The Effect of Therapy Oriented CT in Radiation Therapy Planning

Sung Kyu Kim, Ph. D., Sei One Shin, M.D. and Myung Se Kim, M.D.

Department of Therapeutic Radiology, College of Medicine, Yeung Nam University

The success of radioation therapy depends on exact treatment of the tumor with significant high dose for maximizing local control and excluding the normal tissues for minimizing unwanted complications. To achieve these goals, correct estimation of target volume in three dimension, exact dose distribution in tumor and normal critical structures and correction of tissue inhomogeneity are required.

The effect of therapy oriented CT (plannng CT) were compared with conventional simulation method in necessity of planning change, set dose, and proper distribution of tumor dose.

Of 365 new patients examined, planning CT was performed in 104 patients (28%). Treatment planning was changed in 47% of head and neck tumor, 79% of intrathoracic tumor and 63% of abdmonial tumor. In breast cancer and musculoskeletal tumors, planning CT was recommended for selection of adequate energy and calculation of exact dose to critical structures such as kidney or spinal cord. The average difference of tumor doses between CT planning and conventional simulation was 10% in intrathoracic and intra-abdominal tumors but 20% in head and neck tumors which suggested that tumor dose may be overestimated in conventional simulation.

Although some limitations and disadvantages including the cost and irradiation during CT are still criticizing, our study showed that CT planning is very helpful in radiotherapy planning.

Key Words: Therapy oriented CT, Planning CT, Conventional simulation

INTRODUCTION

Since advent of computed tomography (CT) in 1972, its use has been propagated rapidly not only in diagnostic radiology but also in therapeutic radiology. But routine CT gives mainly topographic or quantitative image informations in only 2 dimension according to demand of diagnostic radiologists.

Direct application of routine CT to the therapeutic use has still some limitations such as three dimensional calculation of target volume[1~5], correction of inhomogeneities[6~10] and uncertainty due to change of tumor size by respiration or therapeutic responses[3,5,6,11], etc. These have stopped us thinking of treatment phantoms for evaluation of patients, planning and suggested the need of specific treatment planning for individual patient including in vivo dosimentry.

In spite of those problems, there is no doubt that CT is superior than conventional simulation to obtain quantitative data on tumor localization, measurement of target volume and estimation of electron densities at different levels throughout treatment volume in treatment position. Now, images, including conventional radiography and CT, and radiation therapy would be "Symbiosis" and their use has become universal in treatment planning. but we should remember that whatever is attempted, it must be evaluated against the yardstick of clinical results.

The purposes of this study are 1) review of the use of therapy oriented CT (planning CT), 2) to assess its contribution in treatment planning, 3) to discuss its advantage and limitation, compare CT with conventional simulation based on our experience.

MATERIAL AND METHOD

From May first, 1986 to April 30, 1987, planning CT for treatment planning was performed in 106 histologically proven cases out of 365 new patients. All patients underwent conventional simulation first and determined the radiation field which would adequately encompass the sufficient tumor volume and exclude the normal structures. Adequate margin was ensured the coverage of target volume change by respiratory movement. IVP was routinely perfomed at the time of simulation in abdominal and lower thoracic cancer to confirm the function and location of both kidneys.

Planning CT was carried out using Hitachi, CT W4 scanner. All patients should be in the same position as in treatment (Fig. 1 & 2) during CT with quiet respiration instead of in deep suspended respiration as used for diagnostic CT scans. both lateral margin and the center line of the treatment field were marked on the patients' skin using angiography catheter which produced the least artifacts in CT images (Fig. 3 & 4). All planning CT scans were compared with conventional simulation in adequacy of field size, distribution of radiation dose and any other change of treatment planning (Fig. 5 & 6). Set dose and tumor dose distribution calculated by planning CT were also compared with contour calculation by conventional method (Fig. 7, 8).

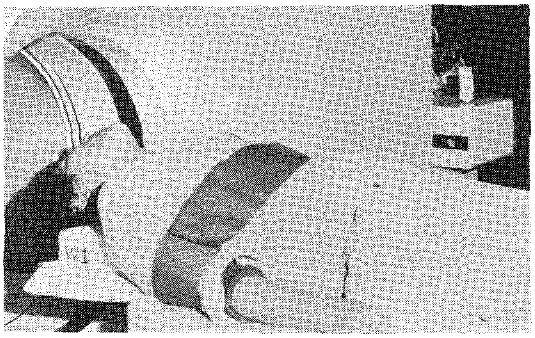

Fig. 1. Patient position of planning CT for intrathoracic tumor. Note * lwedge under the shoulder for flattening of upper chest.

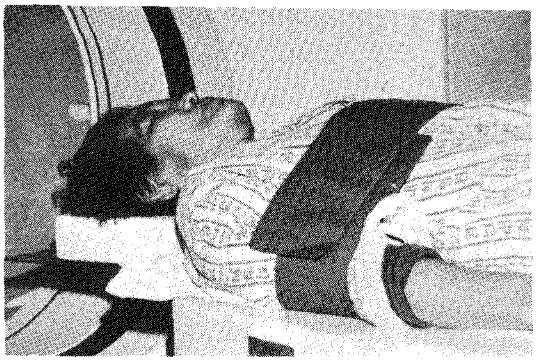

Fig. 2. Patient position for planning CT of head. Note a head rest.
(Same patient in Fig. 1. This patient had mediastinal tumor & metastasis to skull).

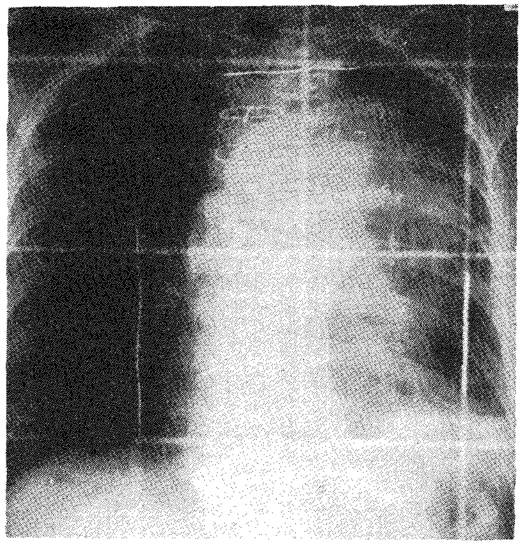

Fig. 3. Simulation film outlined the proposed treatment volume of same patient in Fig. 1.

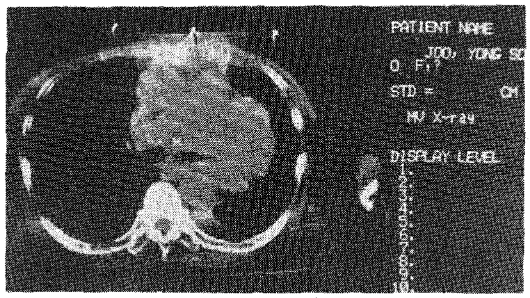

Fig. 4. Midline slice of planning CT.
Sharply demarcated both lateral margin & center of the field which obtained from conventional simulation are well visualized.

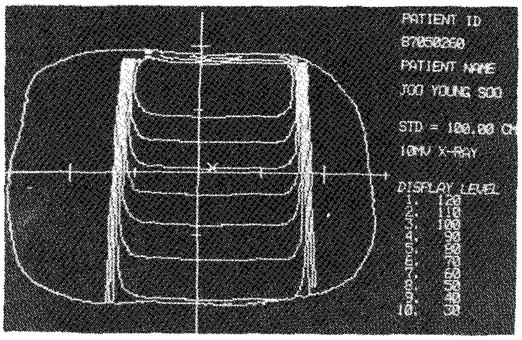

Fig. 5. Isodose curve obtained from conventional simulation of same patient in Fig. 1.

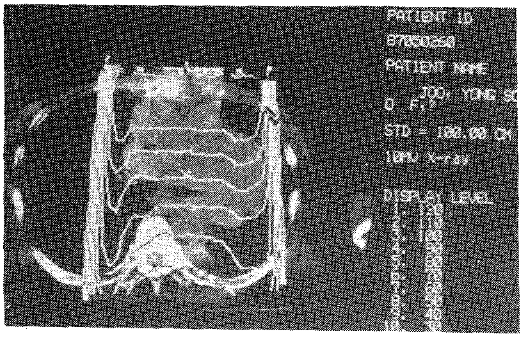

Fig. 6. Isodose curve obtained from planning CT of same patient in Fig. 5. Whole field was shifted 1 cm to the left side due to inadequate coverage of both margin.

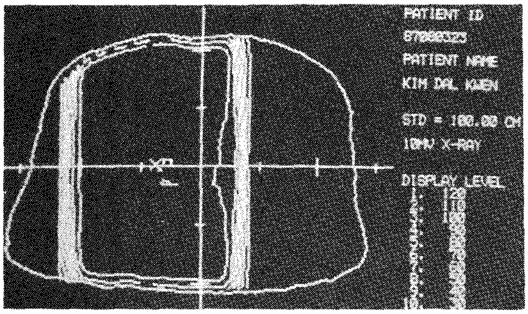

Fig. 7. Isodose curve obtained from conventional technique. 100% line showed adequate coverage of tumor volume.

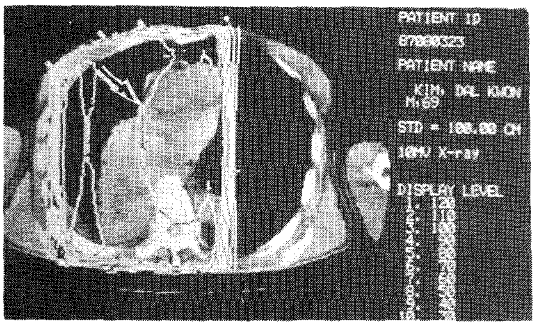

Fig. 8. Isodose curve obtained from planning CT of same patient in Fig. 7. 100% line showed inadequate coverage of tumor (arrow).

RESULST

Of 365 patients who were treated in Therapeutic Radiology Department for curative or palliative intent, planning CT was taken in only 106 patients (29%). The details of patients were summerized in Table 1.

Table 1. Analysis of Total Patients and CT Planning Patients

	Total	CT	%
Head and neck tumors	86	43	50
Chest tumors	91	28	31
Abdominal tumors	44	8	18
G–U tumors	102	3	3
Breast tumors	32	16	50
All others	10	8	80
Total	365	106	29

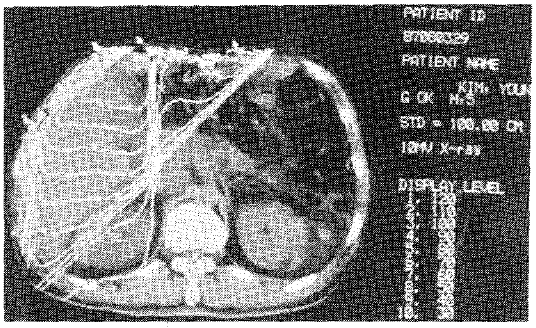

Fig. 9. Slice of lower margin of the field in a patient with symptomatic liver metastasis. Oblique portal was planned for minimizing irradiation of right kidney.

In head and neck cancer patients, planning was changed in 20 of 43 patients (47%). 12 patients (28 %) had geometric changes and in only 1 patient (2 %) field size had to be extended. Tumor dose was changed in 4 patients (9%) in and 3 patients (7%). selected energy was changed for enough coverage of tumor depth.

In intrathoracic tumors, planning was changed in 22 of 28 patients (79%). 20 patients (71%) and geometric change but in only 1 patient the field size was reduced.

In intraabdominal tumors, planning was changed in 5 of 8 patiets (63%). 2 patients (25%) had geometric change and 4 (50%) had change of total tumor dose due to critical structures (Fig. 9).

In breast cancers, planning CT was performed in 16 patients for selection of energy for chest wall treatment.

In genitourinary tumors, mainly uterine cervix cancer, planning CT was recommended for only 3 patients and all had no planning changes.

In other tumors, including musculoskeletal tumor and metastatic tumors, all 28 patients were recommended planning CT for selection of energy (Fig. 10). 2 patients added geometric changes due to more extension of tumor mass than we expected. All of the results were summerized in Table 2.

The set dose and isodose curve including target volume between planning CT and contour were also estimated. This results are summerized in Table 3. These results showed that contour calculation overestimated than CT and the average difference was about 20% in head and neck cancer, 10% in intrathoracic and intraabdominal cancer.

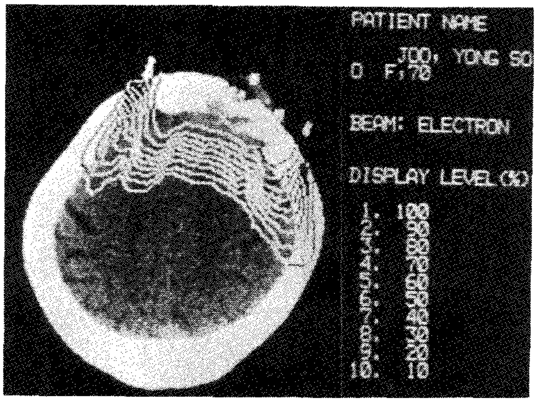

Fig. 10. Planning CT of same patient in Fig. 1. CT was recommended for selection of proper energy.

DISCUSSION

With increasing use of systemic therapy to control metastatic disease, local regional control becomes more important in cancer treatment. Obviously, local control depends on maximizing

Table 2. Analysis of Planning Change as a Result of Therapy Oriented CT

Tumor No. of total patients Alternation in planning	Head & neck 43	Thorax 28	Abdomen 8	Breast 16	GU 3	Others 8
Change in field geometry	7	12	1	3	–	2
Extension	1	8	–	3	–	–
Reducing	3	1	1	–	–	–
Shifting	5	6	1	–	–	–
Change in tumor dose	5	2	2	–	–	–
Increasing	4	1	2	–	–	–
Decreasing	1	1	–	–	–	–
Both factors	5	8	1	–	–	–
Energy change	3	–	1	–	–	–
Selection of energy	–	1	1	16	–	7
No change	23	5	3	–	3	–

Table 3. Comparison of the Difference in Set Dose and Isodose Curve Obtained with CT and Conventional Simulation

	Set dose			Isodose curve including tumor		
	Contour (rad)	CT (rad)	Difference (%)	Contour (%)	CT (%)	Difference (%)
Head and neck	209.1	238.4	– 12.3	100	80	+ 20
Intrathoracic	213.0	201.0	+ 6.0	100	90	+ 10
Intraabdominal	224.4	209.9	+ 6.0	100	90	+ 10
Pelvis	196.1	197.6	– 0.7	100	100	0

tumor dose and minimizing complication by excluding normal structures from irradiation field.

But balancing these goals is still one of the most difficult task in radiation therapy field. For achieving these goals, detection of exact tumor location and its extension, its relation to critical organ and correct dose distribution should be known. Therefore, the role of CT became important for correct informations and its effective use requires close cooperation between diagnostic radiologist and radiation therapist.

Even though CT has many advantages for treatment planning, direct application of routine CT had some limitations. The following are particularly important to solve those limitations.

1. Identical positioning of patients, just like treatment position is absolutely necessary for correct estimation of target volume and extent of tumor[5,6,11~14]. But in routine CT, patients' position is usually different from treatment position especially in head and neck CT.Breit et al.[11] emphasized that all problems arose from incorrect position of the patient. Goitien and Meyer[12] reported that patients' position varied with respiration so that radiation therapist had to learn to take them into account by adding appropriate margin to the treatment field especially for upper abdominal and lower thorax cancer. During planning CT authors tried to keep patient in treatment position and permit quiet respiration as treatment condition.

2. Informations of tumor localization from routine CT display only 2 dimensional cross-sectional images. Tumor spreads in 3 dimension but longitudinal plane of target volume is difficult to estimate from routine CT[1~3,5]. This may result in inaccurate estimation and may cause significant error in treatment planning. We did not measure tumor volume but we examined CT on upper, midline and lower margin of the field for decreasing geometric miss and excluding normal tissue.

3. Correct information of electron density is very important especially in intra-thoracic, upper intra-abdominal and head and neck cancer treatment planning because any change of electron density may cause different calculation by planning because any change of electron density may cause different calculation by planning computer. Since electron densities are calculated from CT numbers and it depend upon various technical factors, each operational parameters, machinary and technically, also may cause incorrect calculation[5~7,15~17]. Parker[5] insisted that this error can be up to 20% of dose calculation unless suitable correction is made. We use angiography catheter as a skin marker for reducing artifact in CT image and we do not use any contrast material in planning CT because uniformity of dose distribution in target volume may be affected by these high density material or artifacts.

4. Routine diagnostic CT should be matched by same degree of beam direction and correct identifying the field size by using reference mark on the skin in treatment position. This is very important for planning of small tumor volume which closely located to critical organ. We use angiography catheter on the skin as a reference point for field size in CT images. We found that this mark was very useful for exact determination of field size because error of several millimeters may be critical when target volume is close to the kidney or spinal cord.

In spite of those limitations, there is no doubt that CT is effective tool for detecting the primary tumor, exact localization of tumor and normal tissue and accurate measurement of dose distribution, compared with conventional simulation.

Many authors reported that the effects of these advantages are varible according to tumor location. In head and neck cancer planning, Shuman et al.[4] reported that 77% of planning changes and Adam et al.[23] reported 93% of planning change when they used CT planning, compared to conventional simulation. Our result showed 47% of planning changes which was much lower than others. In intra-thoracic tumors, our study showed 79% of planning change which is a little higher than 33% by Adam et al.[13], 71% by Emami et al.[18] and 74% by Seydel et al.[19]. Intra-abdominal cancer is poor location for accurate dose calculation based on CT information because intestinal gas makes inhomogeneities and obscures tissue demarcation. Rostock et al.[20] reported 70% of planning change in liver treatment and Dobbs and Parker[17] reported 72% in pancreas cancer. In our study, 63% of patiets who had treatment for liver, pancreas and stomach cancer had treatment planning change, mainly for reducing dose to the kidney or spinal cord. Husband et al.[21] reported that CT was valuable in 95% of recurrent rectal cancer but our result showed no planning changes except for boost dose planning in inoperable rectal cancer. For irradiation of carcinoma of breast, Dobbs and Parker[17] reported that good information about the thickness of the chest wall could be obtained by scanning in treatment postion. We use CT images for selection of adequate energy for chest wall irradiation, which was useful for reducing irradiation dose to underlying lung. In genitourinary cancer, Ash et al.[22] reported significant errors of localization in 37% of bladder cancer cases and Rothwell et al.[23] noted significant discrepancies of target volume in 85% of bladder cancer patients between conventional simulation and CT plannig. At the beginning, we tried planning CT for uterine cervix cancer patients but we had no planning change in consecutive 3 cases. Thereafter we use contour dose calculation without planning CT for uterine cervix cancer. We did not evaluate the advantages of planning CT in bladder or prostate cancer because of scanty cases.

Now we have another problem which is the tendency of the rapid spreading of this technique without careful estimation of efficacy on health care cost including radiation dose during CT[25~27] and additional cost for CT[13,19,28]. McCullough & Payne estimated absorbed dose during CT as 2-10 rad/study and 1-2 mrad/scan at 1 meter even though patient dosage may differ by different CT scanners. In spite of these problems, kotre et al.[14], Adam et al.[13], Seydel et al.[19] and Stewart[28] insisted that CT is very useful and can contribute to improve patient management although the unit cost is high.

Conclusively, our results showed that planning CT is an accurate tool for localization of tumor and critical normal tissues so that higher dose could be administrered to tumor. This may decrease the incidence of local failure. Furthermore, this will improve tumor control and also avoid normal tissue irradiation, causing decreased complication rates. Taking all of those measured factors into account, we concluded that planning CT is quite helpful in the treatment planning especially head and neck tumors, intrathoracic, intraabdominal and breast tumors not only for curative but also for palliative treatment.

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=국문초록=

치료 계획용 전산화 단층촬영이 방사선 치료계획에 미치는 효과

영남대학교 의과대학 치료방사선과학교실

김 성 규·신 세 원·김 명 세

전산화 단층촬영(CT)은 진단 분야 뿐 아니라 방사선 치료 계획 및 치료효과의 추적 등 치료분야에 까지 광범위하게 사용되고 있다. 그러나 환자의 체위가 치료시와는 다름으로 얻어진 영상이 치료시의 영상과는 차이가 있으며, 삼차원적인 치료면적의 계산이 곤란할 뿐 아니라 조영제를 사용함으로 생길 수 있는 선량계산의 오차 및 정확한 조사야가 표현되지 않음으로 병소 및 중요 정상장기의 선량 측정이 정확하지 못한점 등의 단점이 있다. 저자들은 1986년 5월 1일부터 1987년 4월 30일까지 영남대학병원 치료방사선과에서 치료받은 총 365명의 환자중 일반 CT의 단점을 보완한 치료용 CT와 종래의 simulation을 병행한 106명의 치료계획을 비교분석하여 다음과 같은 결과를 얻었다.

치료용 CT 후 두경부 암 환자의 47%, 흉부암 환자의 79%, 복부암 환자의 63%에서 치료계획의 변경이 있어 치료용 CT가 두경부암, 흉부암, 복부암에서 거의 필수적임을 시사하였다. 그러나 직장암, 자궁경부암에서는 추가치료의 조사야의 측정 및 선량계산 이외의 전예에서 치료계획의 변경이 없었다.

선량분포의 비교측정에서는 윤곽만을 사용한 종래의 선량계산이 CT를 사용한 경우에 비해서 두경부암에서는 평균 20%, 흉부암, 복부암에서는 약 10%의 차이를 보여 전례에서 CT보다 과측정 되었음을 보여 종래의 윤곽만을 사용한 치료계획시의 저선량 조사에 대한 보정이 필요함을 시사하였다.