BRACHYTHERAPY PLAN EVALUATION IN HEAD AND NECK CANCERS

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INTRODUCTION

- In radiotherapy treatment planning, dose homogeneity inside the target volume poses a serious problem both in external beam as well as in brachytherapy.
- In contrast to external beam radiotherapy, brachytherapy implants provide great dose conformity with significant dose inhomogeneity inside the treatment volume.
- The dose inhomogeneity inside the target volume depends on many factors such as the
- type of sources,
- placement of these radioactive sources,
- distance between the applicators/ implant tubes,
- dwell time of the source, etc.

J C B 2010; 2, 2: 71-75

PRE PLAN

- In interstitial brachytherapy it is customary to determine prior to implantation the optimal dose distribution.
- This planning procedure is usually based on one of the well-known dosimetry systems.
- Quality of the implant may have an important impact on the clinical result, careful consideration has to be given to implant techniques to achieve dose agreement between forecast and actual source arrangement.
- A three-dimensional volume-dose relationship is preferable for the qualitative assessment of brachytherapy implants.

BASIC PRINCIPLES PARIS SYSTEM

1. The active sources should be parallel and straight.

1. The lines should be equidistant.

2. The line or plane on which the midpoints of the sources lie should be at right angles to the axis of each source.

3. The linear activity of the lines should be uniform along the length of each line and identical for all lines.

BASIC PRINCIPLES PARIS SYSTEM (cont)

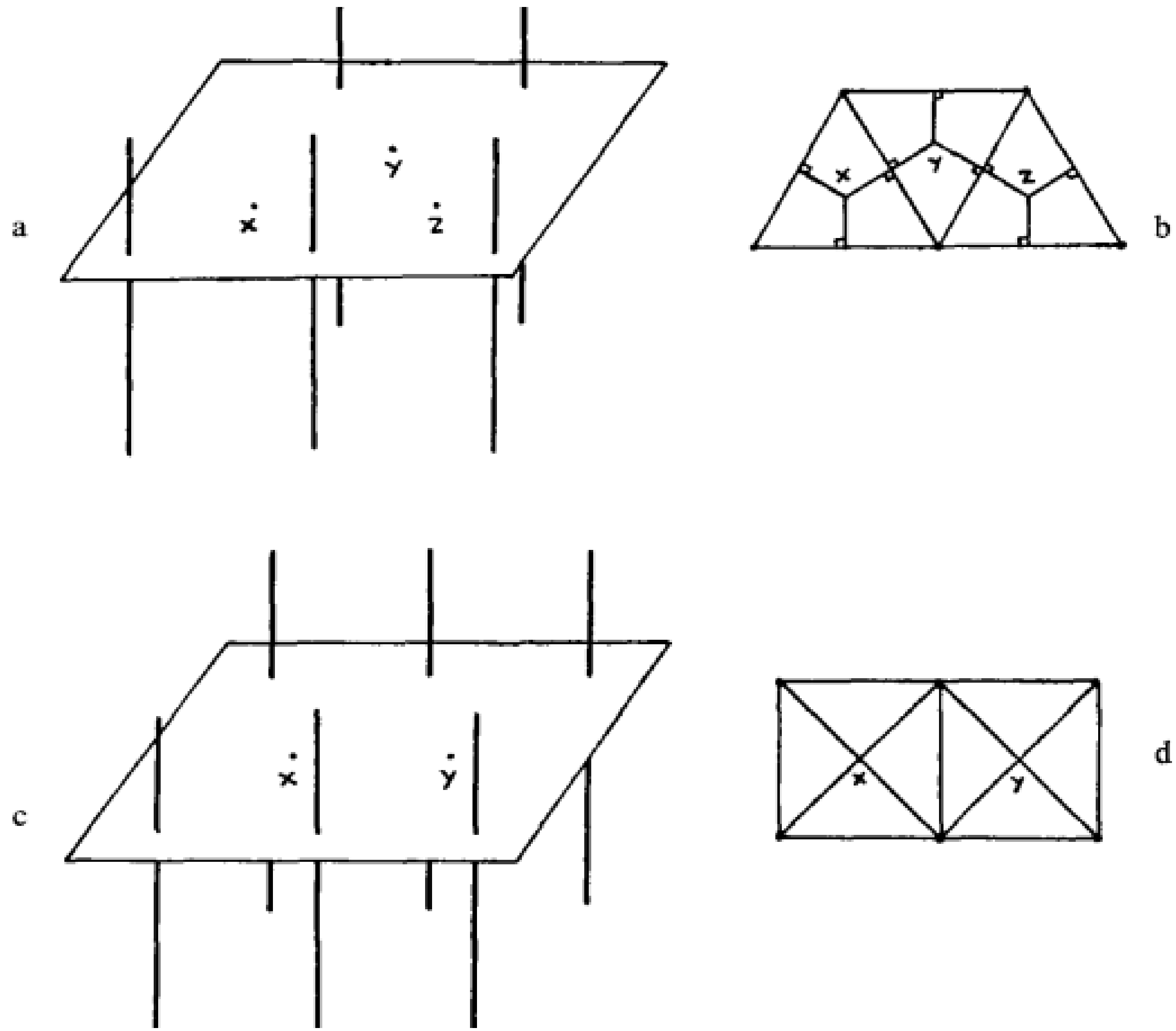
5. Although in any one implant the sources are all separated equally from each other from one implant to another source separation may be varied.
6. For volume implants, the distribution produced in cross section (central plane) should be either an equilateral triangle or square.
7. As the ends are not crossed usually the length of the wire must be longer than the target volume by 25-30% depending upon the number and separation of sources used.

INTERSOURSE SPACING

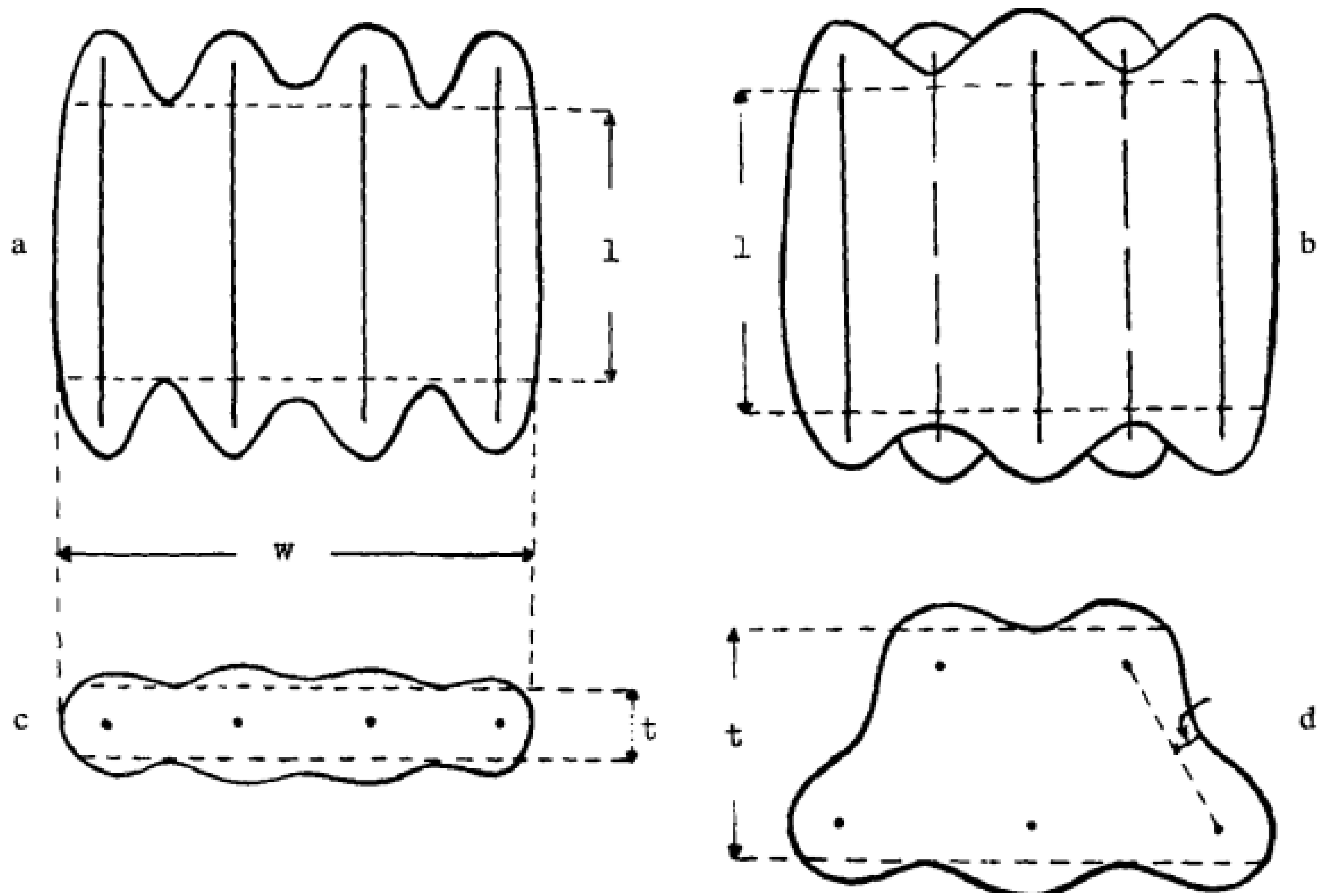
- Intersource spacing has a major influence on the dose distribution in interstitial brachytherapy.
- 15-20 mm intersource spacing is associated with a higher risk of local failure than 9-14 mm intersource spacing;
- Higher risk of necrosis than 9-14 mm intersource spacing, for patients treated for a mobile tongue carcinoma.
- To maximize local control and to minimize necrosis, intersource spacing should be less than 15mm.

Radiotherapy and Oncology, 26 (1993) 19-25

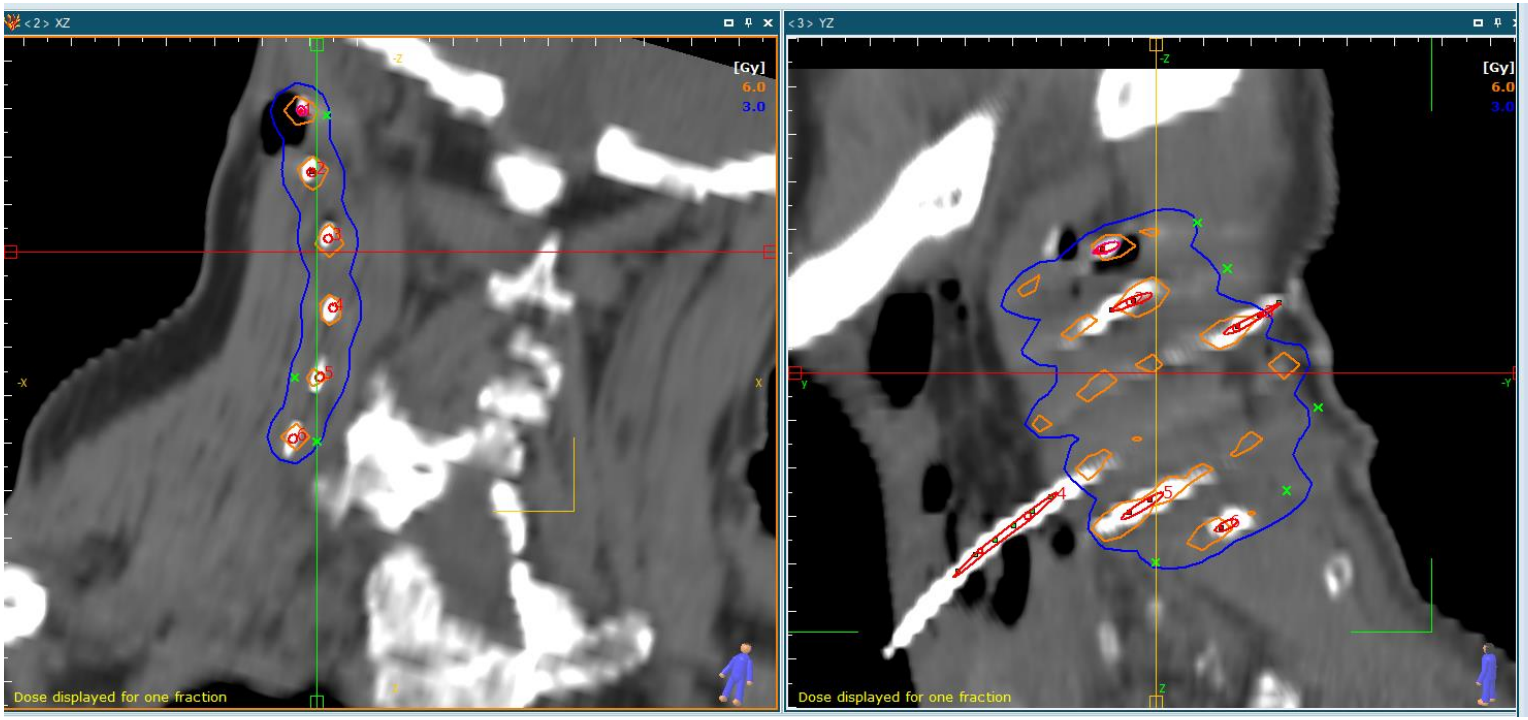
PARIS SYSTEM



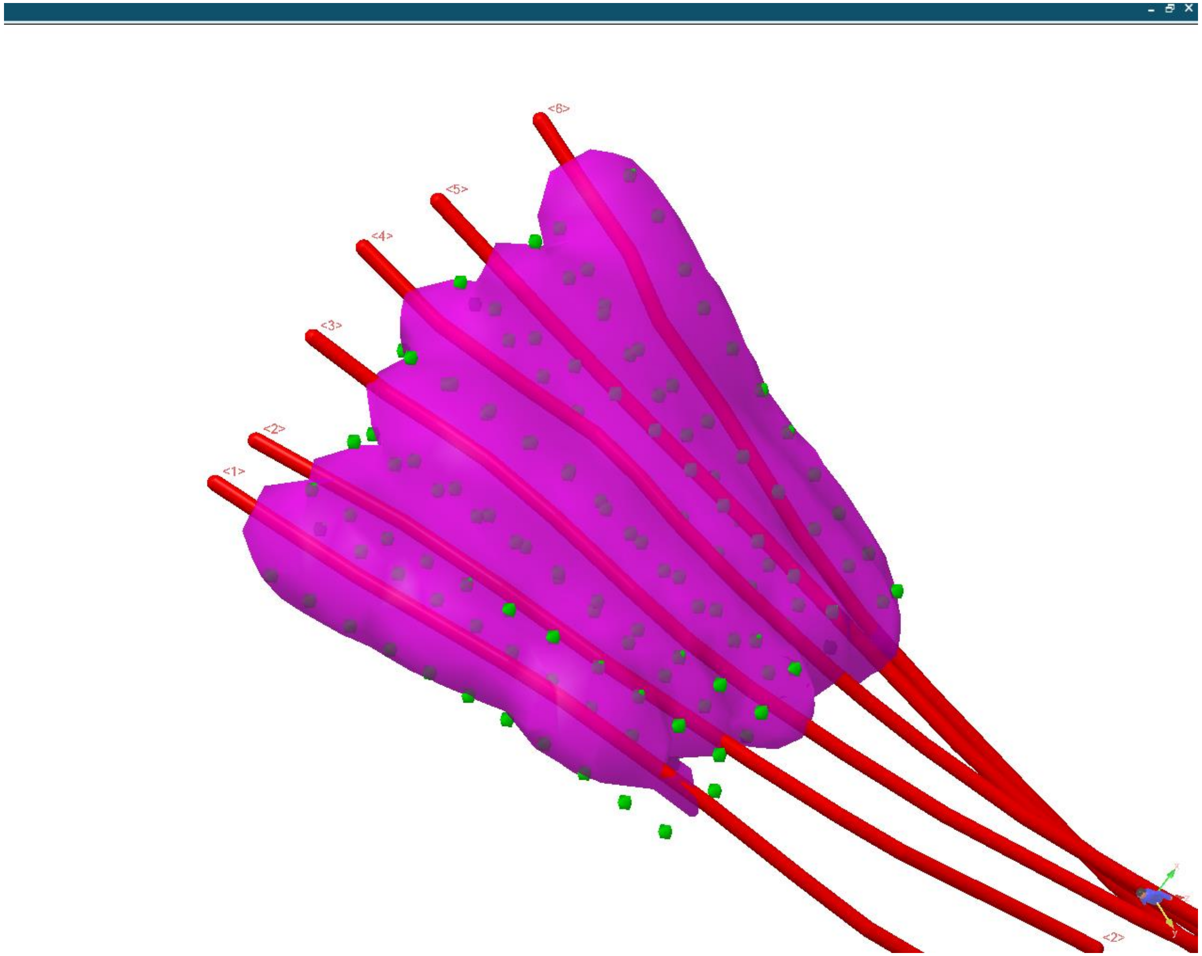
PARIS SYSTEM



SINGLE PLANE IMPLANT



3D VIEW



Rep Radiother Oncol. 2019 December; 6(1):e98391. doi: 10.5812/rro.98391.
Published online 2019 December 16. Research Article

High Dose-Rate Brachytherapy in Recurrent High-Risk Head and Neck Cancer

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Received 2019 September 25; **Accepted** 2019 November 27.

Abstract

Background: Thirty to fifty percent of HNSCC patients treated with chemoradiation therapy present with recurrence and can be treated with maximum debulking surgery combined with re-irradiation. Re-irradiation can be done using external beam radiation therapy (EBRT) or brachytherapy. The advantage of brachytherapy over EBRT is that owing to rapid dose falls off, a higher dose can be delivered to the target area sparing normal tissue. Hence, we evaluated toxicity and outcomes [overall survival (OS) and disease-free survival (DFS)] in high-risk (HR) recurrent HNSCC patients undergoing re-irradiation using interstitial brachytherapy following surgery.
Objectives: To evaluate toxicity and outcomes of re-irradiation using Interstitial High Dose-Rate Brachytherapy (HDR-BRT) in high-risk Head and Neck Squamous Cell Carcinoma (HNSCC) patients.
Methods: Ten biopsy-proven recurrent HNSCC patients treated with primary chemoradiation therapy who had the HR of the second recurrence at nodal disease were evaluated. All patients underwent surgery followed by the intraoperative placement of catheters in a single plane, at 10 - 12 mm apart and fixed with stay sutures. The CT simulation was done on the 5th - 7th postoperative day. Volumetric optimization was done with a 5-mm dwell position. The dose of 30 Gy/10 Fractions, 3 Gy/Fraction, two fractions per day, 6 hours apart after 5 days was planned.
Results: The DFS and OS for the entire cohort in 1 and 2 years were 60% and 40%, respectively. One patient had carotid blowout where the disease was stuck to the carotid vessel. No other significant acute or late toxicity was noted.
Conclusions: The HDR-interstitial brachytherapy in the recurrent HR, HNSCC with the intraoperative placement of catheters at

OPTIMIZATION OF DOSE DISTRIBUTION

- In brachytherapy optimization of dose distribution is usually achieved by establishing the relative spatial or temporal distribution of the sources and by weighting the strength of the individual sources.
- Current optimization approaches fall into one of the following categories:
- Source distribution rules.
- Geometry.
- Specified dose points.
- Trial and adjustment

OPTIMIZATION OF DOSE DISTRIBUTION(cont)

- Optimization in HDR and PDR treatment planning for a single stepping source involves manipulation of source dwell positions and the relative dwell times to produce the desired dose distribution.
- Most current optimization methods are analytic.
- Other approaches use random search techniques in which the performance of the system is made to improve through the use of objective functions

GEC-ESTRO RECOMMENDATIONS

- The use of 3D imaging in head and neck brachytherapy to delineate the GTV and CTV and the organs at risk including the mandible makes it possible to obtain objective data on dose volume histograms (DVHs).
- Identifying hot spots on contiguous areas or cold spots in organs at risk also provides elements, which allow the optimization of dose distribution.
- The optimization method should be specified.
- Quality parameters such as the Dose Non-Uniformity Ratio (DNR), Homogeneity Index (HI) and Uniformity Index (UI) together with other parameters should be documented.
- Optimization should not be used as a substitute for poor-quality catheter implantation.

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IBS RECOMMENDATIONS

- Description of clinical conditions, including GTV and CTV.
- Description of the technique.
- Source specification, including reference air-kerma rate (RAKR) and total reference air-kerma (TRAK)
- A complete description of the time-dose pattern
- Treatment description.
- Evaluation of mean central dose (MCD), minimum target dose, homogeneity index volumes, and their dimensions, including PTV/ITV, treated volume, high-dose regions, low-dose regions, reference volume, and irradiated volume
- Coverage and conformity index.
- Dose non-uniformity ratio (DNR); ideally should be 0.35.
- Dose for organs at risks (as followed for EBRT).

J C B (2020/volume 12/number 5)

PTV RELATED PARAMETERS

- For high quality image-based BT, 3D tomographic image sets of target and critical structures are highly recommended.
- Therefore, the dose plan evaluation for implant, PTV, and critical structures using DVH data have great significance.
- GEC-ESTRO recommends; the prescription dose is usually the minimum dose delivered to the clinical target volume (CTV) or a CTV surrogate (i.e., the D90 > 100, V100 > 90%).or
- CTV coverage ,-- D90 is at least 90% of the prescribed dose.
- D90 is a good parameter to evaluate the target coverage.
- The volume of the PTV (VPTV) has shown a good correlation with the irradiated volume of 100% PD (V100).

J C B (2017/volume 9/number 6)

PLAN EVALUATION

- Brachytherapy plan evaluation is performed either qualitatively or quantitatively.
- The qualitative evaluation of the brachytherapy plan is usually carried out by visualizing the dose distribution in each and every slice of the CT.
- For quantitative evaluation several indices and ratios have been defined by various authors.

QUANTITATIVE PLAN EVALUATION

- Some of the indices routinely used for plan evaluation are
- Coverage index (CI),
- External volume index ,
- Over dose volume index (ODI) ,
- Dose homogeneity index (DHI) ,
- Dose non-uniformity ratio (DNR) ,
- Dose volume uniformity index (DVUI) etc.
- Besides these indices and ratios, the rival plans are also analysed with a dose volume histogram such as the
- Cumulative dose volume histogram (cDVH),
- Differential dose volume histogram (dDVH) and the
- Natural dose volume histogram (nDVH)

J Contemp Brachyther 2010; 2, 2: 71-75

PARAMETERS FOR IMPLANT QUALITY

- Dose non-uniformity ratio (DNR) was defined as the ratio of volume receiving 1.5 times of the PD and the PD.
- DNR = V150/V100;
- Dose homogeneity index (DHI), ;
- DHI = (V100 – V150)/V100;
- Conformal index;
- COIN = (PTV100/VPTV) x (PTV100/V100).
- PTV100; absolute partial volume of the PTV, receiving 100% of the PD, VPTV;absolute volume of the PTV.
- COIN takes into account the coverage of the planning target volume (PTV) and dose outside the PTV

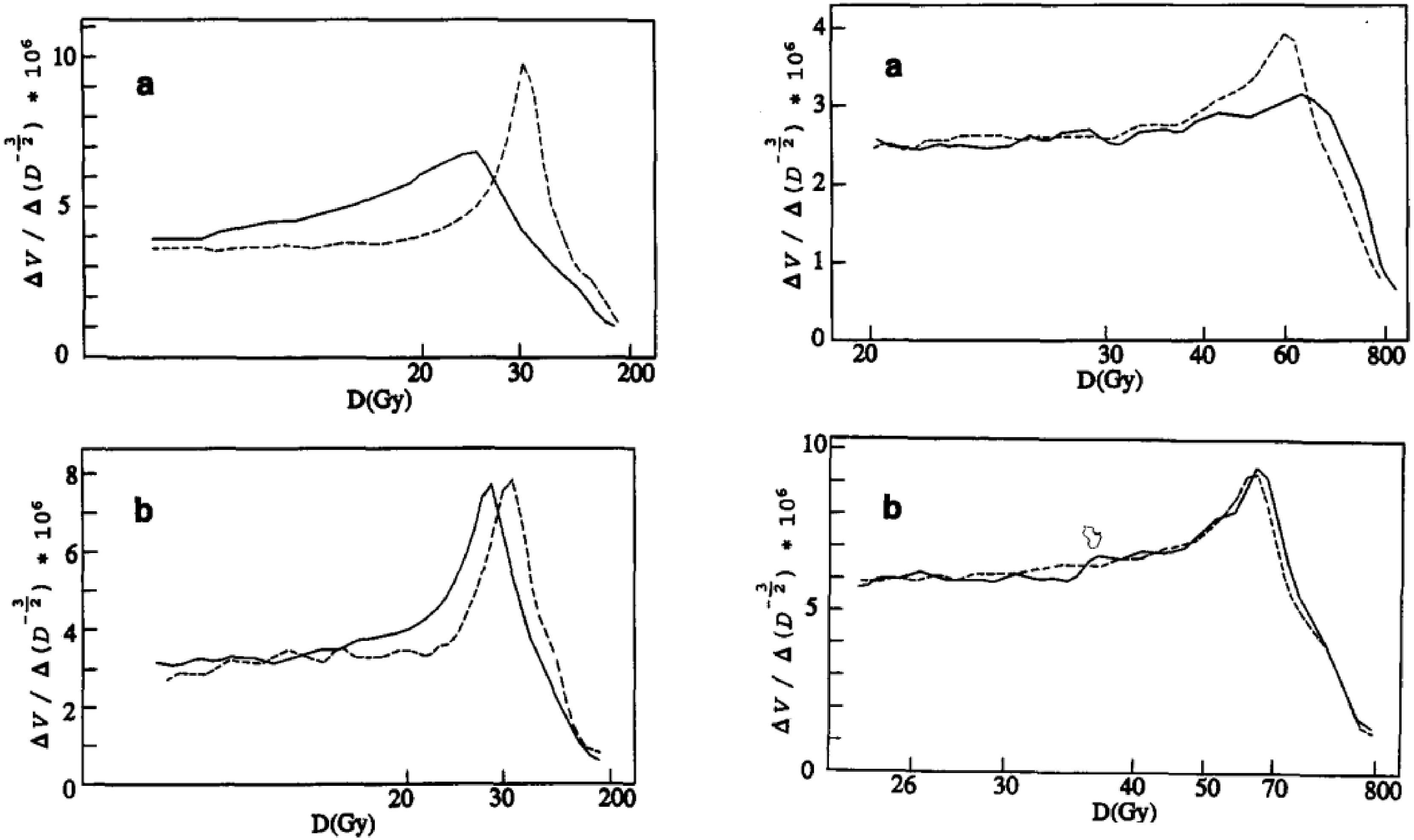
PARAMETERS FOR IMPLANT QUALITY (cont)

- Homogeneity index (HI) relation of the minimal dose (peripheral dose), that envelops the target volume to the mean central dose (MCD) in the central plane.
- Ideally in the Paris-system MCD is located in the centre of an equilateral triangle or square.
- This ratio describes the quality of an implant in terms of the spread of isodoses encompassing the primary tumor volume (PTV)

GRAPHICAL EVALUATION

- In a plot of the standard cumulated volume-dose histogram, however, largely as a result of the ubiquitous influence of the inverse square law, the much higher volume associated with low doses tends to obscure any interesting variations occurring at higher doses.
- A volume-dose histogram which suppresses inverse square law effects resulting in a model which reveals even small differences between implants was originally developed by Anderson, called the "natural" volume-dose histogram.
- The "natural" volume-dose histogram of a regular multisource implant demonstrates a peak. Greater dose uniformity is implied by higher, narrower peaks

NATURAL VOLUME-DOSE HISTOGRAM.



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IMPLANT RELATED PARAMETERS

- There is no agreement on what degree of dose non-uniformity is permitted in the image-based head and neck HDR BT.
- Systematic collection and documentation of implant quality measures (COIN, DNR, etc.) for future evaluation are advisable .
- Strnad et al. reported that DNR should be equal to or lower than 0.36 and in IMBT (intensity modulated brachytherapy), this value should be 0.42.
- Guinot et al. did not allow a hot spot joining two tubes in order to keep DNR under 0.35.
- Paris system allows 200% isodose volume to be 8-10mm.
- In small gross tumor volumes (few cm^3 and applicator spacing is less than 10 mm), the DNR may be as high as 0.50-0.52 .

J C B (2014/volume 6/number 4)

Radiotherapy and Oncology 91 (2009) 150–156

Brachytherapy 9 (2010) 227e234

TARGET VOLUME EVALUATION

- For quantitative estimation of doses for the target volume coverage, the following dose-volume parameters are calculated using dose-volume histograms (DVH):
- Percentage volume of the PTV receiving more than 100% and 150% of the PD (V100 and V150);
- Minimum percentage dose of the PD that was given to 90% and 100% of the PTV (D90 and D100).
- To analyze homogeneity and conformity of dose distributions, dose non-uniformity ratio (DNR), dose homogeneity index (DHI), and conformal index (COIN) can be used.

CRITICAL STRUCTURES EVALUATION

- As critical structures, mandible, spinal cord, and salivary glands.
- For the mandible and spinal cord, minimum percentage doses of the PD that was given to maximally irradiated 0.1 cm3, 1 cm3, and 2 cm3 volumes (D0.1cm3, D1cm3, and D2cm3) can be calculated from DVH.
- No specific tolerance doses to critical structures are given in the GEC-ESTRO recommendations. They only prescribe to keep the doses to organs at risk as low as possible.

Recommendations for reporting interstitial therapy according to ICRU report 58

- Description of the clinical conditions, including GTV and CTV Description of the technique ,Source specification, including RAKR (Reference Air Kerma Rate) and TRAK (Total Reference Air Kerma).
- Complete description of the time-dose pattern.
- Treatment description
- Mean central dose (MCD), Minimum Target Dose, Homogeneity Index Volumes and their dimensions, including PTV, Treated Volume, high-dose regions, low-dose regions, reference volume, irradiated volume
- Coverage and conformity if possible
- Organs at risks

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Optimal Dose Distribution with Isodose Curves

- Curative therapy will include CTV goals of dose to 90% of the CTV (D90)>than 100% of the prescription dose and volume of the 100% isodose (V100) should encompass >90% of the CTV.
- The primary OARs are the spinal cord, brain stem, eyes, and mandible.
- Consideration should also be given to major blood vessels and cranial nerves, but the latter are hard to delineate with CT images alone.
- The commonly used dose homogeneity factor of volume of the target that receives 150% of the prescription dose (V150) ranges from 20 to 35% in most cases where a generous array of catheters encompasses the target.
- Higher V150 can be expected when the implant fails to encompass the lesion or there are large portions of the CTV without catheters

CONCLUSIONS

- Quality parameters such as the inter-tube distance, volume of the reference isodose, the volume gradient ratio, the high dose, the peak dose and the quality index are also important in estimating the risk of late complications and the probability of local control .
- The quantitative plan evaluation may help us find correlations between dosimetric parameters and clinical outcome, and may lead to improve the quality of the treatment, but it requires longer follow-up and results.