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The Physical Penumbra of the 6MV X-ray*

Moon-June Cho, M.D.

Department of Radiology, College of Medicine and Cancer Research Institute, Chungnam National University, Taejon, Korea

Wee-Saing Kang, Ph.D.

Department of Therapeutic Radiology, College of Medicine, Seoul National University, Seoul, Korea

High energy photon beam has a sharp beam margin due to a less side scatter and the other things. But there still remains a penumbra where the dose changes rapidly in the region near the edge of a radiation beam, although it is short in width. It is suggested that the width of the penumbra depends on the source size, distance from source to diaphragm, source to skin distance, and depth in tissue. However, it is also supposed that the other factors influence the penumbra width. In this paper, we investigate changes of the physical penumbra widths according to various field sizes and depths, by using the three dimensional dosimetry system. As a result, we found that as field size and depth increase, the physical penumbra width also increases.

Key Words: Physical penumbra, 6MV X-ray, Field size, Depth

INTRODUCTION

Recently, the use of linear accelerator has been increasing. Megavoltage X-ray produced by linear accelerator is superior to orthovoltage radiation in the following respects: homogeneous dose distribution, less side scatter ray, better skin sparing effect, and better depth dose. However, there is a sharp dose gradient zone even in megavoltage X-ray due to source size, collimator, other accessories, and internal scatter ray[1,2]. The region, near the edge of a radiation beam, where the dose changes rapidly according to the distance from the beam axis is known as the penumbra.

Transmission penumbra is the region irradiated by photons which have traversed a part of a collimator. Geometric penumbra is the region irradiated only by primary photons, issuing directly from a part of the source. The transmission and geometric penumbra causes a region of dose variation near the field edges[1](Fig. 1). However, thus, in the patient the dose variation near the field border is not only a function of geometric and transmission penumbra but also the scattered radiation produced in the patient. Thus, dosimetrically, the physical penumbra width has been defined as the lateral distance between two specified dose levels at a specified depth[3]. The extent of penumbra will be expanded at the large field size as the obliquity of the rays at the edges of the blocks in larger collimator openings and scattered radiation increase. The extent of penumbra will also expand with depth increase.

Thus, it is supposed that both the field size and the depth influence the physical penumbra. We, therefore, has investigated the variation of the phyiscal penumbra widths according to the change of field size and depth.

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MATERIALS AND METHODS

1. Radiation

We use 6MV X-ray generated from linear accelerator (Mevatron 67, Germany, Siemens). The diameter of source of this linear accelerator is 3 mm and the distance between the source and the low margin of the upper collimator is 27.1 cm. The geometric penumbra width (Pg) is theoretically defined as

$$Pg=\frac{S}{2}\left[\frac{(SSD+d)\sqrt{SSD^2+r^2}}{SSD}\left(\frac{1}{SDD}+\frac{1}{SDD-t}\right)-2\right]$$

and transmission penumbra (Pt) is

$$Pt=S\left[\frac{(SSD+d)\sqrt{SSD^2+r^2}}{SSD(SDD-t)}-1\right]$$

where S is the diameter of a source, r is one half

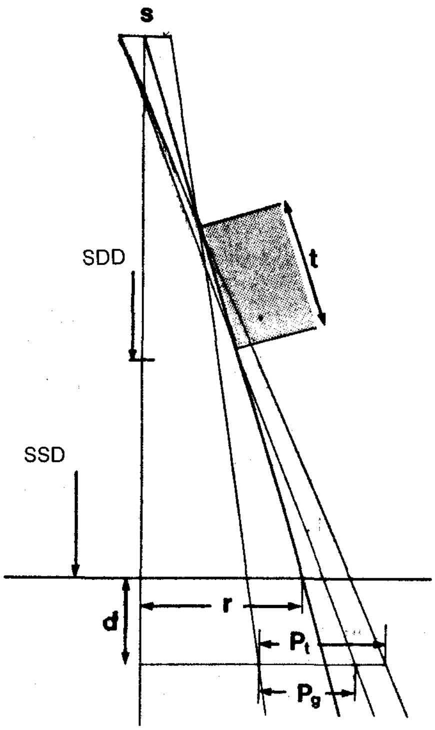

Fig. 1. Diagram for calculating geometric penumbra (Pg) and transmission penumbra (Pt). S is the diameter of a source, r is one half of a side of field at SSD, t is the thickness of collimator, d is depth in tissue, SDD is source to diaphragm distance, and SSD is source to skin distance.

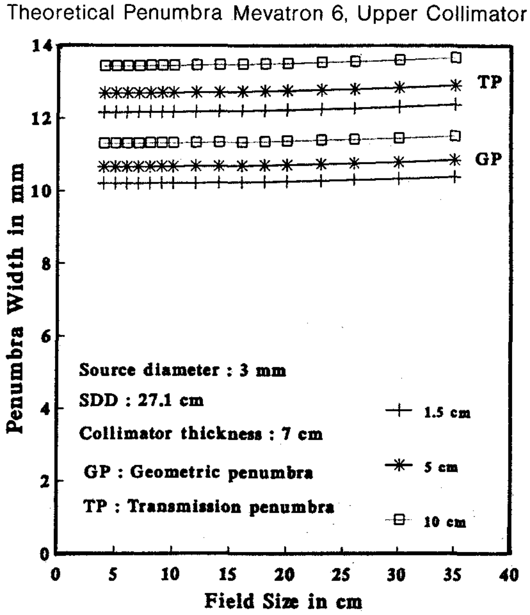

Fig. 2. The calculated geometric and transmission penumbra. The number in the X-axis represents a side of a square radiation field.

of a side of field at SSD, t is the thickness of a collimator, d is depth in tissue and SDD is source to diaphragm distance when a pair of collimators are completely closed, that is, r=o.

2. Measurement of Penumbra

The device for measurement is the three dimensional dosimetry system (Multidata 9050, Multidata, USA) composed of 2 ion chambers (IC-10 type, chamber volume 0.125 cc, wall thickness 0.4 mm), a water tank (590×680×550 mm), and an electrometer. This system is controlled by a personal computer. The data measured is graphically displayed on a CRT monitor and transfered to a printer.

ICRU defined that penumbra width is a lateral distance between two specified isodose curves at a specified depth in a plane perpendicular to the beam axis[3]. So, we obtain the lateral distance between 90% and 20% isodose levels, and 80% and 20%. We can directly get physical penumbra widths from a CRT monitor.

For the measurement of the penumbra width, we set up the system on the following conditions: the distance between the source and the surface of the water tank is 100 cm, and the ion chamber is on principal plane of the beam bisecting beamside. A reference chamber, the same model as scanning chamber, was fixed in the field above water level and was used for the correction of linear accelerator output variation during measurement.

In order to measure the effect of upper collimator which exerts more influence on the penumbra than lower collimator, we moved the ion chamber in the perpendicular direction to the upper collimator. To study the variation of physical penumbra width according to field sizes and depths change, we measured the physical penumbra for the field size from 4×4 cm to 35×35 cm at the depth of 1.5 cm, 5 cm, and 10 cm.

RESULTS

The calculated geometric and transmission penumbra widths are presented at Fig. 2. The field size change does not exert much influence on the widths variation. The variation shows within 2%. The

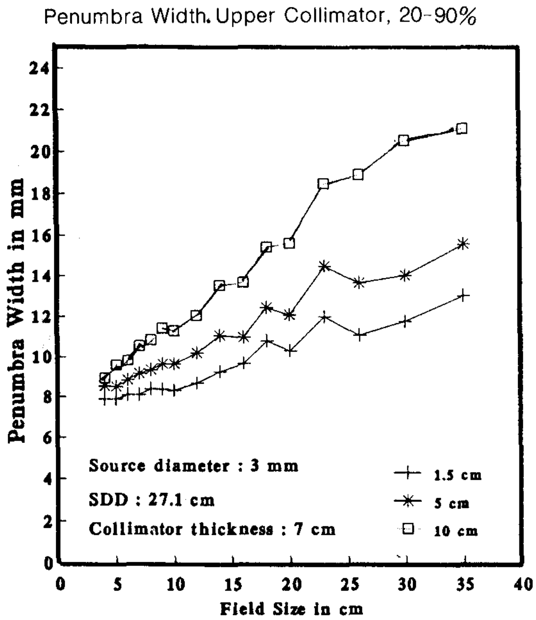

Fig. 3. Physical penumbra width between 90% and 20% dose levels. The number in the X-axis represents a side of a square radiation field.

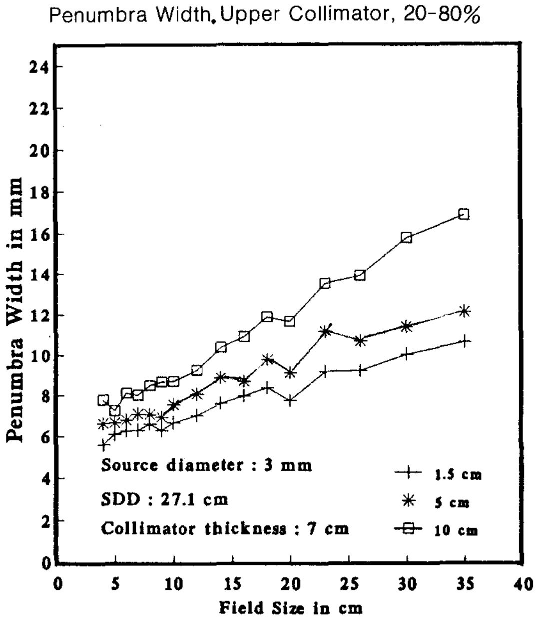

Fig. 4. Physical penumbra width between 80% and 20% dose levels. The number in the X-axis represents a side of a square radiation field.

physical penumbra widths between 90% and 20% isodose levels are presented in Fig. 3. As the depth increases, the physical penumbra width increases. Physical penumbra width at 5 cm depth is about 2 mm larger than physical penumbra width at 1.5 cm, and physical penumbra width at 10 cm depth is also about 2 mm larger than physical penumbra width at 5 cm depth. As the field size increases, the pysical penumbra width also increases. Physical penumbra width at 1.5 cm depth, 4×4 cm, 35×35 cm field size is 0.79 cm, 1.2 cm respectively. Although there is some difference according to condition, when the field sizes are smaller than 10 cm, the physical penumbra widths, mostly, are smaller than calculated geometric and transmission penumbra, but when the field size are larger than 10 cm, the result are reversed. It shows that the larger the field size becomes, the more increased the gap is between the physical penumbra and calculated penumbra. The physical penumbra widths between 80% and 20% isodose levels are presented in Fig. 4. Overall pattern is similar to that of 90% and 20% dose levels. Physical penumbra width at 90% and 20% dose levels is slightly larger than that of 80% and 20% dose levels. The result is that as field size and depth increase, the difference between 90%/20% and 80%/20% becomes larger.

DISCUSSION

When we consider the region of dose variation near the field edges, we usually first take geometric penumbra into account. Supposing that collimator completely blocks radiation, calculated geometric penumbra widths means the lateral distance between 0 to 100% dose levels. However, measured physical penumbra widths are defined relatively as the lateral distance between two specified dose levels such as 90% to 20% or 80% to 20%. Other factors especially such as the real source size, air volume of ion chamber used to measurement, and some instrumental error in dosimetry system also influence physical penumbra widths. So, measured physical penumbra width does not accord with calculated geometric penumbra. It is not certain yet which one is more clinically useful.

To decrease the physical penumbar width, source must be smaller in size, and SDD be longer, but with the mechanical stability. When we simulate the two adjacent beams, it is better to use upper collimator side because upper collimator has larger penumbra widths than lower collimator, especially in large fields.

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= 국문초록 =

6MV 방사선의 물리학적 Penumbra

충남대학교 의과대학 방사선과학교실 및 암 공동 연구소

조 문 준

서울대학교 의과대학 치료방사선과학교실

강 위 생

충남대학교병원 치료방사선과내 설치되어 있는 6MV 선형가속기를 이용하여 음영을 측정하여 다음과 같은 결과를 얻었다.

1) 조사면 크기가 커질수록 음영폭은 증가하였으며 10×10 cm 이상의 조사면에서는 계산한 음영폭보다 측정치가 대개 크게 나타났다. 조사면이 커질수록 이 차이는 더욱 증가하였다.

2) 깊이가 증가하면 음영폭도 증가하였다.

3) 90%~20%의 음영폭이 80%~20%의 음영폭보다 컸으며 조사면이 커지고, 깊이가 증가할 수록 이 차이는 더 커졌다.