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RADIOLOGY CASE REPORTS

Case Report

Embolization of prostatic brachytherapy seeds to pulmonary arteries: a case study

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ABSTRACT

Pulmonary seed embolization is a complication of prostatic brachytherapy with varying incidence rates. Key factors that reportedly influence the incidence of seed embolization include planning volume, quantity of seeds, seed placement, and type of seeds (stranded vs free). The clinical implications of seed migration are unclear because sequelae were not demonstrated in multiple short-term studies yet there have been several reports of long-term complications. We report a case of a 56-year-old patient who presented with dyspnea approximately 6 years after brachytherapy treatment for a very low-risk prostate cancer. Chest radiograph showed multiple linear densities overlying the right suprahilar lung. Computed tomography confirmed the location of the densities within the pulmonary arteries in the right upper lobe.

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Case report

A 56-year-old African American male former smoker was referred to urology for a rising prostate-specific antigen and a history of decreased force of stream and hesitancy. Transrectal ultrasound with sextant biopsies revealed a moderately differentiated adenocarcinoma with a Gleason score of 6 (3 + 3) without evidence of local invasion. Clinically staged as T1c N0 M0, the carcinoma was considered very low risk and low dose-rate (LDR) brachytherapy as monotherapy was indicated. A total of 88 stranded brachytherapy seeds were implanted anteriorly to posteriorly using transrectal ultrasound and fluoroscopy (Fig. 1). At the end of the procedure, x-ray and ultrasound were used to assess for aberrant seeds, and a cystoscopy revealed no misplaced seeds within the bladder.

One month after the procedure, a computed tomography (CT) of the pelvis without contrast showed multiple implant seeds within the prostate gland (Fig. 2). Postoperative dosimetry was also performed and demonstrated dose volume values that were lower than expected. The minimum planned dose was 145 Gy, yet the patient had a dose volume of 137.67 Gy, or 94.94% of planned dose, and a V100 of 87.38%. The dose reduction was attributed to breaks in the dose distributions, or isodose lines, at the base of the prostate.

Approximately 6 years later, the patient presented to his primary care provider complaining of dyspnea and due to his history of prostate cancer, a chest radiograph was ordered to assess for metastasis. The chest radiograph revealed multiple linear metallic densities overlying the right suprahilar lung suggestive of involvement in the ascending branches of the
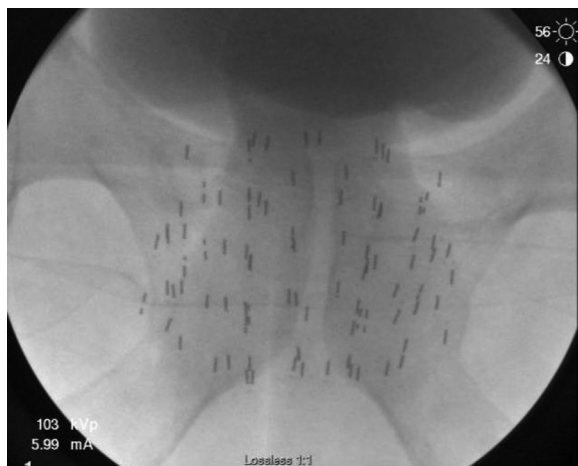
Fig. 1 – A 56-year-old male with brachytherapy seeds in prostate. Technique: Fluoroscopy. Findings: Operative fluoroscopy was used for assistance in brachytherapy implantation seeds within the prostate. Approximate fluoroscopy time was greater than 1-hour standard.

right upper pulmonary artery. Additional findings included scarring of both lung bases and slight hyperexpansion (Fig. 3). A thoracic CT without contrast confirmed that the densities were located within the pulmonary artery branches of the right upper lobe and also demonstrated moderate centrilobular emphysematous changes predominantly in the upper lobes (Fig. 4). The patient exhibited a significantly higher seed migration rate (8%) than those demonstrated in published studies (~0.08%). Management of care was directed by the primary care provider and did not include a further workup within our health care system.

Discussion

Etiology

Prostate brachytherapy requires placement of radioactive sources or seeds within target tissue and provides a high-radiation dose to the tumor with only a modest dose to surrounding normal tissue. The standard technique uses either a transrectal or transperineal ultrasound-guided approach to visualize placement of the radioactive seeds. Permanent implants are commonly used to provide LDR radiation with a high total dose, which is indicated in low-risk and select low-volume intermediate-risk prostate cancers [1].

Steinfeld et al. were the first to report pulmonary seed embolization as a complication after prostatic brachytherapy [2]. Ensuing studies varied in tumor and patient characteristics but have determined that key parameters influencing the incidence and rate of seed embolization included planning volume, the number of seeds, seed placement, and type of seeds (stranded vs free) [3–5]. The planning volume determines the number of seeds required for implantation, thus an increased planning volume requires a greater quantity of seeds. Merrick et al. found that planning volume and seed quantity of the brachytherapy plan correlated with local seed loss and raised the overall probability of seed migration [5]. Seed placement is a major factor in developing a brachytherapy plan, and current techniques are generally based on peripheral loading to reduce the dose to the urethra [4]. Unfortunately, prostatic tissue is an unpredictable matrix, and seeds implanted close to the prostatic margin can shift into the dense venous plexus surrounding the prostate resulting in distal site migration [2]. Additionally, seed placement never completely mirrors the ideal plan, and a margin of error is expected [6]. Another risk factor for embolization is the type of seeds used for the brachytherapy. Because stranded seeds were introduced over a decade ago, free seeds are used less frequently in prostatic brachytherapy [7]. Stranded seeds have a tissue absorbable suture linking the seeds together and absorption occurs between 60 and 90 days postoperatively, which is adequate time for epithelialization to occur [4]. Multiple studies have demonstrated the effect of stranded seeds to substantially lower the incidence of seed migration, particularly to the lung. At dose delivery, 5.5% of cases with free seeds had seed migration, whereas those with stranded seeds had no migration initially. After 4 months, 25.3% of cases with free seeds demonstrated a migration versus only 3.8% of those with stranded seeds. Although seed embolization had a considerable incidence, only 24 of 31,856
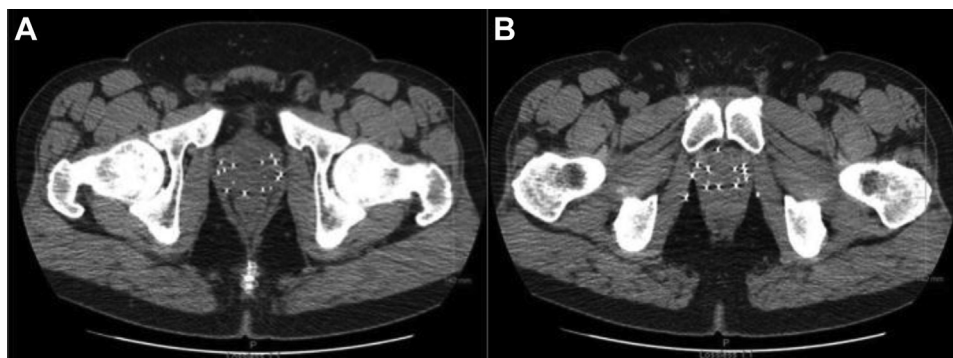

Fig. 2 – A 56-year-old male with brachytherapy seeds in prostate. Technique: Axial computed tomography (CT) of pelvis without contrast. A 2.5-mm contiguous imaging was obtained. Findings: Multiple small densities within the prostate gland consistent with radiation implant seeds. Superior (A) and inferior view (B) provided.
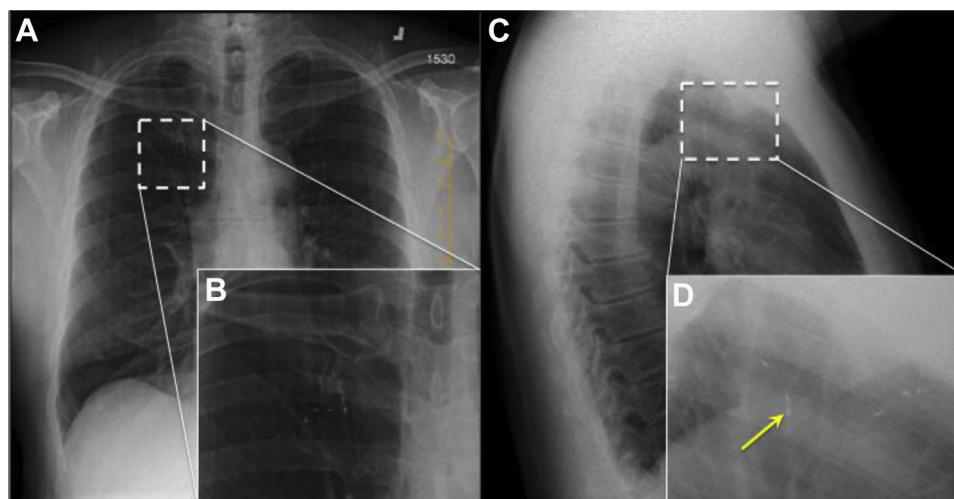
Fig. 3 – A 56-year-old male with brachytherapy seed migration. Technique: Frontal (posterior to anterior technique) and lateral chest radiograph. Findings: Frontal chest radiograph demonstrates six migrated brachytherapy seeds in right suprahilar lung (A), which is better illustrated in a magnified view (B). Lateral chest radiograph demonstrates seven brachytherapy seeds located in right suprahilar lung suggestive of involvement in the ascending branches of the right upper pulmonary artery (C). Two seeds are adjacent to each other and best appreciated in a magnified view (yellow arrow in D).

stranded seeds migrated to the pulmonary vasculature. Owing to the variation between studies in the timing of postimplant films, the total number of migrated seeds is likely higher than reported because most of the seeds were from a study that evaluated migration before suture resorption and reported no seed migration. In the two studies that evaluated for migration after 90 days, stranded seed migration to the pulmonary vasculature was more common (16.8% of cases, 0.2% of implanted seeds) and is likely a better indicator of true seed migration [8].

Imaging findings

Brachytherapy seeds are tiny, linear seeds with a silver or titanium shell that create a distinct radiopaque pattern easily identified on chest radiographs. Despite the unique pattern, visualization may be influenced by several factors to include obstructed visibility in high-attenuation regions [9]. Computed tomography (CT) of the chest depicts brachytherapy seeds as punctate hyperdense attenuations with streak artifacts which can obscure the image and limit soft-tissue contrast near the seeds [10]. CT is useful in the detection of radiation-induced lung disease and exact localization of the seeds; however, the chest radiograph provides greater appreciation of seed appearance [11,12].

Treatment and prognosis

One concern of brachytherapy seed embolization is the dose reduction to the prostate gland. Studies have shown that <1% of all implanted brachytherapy seeds migrate (0.34% for free seeds and 0.08% of stranded seeds) which indicates that even in embolization cases, the vast majority of seeds remain within the prostate and have little to no impact on the dose [8].

Additionally, Lee et al. demonstrated that stranded seeds had increased activity per unit volume and significantly improved dosimetry quantifiers when compared to free seeds (mean V100 for stranded was 94.10% compared to 86.54%) [13]. Although both groups achieved adequate dosing, the dosimetry differences were due to local seed loss and the greater propensity for free seeds to migrate. In our case, the patient had a significant migration rate of 8% of implanted seeds, yet the radiation dose remained adequate for treatment with a V100 of 87.38%.

An additional concern of seed embolization includes iatrogenic irradiation, particularly within the first few months after the procedure. Although retrospective studies are lacking, the average energy of 28 keV for 125-I could potentially cause irradiation damage to nonrenewing tissues and predispose to adverse sequelae to include pneumonitis and carcinogenesis [4]. Several studies have demonstrated that multiple seed emboli can damage normal lung tissue in limited volumes because dose distribution varies based on lung tissue density [14,15]. In fact, several reports have described serious adverse outcomes to include radiation pneumonitis, small-cell lung cancer, and an acute myocardial infarction without evidence of a shunt [16–18]. Although the incidence rates varied between studies due to seed placement techniques and timing of postimplant imaging studies, none showed any identifiable short-term sequelae. Ankem et al. suggested that if postimplant chest x-rays reveal seed migration, patients should be informed and followed on a long-term basis with chest radiographs and pulmonary function studies [14]. In our particular case, the patient presented years after brachytherapy with dyspnea and an incidental finding of multiple brachytherapy seeds within the pulmonary vasculature. The embolized seeds could not be directly attributed as the cause of the patient's symptoms but
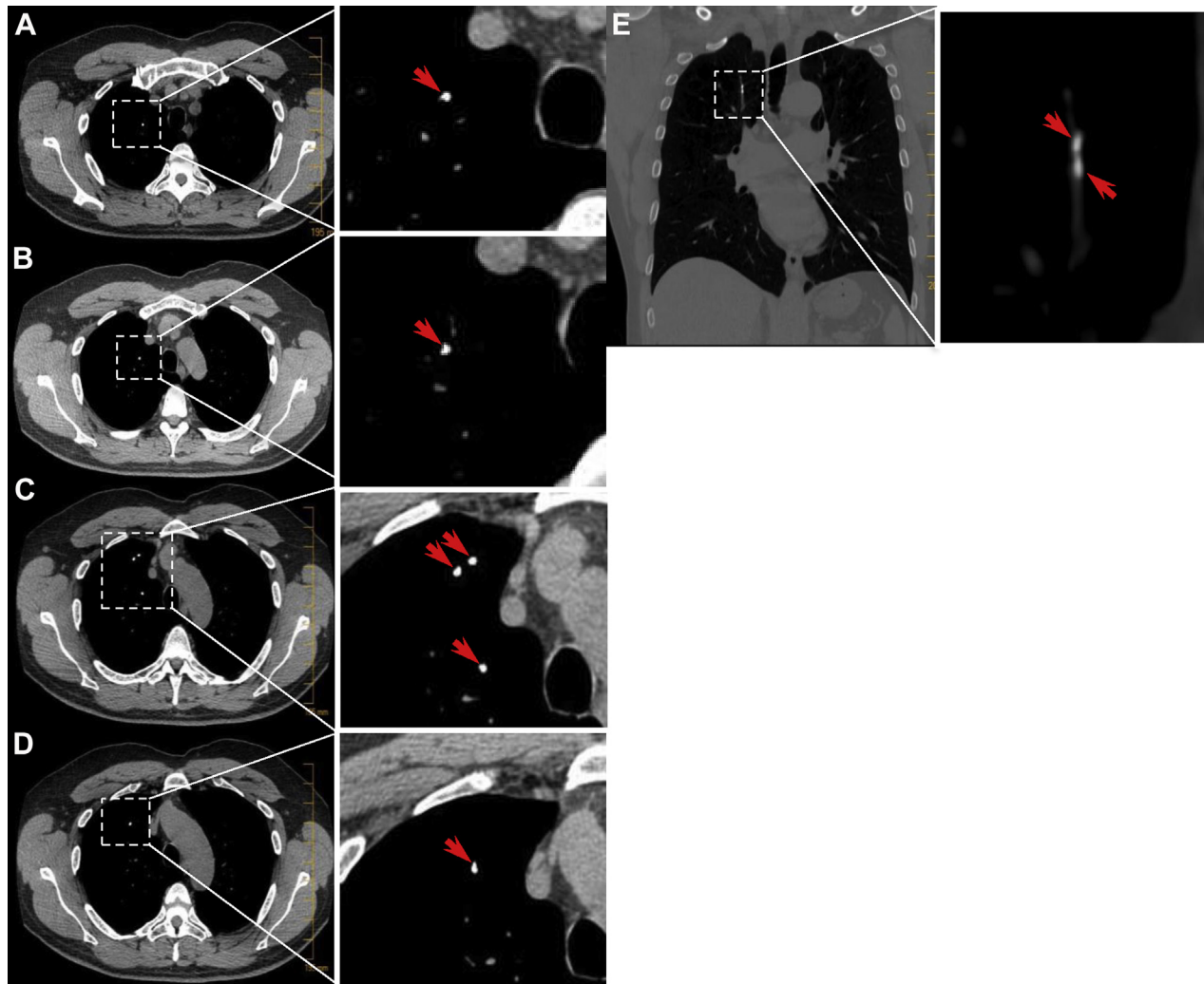
Fig. 4 – A 56-year-old male with brachytherapy seed migration. Technique: Axial and coronal CT images of the thorax without contrast. Findings: Seven brachytherapy seeds (two of which are adjacent to one another in (B)) located within the pulmonary artery branches of the right upper lobe (red arrowheads). Moderate centrilobular emphysematous changes predominately in the upper lobes. Images oriented from superior (A) to inferior (D). Two brachytherapy seeds adjacent to one another within the pulmonary artery branches of the right upper lobe (E).

there was minimal impact if that were the case. Additionally, a postimplant chest x-ray or CT would not have changed the course of management for our patient and would therefore be unwarranted.

Differential diagnosis

The differential diagnosis of brachytherapy seed migration to the pulmonary arteries includes foreign objects, segmental atelectasis, and emboli from iodized oil, acrylic cement, or metallic mercury. Foreign objects consisting of metallic materials or glass are radiopaque and easily detected on radiograph [12]. Segmental atelectasis may present as broad, linear opacities that could give the appearance of brachy-therapy seeds but typically conforms to the anatomic distri-bution of bronchopulmonary segments rather than the course of pulmonary vessels [19].

Iodized oil, or lipiodol, is used in the management of iodine deficiency and locally unresectable hepatocellular carcinoma to promote chemotherapy retention. Embolization is a complication of the treatment and can appear in the upper lobes as multiple radiopaque densities without evidence of pulmonary parenchymal abnormality. When compared to the surrounding vasculature, the hyperdense segments of the pulmonary vasculature will have a plaster-cast-like appearance [20].

Pulmonary cement embolism can occur after percutaneous vertebroplasty as a result of leakage of polymethylmethacrylate, an acrylic cement, into the peri-vertebral venous system, and subsequently, the inferior vena cava. The emboli appear as multiple high-density opacities in a tubular branching pattern scattered sporadically or distributed diffusely throughout the lungs corresponding to pulmonary arterial distribution [21,22].

Embolization of metallic mercury is very rare and usually caused by deliberate injection of mercury into a peripheral vein from a suicide attempt or drug abuse. Metallic mercury emboli are usually asymptomatic and appear as small globules in the peripheral branches of the pulmonary arteries, sometimes as beaded chains filling pulmonary arterioles [23,24].

Teaching point

After a prostatic brachytherapy procedure, seed embolization to the pulmonary vasculature is a potential complication with the greatest risk within 90 days of placement. Because brachytherapy has assumed an increasing role in the management of early-stage prostate cancer, providers should be aware of the complication and understand that the clinical implications are minimal at worst based on current studies and our particular case; therefore, screening and monitoring are unnecessary.

Acknowledgment

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