DOI:10.3969/j.issn.1005-202X.2016.05.022

医学放射物理

容积旋转调强与固定野动态调强低剂量区比较

姚升宇,颜歌,赵国旗,许奕,陈廷锋,王子杰,胡喆恺,刘勇
上海第一人民医院肿瘤放疗科,上海 201620

【摘 要】目的:对容积旋转调强(VMAT)和不同射野数的固定野动态调强(IMRT)的低剂量区进行比较,探讨具有低剂量敏感危及器官的肿瘤适用射野技术。 方法:用Eclipse 10.0计划系统,在(30×30×30) cm³均匀模体中模仿常见肿瘤,从简单到复杂依次勾画圆形、C形、H形、S形、X形及π形靶区,给予处方50 Gy/25 Fx,用5野、7野、9野IMRT和VMAT进行计划设计,所有优化限制条件均相同。将靶区外缘2.5 cm至模体表面区域作为低剂量统计区,统计不同技术低剂量区的V_5、V_{10}、V_{15}、V_{20}、V_{30}及平均剂量差异, 以及靶区适形指数(CI)。 结果:5野IMRT V_5、V_{10}、V_{15}低剂量区与VMAT和7,9野IMRT相比较低,有统计意义。VMAT的CI比IMRT好,VMAT的V_{30}体积与5野和7野IMRT相比更低,与9野技术没有统计学差异。其他低剂量区VMAT和IMRT相比没有统计学意义。 结论:对于肿瘤周围有低剂量敏感危及器官的肿瘤,比如胸部肿瘤,V_5低剂量区会增加2级以上放射性肺炎发生率,所以尽可能采用5野以下IMRT。危及器官对低剂量区不敏感的其他部位肿瘤,VMAT技术与IMRT相比有更好的靶区适形度,治疗时间更短,所以VMAT技术有较大优势。

【关键词】容积旋转调强;固定野动态调强;低剂量体积
【中图分类号】R739.4 【文献标识码】A 【文章编号】1005-202X(2016)05-0538-03

Comparison of low dose area in volumetric modulated arc therapy and static intensity modulated radiotherapy

YAO Sheng-yu, YAN Ge, ZHAO Guo-qi, XU Yi, CHEN Ting-feng, WANG Zi-jie, HU Zhe-kai, LIU Yong
Department of Radiation Oncology, Shanghai First People's Hospital, Shanghai 201620, China

Abstract: Objective To discuss on the appropriate treatment technology for the tumor with organs at risk sensitive to low dose volume by comparing the low dose area of volumetric modulated arc therapy (VMAT) and static intensity modulated radiotherapy (IMRT) with different field numbers. **Methods** Eclipse 10.0 planning system was used to simulate common tumors, and contour target volumes from simple to complex including the volumes of circular, C, H, S, X and π shapes in the homogeneous phantom of (30×30×30) cm³. All the target volumes were given the prescription dose of 50 Gy/25 Fx. Based on the same optimizing constrains, VMAT and static IMRT respectively with 5, 7, 9 fields were used to design the treatment plan. The area between 2.5 cm outside the target volume and the surface of phantom was taken as the low dose statistical area. The differences in V_5, V_{10}, V_{15}, V_{20}, V_{25}, V_{30} and mean dose of low dose area, and conformal index (CI) were statistically analyzed. **Results** The V_5, V_{10}, V_{15} of 5-field static IMRT were less than those of VMAT and IMRT with 7 or 9 fields, with statistical significance; CI of VMAT was better than that of static IMRT; the V_{30} of VMAT was less than that of static IMRT with 5 or 7 fields, and the V_{30} of VMAT didn't show statistical differences with that of 9-field static IMRT. No significant differences were found in the other low dose areas among VMAT and IMRT with 5, 7 or 9 fields. **Conclusion** For the tumor surrounded by organs at risk sensitive to low dose volume, such as thoracic tumor, V_5 low dose area increases the incidence of radioactive pneumonia above level 2, so static IMRT with 5 fields or less than 5 fields is much better. For other tumors without organs at risk sensitive to low dose volume, VMAT has greater advantages, with better CI and treatment time than static IMRT.

Key words: volumetric modulated arc therapy; static intensity modulated radiotherapy; low dose volume

【收稿日期】2015-10-23
【作者简介】姚升宇,物理师,E-mail:jordanyao11@126.com,Tel:13761528841。
【通信作者】颜歌(1982-),女,硕士,主治医师,E-mail:yangeyg24@aliyun.com。

前 言

容积旋转调强(Volumetric Modulated Arc Therapy, VMAT)是1995年Yu[1]提出的,该技术以动态旋转的形式,同时动态、同步、连续调节各种参数,包括机架、多叶准直器的位置、运动速度及射线束的剂量

率。对VMAT和IMRT这两种调强技术进行了相关的对比研究，VMAT的剂量分布不论是头颈部肿瘤[2-3]，还是盆腔肿瘤[4-6]都能达到或者好于IMRT，同时有效减少了治疗时间，提高了治疗的有效性。也有VMAT技术应用于胸部肿瘤的报道[7-8]，但是由于容积调强是360°旋转治疗，有可能会造成低剂量区体积的增加，所以对于肺这种对低剂量区体积比较敏感的组织[9]，胸部肿瘤如果运用VMAT技术可能会造成肺组织的损伤。本研究对VMAT和固定5、7、9野IMRT的低剂量区进行比较，分析这些技术的适用肿瘤范围。

1 材料与方法

本研究运用Varian Eclipse 10.0治疗计划系统，建立一个（30×30×30）cm^3的模体，在模体中模仿各部位肿瘤，从简单到复杂依次勾画圆形、C形、H形及X形靶区，给予处方50 Gy/25 Fx，然后将靶区外2.5 cm至模体表面的体积作为低剂量统计区。运用Rapidarc双弧技术和5、7和9野IMRT进行计划设计，均采用相同的计划优化限制条件，使靶区95%的体积达到50 Gy，然后统计低剂量区的V_5、V_{10}、V_{15}、V_{20}、V_{30}体积和平均剂量，以及靶区适形指数（Conformal Index，CI），比较统计学差异。

$$CI=(V_{T,ref}/V_T)(V_{T,ref}/V),$$

$V_{T,ref}$为参考等剂量线所覆盖的靶体积，V_T为靶体积，V为参考等剂量线所覆盖的总体积。CI值范围为0~1，CI值越大表示适形度越好。

VMAT双弧一个弧从178°逆时针旋转到182°，准直器为0°，另一个弧从182°顺时针旋转到178°，准直器为90°。固定野调强采用均匀分布射野，准直器均为0°。5野为0°、72°、144°、216°和288°，7野为0°、51°、102°、153°、204°、255°和306°，9野为0°、40°、80°、120°、160°、200°、240°、280°和320°。

数据统计分析采用SPSS22对每个分析指标做配对*t*检验，$P<0.05$为有统计学意义。

2 结 果

在靶区剂量达到要求的条件下，各项技术的不同靶区的低剂量区V_5、V_{10}、V_{15}、V_{20}、V_{30}体积和CI及平均剂量对比统计见表1、表2、表3。从表1可以看出，5野IMRT的V_5、V_{10}、V_{15}比7野、9野IMRT及VMAT低，有统计学意义（$P<0.05$）。而7野、9野IMRT与VMAT相比，V_5、V_{10}、V_{15}、V_{20}体积没有统计学差异（$P>0.05$）。低剂量区的平均剂量各个技术之间也没有显著差异。VMAT的V_{30}体积与5野和7野IMRT相比更低，与9野技术没有统计学差异，见表2。VMAT与IMRT相比，CI普遍更好，说明VMAT的靶区适形度更好，见表3。

3 讨 论

容积旋转调强从1995年由Yu[1]提出后，在2007年Otto对优化算法进行改良和提高优化效率后开始

表1 5野IMRT与7、9野IMRT及VMAT的V_5、V_{10}、V_{15}体积比较

Tab.1 V_5, V_{10}, V_{15} comparison between 5 fields IMRT and 7,9 fields IMRT, VMAT

Item	V_5 (cc)	*P* value	V_{10} (cc)	*P* value	V_{15} (cc)	*P* value
5-IMRT	7268.8±492.4	-	5120.8±402.0	-	4303.1±360.6	-
7-IMRT	7714.4±367.5	0.004*	6171.0±495.6	0.000*	5317.8±440.4	0.000*
9-IMRT	7825.3±392.2	0.001*	6415.6±455.5	0.001*	5341.5±471.9	0.001*
VMAT	7727.3±465.2	0.035*	6441.6±401.5	0.002*	5254.8±448.3	0.001*

*: *P* value compared with 5-IMRT

表2 VMAT与5、7、9野IMRT的V_5、V_{10}、V_{15}、V_{20}、V_{30}体积比较

Tab.2 V_5, V_{10}, V_{15}, V_{20}, V_{30} comparison between VMAT and 5, 7, 9 fields IMRT

Item	V_5(cc)	*P* value	V_{10}(cc)	*P* value	V_{15}(cc)	*P* value	V_{20}(cc)	*P* value	V_{30}(cc)	*P* value
VMAT	7727.3±465.2	-	6441.6±401.5	-	5254.8±448.3	-	3488.4±795.1	-	816.6±526.8	-
5-IMRT	7268.8±492.4	0.035*	5120.8±402.0	0.002*	4303.1±360.6	0.001*	3607.9±361.8	0.800*	1118.3±682.2	0.048*
7-IMRT	7714.4±367.5	0.934*	6171.0±495.6	0.162*	5317.8±440.4	0.686*	3832.8±361.8	0.318*	1037.4±488.3	0.022*
9-IMRT	7727.3±465.2	0.439*	6415.6±455.5	0.811*	5341.5±471.9	0.681*	3351.9±979.8	0.279*	1066.3±674.6	0.059*

*: *P* value compared with VMAT

表3 VMAT与5、7、9野IMRT的CI比较

Tab. 3 Conformal Index (CI) comparison between VMAT and 5 、7、9 fields IMRT

Item	CI	*P* value
VMAT	0.89 7±0.021	-
5-IMRT	0.848±0.068	0.097*
7-IMRT	0.886±0.021	0.121*
9-IMRT	0.889±0.019	0.016*

*:*P* value compared with VMAT

应用的另一种旋转调强方式的容积旋转调强(Intensity Modulated Arc Therapy, IMAT)。近年来国内外对于VMAT应用越来越多,主要用在头颈部和腹盆部肿瘤,因为其剂量分布可以达到IMRT甚至优于IMRT,且治疗时间可以大大减少。也有报道VMAT技术用于胸部肿瘤的。但是有研究表明肺组织的低剂量V_5增加会导致2级以上放射性肺炎的增加[10]。因为VMAT的360°治疗可能会增加低剂量的体积。

本研究对5、7、9野IMRT和VMAT技术的低剂量区体积进行了对比分析,发现对于V_5、V_{10}、V_{15}体积5野IMRT与VMAT技术和7、9野IMRT相比较少,这与张耀文等[11]的研究一致。7、9野IMRT的V_5、V_{10}、V_{15}、V_{20}体积与VMAT技术相比没有统计学差别。VMAT的V_{30}体积与5野和7野IMRT相比更低,与9野技术没有统计学差异。平均剂量没有统计学差异。所以对于像肺组织等对于V_5低剂量区比较敏感的危及器官,设计计划时尽量采用5野或以下固定野调强技术,而不采用7、9野或者VMAT技术,这样能降低低剂量体积,从而减少放疗并发症。而对于肿瘤周围没有对低剂量敏感的危及器官,或者对于V_{30}以上敏感的危及器官,可以采用VMAT技术,因为VMAT技术拥有较优的剂量优势且只需要更少的治疗时间[12]。

【参考文献】

[1] YU C X. Intensity modulated arc therapy with dynamic multi-leaf collimation: an alternative to tomotherapy[J]. Phys Med Biol, 1995, 40(9): 1435-1449.

[2] DAI X F. Volumetric-modulated arc therapy for oropharyngeal carcinoma: a dosimetric and delivery efficiency comparison with static-field IMRT[J]. Phys Med, 2015, 31(1) : 54-59.

[3] LU S H. Volumetric modulated arc therapy for nasopharyngeal carcinoma: a dosimetric comparison with TomoTherapy and step-and-shoot IMRT[J]. Radiol Oncol, 2012, 104(3): 324-330.

[4] COZZI L. A treatment planning study comparing volumetric arc modulation with RapidArc and fixed field IMRT for cervix uteri radiotherapy[J]. Radiother Oncol, 2008, 89(2): 180-191.

[5] 李军. 宫颈癌术后常规与旋转容积调强放疗计划剂量学研究[J]. 中华肿瘤防治杂志, 2014, 21(14): 1104-1108.
LI J. Dosimetric study of conventional intensity modulated radiotherapy and volumetric intensity modulated arc radiotherapy for post operation of cervix cancer[J]. Chinese Journal of Cancer Prevention and Treatment, 2014, 21(14): 1104-1108.

[6] 刘培培, 曹永珍. 容积旋转调强与固定野调强在宫颈癌根治性放疗中的剂量学比较[J]. 中国辐射卫生, 2015, 24(1): 109-112.
LIU P P, CAO Y Z. Dosimetric comparison of volumetric modulated arc therapy with fixed field intensity modulated radiotherapy for cervical carcinoma [J]. Chinese Journal of Radiological Health, 2015, 24(1): 109-112.

[7] 陈婷婷, 张西志, 花威, 等. 容积旋转调强与固定野动态调强在上段食管癌治疗中的剂量学比较[J]. 临床肿瘤学杂志, 2013, 18(2): 151-154.
CHEN T T, ZHANG X Z, HUA W, et al. Dosimetric comparison between RapidArc and fixed gantry dynamic IMRT for upper esophageal cancer [J]. Chinese Journal of Clinical Oncology, 2013, 18(2): 151-154.

[8] BREE I D. High-dose radiotherapy in inoperable non-small cell lung cancer: comparison of volumetric modulated arc therapy, dynamic IMRT and 3D conformal radiotherapy [J]. Med Dosim, 2012, 37(4): 353-357.

[9] TANG C, LIAO Z, GOMEZ D, et al. Lymphopenia association with gross tumor volume and lung V_5 and Its effects on non-small cell lung cancer patient outcomes[J]. Int J Radiol Oncol Biol Phys, 2014, 89(5): 1084-1091.

[10] JO I Y, KAY C S, KIM J Y, et al. Significance of low-dose radiation distribution in development of radiation pneumonitis after helical-tomotherapy-based hypo-fractionated radiotherapy for pulmonary metastases[J]. J Radiat Res, 2014, 55(1): 105-112.

[11] 张耀文. 胸上段食管癌容积旋转调强与静态调强放疗计划的剂量学比较 [J]. 中华肿瘤防治杂志, 2014, 21(23): 1902-1906.
ZHANG Y W. Dosimetric comparison between Volumetric modulated arc therapy and step-and-shot IMRT for upper-thoracic esophageal cancer [J]. Chinese Journal of Cancer Prevention and Treatment, 2014, 21(23): 1902-1906.

[12] 李湔, 单国平, 狄小云, 等. 直肠癌术后容积旋转调强和静态调强放疗的剂量学研究[J]. 中国医学物理学杂志, 2013, 30(3): 4115-4117.
LI P, SHAN G P, DI X Y, et al. Dosimetric comparison between rapidArc and IMRT for postoperative rectal cancer [J]. Chinese Journal of Medical Physics, 2013, 30(3): 4115-4117.

(编辑:薛泽玲)