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Review

Evaluation of collimators' response: Round and hexagonal holes in parallel and fan beam

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ABSTRACT

With regard to the different requirements, various collimators are widely employed within nuclear medicine systems in order to evaluate the metabolism of organs as well as improve the contrast of images and better diagnosis. In this study, Fan Beam (FB) and Parallel Beam (PB) collimators in the shapes of round and hexagonal holes have been investigated and compared based on the Geometric Efficiency (G), Geometric Resolution (R_c), Total Resolution (R_t), FWHM and Scatter and Penetration ($S + P$) components using the Monte Carlo simulation. Calculations demonstrated that the G was improved with the increase in the distance between point source and collimator face (z). In contrast, the G was reduced with an increase in the angle of slant hole. In the FB collimator, the R_c and R_t were increased when the increase in the hole angle and/or the distance. The simulated results indicated in both collimators with the increase in z, a) the FWHM was increased as well as the peak of the PSF curve was decreased, and b) the $S + P$ amounts decreased, but in the distinct z, the FWHM of the FB collimator is better than that of the PB collimator. It is shown that the results were in agreement with the ADAC company data. Also, Benchmark for measuring ADAC company demonstrated the calculated and simulated amounts of the R_c and R_t with round and hexagonal holes shapes had maximum and minimum average relative differences equal to −7.6% for PB and 1% for FB, respectively.

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1. Introduction

The collimators employed within SPECT imaging systems may be formed as parallel and focusing. The former represents a good compromise between the resolution and the sensitivity, and is very versatile. Moreover, reconstruction is straightforward. Therefore, this type of collimation is widely used in clinical routine. The latter enhances sensitivity and is applicable when imaging smaller organs such as the brain and heart (Jaszczak et al., 1979; Tsui et al., 1986; Li et al., 1994). Fan Beam collimators are a special type of converging collimators, with the holes focusing toward a so-called focal line parallel to the axis of rotation of the camera (Koole et al., 2001). Therefore, investigating of collimators' geometric properties is very important in clinical use.

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Table 1
Geometric characteristics of parallel and fan beam collimators (in terms of cm).

Collimator	Parallel and fan beam
Hole shape	Round and hexagonal
Central hole length (l)	3.28
Hole size (a)	0.140
Septal width	0.0152
A(open)/*A*(unit)[a]	0.7682

[a] Ratio of hole area to septal area.

Simulation of photon interactions in gamma camera collimators is important for studies of radioisotopes that emit low to high energy gamma rays and for collimator design optimization (Vries and Moore, 2001; Gullberg et al., 1987; Tusi, 1988). To study the effects of interactions, Monte Carlo N-Particle version 5 (MCNP5) code may be used. The MCNP5 input files would specify geometry of source objects, collimators and detector planes for a given simulation, which input files and geometry specifications are often complex and can be very cumbersome (Yancht et al., 1992; Briesmeister, 2001b). Recently, some research and analysis represent comparison of PB and FB collimators as clinically (Yancht et al., 1992; Buvat et al., 2001; Celler et al., 1998; Kim et al., 1996; Gilland et al., 1998; Matsunari et al., 1998; Tsui and Gullberg, 1990; Husak and Perinova, 1969; Eckholt and Bergmann, 2000; Beekman et al., 1998), but FB collimator considerably wasn't mentioned using MCNP code (Li et al., 2003, 2005; Lu et al., 2002; Rosenthal et al., 1995; Saripan et al., 2005a, 2005b, 2008; Demers and Stein, 2002; Toossi et al., 2010; Assie et al., 2004; Berthot et al., 2000; Bevilacqua et al., 2001; Ljungberg et al., 1998; Saripan et al., 2007; Ogawa and Kato, 2003; Briesmeister, 2001a; Jangha et al., 2001).

We tend to estimate and to compare the response of round and hexagonal holes with the similar sensitivity in PB and FB collimators with Low Energy (LE) photon, calculation of slant holes angles, determination of Geometric Efficiency (G), Geometric Resolution (R_c) and Total Resolution (R_t).

2. Simulation method and computation of geometrical parameters

Two sets of parameters are important in collimator design. The first set of parameters describes the collimator geometry, typical source positions, and location of the collimator with respect to the imaging plane of the camera. The second set of parameters describes the resultant imaging characteristics of the collimator (Jaszczak et al., 1979; Tsui et al., 1986; Gunter et al., 2000). Geometric characteristics of low energy PB and FB collimators for ADAC company (ADAC Laboratories) is shown in Table 1. In this manuscript we have applied the PB geometric dimensions for FB collimator, which this way was referred to Gunter et al. (2000) paper which PB parameters can be chosen locally for FB collimator. Meanwhile, FB collimator along the central z-axis has the same hole length like PB collimator, but in FB collimator whereas offset distance on the x-axis changes, the hole length becomes longer with different angle and hole size.

Matlab software and MCNP5 code were modified to simulate collimators with round and hexagonal holes as shown in Fig. 1. In the Fan Beam collimator we calculated angles of about 89,600 slant

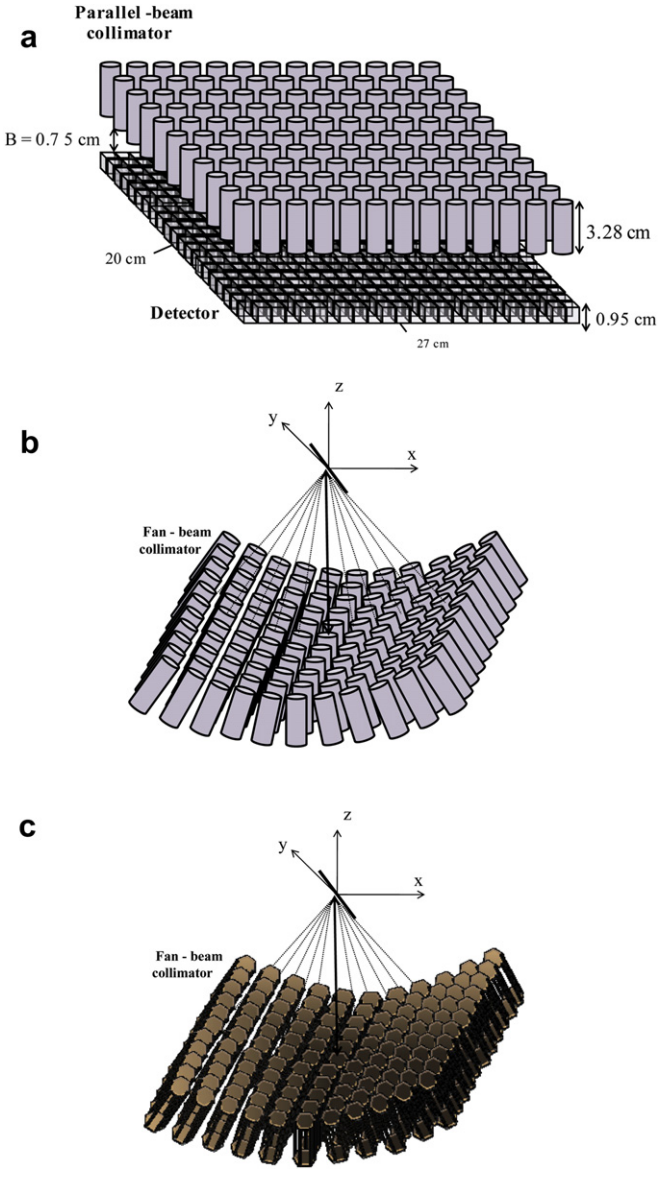

Fig. 1. (a) PB design, (b) FB collimator which round holes focus to a line. (c) FB design with hexagonal holes.

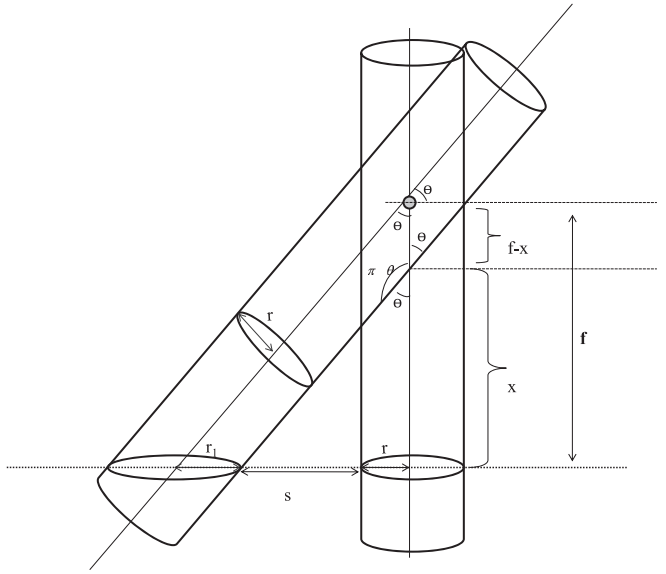

Fig. 2. Calculation of angles in FB collimator, which the slant round hole has different cross section with larger radius.