Original Article

Deep Regional Hyperthermia Treatment Using Thermotron-RF8: An Initial Experience at Chulabhorn Hospital

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Background: Adding hyperthermia to radiation or chemotherapy has been shown to improve outcomes in patients with various malignancies.

Objective: To evaluate response rates and toxicities of deep regional hyperthermia combined with radiation or chemotherapy in cancer patients.

Materials and Methods: Medical records of 30 cancer patients treated with deep regional hyperthermia combined with radiation therapy or chemotherapy from April 2014 to April 2017 were retrospectively reviewed. Treatment outcomes were reported in terms of response rates and toxicities.

Results: The median follow-up time was 15 months (range 4 to 38 months); 53% of patients received hyperthermia combined with radiation therapy, and 37% received hyperthermia combined with chemotherapy. The most commonly treated sites were within the pelvic cavity (46.7%) and abdomen (40%). Of the 30 patients, 16.7% achieved complete response, 36.7% achieved partial response, 13.3% had stable disease, and 33.3% had progressive disease. Among patients in the curative intent group, 50% achieved complete response and 50% achieved partial response. In the palliative intent group, 30% achieved partial response, 20% had stable disease, and 50% had progressive disease. The most common toxicity was skin reaction grade 1.

Conclusion: Adding hyperthermia to radiation or chemotherapy is feasible, with minimal adverse effects. Treatment outcomes were comparable with previous published data.

Keywords: Deep regional hyperthermia; Thermotron-RF8; Radiation therapy; Chemotherapy; Response; Toxicity

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Hyperthermia is a cancer treatment modality in which the tumor is exposed to temperatures above normal body temperature. Hyperthermia has been used to treat various cancers since the 1960s[1]. It can be divided into three categories: whole body, local, and regional hyperthermia. Whole body hyperthermia is used to treat metastatic cancers; however, it can cause serious side effects, including cardiac and vascular disorders[2,3], and its use has therefore declined. Local hyperthermia uses temperatures as high as 80°C to ablate the tumor, whereas regional hyperthermia only uses temperatures of about 42 to 43°C. The rationale for the use of regional hyperthermia in cancer treatment is based on several mechanisms, including direct cell

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killing, decreased damage repair, and activation of the immune system[4-8]. Although regional hyperthermia alone has limited efficacy in clinical practice, many recent reports have demonstrated its efficacy when combined with radiation therapy and/or chemotherapy. The combination of regional hyperthermia with radiation therapy and chemotherapy has also shown benefits in both superficial and deep tumors.

A meta-analysis of five phase III trials compared radiation therapy with or without hyperthermia in patients with advanced primary or recurrent breast cancer, showing that radiation combined with hyperthermia significantly increased the response rate compared with radiotherapy alone (59% vs 41%; $p<0.001$), especially in re-irradiated breast cancers[9]. van der Zee et al conducted a phase III randomized trial inpatients with locally advanced pelvic tumors and found that radiation therapy plus hyperthermia significantly improved the complete response rate (55% vs. 39%; $p<0.001$) and 3-year local control rate (38% vs. 26%; $p = 0.04$)[10]. Furthermore, subgroup analysis showed that 3-year overall survival was also significantly higher in cervical cancer patients following combined treatment[10]. Maluta et al reported that hyperthermia combined with chemoradiotherapy increased the median overall survival in patients with primary or recurrent pancreatic cancer, compared with chemoradiotherapy alone[11]. However, randomized controlled trials of combined hyperthermia treatments in deep-seated tumors are limited.

Hyperthermia has previously been used to treat cancer patients in certain medical schools in Thailand but the capacitive heating devices used microwaves and were thus only suitable for treating superficial tumors. Chulabhorn Hospital installed a Thermotron-RF8 regional hyperthermia machine in April 2014, which generates heat at a radiofrequency [RF] of 8 MHz, making it suitable for the treatment of both superficial and deep tumors. The current retrospective study aimed to evaluate the outcomes of patients treated with deep regional hyperthermia using the Thermotron-RF8 in Thailand.

Materials and Methods

Patient characteristics

This study was approved by the Ethics Committee for Human Research, Chulabhorn Research Institute (EC No. 024/2557). A retrospective review of medical records of 30 cancer patients treated with regional hyperthermia combined with radiation therapy or chemotherapy at Department of Radiation Oncology, Chulabhorn Hospital, from April 2014 to April 2017 was performed. Patient data, treatment details and outcomes were collected.

Hyperthermia

Hyperthermia treatments were delivered once or twice a week within 60 minutes after radiation or chemotherapy, using Thermotron-RF8. A pair of electrodes with diameters of 7 to 30 cm, depending on the tumor site and patient body size, was applied on both sides of the target lesion, such as on the chest, abdomen, or pelvic region. The temperature was monitored by thermocouples placed on the skin over the target lesion, or inserted into the vaginal or rectal cavity. The power output was increased up to the patient's tolerance. Each heating session lasted for 50 minutes. Patients' vital signs were monitored before and after treatment by a registered nurse.

Radiation therapy

Computed tomography [CT] simulations were done within 1 to 2 weeks before irradiation. All target volumes and normal structures were contoured by a radiation oncologist. Patients were treated with three-dimensional conformal radiotherapy, intensity modulated radiation therapy, or volumetric modulated arc therapy. Radiation therapy was delivered using 6, 10, or 15 MV from a linear accelerator. The radiation dose prescription was based on the disease stage, histopathology, and tumor location, and was delivered in 1.8 to 2 Gy/fractions, once daily for five fractions per week, in patients treated with curative intent. However, some patients who had received prior radiotherapy or who were treated with palliative intent received hypofractionated radiation therapy, usually with >2 Gy/fraction.

Chemotherapy

The chemotherapy regimens differed among patients and were based on the diagnosis, disease stage, histopathology, and patient performance status. All chemotherapy regimens were approved by a team of experts at a tumor-board conference.

Follow-up

After the completion of treatment, patients were followed-up at 1 month and 3 months, and then every 3 months for 2 years. Tumor response was evaluated by physical examination and CT or magnetic resonance imaging at 1 month and 3 months, using RECIST criteria version 1.1.

All toxicities were noted from hospital records. Toxicities were graded according to the Common Terminology Criteria for Adverse Events [CTCAE] v4.0.

Data analysis

Response rates were reported as the percentages of patients who achieved complete or partial response, or stable or progressive disease. Toxicities were reported as the percentages of patients who experienced grade 1, 2, 3, or 4 toxicities.

Results

A total of 49 cancer patients were treated with regional hyperthermia combined with radiation therapy or chemotherapy at the Department of Radiation Oncology, Chulabhorn Hospital, from April 2014 to April 2017. Among these, 30 patients were enrolled in this study, and 19 were excluded because of superficial hyperthermia (n = 13) or follow-up at other hospitals (n = 6).

The enrolled patients included 27 females (90%) and three males (10%), with a median age of 62 years (range 33 to 88 years). The median follow-up time was 15 months (range 4 to 38 months). Most patients had good performance status (ECOG 0-1). The patients presented with various malignancies, with cervical carcinoma (40%) being the most common. About 53% of the patients received hyperthermia combined with radiation therapy, 37% received hyperthermia combined with chemotherapy, and trimodality treatment was administered in 10% of the patients. The most commonly treated sites were within the pelvic cavity and abdomen. The patient characteristics and treatment features are summarized in Table 1.

Treatment response

Treatment response rate was evaluated at least 3 months after the completion of treatment. Five patients (16.7%) achieved complete responses, 11 (36.7%) had partial responses, four (13.3%) had stable disease, and 10 (33.3%) had progressive disease (Table 2). All patients with planned curative treatment achieved at least a partial response, and none had stable or progressive disease. Half the patients receiving palliative treatment had partial responses and stable disease, respectively.

Treatment toxicities

The treatment toxicities are summarized in Table 3. The most frequent toxicity was skin complications, though these were usually mild and did

Table 1. Baseline characteristics

	All patients (n = 30)
Age (yr), median (range)	62 (33 to 88)
Gender	
Male	3 (10%)
Female	27 (90%)
Performance status	
0	3 (10%)
1	23 (76.7%)
2	4 (13.3%)
Disease category	
Cervical cancer	12 (40%)
Cholangiocarcinoma	3 (10%)
Pancreatic cancer	3 (10%)
Sarcoma	3 (10%)
Bladder cancer	2 (6.7%)
Endometrial cancer	2 (6.7%)
Colon cancer	2 (6.7%)
Lung cancer	1 (3.3%)
Gallbladder cancer	1 (3.3%)
Hepatocellular carcinoma	1 (3.3%)
Disease state	
Primary	12 (40%)
Local recurrence	5 (16.7%)
Metastasis	13 (43.3%)
Aim of treatment	
Curative	10 (33.3%)
Palliative	20 (66.7%)
Treatment	
RT + hyperthermia	16 (53.3%)
CMT + hyperthermia	11 (36.7%)
RT + CMT + hyperthermia	3 (10%)
Region of treatment	
Chest	4 (13.3%)
Abdomen	12 (40%)
Pelvic	14 (46.7%)
Radiation dose (Gy)	Median (range)
Curative aim	
Total RT dose	57.5 Gy (50 to 63.8)
Total fraction	25.3 F (25 to 32)
Dose/fraction	2 Gy/F
Palliative aim	
Total RT dose	40 Gy (10 to 60)
Total fraction	17.2 F (2 to 30)
Dose/fraction	2.7 Gy/F (2 to 5)
Chemotherapy regimens	
Cisplatin/gemcitabine	3 (21.4%)
Carboplatin	2 (14.3%)
Carboplatin/paclitaxel	2 (14.3%)
Gemcitabine	2 (14.3%)
FOLFIRI	1 (7.1%)
FOLFOX	1 (7.1%)
FOLFOX+ Bevacizumab	1 (7.1%)
Gemcitabine/docetaxel	1 (7.1%)
Mitomycin-C	1 (7.1%)

not present clinical problems.

Discussion

There are several rationales for the use of hyperthermia in combination with radiation therapy or chemotherapy to improve treatment outcomes. Hyperthermia has been shown to induce direct cell killing, interfere with sub-lethal damage repair, increase sensitivity to hypoxia, and also act as a radio- and chemosensitizer[4-8]. On these bases, hyperthermia has been applied for the treatment of many types of cancers.

Of the 30 patients in the current study, 53.4% achieved responses. All patients with complete responses had tumors located in the pelvic cavity, including three patients with cervical cancer, one with endometrial cancer, and one with bladder cancer. Although the current standard of care for these tumors involves concurrent chemoradiation, most of these patients did not receive chemotherapy because of poor performance status or impaired renal function; four patients received radiation therapy combined with hyperthermia, but only one received concurrent chemoradiation combined with hyperthermia. These finding were in accord with those of the Dutch Deep Hyperthermia Group, who showed that radiation therapy combined with hyperthermia significantly improved the complete response rate compared with radiation therapy alone inpatients with locally advanced pelvic tumors[10].

About one-third of all patients in the current study had a partial response. One patient with a partial response was diagnosed with adenocarcinoma of the cervix stage IB1 status post-total abdominal hysterectomy and bilateral salpingo-oophorectomy in 2006, and developed local recurrence in February 2014. A CT scan of the abdomen showed a large vaginal-stump mass (7.8x7.4 cm) invading into the urinary bladder, evaluated as unresectable by a gynecologic oncologist. She received whole-pelvis radiation of 50Gy in 25 fractions and gross tumor irradiation boosted to 63.8 Gy, with six courses of carboplatin and weekly hyperthermia during her radiation therapy. Brachytherapy was not performed because of the large mass with bladder invasion. Three months after completing treatment, abdominal CT showed a significant decrease in size of the vaginal-stump mass to about 3.5x3.6 cm. Her disease was then considered to be resectable and she underwent radical en bloc cystectomy with a vaginal stump. The pathological results showed complete tumor excision with negative surgical margins. The patient remained disease-free for about 27 months. The current treatment for patients with localized pelvic recurrence after surgery alone involves whole-pelvis external irradiation (45 to 50 Gy) combined with concurrent chemotherapy, followed by intracavitary interstitial brachytherapy or surgery. Salvage radiation therapy is effective for small central relapses limited to the vagina, with a disease-free survival rate of approximately 40%[12,13]. If the tumor is located outside an accessible region for brachytherapy, radiation dose escalation to at least 60 to 70 Gy should be considered. However, the external radiation dose is limited by small bowel intolerance.

Table 1. Cont.

	All patients (n = 30)
Total No. hyperthermia (range)	154 (1 to 26)
Temperatureand RF power	Median (range)
Chest	
T_{max} (°C)	28.7 (20.2 to 41.5)
RF_{max} (W)	762.8 (637.5 to 989.5)
Abdomen	
T_{max} (°C)	33.5 (26 to 44.1)
RF_{max} (W)	853.6 (510 to 1,349.6)
Pelvis	
T_{max} (°C)	36.7 (22.5 to 41)
RF_{max} (W)	781.5 (410.4 to 1,255.8)
Follow-up time (months), median (range)	15 (range 4 to 38)

RT = Radiation therapy; CMT = Chemotherapy; FOLFIRI = Folinic acid Fluorouracil and Irinotecan; FOLFOX = Folinic acid Fluorouracil and Oxaliplatin; RF = Radiofrequency

Table 2. Treatment response rates of patients receiving hyperthermia with radiation or chemotherapy

Treatment response rate at 3 months after treatment	n (%)
All patients (n = 30)	
Complete response	5 (16.7%)
Partial response	11 (36.7%)
Stable disease	4 (13.3%)
Progressive disease	10 (33.3%)
Curative intent (n = 10)	
Complete response	5 (50%)
Partial response	5 (50%)
Palliative intent (n = 20)	
Partial response	6 (30%)
Stable disease	4 (20%)
Progressive disease	10 (50%)

Some patients who cannot receive standard treatment may therefore benefit from the addition of hyperthermia, which can enhance the effects of radiation and chemotherapy.

In the current study, all patients with stable or progressive disease were among those treated with palliative intent, and most had experienced previous treatment failure or metastatic diseases. Nevertheless, 30% of these patients achieved partial responses. Although hyperthermia combined with radiation or chemotherapy did not show a clear benefit in terms of tumor response in these patients, combined treatment may palliate symptoms and improve quality of life. One patient in the metastatic group had recurrent endometrial cancer to the paraaortic nodes, which failed to respond to systemic chemotherapy. Radiation therapy alone was limited because of the large mass, with a necrotic area inside the tumor. She received radiation combined with hyperthermia, and was able to reduce her analgesic drugs after the second week of treatment, and quit all analgesic drugs after the end of the treatment. Ohguri et al also reported that radiation plus hyperthermia could relieve pain in about 83% of patients with unresectable and recurrent colorectal cancer[14].

The most common adverse effects experienced in the present study were grade 1 skin reactions, including dermatitis (6.7% of patients), subcutaneous fibrosis (10% of patients), fat necrosis (10% of patients), and skin pain (3.3% of patients), which were in accord with other studies. Westermann et al reported grade 1 skin pain in 7.6%, grade 1 burns in 18%, and grade 1 to 2 subcutaneous fatty necrosis in 7.6% of patients[15], while a study of deep regional hyperthermia at Duke University reported subcutane ous fat necrosis in about 10% of cases[16]. One patient in the current study developed grade 3 fat necrosis. She had received radiation therapy combined with hyperthermia in the pelvic region, and developed infected fat necrosis around the umbilicus after the second hyperthermic treatment. She required admission to hospital for intravenous antibiotic treatment and debridement, but recovered fully. Her subcutaneous fat thickness, reviewed by abdominal CT, was about 3.5 cm. Hiraoka et al previously reported that excessive heating of fat occurred in up to 76% of patients with subcutaneous fat thicker than 1.5 cm[17], and Lee et al noted that patients often experienced greater discomfort when the treatment site was covered by a layer of subcutaneous fat thicker than 2 cm[18]. Subcutaneous fat thickness should thus be taken into consideration when selecting patients for hyperthermia treatment.

Invasive thermometry has been established as a basic requirement for measuring intratumoral temperatures during deep regional hyperthermia. However, direct intratumoral measurements involve an invasive procedure that can cause adverse effects such as infection, intolerable pain, patient discomfort, and anxiety[10,19]. Alternatively, temperature can be monitored by non-invasive thermometry, using a catheter measure the temperature within adjacent cavities such as the vagina, rectum, or bladder. Fatehi et al found that intraluminal temperature was highly correlated with intratumoral temperature, with no difference between them in terms of average temperatures. Intraluminal thermometry may therefore be suitable for evaluating temperature during the treatment of intrapelvic tumors[20]. Ohguri et al assessed indirect tumor temperature measured by intraesophageal temperature, and examined the correlation between intraesophageal temperature and RF-output power. RF-output power was significantly correlated with intraesophageal temperature, while median RF-output power ≥1,200 W was predictedto prolong survival, and improve local control and the metastasis-free rate[21]. Accurate thermometry was a limiting factor in our study, and most temperature measurements were made using thermocouples placed on the skin, while a few cervical or endometrial cancer

Table 3. Treatment toxicities

Treatment toxicity	Grade 1 n (%)	Grade 2 n (%)	Grade 3 n (%)
Dermatitis	2 (6.7%)	-	-
Subcutaneous fibrosis	3 (10%)	-	-
Fat necrosis	3 (10%)	-	1 (3.3%)
Pain of skin	1 (3.3%)	-	-
Fatigue	1 (3.3%)	-	-
Nausea and vomiting	-	2 (6.7%)	-

patients had thermocouples inserted into the vagina. The recorded temperatures therefore did not represent the actual tumor temperatures. We therefore aimed to increase the RF-output power to the maximum tolerable level. Further studies are planned to develop a temperature measurement protocol to standardize treatments across different regions. This study also had limitations. Firstly, it was a retrospective study, and some data, including adverse effects, were not well documented and recorded. Secondly, the sample size for each disease was too small to detect the relationship among the variables.

Conclusion

The addition of hyperthermia to radiation or chemotherapy is feasible, with minimal adverse effects. Further studies with larger sample sizes are needed to confirm these preliminary findings.

What is already known on this topic?

Deep regional hyperthermia combined with radiation therapy or chemotherapy has been studied in several malignant diseases. The previous published data showed that hyperthermia provides improved response rate, local tumor control and survival rate for some malignant diseases. Therefore, hyperthermia has been accepted as a method for enhancing the radiation and chemotherapy effects. In palliative care, hyperthermia also improves disease symptoms as well as quality of life of cancer patients.

What this study adds?

This work represents our initial experiences with deep regional hyperthermia in Thai cancer patients. The clinical outcomes of our patients reported in terms of response rate and toxicities were comparable to previously published data. Although this study is a small study, it signifies a potential role of deep regional hyperthermia as an alternative modality for cancer treatment and care in Thailand.

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Potential conflicts of interest

None.

References

1. Kokura S, Yoshikawa T, Ohnishi T. Hyperthermic oncology from bench to bedside. Verlag: Springer Verlag; 2016.
2. van der Zee J. Heating the patient: a promising approach? Ann Oncol 2002;13:1173-84.
3. Wust P, Hildebrandt B, Sreenivasa G, Rau B, Gellermann J, Riess H, et al. Hyperthermia in combined treatment of cancer. Lancet Oncol 2002;3:487-97.
4. Bertone V, Barni S, Silvotti MG, Freitas I, Mathe G, Pontiggia P. Hyperthermic effects on the human metastatic liver: a TEM study. Anticancer Res 1997;17:4713-6.
5. Christophi C, Winkworth A, Muralihdaran V, Evans P. The treatment of malignancy by hyperthermia. SurgOncol 1998;7:83-90.
6. Overgaard J. The current and potential role of hyperthermia in radiotherapy. Int J RadiatOncolBiolPhys 1989;16:535-49.
7. Herman TS, Teicher BA, Jochelson M, Clark J, Svensson G, Coleman CN. Rationale for use of local hyperthermia with radiation therapy and selected anticancer drugs in locally advanced human malignancies. Int J Hyperthermia 1988;4:143-58.
8. Engelhardt R. Hyperthermia and drugs. Recent Results Cancer Res 1987;104:136-203.
9. Vernon CC, Hand JW, Field SB, Machin D, Whaley JB, van der Zee J, et al. Radiotherapy with or without hyperthermia in the treatment of superficial localized breast cancer: results from five randomized controlled trials. International Collaborative Hyperthermia Group. Int J Radiat Oncol Biol Phys 1996;35:731-44.
10. van der Zee J, Gonzalez Gonzalez D, van Rhoon GC, van Dijk JD, van Putten WL, Hart AA. Comparison of radiotherapy alone with radiotherapy plus hyperthermia in locally advanced pelvic tumours: a prospective, randomised, multicentre trial. Dutch Deep Hyperthermia Group. Lancet 2000;355:1119-25.
11. Maluta S, Schaffer M, Pioli F, Dall'oglio S, Pasetto S, Schaffer PM, et al. Regional hyperthermia combined with chemoradiotherapy in primary or recurrent locally advanced pancreatic cancer : an open-label comparative cohort trial. Strahlenther Onkol 2011;187:619-25.
12. Ijaz T, Eifel PJ, Burke T, Oswald MJ. Radiation therapy of pelvic recurrence after radical hysterectomy for cervical carcinoma. Gynecol Oncol 1998;70:241-6.

13. Thomas GM, Dembo AJ, Myhr T, Black B, Pringle JF, Rawlings G. Long-term results of concurrent radiation and chemotherapy for carcinoma of the cervix recurrent after surgery. Int J Gynecol Cancer 1993;3:193-8.
14. Ohguri T, Imada H, Kato F, Yahara K, Morioka T, Nakano K, et al. Radiotherapy with 8 MHz radiofrequency-capacitive regional hyperthermia for pain relief of unresectable and recurrent colorectal cancer. Int J Hyperthermia 2006;22:1-14.
15. Westermann AM, Jones EL, Schem BC, van der Steen-Banasik EM, Koper P, Mella O, et al. First results of triple-modality treatment combining radiotherapy, chemotherapy, and hyperthermia for the treatment of patients with stage IIB, III, and IVA cervical carcinoma. Cancer 2005;104:763-70.
16. Halperin EC, Brady LW, Perez CA, Wazer DE. Perez & Brady's principles and practice of radiation oncology. 6th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2013.
17. Hiraoka M, Jo S, Akuta K, Nishimura Y, Takahashi M, Abe M. Radiofrequency capacitive hyperthermia for deep-seated tumors. I. Studies on thermometry. Cancer 1987;60:121-7.
18. Lee CK, Song CW, Rhee JG, Foy JA, Levitt SH. Clinical experience using 8 MHz radiofrequency capacitive hyperthermia in combination with radiotherapy: results of a phase I/II study. Int J Radiat Oncol Biol Phys 1995;32:733-45.
19. van der Zee J, Peer-Valstar JN, Rietveld PJ, Graaf-Strukowska L, van Rhoon GC. Practical limitations of interstitial thermometry during deep hyperthermia. Int J Radiat Oncol Biol Phys 1998;40:1205-12.
20. Fatehi D, van der ZJ, Notenboom A, van Rhoon GC. Comparison of intratumor and intraluminal temperatures during locoregional deep hyperthermia of pelvic tumors. Strahlenther Onkol 2007;183:479-86.
21. Ohguri T, Imada H, Yahara K, Morioka T, Nakano K, Terashima H, et al. Radiotherapy with 8-MHz radiofrequency-capacitive regional hyperthermia for stage III non-small-cell lung cancer: the radiofrequency-output power correlates with the intraesophageal temperature and clinical outcomes. Int J Radiat Oncol Biol Phys 2009;73:128-35.