Medical Dosimetry 37 (2012) 71-75

Medical Dosimetry

journal homepage: www.meddos.org

Dosimetric evaluation of two treatment planning systems for high dose rate brachytherapy applications

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ARTICLE INFO

Article history:
Received 31 May 2010
Accepted 22 December 2010

Keywords:
Treatment planning system
Optimization
Intracavitary
Dwell position

ABSTRACT

Various treatment planning systems are used to design plans for the treatment of cervical cancer using high-dose-rate brachytherapy. The purpose of this study was to make a dosimetric comparison of the 2 treatment planning systems from Varian medical systems, namely ABACUS and BrachyVision. The dose distribution of Ir-192 source generated with a single dwell position was compared using ABACUS (version 3.1) and BrachyVision (version 6.5) planning systems. Ten patients with intracavitary applications were planned on both systems using orthogonal radiographs. Doses were calculated at the prescription points (point A, right and left) and reference points RU, LU, RM, LM, bladder, and rectum. For single dwell position, little difference was observed in the doses to points along the perpendicular bisector. The mean difference between ABACUS and BrachyVision for these points was 1.88%. The mean difference in the dose calculated toward the distal end of the cable by ABACUS and BrachyVision was 3.78%, whereas along the proximal end the difference was 19.82%. For the patient case there was approximately 2% difference between ABACUS and BrachyVision planning for dose to the prescription points. The dose difference for the reference points ranged from 0.4–1.5%. For bladder and rectum, the differences were 5.2% and 13.5%, respectively. The dose difference between the rectum points was statistically significant. There is considerable difference between the dose calculations performed by the 2 treatment planning systems. It is seen that these discrepancies are caused by the differences in the calculation methodology adopted by the 2 systems.

Introduction

Brachytherapy is recommended to form an important component in the definitive irradiation of cervical carcinoma.[1] High-dose-rate (HDR) intracavitary brachytherapy is a system that allows a high dose to be delivered in a short time of a few minutes to the cervix while sparing the nearby critical organs, such as the bladder and rectum to a large extent. Optimization of HDR tandem and ovoids ensures that the doses are not reduced in the target volume and that the potential for overdose is reduced.[2] HDR brachytherapy often involves optimization methods to calculate the dwell times and dwell positions of a radioactive source along specified applicator paths. The computerized treatment planning systems make it possible to create a patient plan within a short time before the treatment while producing very accurate dose calculations and also reducing the doses to the organs at risk through the optimization procedures. A dosimetric comparison of computerized treatment planning and standardized dose rate template planning by Patone *et al.* concludes that there is a significant dependency of dose rate on applicator geometry, which necessitates the use of computerized treatment planning.[3]

Various commercially available treatment planning systems have been studied and the calculations generated by them are compared. The comparison between NPS and Plato, the older and newer planning systems, respectively, from Nucletron by Elhanafy *et al.* highlighted the effects of differences in the calculation algorithm between the 2 systems.[4] For patient-specific treatment plans, the dose difference between NPS and Plato planning for all patient reference points ranged from 1–4%. The difference in dose between optimized and nonoptimized planning was approximately 0.5% for prescription points (point A), whereas for bladder and rectum the differences were 6% and 20%, respectively, with NPS and 8% and 22%, respectively, with Plato.

The 3 treatment planning systems for gynecologic intracavitary insertions, namely the GE Target II (GE Healthcare), BrachyVision and ADAC Pinnacle (Philips Healthcare) were analyzed for 3 patients by

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0958-3947/$ – see front matter Copyright © 2012 American Association of Medical Dosimetrists
doi:10.1016/j.meddos.2010.12.015

Concannon *et al.*[5] The largest deviation in the averages of the percentage differences in total dose calculated by BrachyVision and ADAC Pinnacle was only ±2.15% for all points compared with target planning system. It was found that most errors were caused by human error during digitization and calculation rounding.

Independently verifying the doses calculated by the optimization software before treatment delivery is an essential part of quality assurance. In-house software that provides an independent verification of dose calculations in a very short duration has been developed by Lachaine *et al.*[6] This verification code was designed specifically for the VariSource/BrachyVision combination, although it could be modified for other HDR units and/or planning software.

At our institute, the BrachyVision treatment planning system has been installed recently. The system that is routinely used for HDR brachytherapy treatment planning is the ABACUS treatment planning system. In this study, the dose distribution calculated by these 2 HDR treatment planning systems from Varian Medical Systems (Palo Alto, CA) was compared and analyzed.

Materials and methods

The calculations generated using ABACUS (version 3.1) and BrachyVision (version 6.5) treatment planning systems (Varian Medical Systems, Inc., Palo Alto, CA) were compared by analyzing 2 different source dwell-position configurations. In the first case, dose distribution around the source with one dwell position was evaluated. In the second case, intracavitary gynecologic applications of 10 patients treated for cervix cancer were compared using calculations performed with the aid of orthogonal radiographs.

Description of treatment planning systems

The 2 planning systems run on Windows-based operating system and use a digitizer to input source positions and dose calculation points from orthogonal radiographs. ABACUS provides different possibilities for dose optimization[7] such as (1) equal times, (2) geometrical optimization, and (3) iterative optimization. The various optimization routines available in BrachyVision[8] are (1) manual dose optimization, (2) geometrical optimization, and (3) volume optimization/inverse planning. BrachyVision has an additional dose shaper tool for altering the dose values by manually dragging the isodose lines.

Methods of dose calculation

The dose calculation of ABACUS is based on the conventional method that is based on converting the air kerma rate to dose to a medium.[7] The dose rate at a point P from a single-source position S is calculated using an equation

$$\dot{D}(P,S_i) = \dot{K}(0,100) \cdot \frac{[\mu_{en}/\rho]^{\mathrm{med}}}{[\mu_{en}/\rho]^{\mathrm{air}}} \cdot m(r) \cdot r(r,\phi) \cdot \frac{1}{r^2}$$

where

$\dot{K}(0{,}100)$ is the air kerma rate
$[\mu_{en}/\rho]^{\mathrm{med}}/[\mu_{en}/\rho]^{\mathrm{air}}$ is the ratio of the mass absorption coefficients in medium and air averaged over the energy distribution in the point of measurement
r is the distance from S to P
m(r) is the value of the Meisberger polynomial ($a_0 + a_1 . r + a_2 . r^2 + a_3 . r^3 + a_4 . r^4 + a_5 . r^5$)
φ is the angle between the vector from S to P and the longitudinal source axis
$f(r, \varphi)$ is the anisotropy correction factor for distance r and angle φ.

The dose calculation algorithm of the BrachyVision planning system is based on the recommendations of the AAPM Task Group 43.[8,9] The dose rate, D(r, θ) at point (r, θ), where r is the distance to the point of interest and θ is the angle with respect to the long axis of the source can be written as,

$$D(r,\theta) = S_k \cdot \Lambda \cdot \left[\frac{G(r,\theta)}{G(r_0,\theta_0)}\right] \cdot g(r) \cdot F(r,\theta)$$

where

S_k is the air kerma strength of the source,
Λ is the dose rate constant
G(r, θ) is the geometry factor
g(r) is the radial dose function
F(r, θ) is the anisotropy function

Comparison of dose distribution

Single dwell position doses were calculated at intervals of 1 cm up to a distance of 10 cm on both sides of the perpendicular bisector and along both sides of the source axis

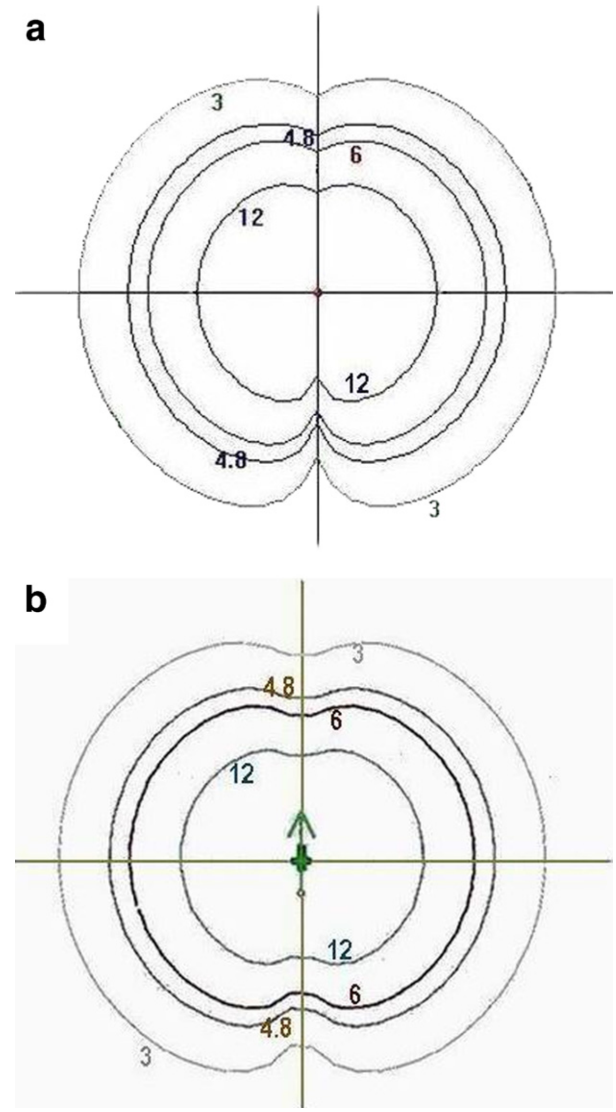

Fig. 1. (a) Dose distribution showing 50%, 80%, 100%, and 200% isodose lines for a single dwell position from ABACUS. (b) Dose distribution showing 50%, 80%, 100%, and 200% isodose lines for a single dwell position from BrachyVision.

with respect to the source center. The prescription dose was 6 Gy at 2 cm from the source and doses were measured at all the reference points.

In the second case, the orthogonal films of patients with intracavitary gynecologic insertions were used for comparison. Patients with 6-cm tandem length were selected for this purpose. The points of interest, such as RA, LA, RU, LU, RM, LM, bladder, and rectum were localized manually on the anterior and lateral films. Point A was taken 2 cm lateral, perpendicular to the midline of the intrauterine canal and 2 cm superior along the tandem from the external cervical OS (represented by flange).[10,11] Points RU and LU lie 1 cm inferior to the tip of the tandem and 1.8 cm both to the right and left of the tandem axis, respectively. Similarly, points RM and LM lie 2 cm inferior to the tandem tip and 2 cm toward the right and left of the tandem axis, respectively. The bladder and rectum points are marked according to the definition of ICRU report 38.[12]

The data were then entered into both the systems using the digitizing board, and treatment planning was performed as instructed in the user manuals.[7,8] ABACUS used a total of 23 dwell positions, whereas BrachyVision used 16 dwell positions for the same application. The tandem contained 13 dwell positions and ovoids contained 5 positions each in ABACUS, whereas the tandem contained 10 dwell positions and ovoids 3 positions each in BrachyVision planning system. A step size of 5 mm was used. Doses were calculated at the prescription points (RA, LA) and reference points RU, LU, RM, LM, bladder, and rectum points. HDR planning can be performed by dose optimization or nonoptimization methods. In this study, optimization was performed using geometrical optimization, which adjusts dwell times in an attempt to produce a uniform dose around the applicators.