DOI:10.3969/j.issn.1005-202X.2016.03.005 医学放射物理

个性化选择食管癌放疗技术

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【摘 要】目的：针对不同长度和不同体积的食管癌个性化选择放射治疗技术。**方法：**选择16例不同靶区大小的食管癌患者，分别用Xio计划系统制定一个三维适形(3DCRT)计划、Monaco计划系统制定一个静态调强(IMRT)计划和一个容积旋转调强(VMAT)计划。应用剂量体积直方图和最小显著差异法比较3种治疗计划中靶区、危及器官的剂量学差异并进行数据分析。**结果：**对于不同大小的靶区，VMAT能较好地控制靶区高剂量在112%处方剂量内，对肺高剂量区、脊髓最大值和心脏剂量的控制均优于其它两种放疗技术。对于头脚方向长度小于13 cm且体积小于200 cc的靶区，3种计划均满足计划要求，且3DCRT的靶区低剂量区面积小于VMAT。对于头脚方向长度大于13 cm且体积大于200 cc的靶区，3DCRT无法满足计划要求，IMRT和VMAT计划可较好地控制肺高剂量区，但低剂量区照射面积稍大。**结论：**对于头脚方向长度较短、体积较小的靶区，考虑肺低剂量面积，可优先选择3DCRT技术；对于头脚方向长度较长、体积较大的靶区，可选择IMRT技术或尽量控制肺低剂量区的VMAT技术，或比较这两种计划，权衡利弊后再选择放疗方式。
【关键词】食管癌；三维适形放射治疗；调强放射治疗；容积旋转调强放射治疗；放射性肺炎
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Personalized selection of radiotherapy techniques for esophageal cancer

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Abstract: Objective To determine personalized radiotherapy technique for esophageal cancer with different lengths and volumes. **Methods** Sixteen esophageal cancer patients with different target volumes were selected. Three radiotherapy techniques were respectively prepared for each patient. A three-dimensional conformal radiotherapy (3DCRT) was established by using Xio planning system. A static intensity-modulated radiotherapy (IMRT) and a volumetric modulated arc therapy (VMAT) were designed by using Monaco planning system. Dose-volume histogram and least significant difference method were used to compare and analyzed the dosimetric difference of target volumes and organs at risk. **Results** For different target volumes, VMAT preferably kept the high dose of target volume within 112% of prescription dose, and had a better control effect for the high dose area of lungs, the maximum dose of spinal cord and cardiac dose than the other two radiotherapy techniques. When the head-feet length was less than 13 cm and the target volume was less than 200 cc, all the three plans met the planning requirements, and the low-dose area of 3DCRT plan was less than that of VMAT. When the head-feet length was more than 13 cm and the target volume was more than 200 cc, 3DCRT didn't met the planning requirements; comparatively, IMRT and VMAT preferably regulated the high dose area of lung, with but had a slightly larger radiation area of the low dose region. **Conclusion** Considering the low dose area of lungs, 3DCRT should be preferred for the target volume with shorter head-feet length and smaller volume. For the target volume with longer head-feet length and larger volume, IMRT or VMAT that could control the low dose area of lungs may be an option, or the radiotherapy technique should be determined after comparing and analyzing the advantages and disadvantages

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of IMRT and VMAT.

Key words: esophageal cancer; three-dimensional conformal radiotherapy; intensity-modulated radiotherapy; volumetric modulated arc therapy; radiation pneumonitis

前 言

食管癌是世界上最普遍的十大恶性肿瘤之一。大约60%食管癌患者诊断时已为局部晚期,因食管癌与周围正常组织的分界不清、纵膈淋巴结转移等原因[1],手术不能全部切除,放疗成为主要治疗手段之一。目前针对食管癌的三维适形(3DCRT)计划、静态调强(IMRT)计划和容积旋转调强(VMAT)计划的剂量学研究[2-9]较多。然而该如何根据靶区头脚方向长度和体积选择合适的放疗方式,未见相关报道。本文用Xio和Monaco计划系统对不同大小的靶区设计不同的放疗计划,依据靶区和正常组织的剂量学比较结果为不同的靶区长度和体积选择最优放疗方式,为放疗医师和物理师选择治疗计划方案提供参考。

根据本院临床统计,头脚方向长度大于13 cm且靶区体积大于200 cc的中段食管癌,3DCRT的双侧肺V_{20}分别高于25%的几率大,所以以靶区头脚方向长度为13 cm且体积为200 cc为界限,把16例患者分为两组数据进行讨论分析,进而个体化选择放疗技术。

1 材料与方法

1.1 材料

配有80对在等中心处5 mm投影宽度的多叶准直器叶片(MLC)并具有VMAT功能及四维图像引导功能的医科达Axesse医用直线加速器;可做3DCRT和IMRT计划的Xio 4.7计划系统及双弧VMAT计划的医科达Monaco3.2计划系统;孔径为85 cm的飞利浦Bigbore CT模拟定位机。

选择在本院放疗的16例中段食管癌患者,无纵膈淋巴结转移,年龄为65~81岁,病变长度为8~22 cm,靶区体积为74~412 cc。采用低温热塑模和放疗体架固定患者体位,CT扫描层厚均为5 mm,将扫描图像传输至Xio和Monaco计划系统。放疗医师根据患者CT图像、参考钡餐及内窥镜等检查信息勾画靶区大体肿瘤体积(GTV)、临床靶区(CTV),并勾画患者皮肤以及周围重要器官(肺、脊髓、心脏)。

1.2 计划设计

X射线能量均为6 MV,放疗剂量保证95%计划靶区(PTV)(CTV外放5 mm)达到60 Gy/30 f。在保证靶区得到足够照射剂量的同时尽量减少正常组织受量,观察脊髓最大剂量D_{max}能否小于40 Gy,单侧肺受照体积V_{20}能否小于25%,心脏体积V_{30}能否小于40%、V_{40}能否小于30%。

在Xio计划系统上设计3DCRT计划。3DCRT计划设置:射野采用一前野两后斜野或前后野两斜野,Superpositon算法,计算网格3 mm,通过多页光栅形成靶区照射适形。在Monaco计划系统上设计IMRT和VMAT计划。IMRT计划设置:计算网格3 mm,最小子野面积4 cm^2,最小子野宽度5 mm,最小机器跳数为5 MU;VMAT放疗计划设置:360°双弧,第一步笔形束算法通量计算,第二步蒙卡算法子野优化,计算网格3 mm,蒙卡标准偏差设置3%,最小子野宽度5 mm。

1.3 评估方法

肿瘤靶区指标:D_{mean}、D_{max}、D_{min}、均匀性指数(HI)、适形指数(CI);危及器官受量指标:脊髓D_{max},单侧肺D_{mean}、V_5、V_{10}、V_{20}、V_{30},心脏D_{mean}、V_{30}、V_{40}。

1.4 统计学处理

用IBM SPSS 19.0软件进行数据方差分析;用最小显著差异法进行3组间的比较,$P\leq0.05$为差异具有统计学意义。

2 结 果

2.1 靶区长度小于16 cm且体积小于200 cc剂量学比较

3种放疗计划均使95%靶区体积达到处方剂量,靶区及正常组织受量结果均达计划要求,如表1所示。靶区D_{max}、D_{mean}、HI和CI均有统计学差异($P<0.05$)。VMAT对靶区高剂量的控制好于3DCRT和IMRT,且热点均控制在处方剂量的112%内;IMRT和VMAT靶区CI和HI好于3DCRT。3种计划的左、右肺V_{20}均小于25%,它们大小比较是:VMAT<IMRT<3DCRT,具有统计学差异($P<0.05$)。从数值可知,左、右肺V_{30}、V_{10}和D_{mean}大小比较,VMAT<IMRT<3DCRT的概率较大;3种计划的左、右肺V_5无统计学差异,但3DCRT的V_5低于VMAT,差异具有统计学差

表1 靶区头脚长度小于16 cm且体积小于200 cc剂量学指标

Tab.1 Dosimetry indexes of target volume with head-feet length less than 13 cm and target volume less than 200 cc

Dosimetry index		3DCRT	IMRT	VMAT	*F* value	*P* value
D_{max}(cGy)		6561.7±161.1	6617.8±80.1	6406.1±80.5	5.571	0.016
D_{min}(cGy)		4905.7±253.4	5074.5±274.0	5161.9±230.7	1.765	0.205
D_{mean}(cGy)		6298.9±94.1	6201.2±19.6	6125.7±26.3	13.678	0.000
HI		1.09±0.03	1.06±0.01	1.04±0.01	14.585	0.000
CI		0.94±0.01	0.95±0.00	0.95±0.00	5.976	0.012
Spinal cord	D_{max}(cGy)	3435.9±678.2	3350.0±678.4	3544.5±115.9	0.183	0.835
Left lung	V_5(%)	59.6±7.0	56.7±10.9	67.5±4.9	2.920	0.085
	V_{10}(%)	45.4±6.9	37.7±10.5	36.2±12.8	1.359	0.287
	V_{20}(%)	20.6±5.7	15.0±5.8	11.7±6.8	5.296	0.014
	V_{30}(%)	9.2±5.6	7.2±3.4	5.1±3.8	1.326	0.295
	D_{mean}(cGy)	1165.3±213.0	1025.1±233.5	1000.8±230.7	0.875	0.437
Right lung	V_5(%)	54.7±7.6	52.8±10.8	63.3±7.1	2.504	0.115
	V_{10}(%)	42.3±8.9	35.2±9.8	31.3±6.9	2.517	0.114
	V_{20}(%)	19.0±4.3	13.5±5.4	10.2±2.3	6.749	0.008
	V_{30}(%)	7.3±2.9	6.5±2.9	5.0±2.1	3.242	0.068
	D_{mean}(cGy)	1092.5±138.5	967.9±186.4	920.2±98.2	2.241	0.141
Heart	V_{30}(%)	23.5±15.4	17.2±14.3	13.7±10.1	0.824	0.458
	V_{40}(%)	9.9±7.5	8.8±7.3	7.6±5.8	0.166	0.849
	D_{mean}(cGy)	1610.2±941.7	1473.3±865.6	1434.6±844.7	0.064	0.939

3DCRT: Three-dimensional conformal radiotherapy; IMRT: Static intensity-modulated radiotherapy; VMAT: Volumetric modulated arc therapy

异(*P*<0.05)。3种计划脊髓D_{max}均在45 Gy内,VMAT相比IMRT、3DCRT更容易控制脊髓D_{max};心脏V_{30}、V_{40}和D_{mean}均达计划要求,但无统计学差异(*P*>0.05)。

综上所述,对于头脚方向长度小于13 cm且体积小于200 cc的靶区,3种计划均可满足要求,3DCRT低剂量面积要低于VMAT,VMAT对肺高剂量部分、脊髓和心脏的限制好于IMRT和3DCRT。

2.2 靶区长度大于13 cm且体积大于200 cc剂量学比较

3种计划均使95%靶区体积达到处方剂量,靶区及正常组织受量结果如表2所示。靶区D_{max}、D_{min}、D_{mean}和HI均有统计学差异(*P*<0.05),VMAT靶区高剂量低于3DCRT和IMRT,且热点均控制在处方剂量的112%内。IMRT和VMAT靶区HI好于3DCRT。3DCRT的肺V_{20}高于25%,VMAT和IMRT的V_{20}均小于25%。VMAT和IMRT的左、右肺V_{30}、V_{10}和D_{mean}均小于3DCRT(*P*<0.05)。3种计划的低剂量V_5无统计学差异(*P*>0.05),从数值上看,3DCRT小于IMRT和VMAT的概率较大。IMRT和VMAT计划的脊髓D_{max}可控制在40 Gy以内,且脊髓D_{max}小于3DCRT。3种计划对心脏受量的控制无统计学差异(*P*>0.05)。

3 讨 论

有研究结果表明[10-11],放射性肺炎发生率和严重程度与肺受照射体积和剂量密切相关,V_{20}是唯一的放射性肺损伤的独立因子,V_{20}<20%时,无放射性肺炎;V_{20}为22%~31%时,8%的患者发生2级放射性肺炎。V_{30}的大小预示放射性肺炎损伤发生的概率,V_{30}>35%时,46%的患者发生放射性肺炎;V_{30}为5%~35%时,放射性肺炎的发生率只有20%。也有研究发现全肺D_{mean}为放射性肺炎发生的独立影响因素,因此常用肺V_{20}、V_{30}和D_{mean}作为权衡放射性肺炎损伤的参数。但Wang等[12]对食管癌术后同期放化疗研究

表2 靶区头脚长度大于16 cm且体积大于200 cc剂量学指标

Tab.2 Dosimetry indexes of target volume with head-feet length more than 13 cm and target volume more than 200 cc

Dosimetry index		3DCRT	IMRT	VMAT	*F* value	*P* value
D_{max} (cGy)		6755.6±214.5	6685.1±122.7	6433.8±80.6	12.705	0.000
D_{min} (cGy)		5106.2±98.0	4792.7±239.5	4710.5±390.1	5.971	0.007
D_{mean} (cGy)		6349.6±92.2	6217.4±40.7	6142.2±40.1	28.123	0.000
CI		0.95±0.00	0.95±0.00	0.95±0.00	-	-
HI		1.10±0.03	1.07±0.01	1.04±0.01	36.379	0.000
Spinal cord	D_{max} (cGy)	3940.9±713.3	3751.8±86.5	3685.9±95.3	1.000	0.381
Left lung	V_5 (%)	75.0±8.7	80.6±9.3	84.1±8.6	2.674	0.087
	V_{10} (%)	64.6±8.7	50.7±10.3	51.9±11.0	5.868	0.008
	V_{20} (%)	36.9±8.6	19.4±5.6	18.0±7.6	20.622	0.000
	V_{30} (%)	24.6±9.5	9.5±3.6	8.6±4.5	19.846	0.000
	D_{mean} (cGy)	1796.7±311.7	1339.1±217.6	1323.8±235.6	10.826	0.000
Right lung	V_5 (%)	69.5±9.4	73.5±10.4	79.7±15.9	1.754	0.192
	V_{10} (%)	57.8±12.1	44.0±11.9	45.1±16.3	3.206	0.046
	V_{20} (%)	31.9±12.0	15.8±8.5	14.6±8.1	9.927	0.001
	V_{30} (%)	16.1±10.3	8.0±5.4	7.2±4.9	4.492	0.021
	D_{mean} (cGy)	1584.5±408.9	1215.9±302.8	1224.8±349.3	3.501	0.044
Heart	V_{30} (%)	47.5±11.3	44.7±11.3	38.1±7.4	2.260	0.124
	V_{40} (%)	29.1±9.9	28.1±10.5	26.0±5.7	0.312	0.734
	D_{mean} (cGy)	3061.6±485.8	2909.5±519.3	2790.8±465.0	0.766	0.475

表明V_5是放射性肺炎发生的独立影响因子。且Lee等[13]研究表明肺组织经过大容积低剂量照射后会发生严重肺部并发症和急性呼吸窘迫综合征，V_{10}的大小也会影响到肺损伤。可见，放射性肺炎的发生与低剂量照射相关，在做食管癌IMRT和VMAT计划时，低剂量区与高剂量区应同等权衡[14]。喻冰琪等[15]提出平衡参数控制调强放疗。

由该研究所得数据可知VMAT较好地控制靶区高剂量在112%处方剂量内，对肺高剂量区、脊髓最大值和心脏剂量的控制均优于其它两种放疗技术。对于头脚方向较短靶区（小于13 cm）且体积较小（小于200 cc）的食道癌，考虑肺低剂量面积，可优先选择3DCRT技术；对于头脚方向较长靶区（大于13 cm）且体积较大（大于200 cc）的食管癌，可选择IMRT技术或尽量控制肺低剂量区的VMAT技术，或者两种计划进行比较，权衡利弊后再选择放疗方式。个别患者若左、右肺体积比较小，肺头脚方向长度小于等于13 cm且食管癌靶区长度为13 cm左右，这时建议采用IMRT和VMAT计划，临床实践可知3DCRT计划的肺受量高。对于靶区长度在13 cm且体积200 cc左右的患者，建议先制定3DCRT计划，评估计划是否满足要求，若不满足，再制定IMRT和VMAT计划，或根据临床医生要求选择治疗方式。本文根据临床经验总结选择靶区头脚方向长度和体积分界分别是13 cm、200 cc，该数值不是绝对的，可认为是一个区域，为临床医生和物理师提供数值参考。

综上所述，对于较长中段食管癌，3DCRT无法满足计划要求。IMRT和VMAT计划可较好地控制肺高剂量区、脊髓和心脏，但肺低剂量区照射面积稍大，IMRT低剂量区低于VMAT的概率大。

【参考文献】

[1] 谷铣之. 肿瘤放射治疗学[M]. 北京: 中国协和医科大学出版社, 2008: 552-553.
GU X Z. Radiation oncology[M]. Beijing: Peking Union Medical University Press, 2008: 552-553.

[2] 王玉祥, 王军, 王祎, 等. 食管癌伴区域淋巴结转移三维适形与调强放疗疗效初步比较[J]. 中华放射肿瘤学杂志, 2011, 20(6): 489-493.
WANG Y X, WANG J, WANG W, et al. Prognosis comparison of three-

dimensional conformal radiotherapy/intensity modulated radiation therapy for esophageal carcinoma with local regional lymph node metastasis[J]. Chinese Journal of Radiation Oncology, 2011, 20 (6): 489-493.
[3] 刘晓静, 张西志, 李军, 等. 胸中段食管癌旋转容积调强与固定野动态调强放疗的剂量学研究[J]. 实用癌症杂志, 2011, 26(6): 630-633.
LIU X J, ZHANG X Z, LI J, et al. Dosimetric comparison between rapid Arc and fixed gantry dynamic IMRT for middle esophageal carcinoma[J]. The Practical Journal of Cancer, 2011, 26(6): 630-633.
[4] 咸婧, 张伶, 李小凯, 等. 胸中段食管癌适形调强放疗和三维适形放疗方案的应用探讨[J]. 西南军医, 2011, 13(4): 583-585.
XIAN J, ZHANG L, LI X K, et al. Comparison between IMRT and 3D-CRT in the therapy of mid-thoracic esophageal cancer[J]. Journal of Military Surgeon in Southwest China, 2011, 13(4): 583-585.
[5] 徐朋琴, 蔡晶, 吴建亭. 胸中下段食管癌三种放疗技术的剂量学比较[J]. 临床肿瘤学杂志, 2012, 17(11): 1016-1019.
XU P Q, CAJ J, WU J T. Dosimetric comparison among three kinds of radiotherapy technologies for middle or low thoracic esophageal carcinoma [J]. Chinese Clinical Oncology, 2012, 17 (11): 1016-1019.
[6] YIN L, WU H, GENG J H, et al. Volumetric-modulated arc therapy *vs* c-IMRT in esophageal cancer: a treatment planning comparison [J]. World J Gastroenterol, 2012, 18(37): 5266-5275.
[7] LIN S H, WANG L, MYLES B, et al. Propensity score-based comparison of long-term outcomes with three-dimensional conformal radiotherapy *vs* intensity-modulated radiotherapy for esophageal cancer [J]. Int J Radiat Oncol Biol Phys, 2012, 84(5): 1078-1085.
[8] NICOLINI G, GHOSHLASKAR S, SHRIVASTAVA S K, et al. Volumetric modulation arc radiotherapy with flattening filter-free beams compared with static gantry IMRT and 3D conformal radiotherapy for advanced esophageal cancer: a feasibility study [J]. Int J Radiat Oncol Biol Phys, 2012, 84(2): 553-560.
[9] VIVEKANANDAN N, SRIRAM P, SYAMKUMAR S A, et al. Volumetric modulated arc radiotherapy for esophageal cancer[J]. Med Dosim, 2012, 37(1): 108-113.
[10] GRAHAM M V, PURDY J A, EMAMI B, et al. Clinical dose-volume histogram analysis for pneumonitis after 3D treatment for non-small-cell lung cancer (NSCLC)[J]. Int J Radiat Oncol Biol Phys, 1999, 45(2): 323-329.
[11] MARKS L B, SPENCER D P, SHEROUSE G W, et al. The role of three dimensional functional lung imaging in radiation treatment planning: the functional dose-volume histogram[J]. Int J Radiat Oncol Biol Phys, 1995, 33 (1): 65-75.
[12] WANG S L, LIAO Z X, VAPORCIYAN A A, et al. Investigation of clinical and dosimetric factors associated with postoperative pulmonary complications in esophageal cancer patients treated with concurrent chemoradiotherapy followed by surgery[J]. Int J Radiat Oncol Biol Phys, 2006, 64(3): 692-699.
[13] LEE H K, VAPORCIYAN A A, COX J D, et al. Postoperative pulmonary complications after preoperative chemoradiation for esophageal carcinoma: correlation with pulmonary dose-volume histogram parameters[J]. Int J Radiat Oncol Biol Phys, 2003, 57 (5): 1317-1322.
[14] 张丹丹. 呼吸运动对靶区受照剂量分布影响的研究[D]. 北京: 北京协和医学院, 2009.
ZHANG D D. The study of the influence of respiratory motion on target dose distribution [D]. Beijing: Peking Union Medical College, 2009.
[15] 喻冰琪, 王谨, 徐裕金, 等. 放疗技术与放射性肺损伤: 高剂量小体积还是低剂量大体积?[J]. 中国肺癌杂志, 2015, 18(12): 752-757.
YU B Q, WANG J, XU Y J, et al. Radiotherapy techniques and radiation pneumonitis: a lot to a little or a little to a lot? [J]. Chinese Journal of Lung Cancer, 2015, 18(12): 752-757.

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CCTA: 128-slicedual-source high-pitch spiral versus 64-slice single-source sequential acquisition[J]. Int J Cardiovasc Imaging, 2012, 28 (5): 1217-1225.
[20] HAUSLEITER J, MEYER T, HERMANN F, et al. Estimated radiation dose associated with cardiac CT angiography[J]. J Am Med Assoc, 2009, 301(5): 500-507.
[21] HUSMANN L, VALENTA I, GAEMPERLI O, et al. Feasibility of low-dose coronary CT angiography: first experience with prospective ECG-gating[J]. Eur Heart J, 2008, 29(2): 191-197.
[22] WINKLEHNER A, GOETTI R, BAUMUELLER S, et al. Automated attenuation-based tube potential selection for thoracoabdominal computed tomography angiography: improved dose effectiveness[J]. Invest Radiol, 2011, 46(12): 767-773.
[23] HYUN J S, YONG E C, YOUNG H L, et al. Radiation dose reduction via sinogram affirmed iterative reconstruction and automatic tube voltage modulation (CARE kV) in abdominal CT [J]. Korean J Radiol, 2013, 14(6): 886-893.
[24] SCHABEL C, FENCHEL M, SCHMIDT B, et al. Clinical evaluation and potential radiation dose reduction of the novel sinogram-affirmed iterative reconstruction technique (SAFIRE) in abdominal computed tomography angiography [J]. Acad Radiol, 2013, 20(2): 165-172.
[25] 刘昌盛, 魏文洲, 郑晓华, 等. 低剂量CT扫描对婴幼儿颅脑病变检查的防护价值[J]. 中华放射医学与防护杂志, 2004, 24(3): 270-271.
LIU C S, WEI W Z, ZHENG X H, et al. Radioprotection with low dose CT scanningin infant and child's intracranial disease [J]. Chinese Journal Radiological Medicine and Protection, 2004, 24 (3): 270-271.
[26] 钟智勇, 汤伟军, 李克. CareDose 4D技术在头颅CT检查中的价值[J]. 中国医学计算机成像杂志, 2013, 19(6): 481-484.
ZHONG Z Y, TANG W J, LI K. Value of CareDose 4D technique in skull CT exam[J]. Journal of Chinese Computed Medical Imaging, 2013, 19(6): 481-484.
[27] 卞佳, 张培功, 姜兴岳, 等. 原始数据域迭代重建技术在颅脑CT检查中的初步应用[J]. 实用放射学杂志, 2013, 29(11): 1840-1843.
BIAN J, ZHANG P G, JIANG X Y, et al. Preliminary application of sonogram affirmed iterative reconstruction in brain CT examination [J]. Journal of Practical Radiology, 2013, 29(11): 1840-1843.
[28] 付雨菲, 何波, 韩丹. 头颅CT平扫100kV结合SAFIRE技术的临床应用[J]. 临床放射学杂志, 2014, 33(1): 125-129.
FU Y F, HE B, HAN D. The application of SAFIRE technique in head scan with low radiation dose [J]. Journal of Clinical Radiology, 2014, 33(1): 125-129.