Original Article

A Simplified Approach for Determination of Inflection Points of Flattening Filter-Free Photon Beam Using In-House Developed Software and Derivation of Reference Levels

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Abstract

Aim: This article aimed to present the salient features of the in-house developed Java program for the determination of inflection point and dosimetric parameters of flattening filter-free (FFF) photon beam. Reference levels for the dosimetric parameters of the FFF photon beams were also presented. **Materials and Methods:** Beam profiles of 6 MV FFF and 10 MV FFF photon beams for a collimator setting of 20 cm × 20 cm measured at 10 cm depth in an isocentric setup acquired from various institutions were analyzed using an in-house developed Java program and manual method. The values of reference dose value (RDV), field size, penumbra, and degree of un-flatness (defined as the lateral separation between 90% [$X_{90\%}$], 75% [$X_{75\%}$], and 60% [$X_{60\%}$] dose points on the profile) were calculated and compared. The reference values of field size, penumbra, and degree of un-flatness were also determined for Varian and Elekta medical electron linear accelerators (LINACs). **Results:** The maximum differences for RDV determined using the Java method and manual method are 2.4% and 2.7% for 6 and 10 MV FFF photon beams, respectively. The maximum difference between the values of field size, penumbra, and degree of un-flatness determined using Java and manual methods is within 1.3 mm. The reference values of field size and penumbra for Varian LINACs are 19.94 ± 0.10 cm and 0.83 ± 0.08 cm (6 MV FFF) and 19.95 ± 0.10 cm and 0.83 ± 0.08 cm (10 MV FFF). Similarly, the reference values of field size and penumbra for Elekta LINACs are 20.02 ± 0.09 cm and 0.94 ± 0.12 cm (6 MV FFF) and 20.03 ± 0.11 cm and 0.97 ± 0.16 cm (10 MV FFF). **Conclusions:** A software program was developed in Java for analyzing the beam profiles of FFF photon beams. The results of Java-derived values of dosimetric parameters of FFF photon beams were found in good agreement with the values determined using the manual method. The reference values of these parameters were also derived and quoted using a large cohort of the data.

Keywords: Flattening filter-free beam, inflection point, Java, reference dose value, un-flatness

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Introduction

Medical electron linear accelerators (LINACs) of recent technologies are capable of generating both filtered (also called photon beam with flattening filter [FF]) and unfiltered (also called FF-free [FFF]) photon beams. The FFF photon beams are widely used in clinics for the treatment of a variety of cancer cases by various radiotherapy techniques, including stereotactic radiosurgery, stereotactic radiation therapy, and stereotactic body radiation therapy due to relatively high dose rates. FFF photon beams are having special characteristics of a softer X-ray spectrum, reduced scattered photon radiation, as well as neutron and photon leakage from the treatment head.[1-5] Removal of the FF also results in a change in the dosimetric parameters, such as beam quality, off-axis ratio, surface dose, flatness, penumbra, and depth dose. In addition, the field size definition of the FFF beam is also different from the filtered photon beam.[5]

Evaluation of the characteristics of photon beams is one of the important requirements for their clinical commissioning.[6-8]

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In this context, a few protocols were proposed to analyze and specify some of the quality assurance (QA) parameters of FFF photon beams owing to the difference in their beam profiles in comparison to filtered beams. Revised definitions for evaluating the beam characteristics of FFF photon beams were proposed for the establishment of QA programs by modifying the existing definitions of dosimetry parameters of FF photon beams.[2,9] However, evaluating the dosimetry parameters of FFF photon beams using the definitions proposed by Fogliata *et al*.[9] and Pönisch *et al*.[2] is complex to implement because it requires normalization/renormalization of the beam profiles.

To eliminate the complexity of the modified definitions proposed by Fogliata *et al*.[9] and Pönisch *et al*.,[2] a committee constituted by the National Regulatory Authority (Atomic Energy Regulatory Board [AERB]) proposed simplified acceptance criteria for determining QA parameters of FFF photon beams.[10] Proposed acceptance criteria are widely used for evaluating the dosimetric characteristics of FFF photon beams in India. As per these acceptance criteria, the evaluation of inflection point (IP) is a prerequisite for the determination of field size, and extent of beam penumbra. However, locating IPs on FFF beam profiles by manual analysis is tedious and time-consuming. This necessitated the development of an automated approach for locating the IPs on the FFF beam profiles.

A few approaches based on polynomial functions, physical concepts, and mathematical methods through Python programming were proposed to determine IPs.[11-13] However, these approaches to determining IPs were validated with the FFF beam profiles measured at only one institution. Thus, these methods of evaluating IPs are institution specific. There is a need to develop a versatile universal software program to locate the IPs on FFF beam profiles. A software program in Java was developed to locate IPs and determine the values of field size and penumbra. This article presents the salient features of this program and the results of the analysis carried out on FFF beam profiles.

Moreover, the variability of dosimetric parameters of FFF photon beams is not yet well-documented compared to FF beams. There is a non-availability of the reference value of a dosimetry parameter of the FFF photon beam. It is highly required that data from FFF photon beams of different energies from different models should be collected and analyzed for generating a consistent value that can eventually be accepted as reference levels. This article also presents reference levels for the dosimetric parameters with specific tolerance values. As per our knowledge, no publications have listed reference levels derived from larger datasets of dosimetric parameters of FFF photon beams as per the definitions suggested by Sahani *et al*.[10]

Materials and Methods

In-line and crossline FFF photon beam profiles generated from various models of medical electron LINACs were obtained for analyzing their dosimetric characteristics. All the profiles obtained for this purpose were analyzed using a manual approach[10] as well as using a software program in Java developed in this study. The details of the medical electron LINACs used in this study are given in Table 1.

We have analyzed FFF photon beam profiles of various models of LINACs (M/s. Varian Medical Systems, USA) equipped with 6 and 10 MV FFF from nine institutions.

These profiles were measured using a three-dimensional scanning radiation field analyzer (RFA) of the institution. RFAs of the institutions are equipped with a cylindrical ionization chamber which is capable of moving in three dimensions for generating beam profiles in the desired direction and depths. The sensitive volumes of ionization chambers used by different institutions for generating the beam profiles of FFF photon beams were in the range of 0.1–0.13 cc with step sizes between 0.35 mm and 1.27 mm. A total of 32 beam profiles for a collimator setting of 20 cm × 20 cm measured at 10 cm depth in an isocentric setup were acquired. Out of 32 profiles, 18 profiles were of 6 MV FFF and 14 profiles were of 10 MV FFF photon beam. These profiles were normalized to 100% at the central beam axis. The ASCII data of these profiles were saved as raw data in an Excel sheet. These raw data were used for the determination of IPs. Dosimetric parameters analyzed using Java program and manual method included field size, penumbra, and degree of un-flatness.

Determination of inflection points

Mathematically, the point at which the rate of change of slope becomes increasing from decreasing or vice versa is known as an IP. In the context of this work, the IP of the FFF photon profile is defined as the point where the slope is maximum. Alternatively, as the slope of a curve at a given point is its first derivative, therefore, the maximum value of derivatives of the curve represents the IPs. As per this definition, the first principle of derivative was used in the Java program to determine IP. As per the nature of the curve, FFF photon beams are having two IPs [Figure 1]. One IP is toward the left side of the central axis (denoted by IP_L) and another is at the right side of the central axis (denoted by IP_R).

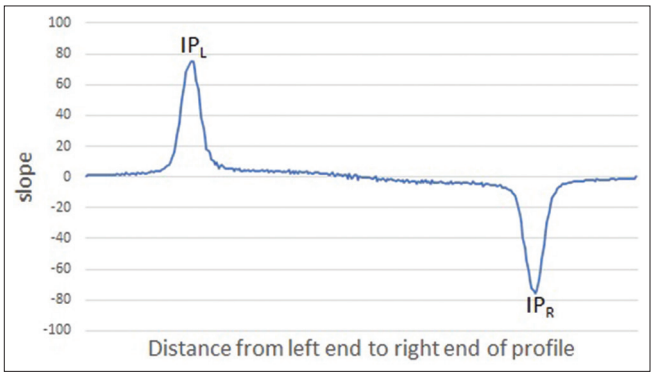

Figure 1: Representation of plot of the slope of flattening filter-free beam profile

Inflection points by the software application

A software application in Java has been developed to automate the determination of IPs as this work involves the evaluation of many FFF photon beam profiles. This development is a step forward toward automation of the process of evaluation of FFF photon beam profiles and quantification of their characteristics. A software program in Java was used to determine IPs of FFF beam profiles and corresponding dosimetric parameters as per the definition by Sahani *et al*.[10] Java version 1.8, with Apache POI and JFreeChart libraries, has been used for this application.

As per the definition of IPs, Java based programming was developed and used for the analysis of FFF profiles. The input file for this program was raw profile data (ASCII data) taken in an Excel sheet. Once the input file is selected, the Java program analyzes data based on its programming code and displays the required results of IPs and corresponding dosimetric parameters as represented in Figure 2. An extract of Java code for this program is provided in Appendix 1.

Inflection points by the manual method

For cross-verifying the values of dosimetric parameters determined using an in-house developed software application, the FFF photon beam profiles were also evaluated using the manual method as recommended by Sahani *et al*.[10] The details of this method have been elaborated in Figure 3.

To determine IPs manually, tangents have been drawn on sharply descending parts by touching the maximum number of points on either side of the high-dose gradient region. The first and last intersection points have been identified as point S and point E, respectively, on the profile. The total perpendicular distance between S and E was determined and denoted as height (h). The midpoint of this height is nothing but the position of the IP. Accordingly, two IPs, one on the left side of the profile (IP_L) and the other on the right side of the profile (IP_R), were recorded. The field size was determined as the lateral separation between IP_L and IP_R.

For determining penumbra, the average of the doses at the points IP_L and IP_R on the profile was taken as reference dose value (RDV), and 1.6 times RDV was identified as the dose value on the Y-axis. For the said dose value, there are positive X-value (P_{RU}) and negative X-value (P_{LU}). Similarly, for 0.4 times RDV, there are positive X-value (P_{RD}) and negative X-value (P_{LD}). Lateral separation between P_{RU} and P_{RD} was determined as right penumbra (P_R). Lateral separation between P_{LU} and P_{LD} was determined as left penumbra (P_L).

The degree of un-flatness defined as the lateral separation between 90% ($X_{90\%}$), 75% ($X_{75\%}$), and 60% ($X_{60\%}$) dose points on the beam profile was also recorded.

Determination of reference values

For the determination of reference values, we have analyzed 90 FFF photon beam profiles obtained from various models of

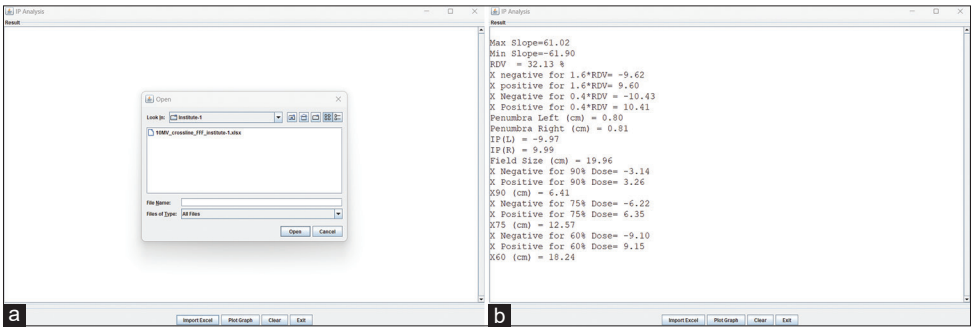

Figure 2: Schematic illustration for the analysis of flattening filter-free profile using software developed in Java (a) Import of the ASCII data of profiles as raw data in Excel sheet (b) determining reference dose value, field size, penumbra, and degree of un-flatness

Table 1: Details of Varian medical electron linear accelerators used in this study

LINAC models	FFF beam energy (MV)	Maximum dose rates (MU/min)	Number of units	Number of beam profiles (including in-line and crosslines)	Step size used in profile generation by radiation field analyzer (mm)
TrueBeam (with FFF mode)	6 and 10 MV	6 FFF - 1400 and 10 FFF - 2400	1	4	0.35
TrueBeam STx (with FFF mode)			1	4	1
TrueBeam SVC with FFF			5	20	1.25
					0.55
					1
					1
					1.2
Halcyon	6	800	1	2	0.625
Ethos			1	2	1.27

LINAC: Linear accelerator, FFF: Flattening filter-free, SVC: Small vault configuration

Varian (M/s. Varian Medical Systems, USA) and Elekta (M/s. Elekta Medical System, UK) LINACs equipped with 6 and 10 MV FFF photon beams. These profiles were collected from 25 institutions. Out of 25 institutions, 13 institutions (including nine institutions for which the validation of software was performed) are having Varian LINACs, while 12 institutions are having Elekta LINACs. The method used for generating these profiles was the same as described earlier. All the profiles were analyzed using the Java program, and field size, penumbra, and degree of un-flatness ($X_{90\%}$, $X_{75\%}$, and $X_{60\%}$) were determined. Reference value, which is also called the consistent value of a physical parameter, is the average value of the large dataset. Hence, the average values of field size, penumbra, $X_{90\%}$, $X_{75\%}$, and $X_{60\%}$ were calculated for 6 MV FFF and 10 MV FFF photon beams of Varian and Elekta LINACs separately.

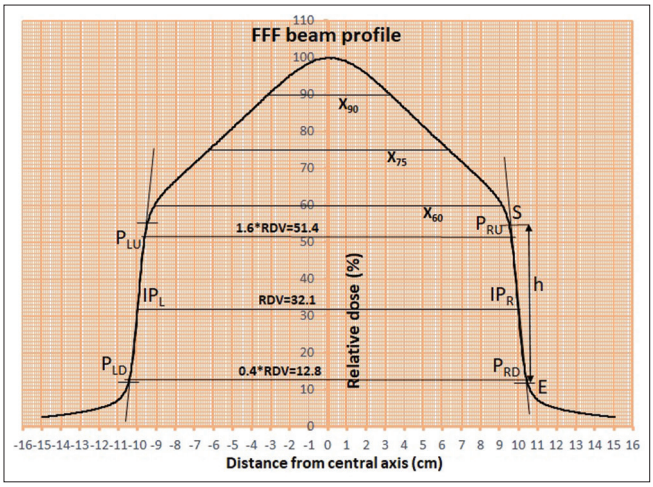

Figure 3: Schematic diagram for determining inflection point, field size, penumbra, and degree of un-flatness using the manual method. FFM: Flattening filter-free, RDV: Reference dose value

Results

Validation of Java program

Table 2 presents the values of RDV derived using IPs determined by the manual method and Java method for 6 and 10 MV FFF beams. The data presented in this table were derived from the profiles obtained from nine different institutions. RDV is the point on the central axis of the beam, which is obtained by joining the left and right IPs of the profile and, hence, directly related to the IPs. A close survey of the data in this table indicates that the maximum difference between RDV_{manual} and RDV_{Java} values is 2.4% and 2.7% for 6 MV and 10 MV FFF photon beams, respectively. This difference between RDV_{manual} and RDV_{Java} may be attributed to the mislocation of the IPs on the beam profile in the manual method.

Parameter associated with inflection points

Figure 4 presents the difference in the values of field size, left penumbra, and right penumbra of 6 MV FFF photon beam, whereas Figure 5 shows the difference in the values of field size, left penumbra, and right penumbra of 10 MV FFF photon beam derived by Java and manual methods. The values of parameters included in these figures were linked with the location of IPs. The maximum difference determined by the Java method and manual method for field size, left penumbra, and right penumbra for 6 MV FFF photon beam

Table 2: Reference dose values derived using inflection points determined by the Java method and manual methods

Institute	Beam profile	RDV					
		6 MV FFF			10 MV FFF		
		Java method (%)	Manual method (%)	Difference (%)	Java method (%)	Manual method (%)	Difference (%)
Institute-1	In-line	39.34	41.50	−2.2	33.00	33.00	0.0
	Crossline	41.74	40.50	1.2	32.12	32.00	0.1
Institute-2	In-line	40.98	41.00	0.0	32.85	33.00	−0.1
	Crossline	40.49	40.25	0.2	32.65	32.00	0.6
Institute-3	In-line	42.00	40.00	2.0	33.59	33.75	−0.2
	Crossline	42.46	41.50	1.0	34.05	34.00	0.0
Institute-4	In-line	40.02	39.50	0.5	35.66	33.00	2.7
	Crossline	41.00	39.75	1.3	31.50	32.50	−1.0
Institute-5	In-line	41.50	41.00	0.5	33.35	33.25	0.1
	Crossline	39.75	41.00	−1.3	31.85	33.00	−1.2
Institute-6	In-line	41.25	39.00	2.3	32.95	33.00	0.0
	Crossline	39.50	39.00	0.5	31.65	32.00	−0.4
Institute-7	In-line	42.40	40.00	2.4	34.05	33.00	1.1
	Crossline	41.90	40.00	1.9	30.50	32.00	−1.5
Institute-8	In-line	42.70	41.00	1.7			
	Crossline	42.00	41.00	1.0			
Institute-9	In-line	40.84	41.00	−0.2			
	Crossline	40.16	40.50	−0.3			

The data include values of reference dose values derived for in-line and crossline FFF beam profiles of 6 and 10 MV photons. FFF: Flattening filter-free, RDV: Reference dose values

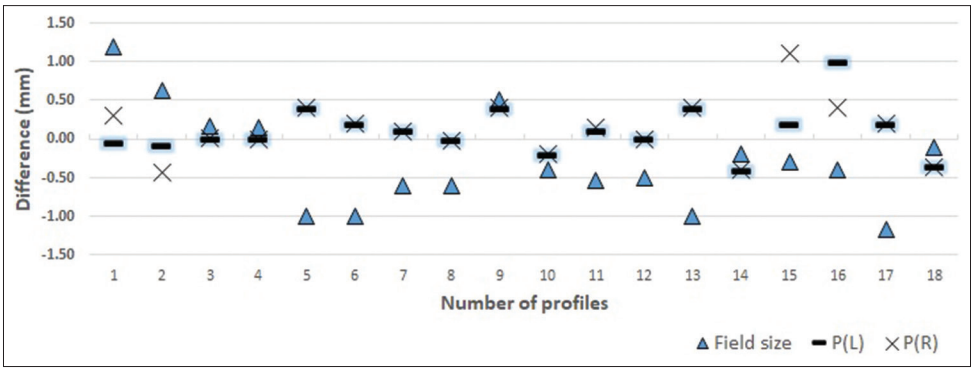

Figure 4: Difference in the values of field size, left penumbra, and right penumbra for 6 MV flattening filter-free photon beams derived by the Java method and manual method. P_L: Left penumbra, P_R: Right penumbra

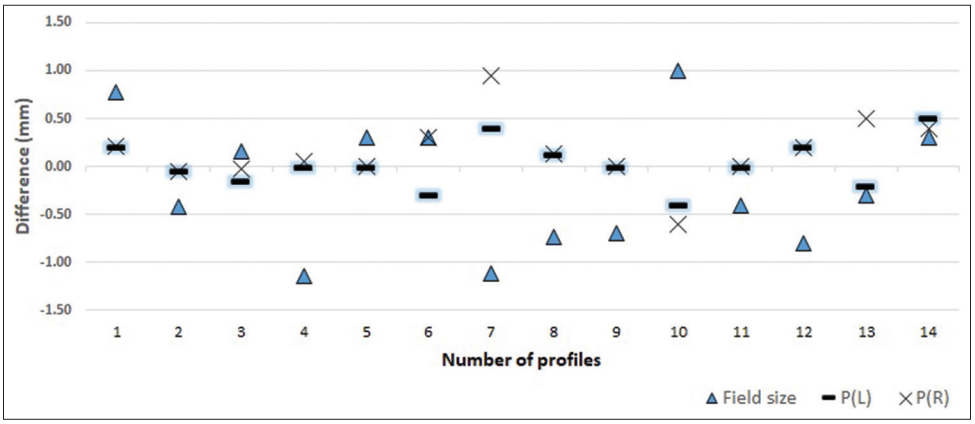

Figure 5: Difference in the values of field size, left penumbra, and right penumbra for 10 MV flattening filter-free photon beams derived by the Java method and manual method. P_L: Left penumbra, P_R: Right penumbra

is found to be 1.2 mm, 1.0 mm, and 1.1 mm, respectively. Similarly, the maximum difference determined by the Java method and manual method for field size, left penumbra, and right penumbra for 10 MV FFF photon beam is found to be 1.1 mm, 0.5 mm, and 1.0 mm, respectively.

Parameters for the measure of the degree of un-flatness

Figure 6 presents the difference in the values of $X_{90\%}$, $X_{75\%,}$ and $X_{60\%}$ of 6 MV FFF photon beam, whereas Figure 7 shows the difference in the values of $X_{90\%}$, $X_{75\%}$, and $X_{60\%}$ of 10 MV FFF photon beam derived by Java method and manual methods. The maximum difference determined by the Java method and manual method for $X_{90\%}$, $X_{75\%}$, and $X_{60\%}$ for 6 MV FFF photon beam was found to be 1.2 mm, 1.3 mm, and 1.1 mm, respectively. Similarly, the maximum difference determined by the Java and manual method for $X_{90\%}$, $X_{75\%}$, and $X_{60\%}$ for 10 MV FFF photon beam was found to be 0.5 mm, 1.3 mm, and 1.2 mm, respectively.

Reference values for the dosimetric parameters

The dosimetric parameters determined through Java for beam profiles of 6 and 10 MV FFF photon beams of Varian LINACs are shown in Table 3. Reference values of field size, penumbra, $X_{90\%}$, $X_{75\%}$, and $X_{60\%}$ for 6 MV FFF photon beam determined through the Java method are 19.94 ± 0.10 cm, 0.83 ± 0.08 cm, 9.92 ± 0.29 cm, 17.32 ± 0.24 cm, and 19.42 ± 0.11 cm, respectively. Reference values of field size, penumbra, $X_{90\%}$, $X_{75\%}$, and $X_{60\%}$ for 10 MV FFF photon beam determined through the Java method are 19.95 ± 0.10, 0.83 ± 0.08, 6.38 ± 0.06, 12.52 ± 0.08, and 18.21 ± 0.12, respectively. It is important to mention here that the factory-generated values for these parameters were obtained, and the results of our measured data were compared for the FFF photon beam of C-arm LINAC and found in excellent agreement.

The dosimetric parameters determined through Java for beam profiles of 6 and 10 MV FFF photon beams of Elekta LINACs are shown in Table 3. Reference values observed for field size, penumbra, $X_{90\%}$, $X_{75\%}$, and $X_{60\%}$ for 6 MV FFF photon beam determined through the Java method are found to be 20.02 ± 0.09, 0.94 ± 0.12, 8.65 ± 0.22, 15.95 ± 0.22, and 19.28 ± 0.11, respectively. Likewise, reference values observed for field size, penumbra, $X_{90\%}$, $X_{75\%}$, and $X_{60\%}$ for 10 MV FFF photon beam determined through the Java method are found to be 20.03 ± 0.11, 0.97 ± 0.16, 6.42 ± 0.23, 12.42 ± 0.28, and 18.21 ± 0.15, respectively.

The average time to determine dosimetric parameters through the manual method is approximately 25–30 min per profile. However, these parameters can be evaluated through the Java method in less than a minute.

Table 3: Reference values of field size, penumbra, $X_{90\%}$, $X_{75\%}$, and $X_{60\%}$ determined through the Java method for 6 MV and 10 MV flattening filter-free photon beams for Varian and Elekta linear accelerator

	FFF beam energy (MV)	Field size (cm)	Penumbra (cm)	$X_{90\%}$ (cm)	$X_{75\%}$ (cm)	$X_{60\%}$ (cm)
Varian LINACs	6	19.94±0.10	0.83±0.08	9.92±0.29	17.32±0.24	19.42±0.11
	10	19.95±0.10	0.83±0.08	6.38±0.06	12.52±0.08	18.21±0.12
Elekta LINACs	6	20.02±0.09	0.94±0.12	8.65±0.22	15.95±0.22	19.28±0.11
	10	20.03±0.11	0.97±0.16	6.42±0.23	12.42±0.28	18.21±0.15

LINACs: Linear accelerators

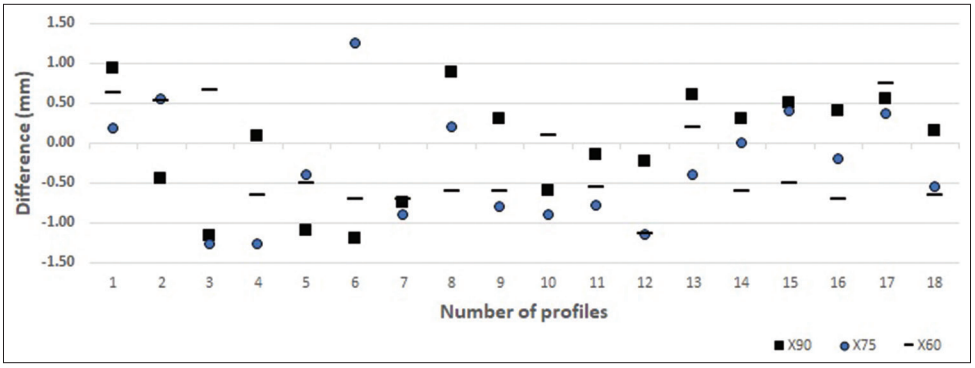

Figure 6: Difference in the values of $X_{90\%}$, $X_{75\%}$, and $X_{60\%}$ for 6 MV flattening filter-free photon beams derived by the Java method and manual method

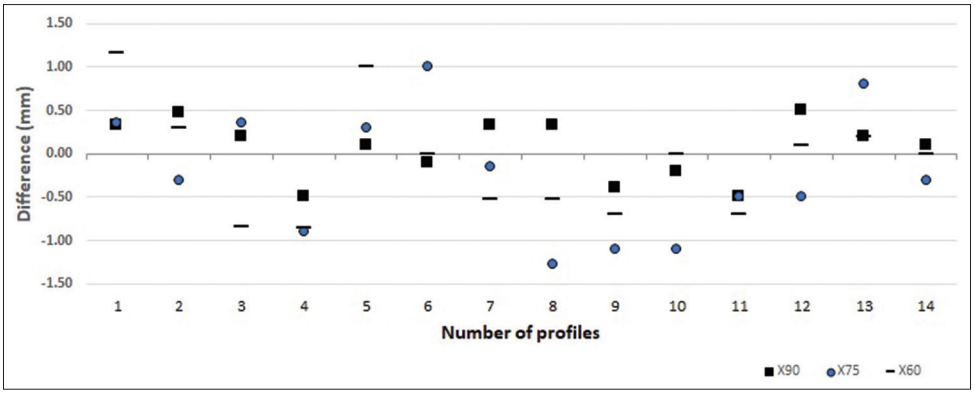

Figure 7: Difference in the values of $X_{90\%}$, $X_{75\%}$, and $X_{60\%}$ for 10 MV flattening filter-free photon beams derived by the Java method and manual method

Discussion

Localizing IP is an important task because the definitions of many dosimetry parameters of the FFF beam are linked with the location of the IP.[2,9,10,14] One of the methods for the determination of IP is the manual method,[10] which is highly laborious and complex in nature.[13] Therefore, a simple method for the determination of IPs is proposed based on a mathematical definition programmed in Java language. RDV values derived by IPs were determined using a manual method, and RDV was used to benchmark the calculation of the Java program.

The present study is the first of its kind where a large number of FFF beam profiles were analyzed through a manual method and compared with dosimetric parameters determined through an in-house developed software-based application. In an analysis of all the profiles, the maximum difference in RDV, determined by these methods, is found to be within 2.7%, which is of the same order reported by Shende *et al*.,[13] while 3% is reported by Kader *et al*.[15] Furthermore, the maximum difference in field size, P_L, and P_R determined by these methods was found to be 1.2, 1.0, and 1.1 mm, respectively, for 6 MV FFF photon beams, which is also of the similar order reported earlier.[13] In contrast to the present study, Kader *et al*[15] reported the maximum difference in penumbra determined by software and manual method as 2.6 mm

The in-house developed software program in Java language for the determination of IP and associated dosimetric parameters of the FFF photon beam can be used by the hospital during the commissioning of the FFF photon beam in the LINACs. This software program may be disseminated to hospitals through notifications at the website of the author's institute as well as through the website of the professional society.

The beam profiles were obtained from various institutions, and these institutions used their own dosimetry systems for

measuring the beam profiles. It was expected that a significant variation may be observed due to the use of different make and models of dosimetry systems. However, the results of this study indicate that the use of different types of measurement systems is not the major source of error as a very small difference was observed in the values of the dosimetry parameters. The mean difference for dosimetric parameters determined through the manual method and Java method is <1% or 1 mm, as applicable.

Considering the manual method associated with user dependent, reference values for field size, penumbra, $X_{90\%}$, $X_{75\%}$, and $X_{60\%}$ determined from the Java method are proposed as consistent. In addition to the above, averaging of dosimetric parameters of in-line and crossline profiles is performed to provide reference values.

Reference values for dosimetric parameters were proposed by Clivio *et al*. based on the measurement at three different Varian LINACs and used the definition proposed by Fogliata *et al*.[9,16] while reference values proposed in the current study are based on the measurement at 13 Varian LINACs and used the definition suggested by Sahani *et al*.[10] Therefore, reference values determined in this work and reference values reported earlier cannot be compared owing to the difference in definitions except for the field size. Clivio *et al*.[16] proposed reference values for field size as 19.98 ± 0.03 cm and 19.98 ± 0.03 cm for 6 MV FFF and 10 MV FFF photon beams, respectively, while reference values derived for 20 cm × 20 cm field size in the current study were 19.94 ± 0.10 and 19.95 ± 0.10, respectively, for 6 and 10 MV FFF photon beams.

One of the limitations of this study is that measurements were performed using RFA with step sizes ranging from 0.35 to 1.27 mm. The mathematical determination of IP is defined for continuous function. It is advisable to use the highest spatial resolution while measuring to get accurate results.

Conclusions

The manual method, which is based on determining IPs, is laborious, time-intensive, and user dependent. The methodology proposed in this study for the determination of IPs and the associated dosimetric parameter is based on a mathematical definition programmed in Java language and found to be simple, quick, and consistent. From this study, we conclude that there is good agreement in the results of all the profiles analyzed through Java with the manual method. Dosimetric parameters determined through software applications are found to be consistent. This software program can be utilized by the user institution while commissioning the FFF photon beam in LINACs and carrying out QA subsequently.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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Appendix

Appendix 1: Java code

```
package ipanalysis;

public class PointXY {

    public int index;
        public double x, y; public double slope = -2222;
    public static double Y1, Y2, maxSlope, minSlope;
    public void calcSlope (PointXY p) {
        double dy = p.y-y;
        double dx = p.x -x;
        slope = dy/dx;
        if (slope > PointXY.maxSlope){ PointXY.maxSlope = slope; PointXY.Y1 = y; }
        if (slope < PointXY.minSlope){ PointXY.minSlope = slope; PointXY.Y2 = y; }
   }

}
package ipanalysis;

import java.text.DecimalFormat;

import java.util.ArrayList;

public class Process {

    private static final DecimalFormat df = new DecimalFormat("0.00");
    public static void calulate(ArrayList < PointXY > list){
        for (i = 0;i < list.size() -1;i++){ list.get(i).calcSlope (list.get(i + 1)); }
        MyData.println("Max Slope="+df.format (PointXY.maxSlope));
        MyData.println("Min Slope="+df.format (PointXY.minSlope));
        double valRDV = (PointXY.Y1 + PointXY.Y2)/2;
        double upperY = valRDV*1.6;
        double lowerY = valRDV*0.4;
        double negUpperX = predictX (upperY, list, -1);
        double posUpperX = predictX (upperY, list, 1);
        MyData.println("RDV = "+df.format (valRDV)+" %");
        MyData.println("X negative for 1.6*RDV= "+df.format (negUpperX));
        MyData.println("X positive for 1.6*RDV= "+df.format (posUpperX));
        double negLowerX = predictX (lowerY, list, -1);
        double posLowerX = predictX (lowerY, list, 1);
        MyData.println("X Negative for 0.4*RDV = "+df.format (negLowerX));
        MyData.println("X Positive for 0.4*RDV = "+df.format (posLowerX));
        double deltaNegativeX = negLowerX - negUpperX;
        if(deltaNegativeX <0){ deltaNegativeX = deltaNegativeX * (-1); }
        MyData.println("Penumbra Left (cm) = "+df.format (deltaNegativeX));
        double deltaPositiveX = posLowerX - posUpperX;
        if(deltaPositiveX <0){ deltaPositiveX = deltaPositiveX * (-1); }
        MyData.println("Penumbra Right (cm) = "+df.format (deltaPositiveX));
        double negAvgX = predictX (valRDV, list, -1);
        double posAvgX = predictX (valRDV, list, 1);
        double diffAvgX = posAvgX- negAvgX;
        MyData.println("IP(L) = "+df.format (negAvgX));
        MyData.println("IP(R) = "+df.format (posAvgX));
        MyData.println("Field Size (cm) = "+df.format (diffAvgX));
        double negX90Y = predictX(90, list, -1);
        double posX90Y = predictX(90, list, 1);
        double diffX90Y = posX90Y- negX90Y;
```

```
            MyData.println("X Negative for 90% Dose= "+df.format(negX90Y));
            MyData.println("X Positive for 90% Dose= "+df.format(posX90Y));
            MyData.println("X90 (cm) = "+df.format (diffX90Y));
            double negX75Y = predictX (75, list, -1);
            double posX75Y = predictX (75, list, 1);
            double diffX75Y = posX75Y- negX75Y;
            MyData.println("X Negative for 75% Dose= "+df.format (negX75Y));
            MyData.println("X Positive for 75% Dose= "+df.format (posX75Y));
            MyData.println("X75 (cm) = "+df.format (diffX75Y));
            double negX60Y = predictX(60, list, -1);
            double posX60Y = predictX(60, list, 1);
            double diffX60Y = posX60Y- negX60Y;
            MyData.println("X Negative for 60% Dose= "+df.format(negX60Y));
            MyData.println("X Positive for 60% Dose= "+df.format(posX60Y));
            MyData.println("X60 (cm) = "+df.format (diffX60Y));
}
public static double predictX (double y, ArrayList < PointXY > list, int isNeg){
     double minDiffWithY = 9999999.0;
     double diffWithY;
     double predictedX = 9999999;
     int xIndex = 0;
     for(int i = 0; i< (list.size() -1);i++){
          PointXY P = list.get(i);
          diffWithY = p.y- y;
          if(diffWithY < 0){ diffWithY = -1* diffWithY; }
          if(diffWithY < minDiffWithY && (p.x*isNeg) >0){
          minDiffWithY = diffWithY;
          xIndex = i;
          predictedX = p.x;
          }
    }
    return predictedX;
    }
}
```