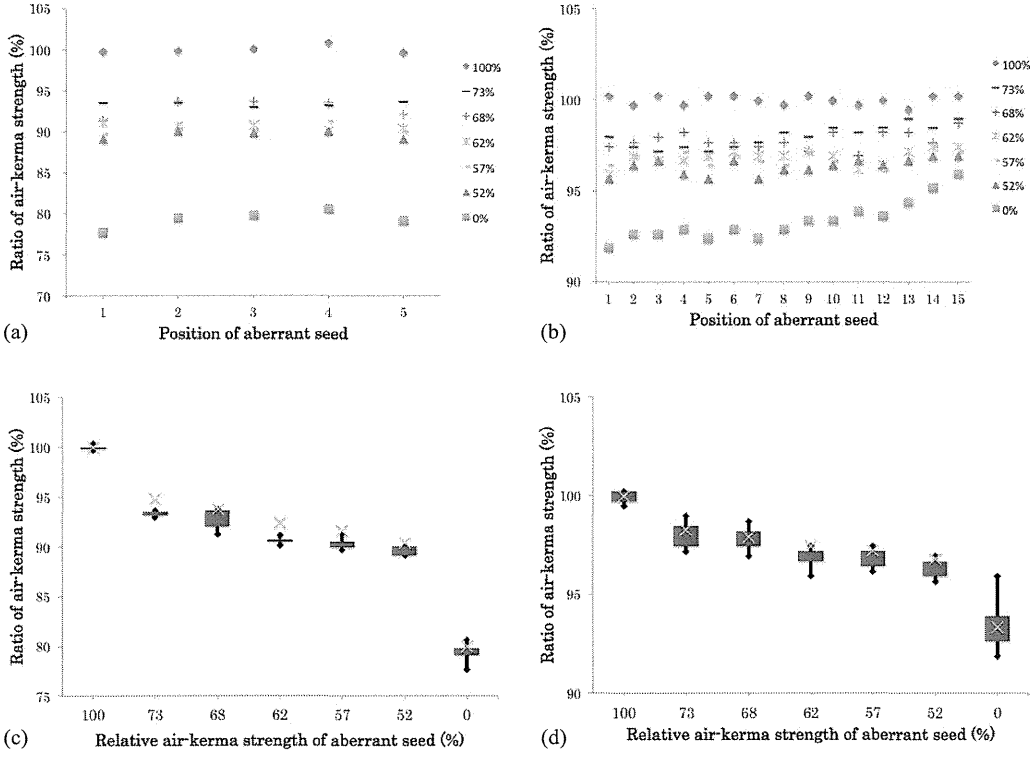

FIG. 6. Plots showing the change in source strength when one seed was replaced with an aberrant seed in (a) the five-seed cartridge and (b) the 15-seed cartridge, and the change in the measured source strength according to the position of the aberrant seed in (c) the five-seed cartridge and (d) the 15-seed cartridge. On the vertical axis, 100% refers to the mean relative source strength in the case when all the seeds in a cartridge were reference seeds. The 60% quintile range and the range of data are displayed. The cross marker shows the theoretical source strength. The theoretical source strength was calculated using the following equation: $(A \times (N - 1) + B) \times 100/A \times N$, where A is the mean source strength of the reference seeds, B is the mean source strength of each aberrant seed, and N is the number of seeds loaded in a cartridge (five or 15).

E. Clinical quality assurance tests

The predicted source strength from the batch assay of the five-seed and 15-seed cartridges, as calculated using the formula of the approximated curve, was found to be 1.60 U and 4.27 U, respectively. Figure 7 shows the measured source strength for the five-seed and 15-seed cartridges sealed within an SCBP. The mean difference between the predicted source strength and the measured source strength in the five-seed and 15-seed cartridges was found to be 0.6% (range: -2.9% to 2.0%) and -0.6% (range: -2.1% to 2.7%), respectively.

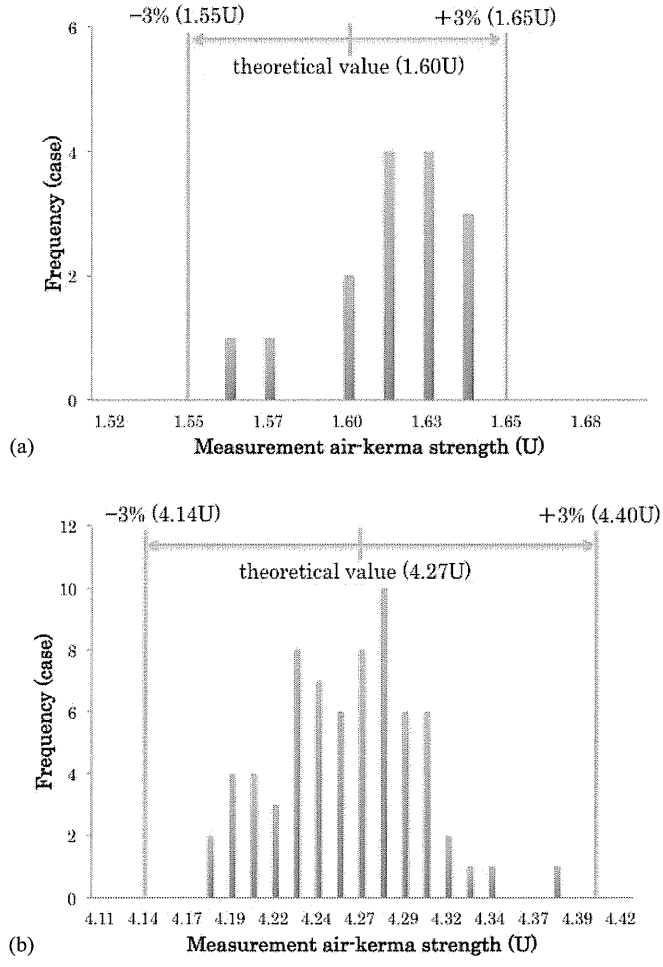

FIG. 7. Frequency histogram of the measured source strength in (a) the five-seed cartridge and (b) the 15-seed cartridge.

IV. DISCUSSION

In this study, a novel jig and a measurement method using a well ionization chamber were developed. This allowed for a batch assay characterization of the total source strength of I-125 seeds within a cartridge sealed within an SCBP. To the best of our knowledge, this study is the first to describe the use of a batch assay to measure the source strength of I-125 seeds with an SCBP. The method can be performed simply and quickly. However, to quantify the performance of the cartridge inspection schemes, Brame et al.[12] demonstrated that in an assay using a shielded 15-seed cartridge, the probability of detecting a missing or extra seed (i.e., a

cartridge containing 14 or 16 seeds) is higher than for a single-seed assay, or 10% of the seeds in a shipment.

The AAPM Low Energy Brachytherapy Source Calibration Working Group recommends that institutional medical physicists determine a source strength against which the measured source strength is evaluated when performing a batch assay. If a difference of more than 3% is found between the measured source strength of each cartridge and the reference value, the Working Group recommends the discrepancy be investigated. If a difference of more than 5% is found, consulting the manufacturer to resolve the difference is recommended.[14] None of the cases investigated in this study exceeded the 3% deviation from the reference value that is generally tolerated, using our batch assay on an intact SCBP (Fig. 7). However, the calibration uncertainty of the well ionization chamber used in this study is 6% (k = 2), so the difference from the normal value could exceed 5% even in normal cases, and even an abnormal reading may still be within the acceptable range. The AAPM TG138 indicates that in the calibration of a well ionization chamber by the University of Wisconsin Accredited Dosimetry Calibration Laboratory (ADCL), the propagation of best practice uncertainty is 2.56%.[15] In other words, if the calibration uncertainty of a well ionization chamber becomes small, the reliability of this quality assurance method will improve.

Figure 6 shows the change in the measured source strength when one seed is exchanged with an aberrant seed. The aberrant seed in the five-seed cartridge was easily detected when performing a batch assay. Nevertheless, the measurement method used in this study may fail to identify the aberrant seed because it cannot measure the source strength of each seed individually. For example, although the seed in position No. 15 in the 15-seed cartridge was dead, the measured source strength was found to have decreased by only approximately 4% (Fig. 6(b)). This finding suggests that the use of an unshielded cartridge would likely allow for improved detection.

Figure 4 shows the rate of increase in source strength according to the source position in the cartridge. The rate of increase for the measurements was high in the No. 1 position and large standard deviations were observed in positions 9–12. The position of No. 1 had a hole in the cartridge and there was no absorption by another source. The position of Nos. 9–12 was close to the SCBP holding portion of the jig, which would have influenced absorption by the jig.

In this study, seeds of a higher activity than the standardized source strength were not used as aberrant seeds. However, Figs. 6(c) and 6(d) indicate that measured source strength was changed by aberrant seed activity and that we took the theoretical value for five-seed cartridges. Therefore, even if higher activity aberrant seeds are used, they will follow a theoretical value.

Among the authors who have investigated different batch assay techniques, Lee et al.[8] recommended the use of a five-seed batch assay method with a plastic spacing holder and a well ionization chamber. Their study revealed that when exchanging a live seed with a dead seed, the measured source strength decreased by 20% with respect to the theoretical source strength. As shown in Figs. 6(a) and 6(c), the current study obtained similar results. Therefore, it can be assumed that our batch assay method has an equivalent dead seed location ability, even for seeds that are within the cartridge sealed in the SCBP.

Furutani et al.[11] proposed the use of an imaging-plate dosimetry system, in which they found a 0.999 correlation between the linear response of the source strength for a 15-seed cartridge and the overall source strength. Use of this method can allow for the simultaneous characterization of 100% of seeds in a sterile environment, but requires that sterile inserts be deployed in the operating room relatively close to the time of the implant.

The results of the study by Furutani and colleagues indicate that the method most likely to detect aberrant seeds in a time-efficient manner is one in which every cartridge in a shipment is measured, as does the method used in this study. Specifically, the method used in our study does not need to be performed in the operating room, poses no time limitations, and does not require resterilization. However, use of this method may pose a time penalty when the cartridge well chamber reading is out of the acceptance range, as the cartridge must be opened and the

seeds individually assayed if this is the case. Despite this, our method offers additional advantages including the decreased probability of seed loss and minimization of personal exposure to radiation.

V. CONCLUSIONS

We developed a novel jig for exclusive use with SCBP and carried out batch assays of source strength by using a well ionization chamber. This method is practical for all institutions needing to assay OncoSeed model 6711 seeds contained in an SCBP.

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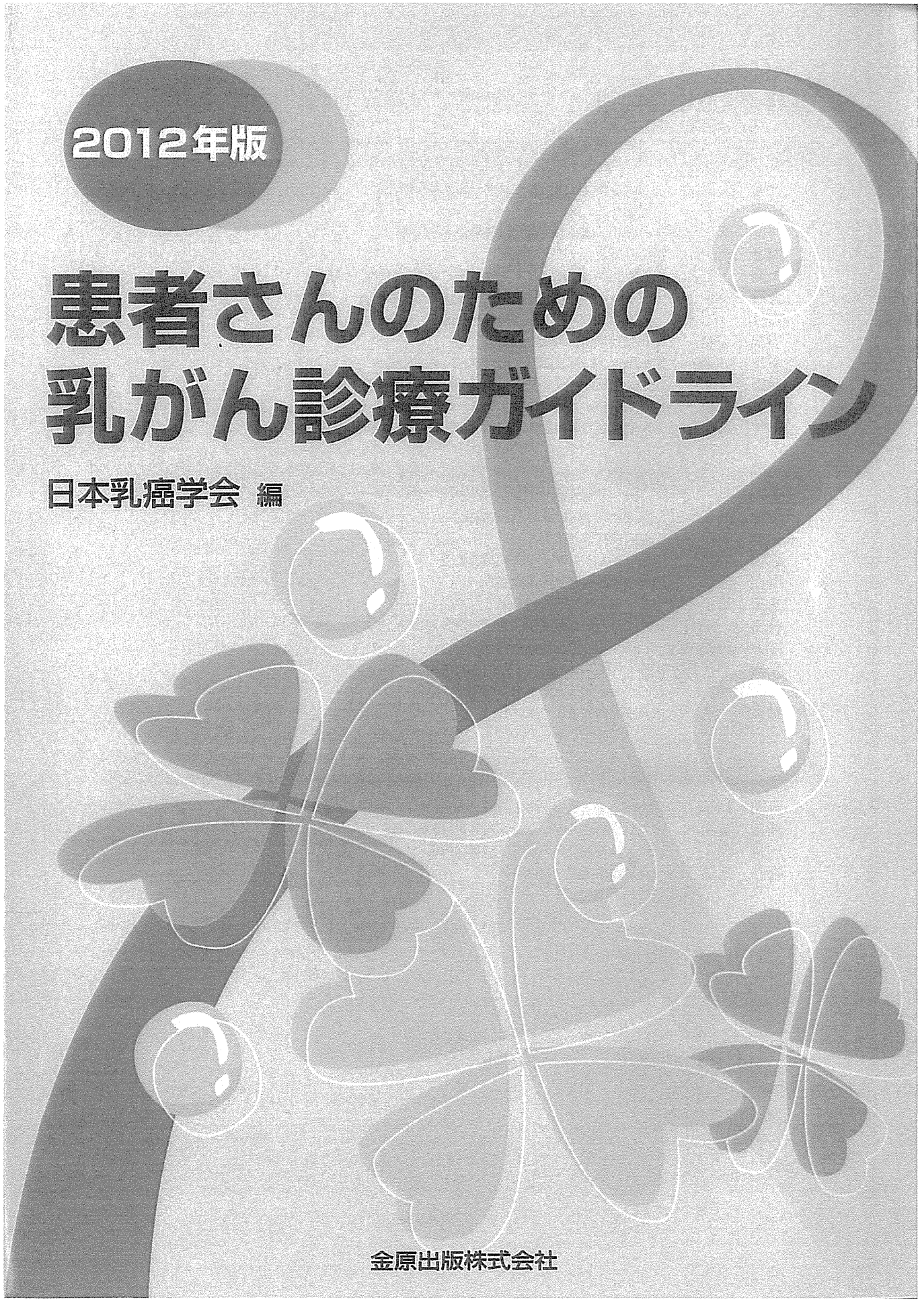
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放射線療法について教えてください。

A 放射線は細胞の中の遺伝子に作用してがん細胞を死滅させます。多くの場合，副作用は軽度で外来治療が可能です。ただし，原則として過去に治療したところに再び照射することはできません。

解説

放射線とはどのようなものでしょうか

電球や太陽は光線を出していて目にみえますが，放射線は目にはみえない光線のようなものです。放射線は宇宙から降り注いでいたり，自然界のいろいろな物質から出ていたりするので，私たちはほんの少しの量ですが，いつも放射線を浴びています。電球の光は熱を感じますが，放射線は熱くも痛くもありません。

放射線の種類はたくさんありますが，がんの治療に使われるのは，X線，γ（ガンマ）線，電子線などです。放射線と目にみえる光が大きく異なるのは，物質を通過する力です。目にみえる光は厚紙1枚でさえぎられて，人間のからだを通過することはできませんが，放射線は人間のからだを通過します。放射線がからだの中の細胞を通過するとき，細胞増殖に必要な情報が書いてある部分（遺伝子）にダメージを与えます。そうすると，細胞は増殖することができなくなって死滅します。放射線はがん細胞も正常細胞も通過するのですが，がん細胞のほうが放射線によるダメージを受けやすく，正常細胞はダメージを受けにくいうえにダメージを受けても回復しやすいため，がん組織を効率よく攻撃することができます。放射線療法では，主にリニアックやマイクロトロンという名前の治療装置を使いますが，これらは通常のX線写真を撮る診断装置よりも格段に高いエネルギーの放射線を発生させるので，からだの深部にある臓器でも効率的に攻撃，治療することができます。装置から放射線を出力し，からだに当てることを照射といいます。

放射線療法はどうやって進めるのでしょうか

まず，放射線療法の専門医が，患者さんが受けた検査（CTなどの画像検査，病理検査など）や治療（手術療法，薬物療法，過去の放射線療法など）の結果等をみながら，治療計画装置を使って，どこにどれくらいの量の放射線をかけたらよいかを決めます。次に，正確に放射線を照射するために，実際に放射線を当てる部分の皮膚だけでなく，いつも同じ体勢を取るための基準となるような線も消えにくいインクで印を付けます。この印は照射範囲を決める大事なものですので，治療が終わるまで付けておきます。色落ちすることも多いので，下着は色が付いてもよいものを着るとよいでしょう。そして，通常は1日に1回放射線をかけます。放射線をかけ

ている時間は1～2分程度です。

放射線療法は入院しなくても受けられますか

多くの放射線療法は外来治療が可能です。しかし，化学放射線療法（化学療法と放射線療法を同時期に行う治療法）の場合や，からだの具合がすぐれず通院がつらい場合（骨転移，脳転移など）には入院治療が勧められます。乳がんの場合，一般的には化学放射線療法は行いませんので，からだの具合がすぐれない場合以外は外来治療が多く行われます。通院の時間やスケジュール調整，放射線療法による疲労から，人によっては通常の就労が困難な場合があります。

放射線療法による副作用はどのようなものがありますか

放射線の副作用は，発生する時期により，急性期副作用と晩期副作用に分けられます。急性期副作用は，治療中から終了後まもなく現れる副作用です。また，晩期副作用は，照射が終わったあと数カ月以降に現れる副作用です。晩期副作用はいったん発生すると治りにくいという特徴があります。詳しくはQ34をご覧ください。

過去に治療したところに再び照射することができないのはなぜですか

患者さんの日常生活においては，放射線の副作用のうち，いったん発生すると治りにくい晩期副作用のほうがより注意が必要です。特に過去に治療したところに再び照射を行うと，初めての照射のときよりも晩期副作用が出やすく，放射線の効果よりもむしろ副作用が前面に現れる可能性が大きくなります。したがって，一部の例外を除いては一度照射したところには再照射しないというのが原則です。乳がんの場合，この例外となるのは脳転移に全脳照射（脳全体に照射すること）をした後の再発病巣に対する定位放射線照射（病巣だけをねらってピンポイント照射すること）や，一度治療を受けたあとに再び症状が悪化している骨転移に対する再照射などです。その他にも再度同じ場所に放射線照射が可能なこともありますが，再照射が可能かどうかの判断は難しく，放射線の副作用と効果を熟知した専門家が細心の注意を払いながら治療する必要があります。なお，過去に治療したところと別の場所であれば，ほとんど問題なく治療できます。

新しい放射線療法にはどのようなものがありますか

放射線を照射する範囲を乳房の腫瘍摘出部付近だけに絞って，1回に通常よりも強い放射線を照射し，治療回数を減らす治療が検討されています（加速乳房部分照射）。しかし，まだ十分には確立されておらず，現時点では基本的には勧められない治療と考えられています。照射される放射線量をコンピュータ制御により適切に配分する強度変調放射線治療（IMRT）という治療法も試みられることがありますが，治療費用が高い，治療準備に日数を要する，普通の放射線療法でも安全かつ効率よく治療ができている，などの理由で，現時点では乳がんではあまり利用される

ことはありません。

その他，最近，陽子線や重粒子線という特殊な放射線を使った治療が種々のがんに対して行われるようになってきました。しかし，まだ限られた施設でしか行われておらず，健康保険の適用もありません。乳がんはからだの表面近くにあり，X線や電子線によって安全かつ効率よく治療できますので，これらの治療は適応にはなりません。