Intensity-modulated arc therapy (IMAT) planning for patients with pancreatic cancer: a planning study

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Background: Intensity-modulated arc therapy (IMAT; RapidArc, Varian®) has been described as allowing the delivery of highly conformal dose distribution to complex shaped radiation target volumes. Here we investigate IMAT related target volume coverage and normal tissue dose exposure in patients with pancreatic cancer, in comparison with established static beam delivery techniques.

Materials and methods: A retrospective planning study was performed in 20 patients with pancreatic cancer who had previously undergone radiation therapy following Whipple resection with risk factors for local tumor recurrence (n=12), or were considered unresectable (n=8). Based on 4DCT simulation imaging, the internal target volume (ITV) was delineated and expanded by 5 mm into a planning target volume (PTV). Treatments were planned in 2 phases, with initial planning to 45 Gy in 25 fractions, followed by re-simulation and boost planning to a total dose of 59.4 Gy (dose prescribed to 95% of the PTV). Three different treatment planning techniques were compared - 3D, IMRT (the clinically used plan), and IMAT. To determine cumulative doses delivered during the 2 courses of radiotherapy, deformable registration between CT data sets was performed (Velocity Medical Solutions®). DVH parameters were obtained for the PTV (D_{mean}), and organs at risk (OAR; kidneys Dmean, kidney V15 and V20, liver Dmean, Liver V30; spinal cord D_{max}). Conformity indices were computed for various dose levels (Fig.3). For statistical analysis, two-way comparisons were performed using the Wilcoxon signed ranks test (significance level: $p<0.05$).

OAR				p-value		
	3D	IMRT	RA	3D-IMRT	3D-RA	IMRT-RA
Left kidney						
Dmean (Gy)	18±7.6	15.1±5.3	16±3.4	0.014	0.05	0.92
Range	7.3-42.2	5.6-31.2	6.6-21.3			
V15 (%)	44±18.6	43.3±17.2	43±16	0.27	0.61	0.5
Range	14-88.6	12-82.2	16-80			
V20 (%)	36.5±2	24±15.5	23±10.5	0.009	0.005	0.46
Range	8-33.2	8.1-74	11.1-52			
Right kidney						
Dmean	24.1±9	15±5	16±3.4	<0.001	<0.001	0.38
	4.6-37.2	7-29.3	6.6-21.3			
V15 (%)	58.5±24.3	40±18.2	43±16	0.013	0.018	0.27
	4.6-88	17-94.5	16-80			
V20 (%)	51.2±23	24.2±15.1	23±10.5	<0.001	<0.001	0.68
	3.1-82	5.2-70.2	11.1-52			
Liver						
Dmean (Gy)	15.7±6.4	14.2±6	14.8±5.6	<0.001	<0.001	0.57
	6.5-27.7	5-25.2	4.5-23			
V30 (%)	22.8±12.2	9±9.5	11±8.5	<0.001	<0.001	0.16
	10.1-49	1.2-35	1-29.2			
Spinal cord						
Dmax (Gy)	37.5±7.5	39.5±8.2	37.1±6	0.94	0.47	0.57
	22.4-50.5	19.2-46.2	19-46.5			

Fig.1 Comparison between the DVH parameter for the OAR for the three different treatment planning techniques and t-test results for the comparisons parameters

Results: PTV D_{mean} was statistically significantly higher in 3D and IMRT plans, compared to the IMAT plans (3D vs. IMRT vs. IMAT: 62.3 Gy vs. 62.4 Gy vs. 61 Gy; $p<0.05$) (Fig.2). Plan conformity indices for the prescribed dose were significantly different between the 3 strategies, in favor of both IMAT and IMRT plans ($p<0.005$; with no statistically significant difference between the IMRT techniques) (Fig. 3). Additionally, the volumes of normal tissue included in the 90%, 50%, and 25% isodose lines were compared. While IMAT plans spared normal tissues better, the difference did reach statistical significance only for the volume encompassed by the 25% isodose ($p<0.001$). IMRT plans showed better OAR sparing than 3D plans. This was statistically significant for all parameters assessed except V15 kidney (statistical benefit for IMRT and IMAT plans compared with 3D conformal plans at $p<0.05$, but not between the IMRT plans) (Fig.1). IMAT plans used significantly lower number of monitor units (MU), compared to IMRT plans ($p<0.001$).

PTV			
	3D	IMRT	RA
D_{mean}			
Mean	62.3±1.4	62.4±1.5	61.4±1.6
Range	60.3-67.1	59.7-65	59-64
$D_{95\%}$			
Median	61±6.3	60.3±8.1	60.4±7.3
Range	37.4-65.2	35-63	35.3-62
p-value			
	3D-IMRT	3D-RA	IMRT-RA
D_{mean}	0.57	0.004	0.018
$D_{95\%}$	0.28	0.01	0.32

Fig 2. Comparison between the DVH parameter of the PTV for the three different treatment planning techniques and the corresponding p-values

				p-value		
	3D	IMRT	RA	3D-IMRT	3D-RA	IMRT-RA
Conformity Index						
Plan to 45 Gy	1.19±1.2	1±0.07	0.96±0.05	<0.001	<0.001	0.001
Range	1.1-1.51	0.97-1.94	0.95-1.18			
Boost	1.17±1.86	1±0.08	0.96±0.2	<0.001	<0.001	0.004
Range	1.09-4.62	0.68-1.08	0.96-1.18			

Fig.3 Comparison between the conformity indices for the different treatment techniques

Conclusions: IMAT delivery is expected to result in overall treatment time reduction without any compromise in pancreatic cancer radiation treatment plan quality. Compared to 3D planning, IMRT techniques allowed for improved OAR sparing.