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Brief communication (Original)

Volumetric modulated arc therapy dosimetry and treatment time compared with conventional intensity-modulated radiotherapy for unresectable cholangiocarcinoma

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Background: Cholangiocarcinoma is a locally extending tumor with a high incidence in Thailand. Most patients are diagnosed when the tumor is unresectable, which requires concurrent chemotherapy and/or radiation. Volumetric modulated arc therapy (VMAT) and conventional intensity-modulated radiotherapy (cIMRT) are advanced techniques that improve survival and reduce radiation-induced complications.
Objectives: To compare conformity, homogeneity, and treatment time between VMAT and cIMRT in unresectable cholangiocarcinoma.
Methods: Between September 2004 and December 2010, CT images of 11 unresectable cholangiocarcinoma patients were retrieved and replanned by VMAT and cIMRT. Comparison was made in conformation number, homogeneity index, and monitor units using a Wilcoxon signed-rank test. Dose constraints for critical organs such as the liver, kidneys, and spinal cord were restricted by Quantitative Analyses of Normal Tissue Effects in the Clinic criteria.
Results: Mean conformation number was 0.91 in both the VMAT and cIMRT plans ($p = 0.477$). Mean homogeneity index was 2% different, 1.11 in VMAT plans and 1.09 in cIMRT plans ($p = 0.008$). Mean monitor units was 529 in VMAT plans and 1,279 in cIMRT plans ($p = 0.003$).
Conclusion: This study is the first VMAT study in unresectable cholangiocarcinoma. Conformity was not different, but treatment time was shorter by VMAT as reported in other cancer studies. Homogeneity was 2% statistically higher by VMAT; however, clinical differences should be evaluated.

Keywords: Cholangiocarcinoma, cIMRT, conformation number, dosimetric study, homogeneity, index monitor units, VMAT

Cholangiocarcinoma is a locally invasive tumor with a high incidence in Thailand [1]. Only radical surgery with a negative resection margin is a curative treatment. However, 50% to 90% of patients have unresectable cases on presentation [2], and require concurrent chemoradiation or radiotherapy alone. Two-dimensional or three-dimensional radiotherapy with dose of 40 to 50 Gy have been used, but the limitation is damage to surrounding organs, such as the liver, kidneys, and spinal cord [3].

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Many advanced radiotherapy techniques have been introduced to improve outcome and reduce complications. Conventional intensity modulated radiotherapy (cIMRT) is used in cholangiocarcinoma [4]. Volumetric modulated arc therapy (VMAT), the more advanced technique, has been used in clinical practice since 2008, but there is no report in cholangiocarcinoma because of disease rarity. Multileaf collimators independently slide across the radiation field to generate multiple intensity modulated beamlets in cIMRT, whereas multileaf collimators, gantry rotational speed, and dose rate are simultaneously modulated in VMAT.

The first VMAT machine in Thailand was installed in 2009 at King Chulalongkorn Memorial Hospital. This

study is the first dosimetric study comparing VMAT and cIMRT in unresectable cholangiocarcinoma. Other disease studies comparing VMAT and cIMRT showed no statistical difference in tumor dosimetry; however, VMAT reduced treatment time.

Materials and methods

Unresectable cholangiocarcinoma without prior curative surgery were included in this study. CT images with contrast study from 11 patients from September 2004 to December 2010 were retrieved for replanning. The study was approved by the Ethics Committee of the Faculty of Medicine, Chulalongkorn University.

Gross target volume (GTV) was defined as a visible tumor on CT images. Clinical target volume (CTV) was defined as GTV plus 1.5-cm margin, without overlapping strong barriers such as bone, the great vessels, diaphragm, abdominal wall, kidney, and bowel. Planning target volume (PTV) was defined as CTV plus 0.5-cm radial margin and 1.0-cm craniocaudal margin to compensate for organ movement and setup errors [8]. Organs at risk (OAR) were defined as the liver, kidneys, and spinal cord.

Both VMAT and cIMRT were planned by 2 experienced physicists. Each technique in aspects of conformity and homogeneity were analyzed. Photon with 10 MV from Varian Clinic iX linear accelerator (Varian Oncology systems, CA, USA) was utilized. Eclipse version 8.9.17 (Varian Medical System, Palo Alto, CA, USA), was used as a treatment planning system. Dose constraints were restricted for VMAT and cIMRT plans as demonstrated in **Table 1** [9-12]. Nine nonopposing fields with single isocenter were optimized in cIMRT plans, whereas three coplanar arcs with single isocenter were optimized in VMAT plans (**Figure 1**).

Table 1. Dose constraints for PTV and OAR

	Dose constraints
PTV	Prescribe dose = 50 Gy (2 Gy/F) Minimum dose = 95% of prescribe dose
Liver	Mean dose < 28 Gy
Kidneys	Mean dose < 18 Gy V12 < 55% V20 < 32% V23 < 30% V28 < 20%
Spinal cord	Maximal dose = 54 Gy

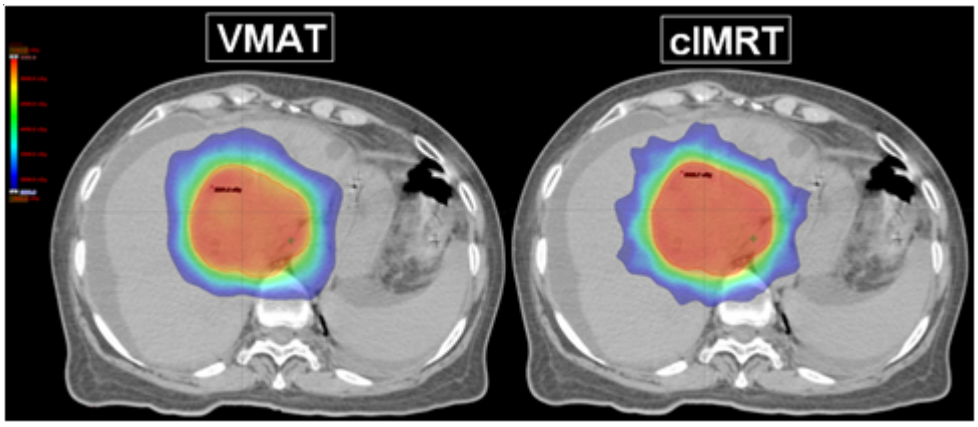

Figure 1. Radiation dose of VMAT and cIMRT plans

The primary end points were conformation numbers proposed by van't Reit et al. and the homogeneity index proposed by Radiation Therapy Oncology Group [13]. The best value is 1. The secondary end point was monitor units, which translated to treatment time. The Wilcoxon matched-pair signed-rank test for nonparametrically distributed data was used to compare the results between cIMRT and VMAT plans. All tests were two-sided with $p \leq 0.05$ set as a significant level. Statistical analysis was processed using SPSS version 17.0.

Results

The results are shown in **Figure 2**. Mean conformation number was 0.91 in both VMAT and cIMRT plans (p = 0.477). Mean homogeneity index was 2% different, 1.11 in VMAT plans and 1.09 in cIMRT plans (p = 0.008). Mean monitor units was 529 in VMAT plans and 1,279 in cIMRT plans (p = 0.003).

Left kidney and spinal cord were viewed within dose constraints. The right kidney and normal liver were difficult to optimize in both techniques because of close distance to PTV; however, dose to organs at risk were not statistically different between techniques as shown in **Figure 3**.

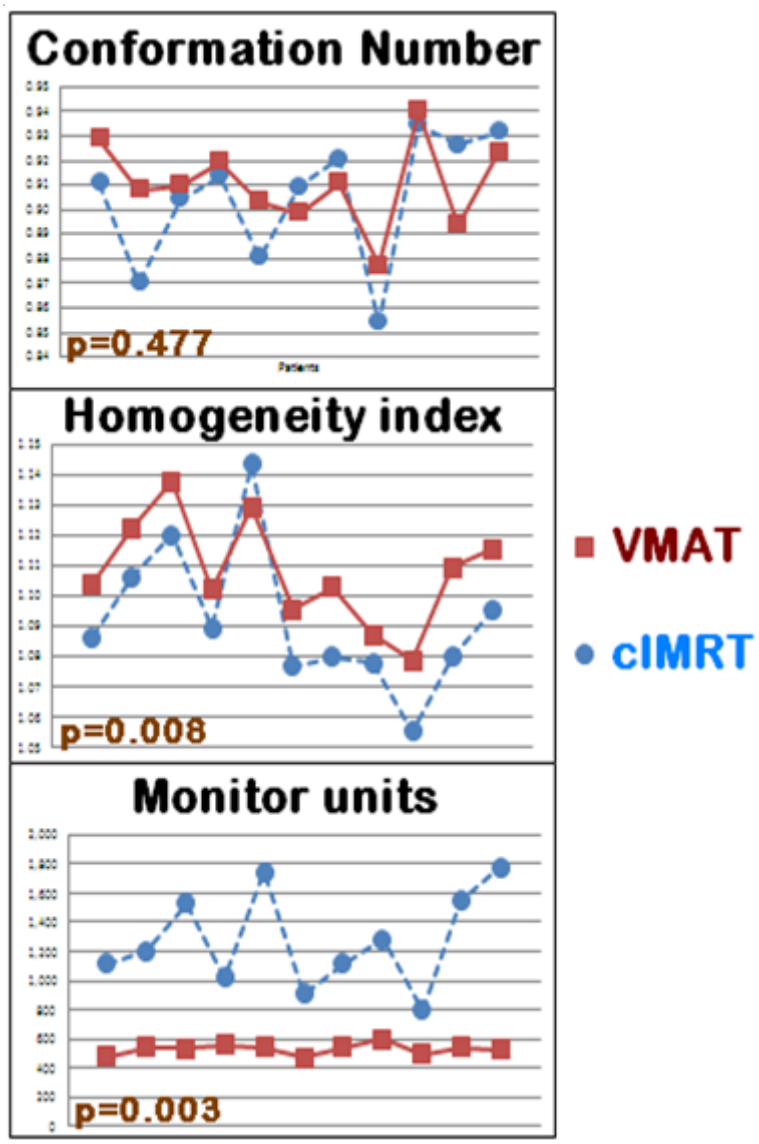

Figure 2. Results of VMAT and cIMRT plans

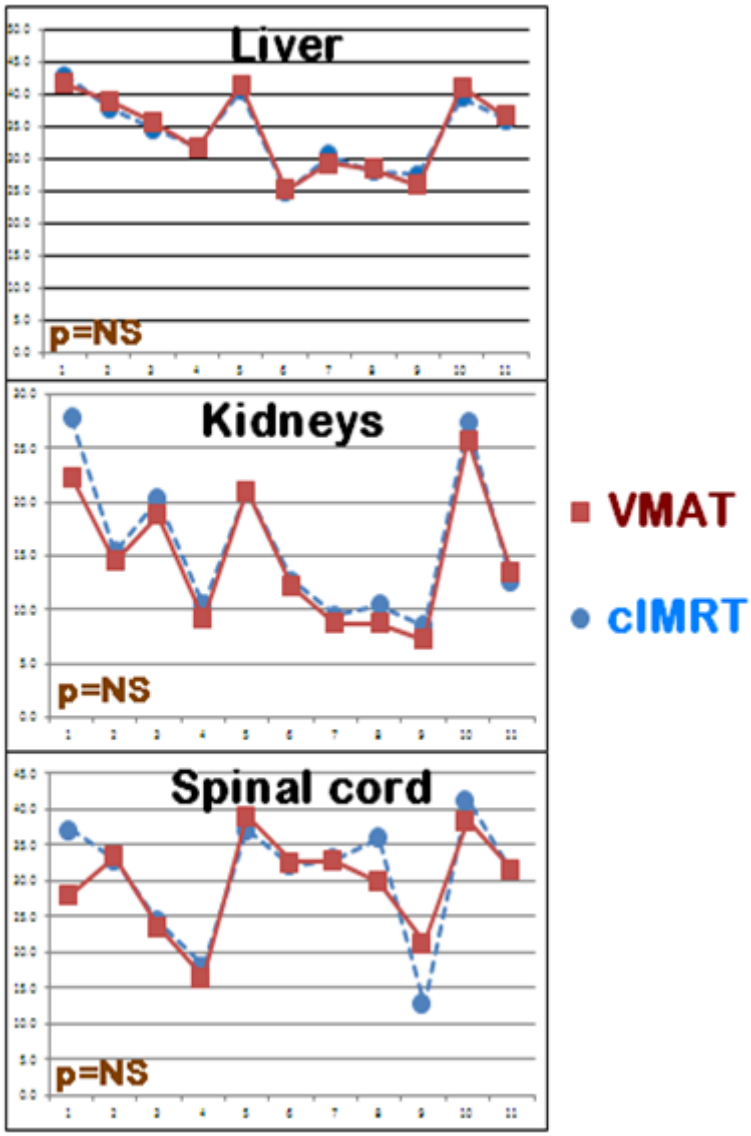

Figure 3. Dose to organs at risk

Discussion

Cholangiocarcinoma is a locally invasive tumor, surrounded by critical organs such as the liver, kidneys, and spinal cord. Most patients are diagnosed in the unresectable stage, which requires concurrent chemoradiation or radiotherapy alone. Higher radiation dose confers a survival benefit; however, it is difficult to use high radiation dose with conventional techniques. VMAT and cIMRT are advanced radiotherapy techniques to improve survival outcome and reduce radiation-induced complications. VMAT and cIMRT achieved comparable target coverage, but VMAT significantly used less treatment time by 30%–60% in several studies. VMAT reduced monitor units by 60% and similarly spared OAR as compared with cIMRT in head and neck cancer. Moreover, double-arcs VMAT demonstrated the best PTV homogeneity as compared with single-arc VMAT and cIMRT [5]. VMAT and cIMRT showed similar PTV homogeneity and sparing of OAR in breast cancer at the University of British Columbia. However, VMAT reduced monitor units by 30% [6]. Simultaneous maximal intraprostatic boost technique was used in prostate cancer to achieve better treatment outcome. VMAT could boost larger volume of CTV and used 48% fewer monitor units as compared to cIMRT [7].

This is the first VMAT study of unresectable cholangiocarcinoma, probably because of disease

rarity. Conformity was not different, but treatment time was shorter by VMAT as reported in other cancer studies. Homogeneity was 2% statistically higher by VMAT; however, clinical differences should be evaluated.

Target delineation is an essential part of successful treatment. CT images are difficult in revealing the outline of the tumor. MRI simulator may provide better images to solve this problem. Respiratory gating or active breathing control may reduce target movement. Image-guided radiotherapy may reduce setup errors.

Conclusion

VMAT and cIMRT are advanced techniques used in various cancers. The target coverage is similar, but VMAT shortens overall treatment time for daily radiotherapy. Clinical outcomes should be observed and analyzed in terms of disease control and radiation-induced complications.

The authors have no conflicts of interest to report in this study.

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