



Original article

Forward-Planned Multisegmented Technique in Resource-Limited Settings: A Feasible Dosimetric Upgrade for 3D-CRT in Locally Advanced Nasopharyngeal Carcinoma

Technique multisegmentée planifiée en amont dans un contexte de ressources limitées : une amélioration dosimétrique réalisable de la radiothérapie conformationnelle tridimensionnelle (3D-CRT) dans le carcinome du nasopharynx localement avancé

AS Badiane*¹, MM Dieng¹, LEF Edimo², I Thiam¹, K Ka³, M Diagne^{1,4}, F Gning³, L Gueye³, PM Gaye³

Résumé

In resource-limited settings, intensity-modulated radiotherapy (IMRT) is often unavailable, forcing reliance on three-dimensional conformal radiotherapy (3D-CRT) for advanced nasopharyngeal carcinoma (NPC). This limits curative potential due to challenges in sparing organs-at-risk (OARs) while covering complex target volumes. This study compared the forward-planned multisegmented technique (FPMS) and the multi-field technique (MFT) in 3D-CRT for NPC, focusing on OAR protection and target coverage. Conducted at two public centres in Dakar, Senegal, between January 2019 and September 2020, this retrospective dosimetric analysis included eight patients. For each, two treatment plans were generated for the initial 50 Gy phase: one using MFT and one

using FPMS. Plans were assessed with dose-volume histograms, conformity and homogeneity indices. FPMS achieved superior OAR sparing, with lower mean maximum doses to the spinal cord (43 Gy vs. 45 Gy) and brainstem (52 Gy vs. 55 Gy). Parotid sparing remained inadequate with both techniques. Coverage of pathological lymph node volumes (PTVN70) was suboptimal in both approaches (80.5% vs. 78.9%). FPMS thus provides better OAR protection than MFT, but neither ensures optimal target coverage in locally advanced NPC. These findings support FPMS as a feasible, interim solution in African centres awaiting IMRT, while underscoring the urgent need for technological advancement.

Keywords: radiotherapy conformal, low-resource setting, nasopharyngeal carcinoma.

Abstract

In resource-limited settings, intensity-modulated radiotherapy (IMRT) is often unavailable, forcing reliance on three-dimensional conformal radiotherapy (3D-CRT) for advanced nasopharyngeal carcinoma (NPC). This limits curative potential due to challenges in sparing organs-at-risk (OARs) while covering complex target volumes. This study compared the forward-planned multisegmented technique (FPMS) and the multi-field technique (MFT) in 3D-CRT for NPC, focusing on OAR protection and target coverage. Conducted at two public centres in Dakar, Senegal, between January 2019 and September 2020, this retrospective dosimetric analysis included eight patients. For each, two treatment plans were generated for the initial 50 Gy phase: one using MFT and one using FPMS. Plans were assessed with dose-volume histograms, conformity and homogeneity indices. FPMS achieved superior OAR sparing, with lower mean maximum doses to the spinal cord (43 Gy vs. 45 Gy) and brainstem (52 Gy vs. 55 Gy). Parotid sparing remained inadequate with both techniques. Coverage of pathological lymph node volumes (PTVN70) was suboptimal in both approaches (80.5% vs. 78.9%). FPMS thus provides better OAR protection than MFT, but neither ensures optimal target coverage in locally advanced NPC. These findings support FPMS as a feasible, interim solution in African centres awaiting IMRT, while underscoring the urgent need for technological advancement.

Keywords: radiotherapy conformal, low-resource setting, nasopharyngeal carcinoma.

Introduction

Cancer of the nasopharynx (NPC) poses significant challenges in radiotherapy due to the anatomical complexity of the region and the proximity of critical organs. Intensity-modulated radiotherapy (IMRT) has become the gold standard for managing NPC, offering superior target volume coverage and better sparing of organs at risk (OAR). However, in resource-limited

settings, IMRT is often inaccessible, leaving three-dimensional conformal radiotherapy (3D-CRT) as the primary treatment modality despite its limitations.

In many cases, the inability of 3D-CRT to adequately protect critical structures leads to a shift from curative to palliative treatment intents, even for patients who could potentially benefit from a radical approach. This is particularly evident in locally advanced stages, where achieving optimal dose coverage while respecting OAR constraints becomes exceedingly difficult.

Conventional planning in 3D-CRT generally consists of irradiation with two lateral photon beams combined with an antero-posterior beam up to the maximum dose permitted on the spinal cord, followed by a reduction of these beams posteriorly to protect it, and the dose is sometimes complemented to the tumour volume by reduced electron beams. [1,2]

Over the years, advancements in 3D-CRT techniques, such as the use of multi-field and then multisegmented (referred to as forward-planned IMRT or forward-planned multisegmented technique) approaches, have aimed to improve dose conformity and homogeneity. These techniques, offer a means of optimizing treatment within the constraints of available resources. [3–6]

However, the clinical benefits of these approaches, particularly in the context of NPC, remain inadequately explored in low-resource settings. Following the implementation of 3D-CRT in our radiotherapy departments in 2018, cases of head and neck cancer have invariably been treated using conventional 3- or 4-field planning. Frequently, difficulties have been observed in achieving the compromise between coverage and constraints on organs at risk, especially in patients with locally advanced tumours of the nasopharynx. The objective of this study was to compare the dosimetric performance of the FPMS technique with the multi-field technique, with the aim of proposing the most efficient treatment for the coverage of target volumes and the protection of organs at risk pending the acquisition of IMRT.

Methodology

Study design: This is a retrospective dosimetric study comparing two radiotherapy techniques for nasopharyngeal carcinoma (NPC): the multi-field technique and the forward-planned multisegmented technique.

Patients and Target Volumes:

The CTV (clinical target volume) was obtained by adding 5 mm of margin around the primary and lymph node GTV. For the PTV (planning target volume), the margins were standardised to 3 mm around the CTVs, which had been corrected by excluding healthy bone and air before the margins were applied. Conventional fractionation of 2 Gy was used in all patients. Prophylactic lymph node volume (PTVN50) was treated to 50 Gy. The prescribed dose was 70 Gy for PTVT70 and PTVN70 (corresponding to the primary and lymph node tumour volumes respectively).

All patients were treated with three-dimensional conformal radiotherapy and received concomitant chemotherapy.

Treatment Planning:

Two treatment plans were drawn up for each patient: each pair of treatments was carried out by the same physicist. For the first 50 Gy phase, for each patient, have been made an initial planning using a multi-field technique (MFT) and a second using the forward-planned multisegmented technique (FPMS).

Basically, the MFT involved at least 5 fields: a posterior field (180°), two postero-oblique fields (between 150° and 220°) hiding the spinal cord and two lateral fields (around 270° and 90° with the table tilted at 15°). The posterior field could be divided into two fields if the spinal cord could not be completely protected. For some patients, adaptation to the tumour configuration would require a change in the angulation of the fields, or even an increase in the entry points by adding additional anterior lateral or oblique beams, making the number of fields vary from 5 to 7. For certain patients, the posterior field was substituted by an anterior field to adapt tumour coverage.

For the FPMS typically seven treatment angles were

used as described in the Lee et al study, involving one anterior, two lateral, two anterior oblique and two posterior oblique fields from which segmentation was performed for optimization. The majority of angles had a distribution of two to three segments, varying the weightings and energies and blocking either the spinal cord or the brainstem in certain segments, or both simultaneously to improve their protection. Plans of 10 to 14 segments were carried out in this way. [4]

For the second 70 Gy boost phase, the conventional technique of two (2) opposing lateral beams was generally used. The same number of fields (2 to 6) was used for each pair of planes; only weightings and angulations varied according to the contribution of the first 50 Gy phase.

Both techniques were mono-isocentric, and energies of 6 MV and 10 MV were used, either alone or in combination. An example of beam distribution in one of the patients for both techniques is shown in Table I.

Plan Evaluation

The aim of the planning was to achieve ICRU recommendations of at least 95% of the prescribed dose in 95% of the PTVs ($D_{95\%} \geq 95\%$). When this was not possible, a $D_{95\%}$ between 90 and 95% was deemed acceptable. At the same time, the objective was to have the most homogenous coverage possible and not to exceed a dose of 45 Gy on the spinal cord (chemotherapy being prescribed for all patients) and 54 Gy on the brainstem.

Setting: It was conducted at the two public radiotherapy centres in Dakar between January 2019 and September 2020. At the time of the study, these two centres were the only public centres in the country and did not offer IMRT. In fact, the equipment utilised at the Dalal Jamm Hospital was the Monaco 3D Treatment Planning System (TPS) of computerised medical system, copyright Elekta (Software release 5.11). This system incorporated the Collapsed-Cone Dose Calculation Algorithm, and the linear accelerator employed was the ELEKTA Synergy Platform, operating at 6 MV, 10 MV photon energy and 6, 9, 12, 15, et 18 MeV electron energy. And at

the Aristide Le Dantec Hospital, the Eclipse three-dimensional Treatment Planning System (TPS) of Varian Medical Systems (Palo Alto, California, USA), Version 15.1, was utilised. This software incorporates the 3-dimensional algorithm AAA (Anisotropic Analytical Algorithm) for dose calculation. The linear accelerator used was a 6 MV Varian Unique model equipped with 120 multi-leaf collimators.

Participants: Patients treated with radiotherapy for nasopharyngeal cancer with curative intent were eligible. All cases of nasopharyngeal cancer treated with palliative intent were therefore excluded.

Sample size: The sample size was determined by including all cases of nasopharyngeal carcinoma treated with curative radiotherapy between January 2019 and September 2020. This selection ensures a degree of homogeneity in the study population and enables radiotherapy techniques to be evaluated in a curative setting. The limited number of cases reflects the rarity of this tumour location in our context, emphasising the value of a targeted analysis; however, this may limit the generalisability of the results.

Variables:

To assess the coverage of PTVs, the D95% (Dose received by 95% of PTVs) was collected. The PTVs were also assessed for homogeneity; mean doses (Dmean), minimum doses (Dmin), D5% (Dose received by 5% of PTVs) and treatment volumes receiving 95% and 107% of the dose (V95% and V107%) were collected for this purpose. The analysis also includes conformity and homogeneity indices, which are used to estimate the quality of the treatment plan. The following section describes the methodology of calculation and interpretation used in this study.

For organs at risk (OAR), the maximum doses (Dmax) to the spinal cord, brainstem, chiasma, optic nerves and mandible were recorded, and mean doses (Dmean) to the cochlea, parotid glands and mandible. For parotids and spinal cord, in addition to the parameters listed, the V45Gy (volume of the organ receiving 45 Gy) was also recorded. Validation of the constraints on the OARs was based on the RECORAD

2022 recommendations.[7]

Data sources and measurement

Data collection: These various data on coverage and doses to organs at risk were collected from the dose histogram volume (DVH) of the respective TPS, Monaco 3D Treatment Planning System and Eclipse three-dimensional Treatment Planning System. The conformity index (CI) employed was the one established by the RTOG (Radiation Therapy Oncology Group), which is defined as the ratio between the target volume covered by the reference isodose and the target volume. It ranges from 0 to 1; a value of 1 represents ideal dose coverage calculated for the tumour volume, indicating that there is no ‘underdosing’ in the tumour volume. Below this value, the irradiated volume is not fully included in the reference isodose and at 0, it is completely outside this isodose. Homogeneity was assessed by the homogeneity or heterogeneity index (HI), which is the ratio of D5% to D95% (where D5% corresponds to the maximum dose absorbed by the PTV and D95% to the minimum dose absorbed). A ratio close to 1 indicates a more homogeneous dose. [8,9]

Data entry and statistical analysis

The data were collected in Microsoft Excel 2013 and analyzed using R software version 3.6.1. Descriptive statistics were used to summarize dosimetric parameters (mean and standard deviation). Data were analyzed using the Wilcoxon signed-rank test, with p-values reported and confidence intervals provided to reflect the uncertainty due to the small sample size. A qualitative comparison of dosimetric outcomes was conducted using dose-volume histograms and descriptive statistics.

The potential biases are that the treatment plans were carried out by different teams and with different equipment. To minimize variability due to different treatment planning systems and physicists, a standardized planning protocol was implemented. This included predefined beam arrangements and dose constraints. The low incidence of this disease in our context and the timeframe explains the small sample size.

Ethical considerations

The present study is based on a retrospective analysis of the records of patients treated, without any direct intervention or change in their management. Patient anonymity was rigorously preserved in order to guarantee the confidentiality of the data. Given the retrospective nature of the study and the absence of any impact on patient follow-up, no individual consent was required. However, the ethical principles in force were respected in accordance with the recommendations applicable to observational studies.

Table I: Typical beam configuration for multi-field and forward-planned multisegmented (FPMS) techniques: gantry angle, weight, energy, and monitor units. Example from a patient

Multi-field technique																
	LATR	POST	LATL	O1	O2	O1bis	O2bis	AA*	BB*							
Gantry Angle	270°	180°	90°	113.7°	226.4°	115°	228°	96°	265°							
Weight	17.13%	31.46%	25.84%	11.53%	12.11%	0.96%	0.97%	50%	50%							
Energie (Mv)	10	10	10	10	10	10	10	10	10							
MU** (units)	30.82	61.4	68.91	36.9	29.2	3.02	2.36	111.72	105.73							
Forward-planned multisegmented technique																
	LATR	POST	LATL	O1	O2	O1bis	O2bis	LATR	POST	LATL	O1	O2	O1Bbis	O2Bbis	AA*	BB*
Gantry Angle	270°	180°	90°	113.7°	226.4°	117°	230°	275°	180°	85°	117°	230°	115°	225°	96°	265°
Weight	5.77%	36.99%	34.32%	6.18%	8.82%	1.02%	1.02%	0.83%	0.83%	0.84%	0.84%	0.85%	0.84%	0.85%	50%	50%
Energie (Mv)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
MU (units)	10.38	72.2	91.52	19.61	21.27	3.13	2.48	1.44	1.62	2.11	2.58	2.07	2.64	2.03	111.72	105.73

*Boost fields

**MU: monitor units

Results

Populations characteristics

A total of 10 patients were identified, 8 of the cases of which were selected for analysis, with the remaining two cases excluded due to palliative treatment. Tumour stages and PTV volumes are listed in Table II.

OAR Dose Analysis:

With MFT, the mean dose to the spinal cord was 43.8 ± 4.8 Gy compared with 45.7 ± 2.1 Gy for FPMS. Among the three patients whose spinal cord received doses exceeding 45 Gy, the mean volume receiving 45 Gy (V45Gy) was lower with FPMS (0.07 cm^3 vs. 0.29 cm^3 with MFT) (Table III).

The brainstem received less dose in the multisegmented technique, with a mean Dmax of 52.6 Gy, compared to 55.2 Gy for MFT. The chiasma was also less exposed with FPMS, with an average Dmax of 26 Gy compared with 28 Gy. The constraints on the chiasma were not respected in two patients with MFT, and recuperation was possible with FPMS in one of them. Similarly, doses to the optic nerves were lower with FPMS, and only one patient had a critical dose exceeded with both techniques (72 Gy Vs 66 Gy to the right optic nerve and 66Gy Vs 65 Gy to the left, respectively for FPMS and MFT). Doses to the cochlea were also reduced with FPMS, and neither technique was above the limits. In the mandible, the maximum doses were exceeded for both techniques, but the average doses remained below 60 Gy, and it should be noted that it

was less irradiated with FPMS (Table III).

The parotid glands were not adequately spared by either technique. However, doses were lower with the multisegmented technique, with an average Dmean of 59.9 Gy compared with 63.59 Gy on the right, and 60.41 Gy versus 64.31 Gy on the left (Table III).

PTV Coverage

Prophylactic lymph node and primary tumour volume coverage was acceptable for both techniques. PTVT 70 was better covered by FPMS while PTVN 50 was better covered by FPMS. However, neither approach achieved full coverage of PTVN70 which reached 80.5% with MFT and 78.9% with FPMS. (Table IV) Conformity and homogeneity indices were similar between techniques, but MFT showed a higher V107%, indicating more hot spots. These indices were not calculated for PTVN70 due to insufficient target volume coverage; they would not provide meaningful comparisons and have therefore been omitted.

Qualitative analysis of isodose distributions revealed coverage gaps in the cranial and latero-posterior regions of the primary tumour, near the spinal cord and brainstem in both techniques. Inadequate coverage was also observed in the supraclavicular region (area IV), spinal level (area V), and posterolateral upper lymph node areas (Figure 1). These coverage limitations did not appear to be correlated with PTV size or T-stage, but patients classified as N2-N3 had lower coverage levels.

Table II: Clinical stages and planning target volumes (PTVs) in nasopharyngeal carcinoma treated with curative radiotherapy: prophylactic lymph node treated with 50 Gy (PTVN50) and PTV total (including the primary tumour, prophylactic, and pathological lymph node areas) (n=8)

Patient	Stage T	Stage N	PTVN50 Volume (cm ³)	PTV total Volume (cm ³)
1	T4	N2	353	611
2	T2	N3	232	335
3	T1	N2	344	474
4	T1	N3	368	475
5	T2	N2	330	646
6	T4	N1	430	672
7	T4	N3	188	502
8	T2	N2	324	401

Table III: Doses received by organs at risk with multi-field and forward-planned multisegmented (FPMS) techniques: mean, standard deviation and p value of maximum dose (D_{max}), mean dose (D_{mean}), and volume receiving 45 Gy (V_{45Gy}) (n=8)

Organs at risk	Multi-field technique			Forward-planned multisegmented technique			p value [IC95]		
	D_{max} (Gy)	D_{mean} (Gy)	V_{45Gy} (cm ³)	D_{max} (Gy)	D_{mean} (Gy)	V_{45Gy} (cm ³)	D_{max}	D_{mean}	V_{45Gy}
Spinal cord	45.68 ±2.09	-	0.29 ±0.03	43.82 ±4.78	-	0.07 ± 0.03	0.55 [-5.67,1.60]	-	0.28 [-0.20,0.03]
Brainstem	55.24 ±7.91	-	-	52.62 ±4.02	-	-	0.74 [-9.33,2.18]	-	-
Optical chiasma	28.76 ±25.18	-	-	26.61 ±24.40	-	-	0.84 [-6.02,1.60]	-	-
Rt Optic nerve	28.14 ±22.48	-	-	27.77 ±22.44	-	-	0.55 [-2.50,2.23]	-	-
Lt Optic nerve	24.32 ±23.78	-	-	23.43 ±22.92	-	-	0.15 [-4.29,2.25]	-	-
Rt parotid	-	63.59 ±6.19	-	-	59.90 ±9.35	-	-	0.08 [-10.98,0.11]	-
Lt parotid	-	64.31 ±3.06	-	-	60.41 ±6.48	-	-	0.20 [-10.98,1.55]	-
Mandible	80.32 ±3.84	47.01 ±11.60	-	79.71 ±3.65	53.38 ±6.25	-	0.64 [-4.38,2.73]	0.15 [-0.59,15.49]	-
Rt Cochlea	53.51 ±14.81	44.53 ±18.12	-	50.22 ±11.83	40.46 ±13.74	-	0.20 [-9.09,3.17]	0.38 [-12.38,3.29]	-
Lt Cochlea	51.76 ±13.40	40.30 ±14.76	-	48.91 ±11.63	36.21 ±10.34	-	0.74 [-9.42,1.74]	0.64 [-13.45,2.62]	-
Rt: right. Lt: left									

Table IV: Mean values of planning target volume (PTV) coverage, conformity index, and homogeneity index in multi-field and forward-planned multisegmented (FPMS) techniques (n=8)

	Multi-field technique			Forward-planned multisegmented technique			p value [IC95%]		
	PTVN 50	PTVT 70	PTVN 70	PTVN 50	PTVT 70	PTVN 70	PTVN 50	PTVT 70	PTVN 70
D_{mean} (Gy)	59.18	72.27	67.4	51.87	72.17	66.46	0.64 [-4.76,0.90]	0.84 [-1.44, 0.92]	1.00 -
D_{95%} (%)	90.2	93	80.5	91.5	91.6	78.9	0.74 [-1.52,1.82]	0.15 [-3.23,0.27]	0.06 [4.74,40.90]
D_{min} (Gy)	14.61	47.28	37.29	14.38	44.37	36.37	0.45 [-3.40,1.89]	0.11 [-8.25,1.71]	0.13 [-78.02,1.11]
V_{95%} (%)	91.63	91.82	62.37	90.65	89.48	55.58	0.84 [-4.87,2.46]	1.00 [- 2.99,37.75]	0.44 [- 57.73,25.39]
V_{107%} (%)	64.22	30.30	21.51	62.1	28.36	24.11	0.95 [-14.63,9.98]	0.74 [-19.96,15.41]	0.06 [-39.66,-10.06]
Conformity Index	0.91	0.91	-	0.90	0.89	-	0.87 [-0.05,0.03]	1.00 [-0.03,0.38]	-
Homogeneity Index	0.59	0.83	-	0.60	0.81	-	0.83 [-0.10,0.07]	0.11 [-0.01,0.08]	-
<i>V_{x%}</i> : volume receiving x % of the dose <i>D_{x%}</i> : dose in x% of volume									

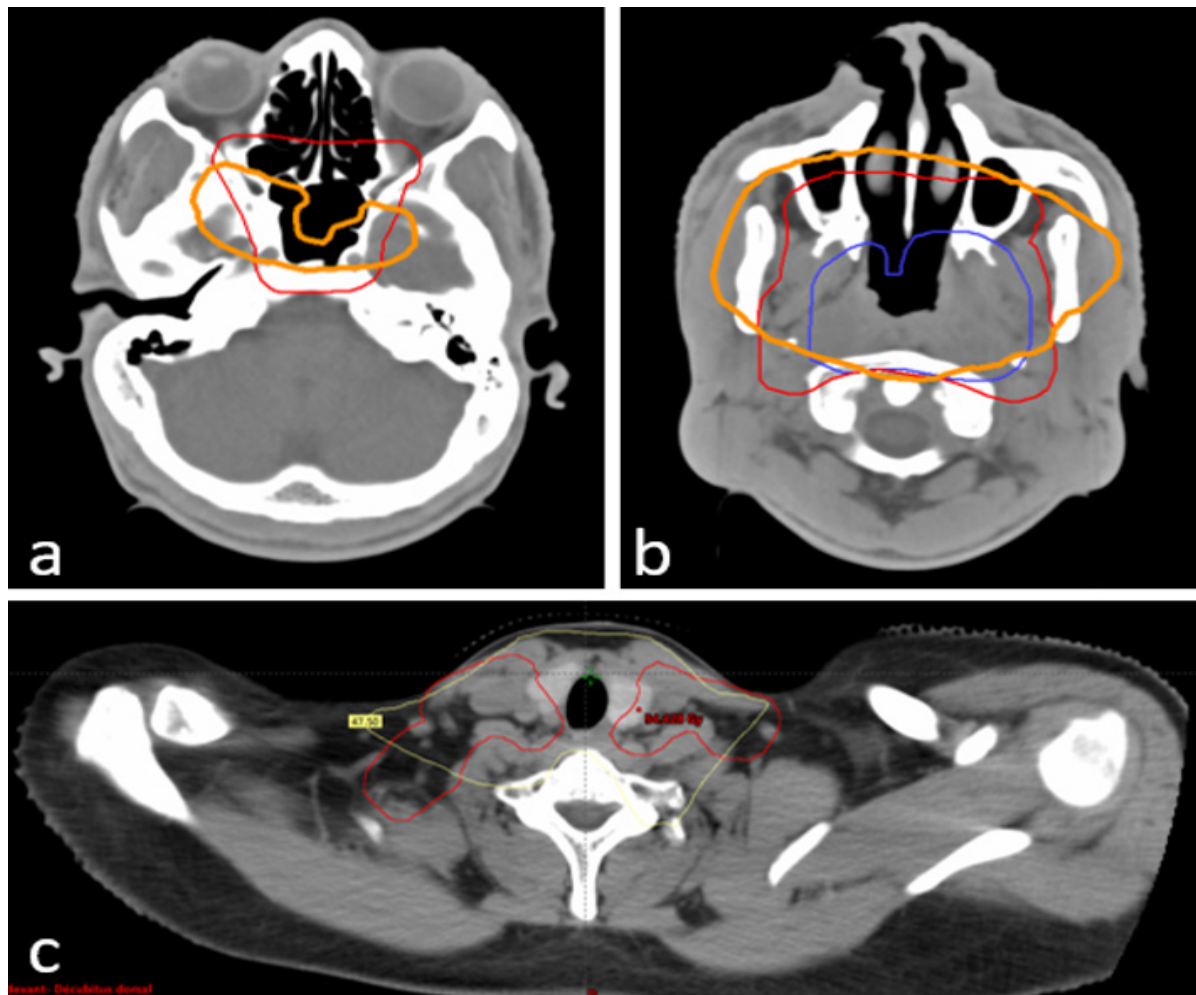


Figure 1: Coverage of primary tumour and prophylactic lymph node PTVs (PTV N 50 and PTV N 70) by 95% isodoses of 70 Gy and 50 Gy: example of a patient a) Coverage gaps in the cranial areas (in orange isodose 66.5 Gy, in red PTV T 70). b) Coverage gaps in the posterolateral areas (in orange isodose 66.5 Gy, in red PTVT70, in blue CTV T 70). c) Coverage gaps in the distal part of the spinal areas (in red PTVN50, in yellow isodose 47.5 Gy)

Discussion

The aim of this study was to identify the potential benefits of the multisegmented technique over the multi-field technique. There was a gain in terms of organs at risk without any major change in the coverage of target volumes. The main strength of this study is that it was conducted in a complex site that exposes the critical organs more than any other site. It also has the particularity of including locally advanced stages and the first study of its kind to be conducted in Africa.

FPMS reduced spinal cord and brainstem doses, consistent with Lee et al. (44 Gy and 54 Gy vs. 43 Gy and 52 Gy in our study). Although the RTOG

allows up to 50 Gy ($\leq 1 \text{ cm}^3$) and DAHANCA sets stricter limits ($\leq 48 \text{ Gy}$, $\leq 45 \text{ Gy}$ over 0.1 cm^3), FPMS respected these volumetric constraints in all patients exceeding 45 Gy. [4,10]

Mean doses to the chiasma and optic nerves were well below tolerance with both techniques, with lower values in FPMS. Although comparative studies on multisegmentation did not specifically assess these structures, available data suggest they remain within safe limits. Previous reports noted higher exposure with multi-beam boosts.[11] In our cohort, only one patient exceeded optic nerve constraints; in such situations, induction chemotherapy could be recommended to improve tolerance, as supported by Yang et al. in their randomized trial. [12]

Parotid sparing with FPMS has shown variable results across studies, with mean doses ranging from 26 to 52 Gy. [1,4,13]

Most studies did not specify tumour profiles, which may partly explain differences in parotid sparing. In our cohort, the elevated doses can be attributed to the high rate of bilateral lymph node involvement (75%), with frequent disease in regions adjacent to the parotid glands (62.5% in area II and 37.5% in area III). In addition, large primary tumour volumes were often located close to the parotids. Similar explanations were reported by Jen et al., supporting the influence of tumour burden and nodal distribution on parotid dose levels.[14]

Significant hearing loss has been reported when cochlear Dmean exceeds 60 Gy [15]. Although our FPMS cohort remained below this threshold, expert consensus recommends stricter limits (≤ 55 Gy without chemotherapy, ≤ 47 Gy with concomitant platinum). [10,16]

Mandibular doses exceeded the recommended Dmax of 65 Gy, but mean values remained below 60 Gy, a level associated with low risk of radionecrosis. [7,10] In terms of target volume coverage, FPMS did not outperform MFT. While Herassi et al. reported improved coverage with FPMS (D95% $\approx 98\%$ vs. 94–95% with other 3D-CRT techniques), our results did not confirm such benefit, particularly for pathological lymph node volumes. [1]

Coverage of PTVN70 remained around 80%, which is clinically unacceptable. Patients with extensive nodal disease should not be managed with 3D-CRT alone; induction chemotherapy should be considered to reduce target volumes until IMRT becomes available. Given the difficulties in achieving ICRU-recommended coverage, treatment plan validation was adapted to accept D95% $\geq 90\%$. Eisbruch et al. similarly reported that multisegmentation failed to reach this threshold in 5% of patients, with occasional underdosage below 90%. In 3D-CRT, most studies have standardized coverage around this level, based on the limited impact of small dose reductions on tumour control probability (TCP). However, recent expert

recommendations for nasopharyngeal carcinoma advocate stricter criteria— $\geq 95\%$ of the prescription dose to 100% of the PTV or $\geq 93\%$ to 99% of the PTV—rendering 3D-CRT increasingly outdated for optimal management. [10,17,18]

Optimal coverage of posterior regions would have led to spinal cord and brainstem overdosing, while cranial coverage increased hot spots. This limitation, more pronounced in pathological lymph node volumes, was not related to PTV expansion or T stage. A Swiss multi-field study similarly reported posterior underdosage in most patients, despite adequate spinal chain coverage, with PTV coverage at 50 Gy comparable to our results but in a cohort with larger mean PTVs (880 cm³ vs. 514 cm³) and a predominance of T4 cases (80%) [19]. Additional parameters such as PTV height should be considered; Hsiung et al. identified vertical length >7 cm or proximity to the eyes as unfavorable factors, and recommended IMRT over 3D-CRT when anteroposterior overlap with the spinal cord exceeded 1 cm, with the brainstem >0.6 cm, or when the target was <0.1 cm from the brainstem [20]. In our study, coverage gaps also appeared linked to nodal extension, particularly in PTVs treated at 70 Gy, and were more frequent in N2–N3 patients, a correlation not yet documented in the literature.

Given the persistent coverage limitations of 3D-CRT, the main value of FPMS lies in improving treatment safety within existing technological constraints. From our experience, several practical implications can be highlighted to guide its implementation in resource-limited settings.

Practical Implications in a Resource-Limited Context

This study demonstrates that the forward-planned multisegmented technique (FPMS) is both feasible and relevant in African centers equipped with 3D-CRT but not yet with IMRT. It represents a transitional step—technically, financially, and organizationally—allowing improved treatment safety without significantly prolonging irradiation time or incurring major additional costs. Based on our experience, the following recommendations may

guide its implementation:

- Patient Selection: Prioritize FPMS for locally advanced stages (T3–T4, N2–N3) or when the target volume is in close proximity to the spinal cord or brainstem.
- Protocol Optimization: Standardize beam arrangements (7 fields, segmentation on postero-oblique beams) and combine energies (6 MV and 10 MV) to optimize dose distribution.
- Team Training: Incorporate FPMS into continuing education for medical physicists and radiation oncologists, with practical workshops on segmentation and manual optimization.
- Transition Strategy to IMRT: Position FPMS within a progressive roadmap toward IMRT acquisition and training, while actively seeking technical and financial partnerships.

Limitations

This study is constrained by several major limitations. First, the relatively small sample size restricts the robustness of the conclusions and precludes definitive statistical validation. Second, the absence of randomization may have introduced selection bias. Third, the involvement of two distinct treatment centers, each equipped with different machines (Elekta vs. Varian) and staffed by different physicists, may have contributed to variability in planning and dosimetric outcomes. Finally, the lack of clinical follow-up data—particularly regarding toxicity and local control—limits the ability to correlate dosimetric findings with patient outcomes. Future studies with larger, randomized cohorts, standardized equipment, and integrated clinical endpoints will be essential to strengthen and refine these results.

Conclusion

This study confirms the feasibility and dosimetric benefit of the forward-planned multisegmented (FPMS) technique as a practical intermediary solution for centers equipped with 3D-CRT but lacking IMRT. FPMS provides meaningful improvements

in OAR protection—particularly for the spinal cord and brainstem—without exacerbating the already challenging target coverage inherent to 3D-CRT in locally advanced nasopharyngeal carcinoma.

Given its lower complexity, reduced requirements for quality assurance, and shorter treatment times compared with IMRT, FPMS offers a feasible and immediately implementable option to enhance treatment safety in resource-limited settings. Its clinical relevance, however, lies primarily in patient selection: FPMS may be most appropriate for smaller tumours without posterior extension, or when the target volume is in close proximity to critical structures such as the spinal cord or brainstem. Protocol optimization (e.g., standardized beam arrangements and mixed energies) and team training are essential to maximize its benefit, while positioning FPMS within a progressive roadmap toward IMRT acquisition.

Nevertheless, the transition to IMRT remains essential. Our findings on target coverage, especially for pathological lymph nodes, underscore that even optimized 3D-CRT cannot fully address the requirements of locally advanced nasopharyngeal carcinoma. FPMS thus constitutes a pragmatic bridge toward IMRT in resource-limited environments, offering an immediately applicable means to enhance treatment safety while underscoring the necessity of transitioning to advanced radiotherapy techniques for optimal management.

Ethical approval

The present research work does not contain any studies performed on animals/humans subjects by any of the authors.

*Correspondence :

Awa Sadikh Badiane

awasadikh@gmail.com

Available online : September 30, 2026

- 1 : Joliot-Curie institute, Aristide Le Dantec University Hospital, Dakar-Senegal
- 2 : Department of Radiation Oncology, General Hospital of Douala, Douala-Cameroun
- 3 : Department of radiation oncology, Dalal Jamm National Hospital, Dakar-Senegal
- 4 : Department of radiation oncology, Cheikh Ahmadoul Khadim National Hospital, Touba-Senegal

© Journal of african clinical cases and reviews 2026

Conflict interest : None

References

- [1] HerrassiMY,BentayebF,MalisanMR.Comparative study of four advanced 3d-conformal radiation therapy treatment planning techniques for head and neck cancer. *J Med Phys*. 2013;38(2):98-105. doi:10.4103/0971-6203.111331
- [2] Lukarski D, Krstevska V, Petkovska S. A treatment planning comparison of two different 3D conformal techniques for irradiation of head and neck cancer patients. In. 2012.
- [3] Kutcher GJ, Fuks Z, Brenner H, Brown AP, Burman C, Cheng E, et al. Three-dimensional photon treatment planning for carcinoma of the nasopharynx. *Int J Radiat Oncol*. mai 1991;21(1):169-82. doi:10.1016/0360-3016(91)90176-5
- [4] Lee N, Akazawa C, Akazawa P, Quivey JM, Tang C, Verhey LJ, et al. A forward-planned treatment technique using multisegments in the treatment of head-and-neck cancer. *Int J Radiat Oncol*. juin 2004;59(2):584-94. doi:10.1016/j.ijrobp.2004.02.005
- [5] Wiggenraad R, Mast M, Van Santvoort J, Hoogendoorn M, Struikmans H. ConPas: a 3-D Conformal Parotid Gland-Sparing Irradiation Technique for Bilateral Neck Treatment as an Alternative to IMRT. *Strahlenther Onkol*. oct 2005;181(10):673-82. doi:10.1007/s00066-005-1413-8
- [6] Lichter AS, Sandler HM, Robertson JM, Lawrence TS, Ten Haken RK, McShan DL, et al. Clinical experience with three-dimensional treatment planning. *Semin Radiat Oncol*. oct 1992;2(4):257-66. doi:10.1016/1053-4296(92)90023-e
- [7] Noël G,Antoni D,Barillot I,Chauvet B.Délinéation des organes à risque et contraintes dosimétriques. *Cancer/Radiothérapie*. sept 2016;20:S36-60. doi:10.1016/j.canrad.2016.07.032
- [8] Feuvret L, Noël G, Mazon JJ, Bey P. Conformity index: A review. *Int J Radiat Oncol*. févr 2006;64(2):333-42. doi:10.1016/j.ijrobp.2005.09.028
- [9] Nikolakopoulou A, Peppas V, Alexiou A, Pissakas G, Terzoudi G, Karaikos P. Comparison and Evaluation of Different Radiotherapy Techniques Using Biodosimetry Based on Cytogenetics. *Cancers*. 29 déc 2021;14(1):146. doi:10.3390/cancers14010146
- [10] Lee AW, Ng WT, Pan JJ, Chiang CL, Poh SS, Choi HC, et al. International Guideline on Dose Prioritization and Acceptance Criteria in Radiation Therapy Planning for Nasopharyngeal Carcinoma. *Int J Radiat Oncol*. nov 2019;105(3):567-80. doi:10.1016/j.ijrobp.2019.06.2540
- [11] Wu VWC, Chan ZHF, Kung SWS, Chau CKF, Fu KCK, Yip KKY. Dose analysis of three 3-D conformal radiotherapy techniques used in booster treatment of nasopharyngeal carcinoma. *J Radiother Pract*. mars 2000;2(1):27-36. doi:10.1017/S1460396900000054
- [12] Yang H, Chen X, Lin S, Rong J, Yang M, Wen Q, et al. Treatment outcomes after reduction of the target volume of intensity-modulated radiotherapy following induction chemotherapy in patients with locoregionally advanced nasopharyngeal carcinoma: A prospective, multi-

- center, randomized clinical trial. *Radiother Oncol.* janv 2018;126(1):37-42. doi:10.1016/j.radonc.2017.07.020
- [13] Portaluri M, Fucilli FIM, Castagna R, Bambace S, Pili G, Tramacere F, et al. Three-dimensional conformal radiotherapy for locally advanced (Stage II and worse) head-and-neck cancer: Dosimetric and clinical evaluation. *Int J Radiat Oncol.* nov 2006;66(4):1036-43. doi:10.1016/j.ijrobp.2006.03.014
- [14] Jen YM, Shih R, Lin YS, Su WF, Ku CH, Chang CS, et al. Parotid gland-sparing 3-dimensional conformal radiotherapy results in less severe dry mouth in nasopharyngeal cancer patients: A dosimetric and clinical comparison with conventional radiotherapy. *Radiother Oncol.* mai 2005;75(2):204-9. doi:10.1016/j.radonc.2005.03.005
- [15] Bhandare N, Antonelli PJ, Morris CG, Malayapa RS, Mendenhall WM. Ototoxicity after radiotherapy for head and neck tumors. *Int J Radiat Oncol.* févr 2007;67(2):469-79. doi:10.1016/j.ijrobp.2006.09.017
- [16] Lee AWM, Ng WT, Hung WM, Choi CW, Tung R, Ling YH, et al. Major Late Toxicities After Conformal Radiotherapy for Nasopharyngeal Carcinoma—Patient- and Treatment-Related Risk Factors. *Int J Radiat Oncol.* mars 2009;73(4):1121-8. doi:10.1016/j.ijrobp.2008.05.023
- [17] Goitein M, Niemierko A. Intensity modulated therapy and inhomogeneous dose to the tumor: A note of caution. *Int J Radiat Oncol.* sept 1996;36(2):519-22. doi:10.1016/S0360-3016(96)00348-3
- [18] Eisbruch A, Marsh LH, Martel MK, Ship JA, Ten Haken R, Pu AT, et al. Comprehensive irradiation of head and neck cancer using conformal multisegmental fields: assessment of target coverage and noninvolved tissue sparing. *Int J Radiat Oncol.* juin 1998;41(3):559-68. doi:10.1016/S0360-3016(98)00082-0
- [19] Fogliata A, Cozzi L, Bieri S, Bernier J. Critical appraisal of a conformal head and neck cancer irradiation avoiding electron beams and field matching. *Int J Radiat Oncol.* déc 1999;45(5):1331-8. doi:10.1016/S0360-3016(99)00319-3
- [20] Hsiung CY, Yorke ED, Chui CS, Hunt MA, Ling CC, Huang EY, et al. Intensity-modulated radiotherapy versus conventional three-dimensional conformal radiotherapy for boost or salvage treatment of nasopharyngeal carcinoma. *Int J Radiat Oncol.* juill 2002;53(3):638-47. doi:10.1016/S0360-3016(02)02760-8

To cite this article

AS Badiane, MM Dieng, LEF Edimo, I Thiam, K Ka, M Diagne et al. Forward-Planned Multisegmented Technique in Resource-Limited Settings: A Feasible Dosimetric Upgrade for 3D-CRT in Locally Advanced Nasopharyngeal Carcinoma. *Jaccr Onco-Palliative Care* 2026; 2(3): 26-32

<https://doi.org/10.70065/2623.jaccrOncopal.002L023009>