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The effect of metallic tracheal stents on radiation dose in the airway and surrounding tissues

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ABSTRACT

Background: Metallic airway stents are often used in the management of central airway malignancies. The presence of a metallic foreign body may affect radiation dose in tissue. We studied the effect of a metallic airway stent on radiation dose delivery in a phantom and an *in vivo* porcine model.

Methods: A metallic tracheal stent was fitted onto a support in a water phantom. Point dosimeters were positioned in the phantom around the support and the stent. Irradiation was then performed on a linear accelerator with and without the stent. Metallic tracheal stents were deployed in the trachea of three pigs. Dosimeters were implanted in the tissues near (Group 1) and away (Group 2) from the stent. The pigs were then irradiated, and the dose perturbation factor was calculated by comparing the actual dose detected by the dosimeters *versus* the planned dose.

Results: The difference in the dose detected by the dosimeters and the planned dose ranged from 1.8% to 6.1% for the phantom with the stent and 0%–5.3% for the phantom without the stent. These values were largely within the manufacturer's specified error of 5%. No significant difference was observed in the dose perturbation factor for Group 1 and Group 2 dosimeters (0.836 ± 0.058 *versus* 0.877 ± 0.088, $P = 0.220$) in all the three pigs.

Conclusions: Metallic airway stents do not significantly affect radiation dose in the airway and surrounding tissues in a phantom and porcine model. Radiation treatment planning systems can account for the presence of the stent. External beam radiation can be delivered without concern for significant dose perturbation.

All work was performed at St. Luke's–Roosevelt Hospital Center, October 10, 2010 to January 11, 2011.

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1. Introduction

Tracheobronchial stenting with or without endobronchial tumor resection is at the forefront of palliative care of malignant central airway obstruction. Restoration of airway patency provides immediate improvement of symptoms and performance status of patients with critical airway obstruction. After stenting with external beam, radiation therapy provides local tumor control and prevents further complications such as bleeding or stent infiltration by tumor. This approach has been shown to provide rapid and durable symptom relief for patients in respiratory distress from central airway malignancies [1–5].

Since the development of the silicone T-tube by Montgomery in 1965, the physical and biomechanical properties of stents have improved significantly [6]. The new generation of airway stents is based on a metallic framework with or without polyurethane covering. The most common metal used is nitinol, an alloy of aluminum and titanium. This composition allows for adaptive contouring of the stents to the complex anatomical distortions of the airways due to malignant obstruction [7–9].

Although stenting has become an important part of the management algorithm for malignant airway obstruction, it is unclear how the presence of metallic stents affects the local delivery of radiation [10–12]. The close proximity of the central tumors with airway stents raises concerns about dose scatter and attenuation of radiation at the interface between the metallic stent and the surrounding tissue. This may affect radiation dose to the tumor and surrounding tissues, possibly compromising local control or predisposing the patient to normal tissue complications [13,14].

These metallic prostheses are theoretically accounted for by radiation treatment planning systems. However, few studies have actually evaluated the effects of a metallic stent on local delivery of radiation *in vivo*. Most studies to date have been conducted with water or plastic phantoms to substitute for tissue in radiotherapy measurements. These *in vitro* phantom studies have shown that the metallic stents can alter dose delivery to the surrounding tissues [15–17]. However, the clinical relevance of this is uncertain, and no study has thus far evaluated the effects of a metallic stent in the airway on radiation dose *in vivo*.

The aim of this study was to assess the effects of metallic stents on radiation dose distribution by comparing the calculated radiation dose with the actual dose received *in vitro* and *in vivo*, as measured by metal oxide–semiconductor field-effect transistor (MOSFET) OneDose (Sicel Technologies, Morrisville, NC) point dosimeters. MOSFET dosimeters have been shown to be a valid measure of radiation dosimetry in a number of studies [18,19]. A phantom model was used for *in vitro* experiments, and a porcine model for *in vivo* studies. In addition, a modern computed tomography(CT)–based planning system was used for dose planning for the *in vivo* experiment.

2. Materials and methods

The experiments were divided into *in vitro* phantom experiments and *in vivo* animal experiments.

2.1. Phantom experiments

A phantom model was constructed with a cylindrical support inside of a water phantom at 5 cm depth. An AERO Tracheobronchial Stent (Merit Medical Systems, Salt Lake City, UT) was fitted onto the cylindrical support (Fig. 1). MOSFET dosimeters were positioned in the phantom at specified locations around the cylindrical support and stent. Two MOSFET dosimeters were placed at 5 cm depth posterior to the stent, one on each side lateral to the stent, and one anterior (upstream from the stent) (Fig. 2). The expected dose to the isocenter and each dosimeter was calculated using Radcalc version 6.1 (Lifeline Software Inc, Tyler, TX) for 300 monitor units based on 95 cm source-surface distance and depth in the phantom. Irradiation was then performed on a Varian iX778 Linear accelerator (Varian Medical Systems Inc, Palo Alto, CA). The phantom was set up at 95 cm source-surface distance on the accelerator table. Three hundred monitor units were delivered with a 6 MV photon beam. The MOSFET dosimeters were then removed from the phantom, and the dose was measured.

As a control, the previously mentioned procedure was repeated using the same phantom without the stent. These measurements were performed for MOSFET dosimeter dose verification. MOSFET dosimeters were placed at the same positions relative to cylindrical support without the stent in place and irradiated in identical fashion. The MOSFET dosimeters were removed after irradiation, and the dose received was measured.

2.2. Animal experiments

The study was approved by the Institutional Animal Care and Use Committee and the Institutional Review Board of St. Luke's-Roosevelt Hospital Center (approval number BH0433.00). The animal experiments were carried out using three Yorkshire pigs (25–35 kg each). Pig models of approximately 25 kg were chosen, as their bronchial size approximates that of human adult of 60–70 kg. Propofol and inhalational anesthesia were used to induce and maintain anesthesia, and fiber-optic intubation was performed with a size 9-mm endotracheal tube. Airway assessment was then performed with a flexible video bronchoscope (KARL STORZ Inc, El Segundo, CA). A 0.035-inch guidewire was then passed through the endoscope, and the distance measured from the endotracheal tube. After taking all the measurements, 16 × 40 mm AERO Tracheobronchial Stent System was

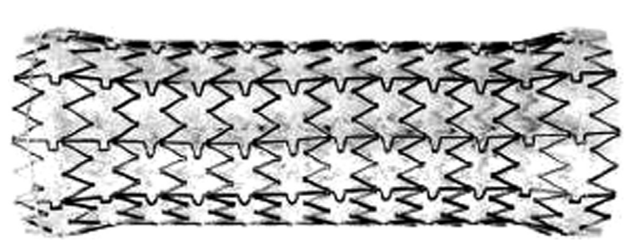

Fig. 1 – AERO tracheobroncheal stent composed of nitinol with polyurethane covering.