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Endoluminal high-dose-rate brachytherapy for locally recurrent or persistent esophageal cancer

Amandeep S. Taggar, MD MS^{1,6}, Kenneth L. Pitter, MD PhD¹, Gil'ad N. Cohen, MS², Mark Schattner, MD³, Hans Gerdes, MD³, Arnold J. Markowitz, MD³, David Ilson, MD⁴, Paul Brady, BS¹, John J. Cuaron, MD¹, Karyn A. Goodman, MD⁵, Abraham J. Wu, MD^{1,*}

¹Department of Radiation Oncology, Memorial Sloan Kettering Cancer Center, New York, NY

²Department of Medical Physics, Memorial Sloan Kettering Cancer Center, New York, NY

³Department of Gastroenterology and Nutrition, Memorial Sloan Kettering Cancer Center, New York, NY

⁴Department of Medical Oncology, Memorial Sloan Kettering Cancer Center, New York, NY

⁵Department of Radiation Oncology, University of Denver, Aurora, CO

⁶Department of Radiation Oncology, Sunnybrook Odette Cancer Centre, Toronto, ON, Canada

Abstract

Background: Management of locally recurrent or persistent esophageal cancer (EC) after standard chemoradiation is challenging. This study updates our experience of treating medically inoperable EC patients with endoluminal high-dose-rate brachytherapy (EHDRBT) including the patients treated with a novel multi-balloon channel centering esophageal applicator (MBCEA).

Methods: Thirty-three consecutive patients with early stage primary (n=7), post-treatment persistent (n=7) and recurrent (n=19) EC treated with EHDRBT at our institution were included. Median dose and treatment lengths were 14Gy (Range: 10–17.5Gy) and 6cm (3.5–9.0cm), respectively. Endoscopy and biopsy was performed three months after EHDRBT and then every 3–6 months thereafter.

Results: Median followup was 17.4 months (R: 5.0–88.3). Grade 1 and 2 toxicities were observed in 13 (44.8%) and 11 (37.9%) patients, respectively. Grade 3 toxicity (tracheoesophageal fistula) was observed in one patient who had previously received two courses of EBRT as well as a stent insertion. Median overall survival for entire cohort was 20.9 months and 1-year OS was 78%. Complete response was achieved in 58.6% of patients with median time to failure and 1-year disease free survival of 10.3 months (R: 5.4–28.2) and 27%, respectively.

*Corresponding author: Abraham Wu, 1275 York Avenue, New York, NY, 10065, 212-639-5257, wua@mskcc.org.

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Conflict of interest: none

Conclusions: For medically inoperable patients with early stage primary or local post-treatment residual or recurrent EC, EHDRBT is a well-tolerated treatment option with minimal grade 3 toxicity. Brachytherapy in our hands continues to be a safe treatment option. Although 58.6% of patients achieved a complete response and the overall survival of this cohort is relatively good, long-term local control and cure remains a challenge.

Keywords

early stage; recurrent; esophageal cancer; brachytherapy; high dose rate

Introduction

Patients with recurrent or persistent esophageal cancer (EC) after standard chemoradiation have limited treatment options, especially those who are medically inoperable. Endoluminal high dose rate brachytherapy (EHDRBT) can play a significant role in management of EC due to its ability to deliver high doses of radiation to the tumor with relative sparing of surrounding normal tissues [1–8]. In the setting of prior radiation therapy, this localized delivery of dose is especially important as further external beam radiation may potentially expose nearby normal tissues such as lung, heart and spinal cord to significant additional dose.

The rapid dose falloff typical of brachytherapy, however, has disadvantages as well, as the dose delivered to the mucosal surface can be much higher (often two- to threefold higher) than that delivered to the prescription depth [8]. Furthermore, when using narrow catheters, the uncertainty of channel position within the lumen of the esophagus may result in a much higher dose to the portion of esophagus nearest the radiation source, potentially resulting in higher risk of severe toxicity such as fistula. We have now introduced a novel multi-balloon channel centering esophageal applicator (MBCEA) (Bionix Medical, Toledo, OH), into our clinical practice (Figure 1A). This applicator has five independently controlled balloons and each balloon can be inflated up to 2 cm diameter, a larger diameter than can be achieved with older techniques. The applicator has 5 mm shaft diameter with central source lumen, which can also be used for placement over a guide wire. Due to the inverse-square relationship of radiation dose vs. distance from source, the larger effective diameter of the MBCEA provides a better ratio of prescription dose vs. mucosal dose compared to smaller-diameter applicators, such as bougie catheters.

We previously reported on the use of EHDRBT on 14 patients with good clinical outcome (freedom from local failure and overall survival at 18 months 46% and 73%, respectively) and limited acute toxicity using a bougie applicator [9]. In this series, our aim is to evaluate and update our institutional experience with endoluminal HDRBT, including the patients treated with the novel MBCEA.

Methods

Patient selection

An endoluminal HDR brachytherapy (EHDRBT) procedure was developed at our institution to treat patients with 1) recurrent or residual esophageal cancer (EC) after chemoradiation or endoscopic mucosal resection; and 2) early stage primary tumors who are not good surgical candidates. Between August 2008 and October 2015, 28 patients with esophageal cancer were treated using a bougie catheter. After November 2015, 5 patients were treated with a novel MBCEA, figure 1.

Brachytherapy procedure

Brachytherapy procedure and workflow with bougie applicator has been previously described [9]. Briefly, after induction and intubation of the patient, upper gastrointestinal endoscopy was performed to visualize the esophageal tumor. The superior and inferior extent of the tumor was identified and radio-opaque markers were placed on the overlying skin of the chest wall using fluoroscopy, unless the lesion was previously implanted with an internal radiopaque fiducial marker at the time of prior staging endoscopic ultrasound procedure. A guidewire was then placed into the esophagus, after which the endoscope is removed. A bougie catheter (generally 14-mm diameter; Varian Medical Systems, Inc., Palo Alto, CA) was passed over the guidewire, and the guidewire was removed. Dummy wires were placed in the central catheter and position verified with plain radiograph.

The procedure with MBCEA has similar workflow, but with some modifications. After, placement of guidewire into the esophagus as described above, brachytherapy applicator is gently inserted over the guidewire, such that the target (tumor plus 1–1.5 cm cranio-caudal margin) is situated within the length of the treatment area of the applicator. The balloons are then individually inflated with 4cc of 10% Omnipaque solution, to achieve a 2-cm diameter of each balloon. The position of the applicator is confirmed with a plain radiograph and adjustments made as necessary by deflating/re-inflating balloons until a satisfactory position is achieved. Subsequently, the patient is transferred to obtain a 3D image data set with CT simulation and treatment planning.

Treatment planning and delivery

With bougie catheter, treatment was planned and delivered with plain radiographs. Dose was prescribed to median depth of 7 mm (range, 4–10 mm) from the surface, with prescription depth determined on the basis of clinical assessment of tumor thickness. A treatment plan was generated to provide the specified dose, generally limiting the mucosal surface dose to 8–10 Gy. The treatment planning system used was ABACUS v3.1 (Varian, previously Isotopen-Technik Dr Sauerwein, Haan, Germany), and the plan is independently checked.

With the MBCEA applicator, the contours of the target (tumor plus margin), non-target esophagus, heart, gastroesophageal junction (GEJ) are drawn on the CT scan dataset and a plan is generated using Brachyvision software (Varian Brachytherapy, Charlottesville, VA) with following planning criteria: target V100 (volume receiving 100% of dose) > 90%, D0.3cc (maximum dose to 0.3cc of volume) 12 Gy/fraction. The target volume included 1–

1.5cm of additional margin beyond the cranial and caudal extent of the endoscopically visualized tumor. In some cases, for deeply situated target volumes, due to the limitation of a high surface dose using the bougie applicator, prescribed dose at depth was reduced in order to preserve the mucosal dose limit. Target prescription dose was 15 Gy. The patient is then connected to a GammaMed Plus remote afterloader (Varian), the room is cleared, and treatment is delivered.

Treatments were delivered in three fractions over 3 weeks, seven days apart. When feasible, patients (n=24) were instructed to take capecitabine for radiosensitization during the three weeks of EHDRBT treatment (weekdays only).

Assessment and followup

Patients were followed with a physical examination, CT scan, and upper gastrointestinal endoscopies every 3–6 months. A biopsy of the treated esophageal segment was typically performed at the first 3 month followup, and again at the time of subsequent additional followup endoscopies. Grading of toxicity was based on the Common Terminology Criteria for Adverse Events v4.0. If a patient had multiple instances of a given toxicity, only the highest grade of that toxicity was counted.

Statistical analysis

All outcomes are measured from the date of first fraction of EHDRBT to the time of the event. Overall survival (OS) is defined as the time of death from any cause. Local failure (LF) is the recurrence of disease at the site originally treated with EHDRBT; regional failure (RF) is the recurrence of disease within thorax, along the esophagus lumen or regional lymphatics outside the treated area; and distant failure (DF) is recurrence anywhere else within the body. Patients were censored at the date of the last followup or death for OS or the date of first recurrence for disease free survival (DFS). Outcomes were estimated using the Kaplan Meier method. Cox proportional hazards regression models were used for univariate and multivariate analyses and curves compared using log-rank analysis. Statistical analysis was performed using SPSS, v.24.0.0 (SPSS Inc., Chicago, IL) and figures were generated using Prism v7.0 (Graphpad Software Inc., La Jolla, CA)

Results

Patient demographics and characteristics

Between 8/2008 and 8/2016, 23 (69.6%) male and 10 (31.4%) female patients underwent EHDRBT. Table 1 outlines the patient, disease and treatment characteristics. Median (range) age and Karnofsky performance status (KPS) of the entire cohort was 74 (65 – 86) years and 80 (40 – 90), respectively. Most of the patients (58%) were treated for locally recurrent tumor, while 7 (21%) patients received EHDRBT for persistent tumor after EBRT or endoscopic mucosal resection, and 7 (21%) were treated with EHDRBT monotherapy for early stage primary tumors. Twenty-five (76%) patients had adenocarcinoma histology, 7 (21%) had squamous cell carcinoma and 1 (3 %) had a neuroendocrine tumor. For 25 out of 33 (75.8%) patients the tumors were located in the lower esophagus/GEJ area, and two-thirds of the tumors were stage T2 at the time of initial presentation.

Treatment parameters

EHDRBT dosimetric parameters are outlined in Table 2. From 2008 to 2015, all 28 (85%) patients were treated with a bougie applicator, whereas after 2015, all 5 (15%) patients were treated with the novel MBCEA. Median treated esophageal length was 6 cm (range, 3.5 – 9 cm). Median total dose was 14 Gy (10 – 17.5 Gy) delivered in 3 fractions. Median diameter of the bougie applicator was 14 mm (10 – 14 mm), with dose prescribed to 7 mm (4 – 10 mm) from the surface. This resulted in a large range of maximal mucosal point doses of 7.9 to 21.2 Gy per fraction, and a median of 10.1 Gy. Patients treated with the MBCEA were all planned with CT simulation and dose was prescribed to a three-dimensional (3D) target volume. For these patients, the target was well covered, as suggested by median V100 (volume receiving 100% of prescribed dose) and D90 (dose to the 90% of the volume) of 91% (70 – 95%) and 5.2 Gy/fraction (4.2 – 5.2 Gy/fraction), respectively. D0.3cc (minimum dose to the hottest 0.3cc volume), used as a surrogate for the maximum mucosal dose to the esophagus within the target, was 11.5 Gy/fraction (10.6 – 12.2 Gy/fraction). D0.3cc to the esophagus or GE junction outside the target volume were low: 5.6 Gy/fraction (3.0 – 7.2 Gy/fraction) and 5.2 Gy/fraction (4.9 – 8.8 Gy/fraction).

Survival

Twenty-nine out of 33 patients were available for final analysis. Two patients were lost to follow up, 1 died during treatment due to unrelated causes and 1 aborted treatment due to interval progression of disease after the 1st fraction. From the time of first fraction of EHDRBT, with a median followup of 17.7 months (range, 5.0 – 88.3 months), median overall survival of 20.9 months was observed for the entire cohort of patients, figure 2, with 1 and 2-year OS of 78% and 46%, respectively. No significant difference was found in OS among patients who had primary versus recurrent or residual tumors, patients who received concurrent chemotherapy versus those who did not, or patients with squamous cell carcinoma versus adenocarcinoma histology. A significant difference was observed for initial tumor stage; patients with initial T3 tumors having OS of 11.3 months, while median OS was not reached for patients with T2 tumors (HR=7.9, 95% CI 2.6 – 24.5). Corresponding 1 and 2-year OS for T2 tumors were 85.6% and 68.4%, respectively and for T3 tumors were 48.0% and 10.0%, respectively.

Twelve out of 29 (41.4%) patients were found to have persistent disease on their first post-EHDRBT followup endoscopic evaluation. Pathological complete response (CR) based on negative endoscopic biopsy was observed in 17 (58.6%) patients. Patterns of failure in those who achieved initial CR are as follows: 5 patients developed local failure, 2 developed both local and regional failure, 2 developed local and distant failure and 2 patients developed distant only failure. For patients who achieved CR, median time to failure was 10.3 months (range, 5.4 – 28.2 months) with 1-year DFS of 27.3%. The subsequent management after a patient developed local, regional or distant metastatic disease is outlined in table 3. Six of 15 (40%) patients remained alive and disease-free until last follow up.

Toxicity

Grade 1 toxicity was observed in 13 patients, and 11 experienced grade 2 toxicity. Most commonly observed toxicities were dysphagia (12 patients, 44.8%), esophagitis (10 patients,

34.5%) and asymptomatic stenosis (7 patients, 24.1%) noted on repeat endoscopy. The rate of toxicity is similar to that reported by Folkert et al. [9]. In our contemporary cohort, we did not observe any strictures on repeat endoscopy. Grade 3 toxicity was observed in a single patient with cervical esophageal cancer who was treated with a bougie applicator; this patient had previously received two courses of EBRT to overlapping areas of esophagus and required a stent placement for symptomatic stenosis and subsequently developed a tracheoesophageal fistula after EHDBRT.

Discussion

Esophageal cancer most commonly presents in advanced stage and continues to pose a major challenge to the treating physician; overall prognosis remains poor [10]. Brachytherapy can play a significant role in management of esophageal cancer due to its ability to deliver high doses of radiation to the tumor with relative sparing of surrounding normal tissues. In our current cohort, 1-year median OS was 78%, which is not significantly different than the 83% previously reported by our group [9]. Furthermore, our study demonstrates a relatively long median survival in medically inoperable patients with early stage primary or local post-treatment residual or recurrent esophageal cancer, adding to the literature that supports the use of brachytherapy in these settings. Median survival of 20.8 months observed in our cohort is relatively longer and compares favorably to 8 to 12.7 months previously reported by others [6, 11, 12].

In the series by Aggarwal et al., 80% of patients had treatment length >10cm and 66% of patients were frail with multiple medical comorbidities [6]. In the series reported by Ghosh et al., patients with KPS ≤ 50 were also treated with brachytherapy [11]. Therefore, the inferior survival in these series could be related to more advanced disease and poor baseline status. In our series, patients had relatively shorter treatment length (median= 6cm), and had a median KPS of 80. This suggests the importance of appropriate patient selection. Furthermore, brachytherapy dose in these series was typically lower, with median dose of 10 Gy delivered in 3 fractions, whereas in our series the median dose was 14 Gy. A recent meta-analysis found that higher prescription doses (18 or 21 Gy) are associated with superior dysphagia free survival compared to lower dose (12 Gy) without any difference in toxicity [13]. Therefore, a higher median dose in our cohort, may also be one of the reasons for longer survival. Further dose escalation studies assessing the impact of dose on disease-free survival and overall survival are warranted to test this hypothesis.

Despite the potential benefits discussed above and multiple guidelines recommending brachytherapy for the treatment of esophageal cancer, its utilization remains low [14, 15, 22]. Patterns of care studies have shown variability in use of brachytherapy even among centers routinely performing other brachytherapy procedures [16–18]. The perceived high rates of complications may be one of the reasons for this trend. It is well documented, both in brachytherapy [2, 19, 20] and SBRT [21] series, that serious esophageal toxicity is related to the maximum esophageal dose, especially when dose is higher than 15 Gy. The high rates of severe toxicities (particularly fistula) observed in earlier series thwarted the interest in use of brachytherapy in EC setting. However, a meta-analysis by Fuccio et al. demonstrated no difference in toxicity based on dose especially when a larger diameter bougie is utilized for

brachytherapy treatment delivery [13]. In our series, we also observed very low rate of grade 3 toxicity; the only recorded fistula in the entire cohort was previously reported by Folkert et al. [9] and in our contemporary cohort of patients no new grade 3 or higher toxicity was observed. The patient who developed fistula was likely at very high baseline risk due to two prior courses of EBRT to the region and placement of an esophageal stent. The low incidence of severe toxicity in our series is likely due to the use of larger diameter bougie applicators, which promote the centering and separation of the source from the esophageal mucosa. In addition, our recent implementation of a novel multi-balloon centering applicator, which provides an even greater diameter for treatment, further decreases the mucosal hotspots and potentially decreases toxicity. The ability of the MBCEA may allow for prescription doses to be increased, the prescription depth to be deeper, and/or the mucosal dose to be lowered, making this applicator a promising platform for future dose escalation studies.

Limitations of this study include small sample size and heterogeneous patient population with diverse initial stages, which could confound interpretation of our results. Nevertheless, our results corroborate and extend our previous findings that this EHDRBT regimen is very safe, with a minimal risk of fistula, and with a reasonable probability of initial complete response, local control, and relatively favorable survival. This report also contains the first clinical series of patients treated with a novel MBCEA, which we are now using routinely in our clinical practice. Given its practical and dosimetric advantages, we suggest that this MBCEA provides a valuable platform for extending the clinical utilization of esophageal brachytherapy and for pursuing future dose-escalation trials, particularly since this is a group of patients who are not otherwise typically eligible for other local treatment modalities.

In conclusion, for medically inoperable patients with early stage primary or local post treatment residual or recurrent esophageal cancer, EHDRBT is a well-tolerated treatment option with minimal grade 3 toxicity. Brachytherapy using our technique continues to be a safe treatment option, which is likely due to use of applicators that effectively center the source within esophageal lumen. Many patients achieve a complete response and the overall survival of this cohort is relatively good, but long-term local control and cure remains a challenge. Because of the low incidence of complications with this technique so far, we plan to increase the prescription dose in hopes of achieving higher rates of complete response and more durable local control.

List of abbreviations:

EHDRBT	endoluminal high dose rate brachytherapy
EC	esophageal cancer
Gy	gray
CR	complete response
OS	overall survival
LF	local failure

RF	regional failure
DF	distant failure
DFS	disease free survival
KPS	Karnofsky performance status
MBCEA	multi-balloon channel centering esophageal applicator
HDR	high dose rate
GEJ	gastroesophageal junction
EBRT	external beam radiotherapy

References:

1. Brewster AE, Davidson SE, Makin WP, et al. Intraluminal brachytherapy using the high dose rate microSelectron in the palliation of carcinoma of the oesophagus. *Clin. Oncol. (R. Coll. Radiol)* 1995;7(2):102–105. [PubMed: 7542470]
2. Gaspar LE, Winter K, Kocha WI, et al. A phase I/II study of external beam radiation, brachytherapy, and concurrent chemotherapy for patients with localized carcinoma of the esophagus (Radiation Therapy Oncology Group Study 9207): final report. *Cancer*. 2000;88(5):988–995. [PubMed: 10699886]
3. Bergquist H, Johnsson E, Nyman J, et al. Combined stent insertion and single high-dose brachytherapy in patients with advanced esophageal cancer--results of a prospective safety study. *Dis. esophagus Off. J. Int. Soc. Dis. Esophagus* 2012;25(5):410–415.
4. Homs MY V, Steyerberg EW, Eijkenboom WMH. Single-dose brachytherapy versus metal stent placement for the palliation of dysphagia from oesophageal cancer: multicentre randomised trial. *Lancet*. 2004; 24(2): 126–133
5. Sur RK, Levin C V, Donde B, et al. Prospective randomized trial of HDR brachytherapy as a sole modality in palliation of advanced esophageal carcinoma--an International Atomic Energy Agency study. *Int. J. Radiat. Oncol. Biol. Phys* 2002;53(1):127–133. [PubMed: 12007950]
6. Aggarwal A, Harrison M, Glynne-Jones R, et al. Combination external beam radiotherapy and intraluminal brachytherapy for non-radical treatment of oesophageal carcinoma in patients not suitable for surgery or chemoradiation. *Clin. Oncol. (R. Coll. Radiol)* 2015;27(1):56–64. [PubMed: 25306490]
7. Nag S, Dally M, de la Torre M, et al. Recommendations for implementation of high dose rate ¹⁹²Ir brachytherapy in developing countries by the Advisory Group of International Atomic Energy Agency. *Radiother. Oncol* 2002;64(3):297–308. [PubMed: 12242118]
8. Lettmaier S, Strnad V. Intraluminal brachytherapy in oesophageal cancer: defining its role and introducing the technique. *J. Contemp. Brachytherapy* 2014;6(2):236–241. [PubMed: 25097567]
9. Folkert MR, Cohen GN, Wu AJ, et al. Endoluminal high-dose-rate brachytherapy for early stage and recurrent esophageal cancer in medically inoperable patients. *Brachytherapy*. 2013;12(5):463–470. [PubMed: 23434221]
10. Zhang Y Epidemiology of esophageal cancer. *World J. Gastroenterol* 2013;19(34):5598–5606. [PubMed: 24039351]
11. Ghosh S, Sau S, Mitra S, et al. Palliation of dysphagia in advanced, metastatic or recurrent carcinoma oesophagus with high dose rate intraluminal brachytherapy--an eastern Indian experience of 35 cases. *J. Indian Med. Assoc* 2012;110(7):449–452. [PubMed: 23520668]
12. Sharan K, Fernandes DJ, Prakash Saxena PU, et al. Treatment outcomes after intraluminal brachytherapy following definitive chemoradiotherapy in patients with esophageal cancer. *J. Cancer Res. Ther* 2014;10(2):337–341. [PubMed: 25022388]

13. Fuccio L, Mandolesi D, Farioli A, et al. Brachytherapy for the palliation of dysphagia owing to esophageal cancer: A systematic review and meta-analysis of prospective studies. *Radiother. Oncol* 2017;122(3):332–339. [PubMed: 28104297]
14. Spaander MC, Baron TH, Siersema PD, et al. Esophageal stenting for benign and malignant disease: European Society of Gastrointestinal Endoscopy (ESGE) Clinical Guideline. *Endoscopy*. 2016;48(10):939–948. [PubMed: 27626318]
15. Stahl M, Mariette C, Haustermans K, et al. Oesophageal cancer: ESMO Clinical Practice Guidelines for diagnosis, treatment and follow-up. Suppl 6. *Ann. Oncol. Off. J. Eur. Soc. Med. Oncol* 2013;24 Suppl 6:6.
16. Fuccio L, Guido A, Hassan C, et al. Underuse of brachytherapy for the treatment of dysphagia owing to esophageal cancer. An Italian survey. *Dig. Liver Dis.* 2016;48(10):1233–1236. [PubMed: 27476465]
17. Murakami Y, Kenjo M, Uno T, et al. Results of the 1999 2001 Japanese patterns of care study for patients receiving definitive radiation therapy without surgery for esophageal cancer. *Jpn. J. Clin. Oncol* 2007;37(7):493–500. [PubMed: 17646277]
18. Opstelten JL, de Wijkerslooth LR, Leenders M, et al. Variation in palliative care of esophageal cancer in clinical practice: factors associated with treatment decisions. *Dis. esophagus Off. J. Int. Soc. Dis. Esophagus* 2017;30(2):1–7.
19. Hishikawa Y, Kurisu K, Taniguchi M, et al. High-dose-rate intraluminal brachytherapy for esophageal cancer: 10 years experience in Hyogo College of Medicine. *Radiother. Oncol* 1991;21(2):107–114. [PubMed: 1714082]
20. Sharma V, Mahantshetty U, Dinshaw KA, et al. Palliation of advanced/recurrent esophageal carcinoma with high-dose-rate brachytherapy. *Int. J. Radiat. Oncol. Biol. Phys* 2002;52(2):310–315. [PubMed: 11872275]
21. Cox BW, Jackson A, Hunt M, et al. Esophageal toxicity from high-dose, single-fraction paraspinal stereotactic radiosurgery. *Int. J. Radiat. Oncol. Biol. Phys* 2012;83(5):e661–7. [PubMed: 22572079]
22. Gaspar LE, Nag S, Herskovic A, et al. American Brachytherapy Society (ABS) Consensus Guidelines for Brachytherapy of Esophageal Cancer. *Int J. Radiat. Oncol. Biol. Phys* 1998;38(1): 127–32

Figure 1. Multi-balloon centering esophageal applicator (MBCEA) (a), coronal and sagittal images (b) and current workflow of esophageal brachytherapy at our institution (c)

Figure 2.
Overall survival. Solid blue line indicates the survival and dashed lines above and below are 95% confidence interval.

Table 1.

Patient, disease and treatment characteristics

Characteristics	N (%)
Total number of patients	33
Median Age, years (range)	73.9 (64.6 – 85.8)
Gender	
Male	23 (69.6)
Female	10 (31.4)
Median KPS (range)	80 (40 – 90)
Disease status	
Primary	7 (21)
Residual	7 (21)
Recurrent	19 (58)
Histology	
Adenocarcinoma	25 (76)
Squamous cell carcinoma	7 (21)
Neuroendocrine	1 (3)
T Stage	
T1	7 (21)
T2	9 (27)
T3	14 (42)
T4	1 (3)
Unknown	2 (6)
Location of the lesion	
Upper	4 (12)
Mid	4 (12)
Distal/GEJ	25 (76)
Previous RT	
Yes	24 (73)
No	9 (27)
Median dose of prior RT, Gy (range)	50.4 (41.4 – 56)
Median followup post HDR brachy, months (range)	17.4 (5.0 – 88.3)
Status at last followup	
NED	6 (21)
Persistent disease	12 (36)
LF only	6 (18)
LF+RF	2 (6)
LF+DF	1 (3)
DF only	4 (12)
DOD	9 (27)
DOC	6 (18)

KPS – karnofsky performance scale, RT – radiotherapy, NED – no evidence of disease, LF – local failure, RF – regional failure, DF – distant failure, DOD – died of disease, DOC – died of other causes.

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Table 2.**HDR brachytherapy parameters**

Treatment parameters [Median (range) unless indicated]	
Treatment length, cm	6 (3.5 – 9)
HDR dose, Gy	14 (10 – 17.5)
Concurrent chemotherapy	
Yes	24 (73%)
No	9 (27%)
Bougie Applicator (n=28)	
Bougie diameter, mm	14 (10 – 14)
Prescription depth, mm	7 (4 – 10)
Mucosal dose, Gy/fraction	10.1 (7.9 – 21.2)
MBCEA (n=5)	
D0.3cc _{target} Gy/fraction	11.5 (10.6 – 12.2)
V100 _{target} %	91 (70 – 95)
D90 _{target} Gy/fraction	5.15 (4.2 – 5.41)
D0.3cc _{normal esophagus} Gy/fraction	5.6 (3 – 7.2)
V100 _{normal esophagus} cc	0.5 (0 – 1.2)
D0.3cc _{GEJ} Gy/fraction	5.2 (4.9 – 8.8)
V100 _{gej} cc	0.4 (0.3 – 6.7)

HDR – high dose rate, MBCEA – multi-balloon centering esophageal applicator, D0.3cc – dose to 0.3cc (Gy/fraction), V100 – volume receiving 100% of dose, D90 – dose to 90% of target

Table 3.

Outcome of patients who failed treatment

Patient No.	Failure	Subsequent treatment	Outcome
1	LF	Endoscopic Excision	Alive without evidence of disease
2	LF	Supportive care	Alive with disease
3	LF	Ablation	Alive without evidence of disease
4	LF	Supportive Care	Alive with disease
5	LF	EMR + chemotherapy	Alive without evidence of disease
7	LF+RF	Supportive Care	Died of disease
8	LF+RF	Weekly Taxol	Died of disease
9	LF+DF	Esophagectomy, RFA, VATS, Endobronchial BT and chemotherapy	Alive without evidence of disease
10	LF+DF	FOLFOX	Died of unknown cause
10	DF	Supportive Care	Alive with disease
11	DF	FOLFOX	Died of disease

LF – local failure, RF – regional failure, DF – distant failure, EMR – endoscopic mucosal resection, RFA – radiofrequency ablation, VATS – video assisted thoracic surgery.