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# The physical and biomedical characteristics of the novel transmission type X-ray equipment

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## HIGHLIGHTS

- The transmission-target X-ray system had a higher X-ray production rate.
- The transmission-target X-ray system had more obvious output of K characteristic radiation.
- The transmission-target X-ray enhanced rose bengal induced cytotoxicity in liver cancer cells.

## ARTICLE INFO

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## ABSTRACT

The radiation output characteristics of the transmission-target X-ray tube are different from those of the traditional reflection-target X-ray tube. The aims of this study were to compare the differences of output dose and spectrum between these two X-ray tubes under the same conditions. The biomedical applications of the transmission-target X-ray in liver cancer cells were also evaluated. For these two systems, the dose output and the mAs appeared to have good linear relations; the dose output and kVp variations also had positive relations. However, under the same parameters, the dose output of transmission-target X-ray system was 2.64–3.21 times higher than the reflection-target system, implying that the transmission-target system had a higher X-ray production rate. The K characteristic radiations reach 22.96% and 8.91% of the spectrum in transmission-target and reflection-target, respectively. The spectrum measurements showed that the transmission-target system had more obvious output of K characteristic radiation. The 1 Gy of transmission-target can induce 16%–23% of cytotoxicity in liver cancer cells. Concerning the synergic effects of transmission-target combined with rose bengal, the data showed that 1 Gy of transmission-target exposure augment the 24%–28% of cytotoxicity at low dose of rose bengal treated condition.



## 1. Introduction

The transmission-target X-ray tube increases the X-ray production rate and reduces the heat energy [Harding et al., 2007]. The cathode of the transmission-target X-ray tube releases electrons which hit the thin target, and X-ray comes out directly from the end-window in front of the metal target (Fig. 1a). Electrons generated by a hot filament after the focus will direct bombing at La target. Angle distribution of X-rays was more than 180°. When the operating conditions are 80 kV, 100 uA, 150 s, the temperature of the target will rise to 270 °C. For the traditional reflection-target X-ray tube, when the cathode gets energy and releases electrons, the electrons are accelerated to hit the target. The radiation produced is released from the side-window (Fig. 1b), and the 90% photon spectrum is shown in the form of bremsstrahlung [Chen et al., 1980]. This traditional reflection-target X-ray tube showed that only 1% of the incident electrons energy will be transformed into X-ray energy and the other 99% will transform into heat energy [Nicholas, 1930].

Primary hepatocellular carcinoma is the fifth most common malignancy worldwide and the third leading cause of cancer-related death [Ferlay et al., 2010]. Sorafenib is the most frequently

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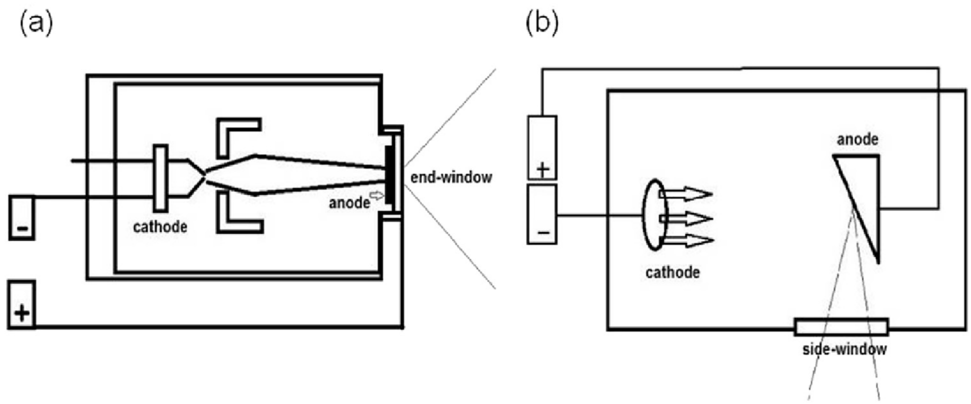


**Fig. 1.** (a) Diagram of transmission-target X-ray tube; (b) Diagram of reflection-target X-ray tube.

used drug for liver cancer, however, Sorafenib just can extent 3 months of survival. Rose Bengal is a water-soluble xanthene dye that had been previously used in liver function studies and is still in use by ophthalmologists [Machado et al., 2009]. Several in-vitro studies showed the direct cytotoxicity of rose bengal in ovarian and sarcoma cancer cells [Koevary, 2012]. This study aimed to compare and analyze the differences of output dose and spectrum between these two X-ray tubes. The cytotoxicity effects of the transmission-target X-ray in liver cancer cells were also evaluated.

**Table 1**
Relationship of output dose (mGy) of the transmission-target X-ray tube and reflection-target X-ray tube under the same parameters.

| | 1.2 mAs | | 1.8 mAs | | 2.4 mAs | | 3 mAs | |
|---|---|---|---|---|---|---|---|---|
| | R※ | T* | R※ | T* | R※ | T* | R※ | T* |
| 50 kVp | 0.11 | 0.37 | 0.16 | 0.52 | 0.21 | 0.65 | 0.25 | 0.80 |
| 60 kVp | 0.18 | 0.53 | 0.26 | 0.75 | 0.33 | 0.98 | 0.41 | 1.20 |
| 70 kVp | 0.27 | 0.75 | 0.39 | 1.05 | 0.50 | 1.38 | 0.61 | 1.66 |
| 80 kVp | 0.37 | 1.05 | 0.55 | 1.46 | 0.71 | 1.90 | 0.87 | 2.31 |

R※: reflection-target X-ray tube.
T*: transmission-target X-ray tube.

## 2. Materials and methods

### 2.1. X-ray system

The transmission-target X-ray system used in this experiment was a NanoRay Biotech NM08X040 (NanoRay Biotech, ROC). It has a Lanthanum target of 50 μm thickness. The traditional reflection-target X-ray system was a Shimadzu CIRCLEX 1/2P33D-85 (Shimadzu, Japan). The target was a 10 mm thick W/Re target. The angle of the positive cathode was 16°.

### 2.2. The relation of output dose, tube voltage and tube current-exposure time

The tube current-exposure time (mAs) settings of the X-ray system were 1.2, 1.8, 2.4, and 3. The tube voltage (kVp) settings were 50, 60, 70, and 80. A Victoreen 6000-529 Mammographic (Fluke, USA) ionization chamber and a CNMC Model 206 (CNMC, USA) electrometer were used to measure the electric charge of the X-ray.

### 2.3. Spectrum measurement

The spectrometer used in this experiment was an Amptek X-123 (Amptek, USA). This spectrometer comprised of a XR-100T-CdTe detector. The XR-100T-CdTe detector was comprised of cadmium telluride crystals of the size of 3 × 3 × 1 $mm^3$. In the front of cathodes was a 100 μm Be window. Around the detector crystals was a temperature monitoring device and a Peltier cooler was attached. The detector would remain at a low temperature

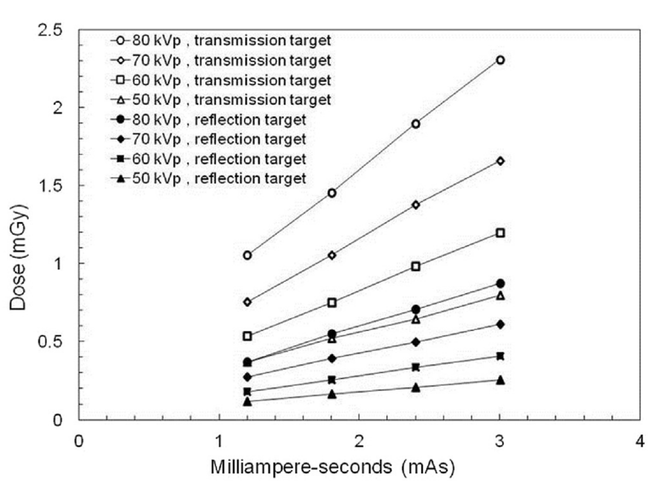


**Fig. 2.** Relationship of dose (mGy) variations with tube current-exposure time (mAs).

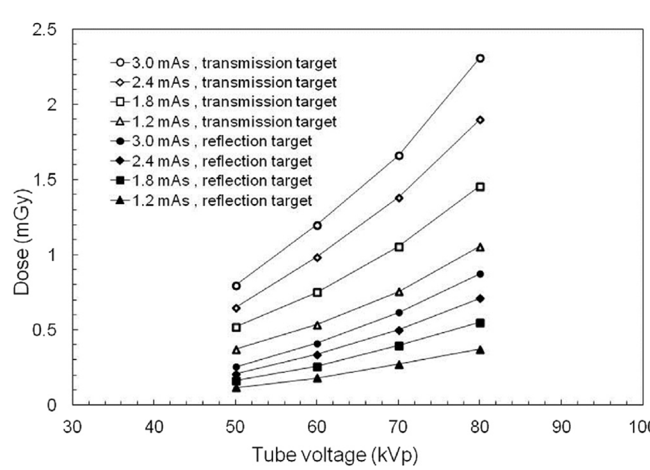


**Fig. 3.** Relationship of dose (mGy) variations with tube voltage.