

1. EXPERIMENTAL DOSIMETRY AND ANALYSIS IN PHANTOM:

The phantom dosimetry experiment was performed three times with same setup and same EBT3 film lot. The dose values were measured with the film for each organ at risk in the same location in the phantom at same position. The radiation dose calculated from the brachytherapy TPS and measured with the EBT3 films in the tissue equivalent phantom were tabulated in Table 4 with standard deviation (SD)

S.N.	OARs in Phantom	Phantom Measured Dose (cGy) (Mean± SD)	TPS Calculated Dose (cGy)
1	A. Aorta & P. Trunk side	80.38±6.31	93
2	C. Artery side	55.65±4.18	64
3	C. Lung Side	71.21±8.40	88
4	D. Aorta side	207.98±11.99	184
5	Esophagus Side	503.6±19.80	464
6	Heart Side	288.11±16.55	255
7	Ipsilateral Lung 1cm	139.98±12.01	164
8	Ipsilateral Lung Side	484.03±6.99	498
9	Spinal Cord Side	240.85±7.43	226
10	Sternum Side	18.32±1.84	22
11	Target Top side	499.08±8.04	483
12	Tip side 1cm	247.56±22.78	202
13	Tip side	600.02±36.01	528

Table 4: Showing the Doses Measured in Phantom and Calculated in TPS for OARs

The mean dose with standard deviation for A.Aorta & P.Trunk side, C.Artery side, C.Lung Side, D.Aorta side, Esophagus Side, Heart Side, Ipsilateral Lung 1cm, Ipsilateral Lung Side, Spinal Cord Side, Sternum Side, Target Top side, Tip side 1cm and Tip side OARs were measured and percentage variation between the phantom and TPS doses were presented graphically in Figure 21 .

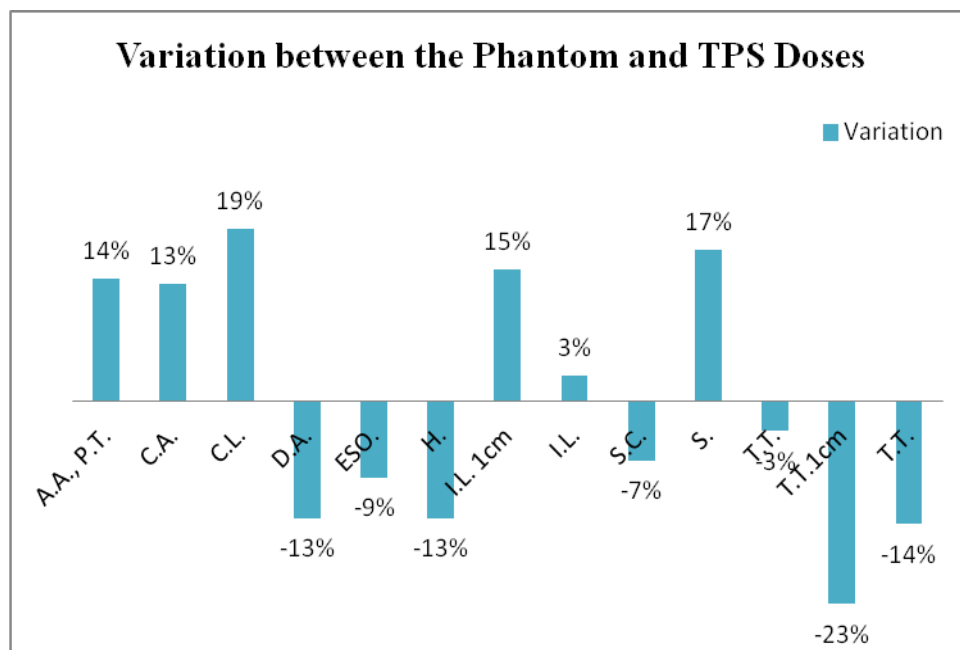


Figure 21: Showing the percentage variation in between the doses measured in phantom and calculated in TPS for OARs

The phantom is fabricated for thoracic cavity site where the organs at risk having oval or spherical shape. The phantom was made in cubic slab shape to make setup easier for placing samples of the film. For clarity, a comparison between the phantom and the corresponding anatomical region (thoracic cavity) is pictorially presented in Figure 7.

The percentage variation between the doses calculated and measured in the tissue equivalent phantom at different OARs was <10% which infers, TPS underestimate the dose to Esophagus, spinal cord, target top and overestimate the dose for Ipsilateral lung where the distance between source and film at surface of esophagus, spinal cord, target top and Ipsilateral lung was 1.5cm, 3.0cm, 1.5cm and 1.5cm respectively.

The distance from source to the film position at surface of Ascending aorta & pulmonary trunk, coronary artery, descending aorta, heart, Ipsilateral Lung (2cm depth) & target tip OARs were 5.5cm, 4.5cm, 3.0cm, 2.5cm, 3.5cm & 0.5cm respectively. The percentage variation was <15% where TPS overestimate the dose for AAPT, CA, IL (2cm) and underestimate for DA, H & TT.

The distance from source to the film position at surface of contra-lateral lung, sternum and target Tip (1cm) were 4.5cm, 8.5cm & 1.5cm respectively. The percentage variation was <20% where TPS overestimate the doses to CL & Sternum and underestimate to TT 1cm film position.

It implies that at the lower distances between source and point of measurement the dose variation was less and as the distance increases the percentage variation increases. At some positions the air inhomogeneity affects the doses either at lower or far distances from the source.

The doses measured in phantom were obtained from three points corresponding to dose point in TPS for each organ at risk. Further dosimetry was done to find out the doses at five positions on same film dosimeters for organs at risk i.e. Ipsilateral Lung, Heart, Spinal cord, esophagus, coronary artery, descending aorta, Ipsilateral lung 2cm, Contra-lateral Lung and target tip 1cm. The measured dose values for OARs at

five positions were represented in table 5. The film measured and TPS calculated dose value's variation at five positions was tabulated for each OARs in table 6. The variation between the two dose values was found out with respect to the distance from the source.

Dose Points	Heart Dose (cGy)	I.Lung Dose (cGy)	C.Artery Dose (cGy)	S.Cord Dose (cGy)	Esophagus Dose (cGy)	D.Aorta Dose (cGy)	C.Lung Dose (cGy)	I.Lung 2cm Dose (cGy)	T.Tip 1cm Dose (cGy)
A	266.58	481.58	67.18	231.61	523.22	244.59	78.85	134.02	285.83
B	300.96	456.62	62.96	284.31	620.23	225.22	72.56	110.07	263.79
C	248.46	452.61	60.85	260.78	543.32	222.49	77.12	117.49	262.07
D	277.95	474.25	63.33	236.05	453.54	237.45	66.27	115.67	279.08
E	251.40	400.97	68.11	224.14	456.66	197.53	55.89	136.88	264.26

Table 5: Showing the film measured Dose values for OARs at five points on a plane

The dose value was measured at a center point of the irradiated area and at 4 points around that center point in the film in phantom. The same steps were carried out for each organ in the phantom and obtained the doses. This shows the variation in the doses among five points in a film which implies that the distance from the source to the point of measurement in same plane effect the doses.

Dose Points	Heart (%)	I. Lung (%)	C. Artery (%)	S. Cord (%)	Esophagus (%)	D. Aorta (%)	C. Lung (%)	I. Lung 2cm (%)	T. Tip 1cm (%)
A	-4.95	-1.81	29.28	-8.23	-15.25	-36.64	17.00	22.53	-113.31
B	-20.87	0.30	33.03	-35.39	-43.24	-27.96	22.81	34.09	-88.42
C	-0.18	2.46	34.56	-26.59	-21.28	-30.11	16.17	30.07	-95.58
D	-24.08	-39.90	30.40	-22.94	-41.29	-51.24	24.69	24.40	-111.42
E	-10.75	5.65	25.16	-15.53	-13.03	-14.18	39.90	18.04	-104.86

Table 6: Showing the Percentage variation in doses measured at five points between phantom and TPS

The film measured doses in the phantom were compared with the doses calculated in TPS for respective OARs position. It showed that there was a variation between the TPS calculated and film measured doses in the phantom, due to the effect of distance and dose calculation algorithm in the TPS. In each film out of five points the center point and point closure to the source was having less variation between TPS calculated and film measured doses.

2. DOSIMETRIC AND VOLUMETRIC ANALYSIS IN EBBT

TREATMENT:

The mean doses of OARs were evaluated after three EBBT sessions to thirty patients. The mean dose to OARs is represented in figure 22. The average of Maximum doses to Esophagus, Heart, Contralateral Lung, Left Coronary Artery, Spinal Cord, Trachea and Descending Aorta were 14.48, 11.22, 3.21, 2.22, 2.14, 9.77 and 9.4Gy and average of the mean dose to Esophagus and Heart were 3.18 Gy and 1.42 Gy in three EBBT sessions respectively. The total mean dose to the OARs denotes, in the endobronchial brachytherapy treatment the organs closer to the target volume receives the higher doses and distant organs received lower doses analyzed in the treatment planning system, while OARs doses in the tolerance limit.

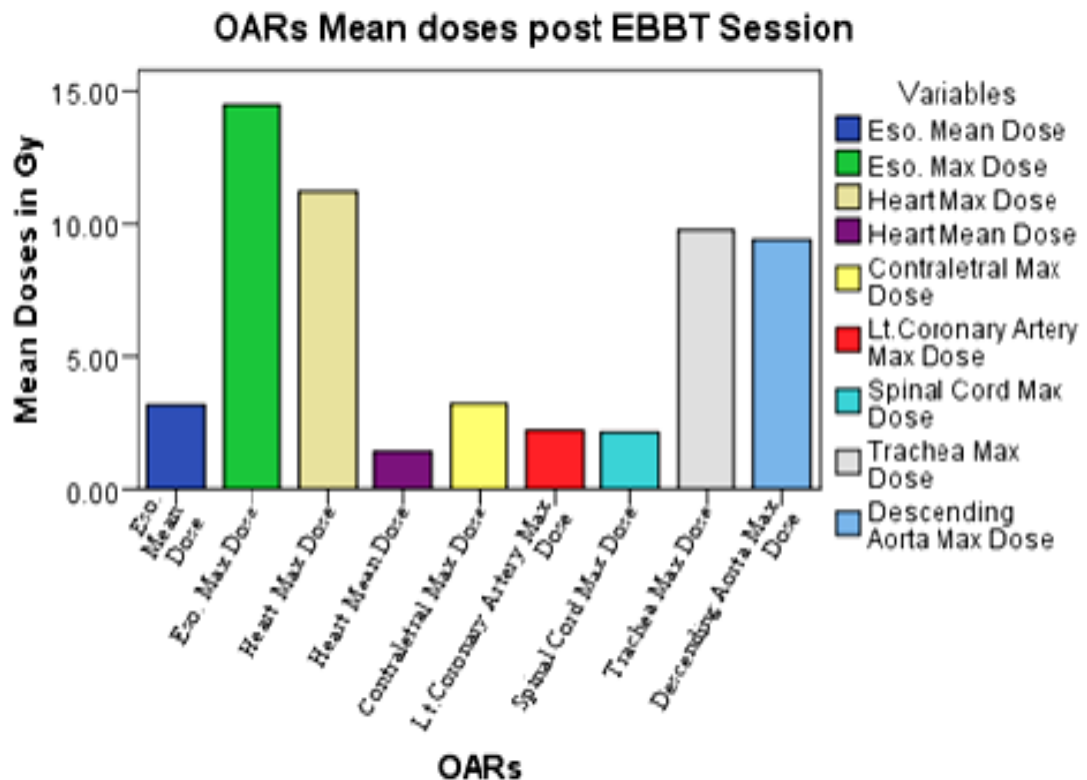
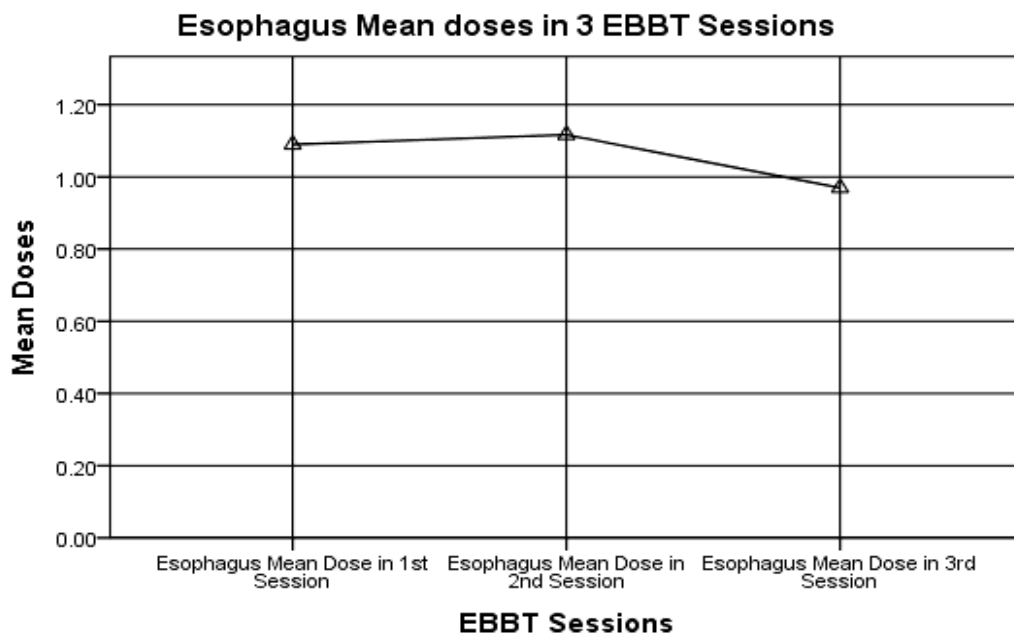


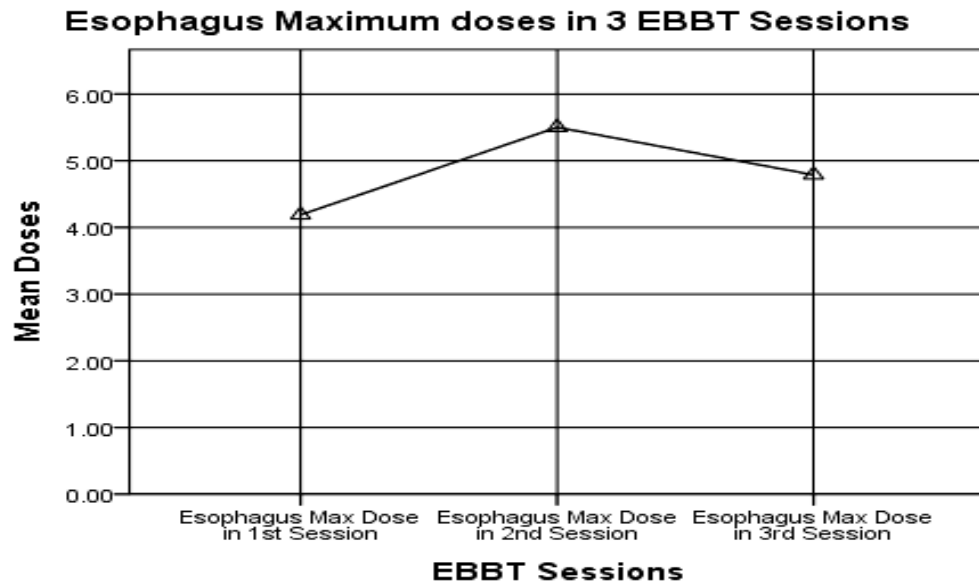
Figure 22: A Chart showing total mean doses to OARs in three sessions of EBBT

2.1 ESOPHAGUS MEAN AND MAXIMUM DOSES:

The esophagus mean and maximum doses were analyzed in thirty patients treated with three EBBT Sessions. The mean dose was decreased and maximum dose was increased in 3rd session as compared to 1st session of EBBT. The esophagus maximum dose increases in 3rd session of EBBT due to the gap or distance reduced between the esophagus and source as the target volume decreases in 3rd session from 1st session of EBBT. Graph 1 and Graph 2 is showing the esophagus mean and maximum dose respectively.



Graph 1: Showing Esophagus mean doses in three EBBT sessions

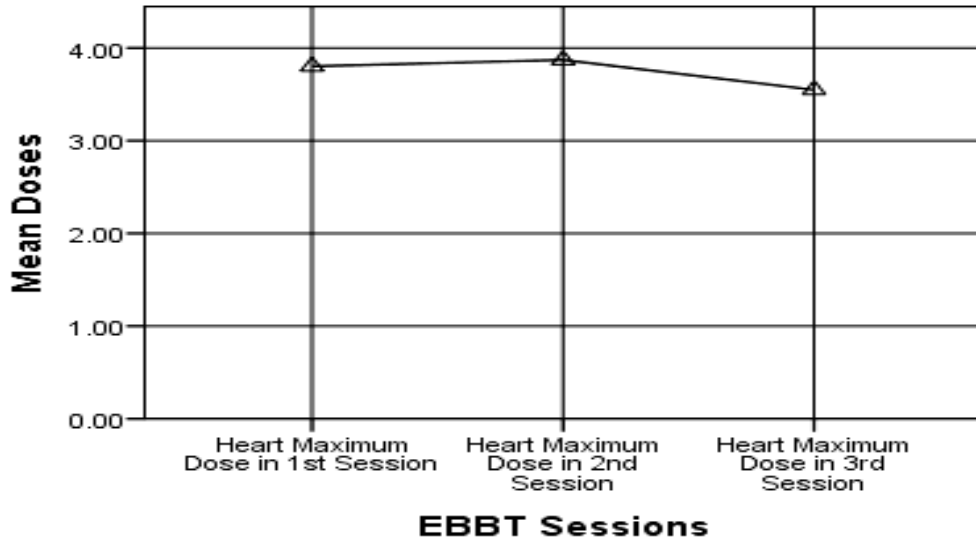


Graph 2: Showing Esophagus maximum doses in three EBBT sessions

2.2 HEART MAXIMUM AND MEAN DOSES:

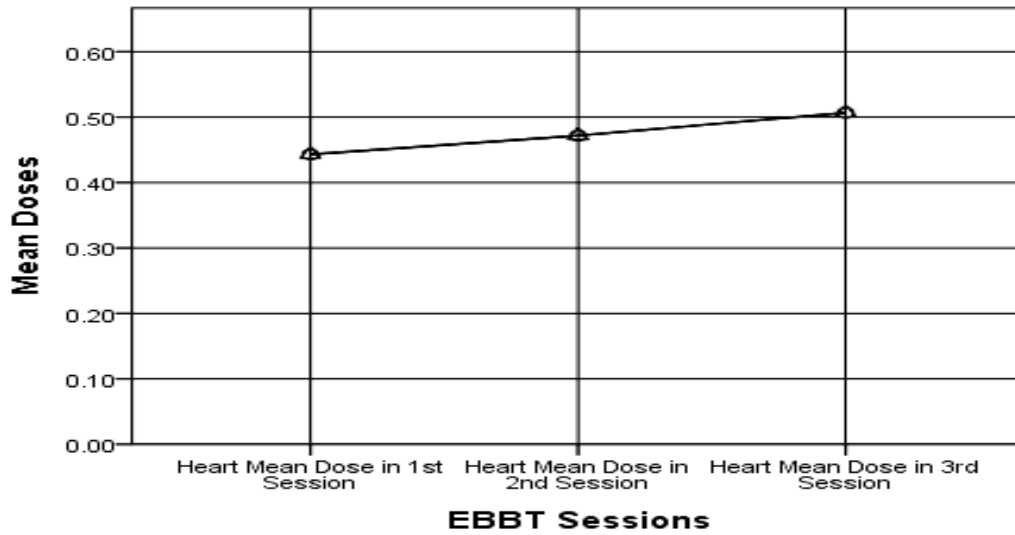
The Heart maximum and mean doses were analyzed in thirty patients treated with three EBBT Sessions. The maximum doses were decreased, and mean doses were increased in 3rd session as compared to 1st session of EBBT. The heart mean dose was increased in the 3rd session of EBBT due to the distance reduced between the heart and the source after the reduction in the target volume in 3rd EBBT Session from 1st session. Graph 3 and Graph 4 is showing below this Heart maximum and mean dose respectively

Heart Maximum Doses in 3 EBBT Session



Graph 3: A Graph showing Heart Maximum doses in three EBBT sessions

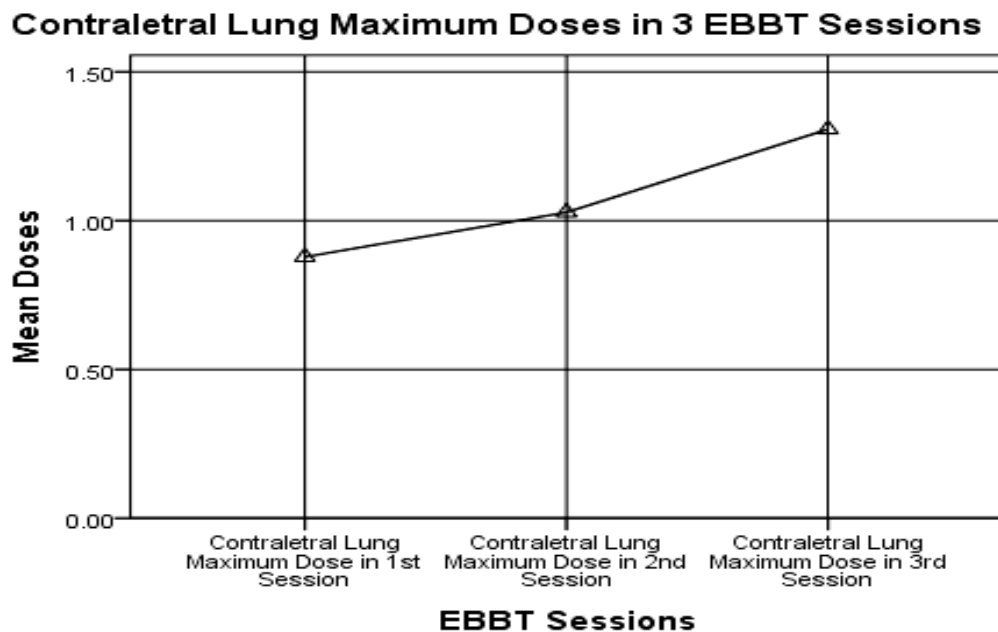
Heart Mean doses in 3 EBBT Sessions



Graph 4: A Graph showing Heart mean doses in three EBBT sessions

2.3 CONTRALETRAL LUNG MAXIMUM DOSES:

The Contraletral Lung Maximum dose was analyzed in thirty patients treated with three EBBT Sessions. The maximum dose was increased in 3rd session as compared to 1st session of EBBT. The Contralateral lung maximum dose increased in 3rd EBBT session which might have a cause of reduction in the target volume in 3rd EBBT session where the gap between the source and contralateral lung reduced. This is shown graphically in Graph 5.

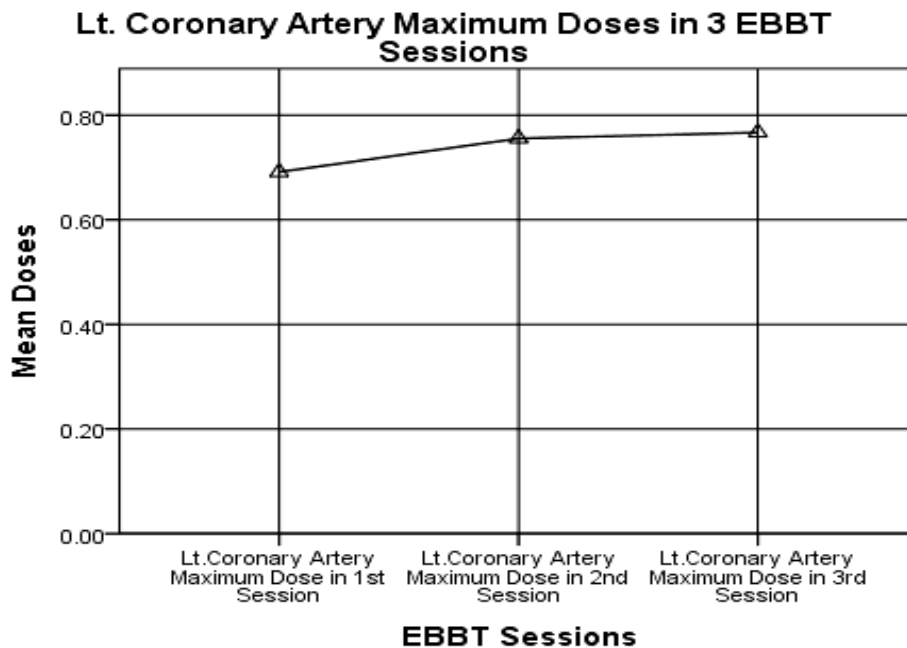


Graph 5: A Graph showing Contraletral Lung Maximum doses in three EBBT sessions.

2.4 LEFT CORONARY ARTERY MAXIMUM DOSES:

The Left Coronary Artery Maximum dose was analyzed in thirty patients treated with three EBBT Sessions. The maximum dose was increased in 3rd session as compared to 1st session of EBBT. This increment in the dose of coronary artery in 3rd EBBT Session is due to the distance reduced between the source and coronary

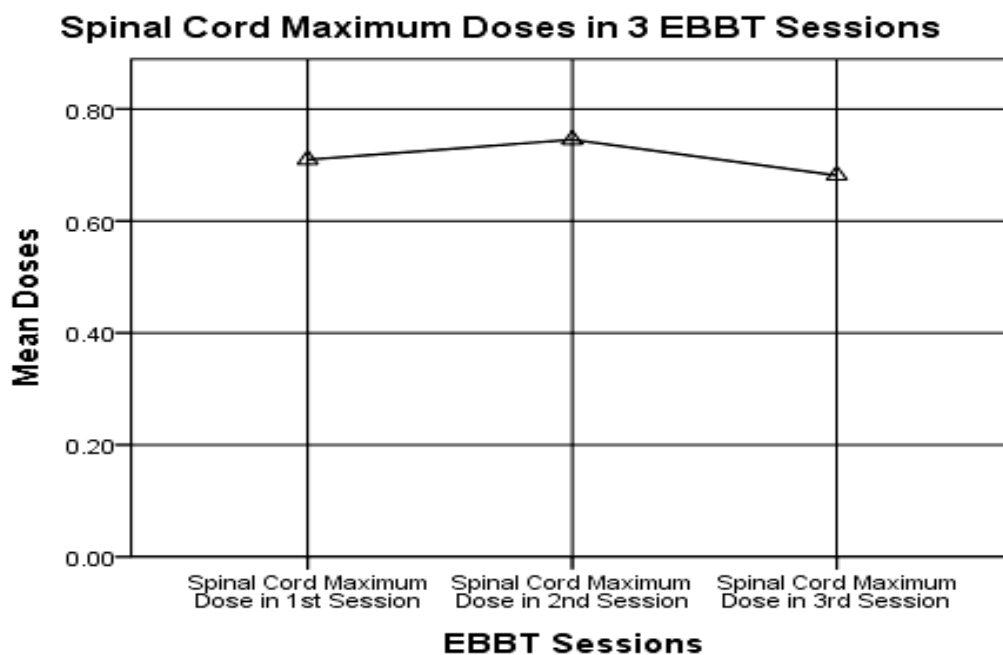
artery with the effect of target volume reduction in 3rd session of EBBT from 1st session. This is shown graphically in Graph 6.



Graph 6: A Graph showing Lt. Coronary artery Maximum doses in three EBBT sessions.

2.5 SPINAL CORD MAXIMUM DOSES:

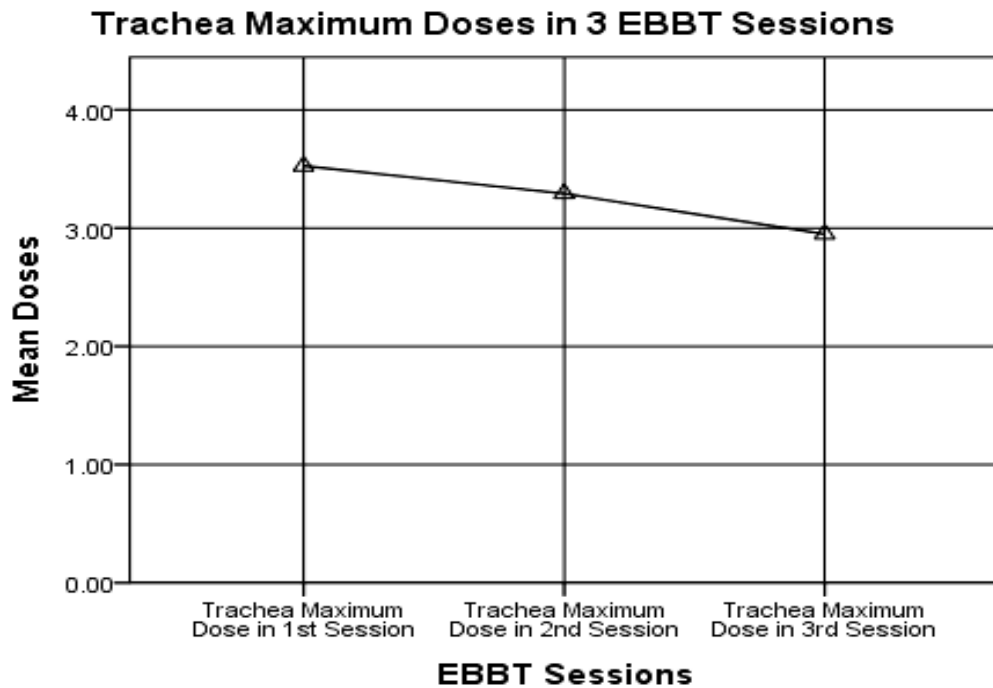
The Spinal Cord Maximum dose was analyzed in thirty patients treated with three EBBT Sessions. The maximum dose was slightly decreased in 3rd session as compared to 1st session of EBBT. The maximum dose to the spinal cord little bit reduced in 3rd session due to the target volume reduction and as the spinal cord is immobile structure inside the vertebral body so the gap between the spinal cord and source does not affect much in the doses while slightly increment seen. This is shown graphically in Graph 7.



Graph 7: A Graph showing Spinal Cord Maximum doses in three EBBT sessions

2.6 TRACHEA MAXIMUM DOSES:

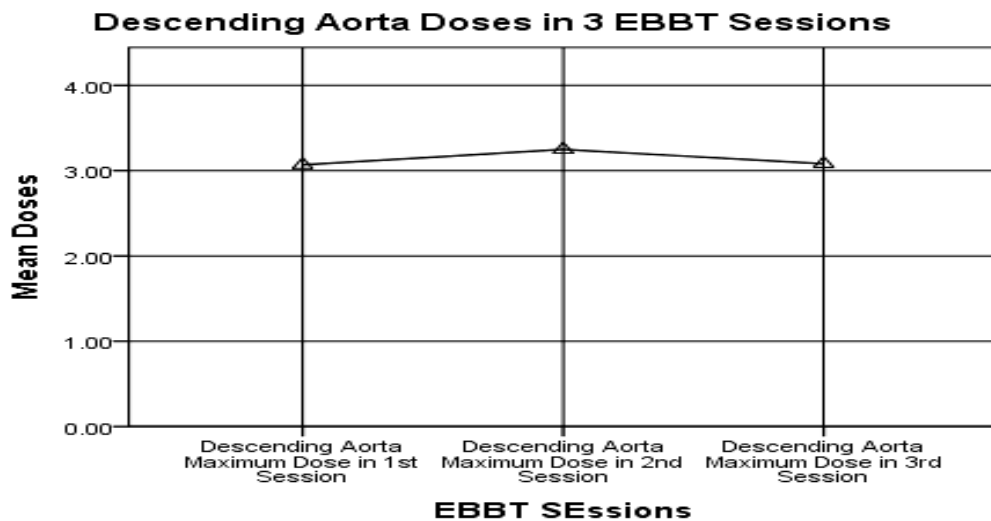
The Trachea Maximum dose was analyzed in thirty patients treated with three EBBT Sessions. The trachea maximum dose was decreased in 3rd session as compared to 1st session of EBBT. The reduction the maximum dose to the trachea is due to the target volume reduction in 3rd session of EBBT and the distance increased between the trachea and the source in 3rd EBBT session. This is shown graphically in Graph 8.



Graph 8: A Graph showing Trachea Maximum doses in three EBBT sessions

2.7 DESCENDING AORTA MAXIMUM DOSES:

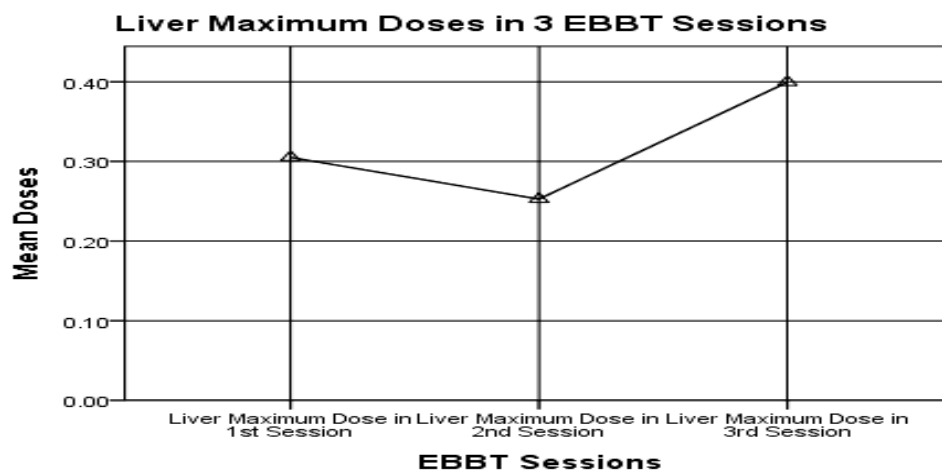
The Descending Aorta Maximum dose was analyzed in thirty patients treated with three EBBT Sessions. The maximum dose was decreased slightly in 3rd session as compared to 1st session of EBBT. There is not much difference in the position of the descending Aorta and the source which did not affect much in the maximum dose to the descending aorta in 3rd session of EBBT. This is shown graphically in Graph 9.



Graph 9: A Graph showing Descending Aorta maximum doses in three EBBT sessions

2.8 LIVER MAXIMUM DOSES:

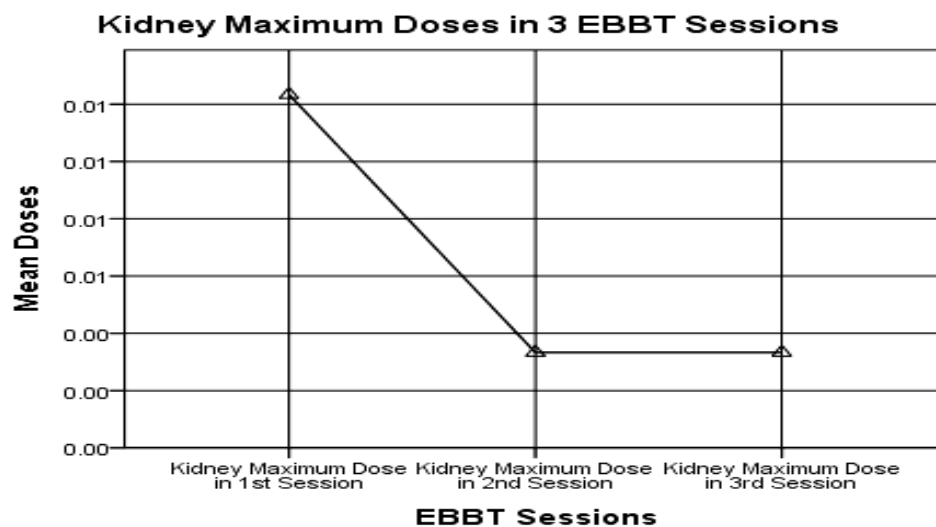
The Liver Maximum dose was analyzed in thirty patients treated with three EBBT Sessions. The maximum dose was increased in 3rd session as compared to 1st session of EBBT. The liver maximum dose increased in 3rd session as it gets closed to the target or source so that dose increased. This is shown graphically in Graph 10.



Graph 10: A Graph showing Liver Maximum doses received in three EBBT sessions for thirty patients.

2.9 KIDNEY MAXIMUM DOSES:

The Kidney Maximum dose was analyzed in thirty patients treated with three EBBT Sessions. The maximum dose was decreased in 3rd session as compared to 1st session of EBBT. This is shown graphically in Graph 11.



Graph 11: A Graph showing Kidney Maximum doses received in three EBBT sessions for thirty patients.

2.10 EFFECT OF TUMOR SITE ON DOSES TO OAR's:

The dosimetric analysis was performed on the groups and sub groups in the included lung carcinoma patients. The OARs doses were found higher in the left bronchus lesion compared to the right bronchus lesion and represented in table 7.

To compare means of the doses to OARs, Independent Sample t-Test was performed to analyze the data. The difference between the left and right lung carcinoma patient's OARs doses was assessed and found that the Esophagus mean Dose, Contraletral Lung_Max dose, Lt. Coronary Artery Max dose and Descending Aorta

max dose was having significant variation among the two groups created for tumor site in Carcinoma lung patients with p-value 0.015, 0.001, 0.002 and 0.000 respectively²⁷.

EFFECT OF TUMOR SITE ON DOSES TO OAR's					
S.N.	Organs at risk	Left Lung [Mean Dose (Gy)]	Right Lung [Mean Dose (Gy)]	Difference in Mean	p-value*
1	Esophagus_Mean Dose	3.7±1.65	2.57±0.70	1.20000	0.015
2	Esophagus_Max Dose	20.6±20.01	8.3±4.2	12.32333	0.027
3	Heart_Max Dose	11.36±3.01	11.07±3.65	0.28800	0.816
4	Heart_Mean Dose	1.50±0.33	1.33±0.60	0.17200	0.340
5	Contraletal lung Max Dose	4.61±2.75	1.80±1.31	2.81067	0.001
6	Lt. Coronary Artery_Max Dose	2.71±1.20	1.70±0.56	1.00933	0.007
7	Spinal Cord_Max Dose	2.16±0.81	2.10±0.86	0.06333	0.839
8	Trachea_Max Dose	10.29±4.18	9.23±4.70	1.06800	0.517
9	Descending Aorta_Max Dose	13.33±5.60	5.45±4.93	7.88533	0.001
10	Liver_Max Dose	0.28±0.37	1.63±3.34	-1.35400	0.130
11	Kidney_Max Dose	0.018±0.069	0.020±0.077	-0.00200	0.941

Table 7: showing the effect of tumor site on doses to OARs in EBBT sessions

2.11 EFFECT OF TUMOR LOCATION ON DOSES TO OAR'S

The affect of tumor location on the OARs doses was analyzed and found that the OARs doses were lesser in case lower bronchus tumor as compared to middle lower bronchus lesion in either side of the lung carcinoma patients²⁷ and represented in table 8.

The effect of tumor location on the OARs doses in left and right lung was analyzed in the carcinoma lung patients who were divided in two groups' lower and middle lower bronchial lesion in the lung. The doses to organs at risk from the TPS analyzed in the SPSS software by using Independent Sample t- Test. The analyzed data result showed that the Contraletral Lung Max dose and spinal cord max dose was having variation among these two groups created as per the tumor location in the lung with p-value 0.024 and 0.023 respectively²⁷.

EFFECT OF TUMOR LOCATION ON DOSES TO OAR'S					
S.N.	Organs at Risk	Lower_Region Mean Dose (Gy) ± SD	Middle_Lower Region Mean Dose (Gy) ± SD	Mean Difference	p-value*
1	Esophagus_Mean Dose	3.17±1.70	3.18±0.98	-0.01018	0.984
2	Esophagus_Max Dose	9.94±5.57	19.65±21.17	-9.70857	0.088
3	Heart_Max Dose	11.26±3.47	11.17±3.20	0.08991	0.942
4	Heart_Mean Dose	1.43±0.59	1.40±0.33	0.02661	0.884
5	Contraletral lung_Max Dose	2.24±1.46	4.31±3.10	-2.07357	0.024
6	Lt. Coronary Artery_Max Dose	2.01±1.46	2.44±1.37	-0.42768	0.277
7	Spinal Cord_Max Dose	1.82±0.68	2.49±0.85	-0.67643	0.023
8	Trachea_Max Dose	8.72±3.48	10.95±5.14	-2.23723	0.170
9	Descending Aorta_Max Dose	9.19±6.78	9.63±6.53	-0.43750	0.859
10	Liver_Max Dose	0.45±0.94	1.53±3.39	-1.07438	0.235
11	Kidney_Max Dose	0.00±0.00	0.04±0.10	-0.04071	0.126

Table 8: showing the effects of tumor location on the OARs doses in the EBBT Session

3. VOLUMETRIC ANALYSIS:

The volumetric analysis was performed on all the included patients in the study. The target volume (TV) of thirty patients was obtained from the TPS and classified in two groups i.e. TV<22cc and TV>22cc for analyzing the effect of TV on the doses to OARs in EBRT. The OARs doses were compared among these two TV groups for left and right-side lung tumor lesions.

3.1 EFFECT OF TUMOR VOLUME TV>22CC ON DOSES TO OAR'S:

It was found that the OARs doses were vary significantly in the group TV>22cc among left and right-side lung tumor lesions. This is represented in table 9.

EFFECT OF TUMOR VOLUME TV>22CC ON DOSES TO OAR'S					
S.N.	Organs at Risk	Mean ± SD [Doses in Gy]		Mean Difference	p-value*
		Left Lung	Right Lung		
1	Esophagus Mean Dose	3.43±1.69	2.33±1.13	-1.6229167	0.002
2	Esophagus Max Dose	15.70±20.86	7.00±9.82	-11.7329167	0.008
3	Heart Max Dose	11.04±3.41	10.89±3.97	-0.9029167	0.671
4	Heart Mean Dose	1.54±0.62	1.25±0.39	-0.4179167	0.027
5	Contra- l ateral lung Max Dose	3.32±3.21	1.57±1.72	-2.2716667	0.003
6	Lt. Coronary Artery Max Dose	3.17±0.58	1.67±1.47	-1.9716667	0.006
7	Spinal Cord Max Dose	2.07±0.62	2.33±0.97	-0.2175000	0.638
8	Trachea Max Dose	8.78±3.29	6.30±4.52	-2.6304167	0.253
9	Descending Aorta Max Dose	13.77±5.76	2.92±6.54	-13.1820833	0.001
10	Liver Max Dose	0.36±0.96	2.38±0.41	0.7058333	0.291
11	Kidney Max Dose	0.03±0.08	00.00±0.09	-0.04500	0.264

Table 9: showing the effect of Target Volume >22cc on the OARs doses in the EBBT session

3.2 EFFECT OF TUMOR VOLUME TV<22CC ON DOSES TO

OAR'S:

It was found that the Contralateral lung max dose was vary significantly while no significant variation was found in rest of the OARs doses in left and right-side lung tumor lesion in the group TV<22cc. This is represented in table 10.

EFFECT OF TUMOR VOLUME TV<22CC ON DOSES TO OAR'S					
S.N.	OARs	Mean \pm SD [Doses in Gy]		Mean Difference	p-value*
		Left Lung	Right Lung		
1	Esophagus Mean Dose	4.16 \pm 2.13	2.84 \pm 0.81	-0.7574603	0.364
2	Esophagus Max Dose	26.27 \pm 27.43	9.81 \pm 5.71	-11.8620635	0.242
3	Heart Max Dose	11.72 \pm 1.56	11.28 \pm 4.76	0.3914286	0.804
4	Heart Mean Dose	1.46 \pm 0.25	1.43 \pm 0.87	0.0450794	0.884
5	Contra- lateral lung Max Dose	6.09 \pm 0.37	2.07 \pm 1.86	-3.0736508	0.046
6	Lt. Coronary Artery Max Dose	2.19 \pm 0.49	1.74 \pm 0.61	-0.3088889	0.225
7	Spinal Cord Max Dose	2.27 \pm 0.68	1.84 \pm 0.52	0.0493651	0.725
8	Trachea Max Dose	12.03 \pm 3.23	12.57 \pm 3.58	0.9614286	0.677
9	Descending Aorta Max Dose	12.83 \pm 4.77	8.34 \pm 6.12	-3.1242857	0.277
10	Liver Max Dose	0.18 \pm 0.32	0.77 \pm 3.31	1.9987302	0.227
11	Kidney Max Dose	0.00 \pm 0.00	0.04 \pm 0.11	0.0428571	0.271

Table 10: showing the effect of Target Volume <22cc on the OARs doses in the EBBT session

3.3 TARGET VOLUME VARIATION IN EBBT:

The volumetric analysis in thirty patients was performed. Average volumetric variation in the Target volume was graphically represented in figure 23 from first to third EBBT session and. It has been observed that the mean of the target volume with standard deviation of thirty patients was 24.4929 ± 6.43815 cc and 17.2033 ± 4.64361 in first and third session of EBBT respectively. It implies that the target volume decreases from first to third session of EBBT.

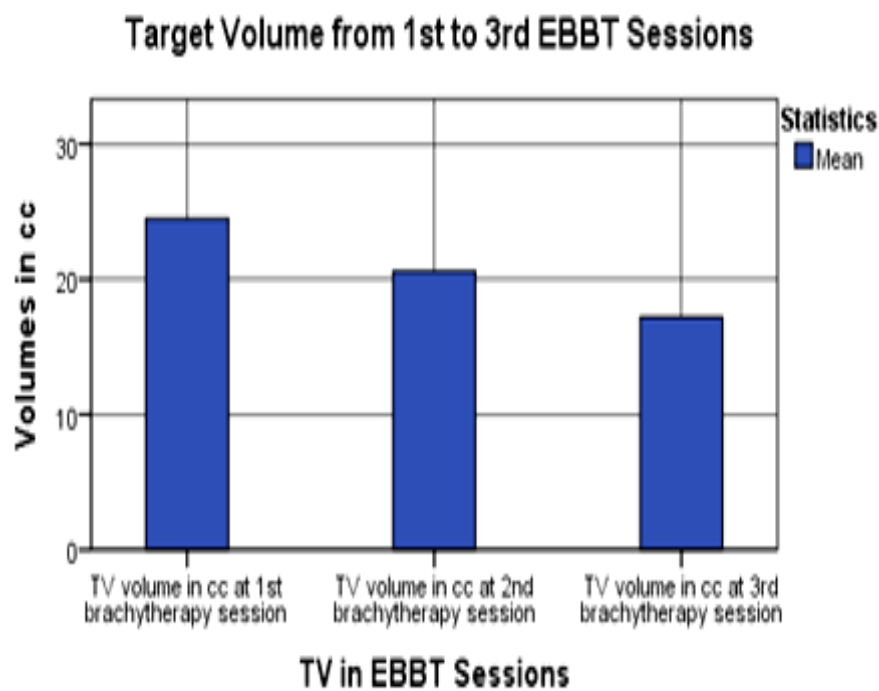


Figure 23: A Chart showing a variation in target volume from 1st to 3rd EBBT sessions

4. CONFORMITY INDEX IN EBBT:

The EBBT plans were analyzed in thirty patients of carcinoma lung. The average Conformity Index (CI) values with standard deviation (SD) for EBBT plans were graphically represented in figure 24. It has been observed that the CI is better in third EBBT session as compared to first EBBT⁶⁴.

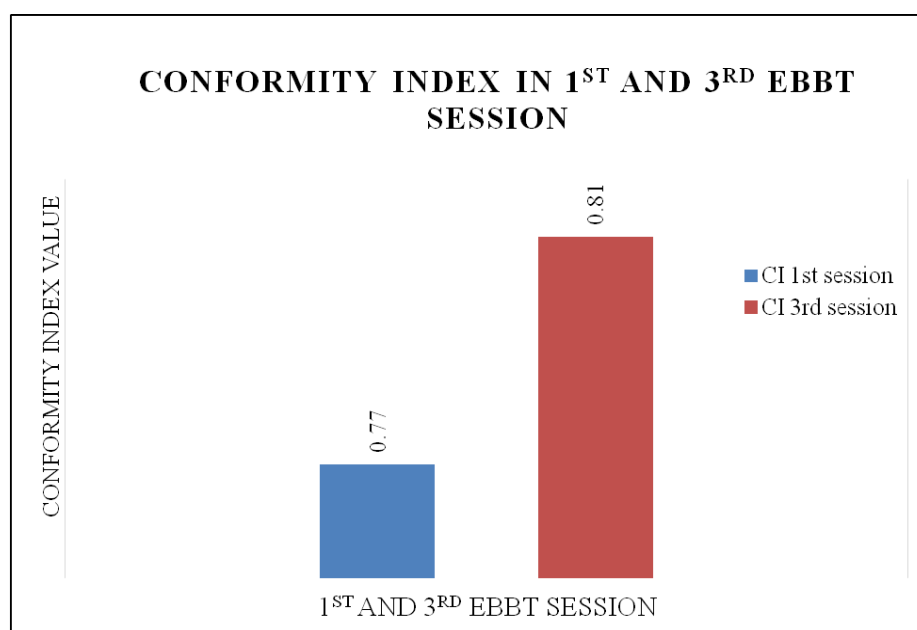


Figure 24: A Chart showing the conformity Index (CI) in EBBT sessions

Correlating the target volume and conformity index in the EBBT treatment plan, as the target volume reduced in third EBBT session and to cover it with the prescribed dose increases the conformity index value. This implies that the target volume coverage and conformity index inversely proportional to each other in this context of EBBT.