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Image guided brachytherapy

Critical structure movement in cervix brachytherapy

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ABSTRACT

Background and purpose: To investigate critical structure movement and subsequent dose received during conformal MR-guided cervix brachytherapy.

Materials and methods: 21 patients (36 HDR fractions) undergoing brachytherapy for cervical cancer underwent a second MR immediately prior to treatment (pre-treatment MR). Bowel (including sigmoid), bladder and rectum were outlined on both planning and pre-treatment MR scans and dosimetry compared.

Results: No statistically significant differences were found between the volumes of the OAR doses across the two scans but there were large variations between patients with differences of up to 3.3 Gy observed. The percentage of fractions for which D_{2cc} was within 10% of that planned was 61.1%, 41.7% and 47.2% for bladder, rectum and bowel, respectively. The average time between MR scans was found to be 4.75 h (SD ± 1.2; range 3.2–9.9 h), with no correlation found with critical structure movement within this range.

Conclusions: OAR movement is difficult to predict though significant changes occur in individual patients. In 61% of cases in our sample the D_{2cc} dose changed by at least 10% for at least one OAR from that planned. Pre-treatment imaging with subsequent adjustment of dosimetry will minimise the impact of organ movement on delivered dose.

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Cervical carcinoma accounts for one in ten cancers worldwide with more than half a million women diagnosed every year [1]. Intracavity brachytherapy is a well established and proven technique for the treatment of cervical carcinoma. Recent developments based on the use of cross-sectional imaging improve tumour and critical structure delineation and enable dose escalation using both CT [2] and MR [3,4].

Brachytherapy for cervical cancer has developed from the use of dosimetry systems such as Manchester and prescribing to point A using lateral radiographs, through to 3D planning using CT and more recently MR to enable better visualisation of the tumour and more accurate voluming of structures as well as improved applicator reconstruction. This improved accuracy in delineation (coupled with the steep dose gradients associated with brachytherapy dosimetry) has recently given rise to discussion regarding quantification of other sources of error incurred during brachytherapy treatments, including imaging modality (slice thickness etc.), applicator reconstruction, structure voluming, source position error and structure movement before or during treatment [5].

Source position error is measured as part of routine QA. Tanderup et al. [5] state that the tolerance for source positioning uncertainties in a straight catheter is usually ±1 mm, whereas in curved applicators (i.e., the ring) source positioning uncertainties can be larger, of the order of 2–4 mm. Applicator reconstruction has been investigated [6–12], as have inter-observer errors associated with structure voluming [13–15]. Very little appears in the literature concerning inter-fraction or intra-fraction structure movement in cervix brachytherapy.

Tanderup et al. [8] simulated applicator shifts and concluded that if systematic uncertainties were avoided the DVH parameters deviated less than 10% for 90% if patients, assuming errors of the order of 2 mm in applicator reconstruction. Hellebust et al. [9] states that under well-controlled circumstances, reconstruction uncertainties are generally smaller than other uncertainties in brachytherapy such as contouring and organ movement. A typical brachytherapy dose gradient for an intracavitary treatment is typically 5–12% per mm at distances of 1–3 cm from the source channels, showing that even small geometric inaccuracies can result in significant dose uncertainty to the tumour or OARs. Applicator reconstruction inter-observer error was reported as less than 0.5–1 mm (1SD) [10] when the recommendations outlined in the paper are followed, which are smaller than inter-observer contouring uncertainties which have been reported to be of the order of 2 mm (1SD) [13]. This paper also states that organ motion has been shown to have more impact than reconstruction uncertainties on

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Table 1
Cervix OAR dose constraints.

	Max D_{2cc} per brachytherapy fraction (Gy)	Total course max D_{2cc} (Gy EQD2 α/β 3.5)	Total course max D_{2cc} (Gy EQD2 α/β 3.0)
Bladder	6	81	82.5
Rectum	5	73	74
Bowel (including sigmoid)	4	66.5	67

DVH parameters between the calculated and the delivered dose [7].

Image-guided HDR cervix brachytherapy has been performed at Mount Vernon Hospital since 2004. At the time of the study, an MR-compatible titanium ring and tandem applicator set is used with a GammaMed HDR afterloader (Varian Medical Systems, Crawley, UK). Planning was carried out using Brachyvision V7 (Varian Medical Systems, Crawley, UK), using a standard plan (ICRU38/Manchester system) as a starting point and then optimising manually and graphically to maximise coverage to the HR-CTV

Table 2
Change in OAR parameters between planning and pre-treatment MR scans, $n = 36$.

	Change in OAR volume (cc)				Change in D_{2cc} (physical dose) (Gy)			
	Median (cc)	Mean absolute difference (mean ± 1SD)	Max difference (planning – pre-treatment)		Median (Gy)	Mean absolute difference (mean ± 1SD)	Max difference (planning – pre-treatment)	
			+ve	−ve			+ve	−ve
Bladder	5.1	22.5 ± 24.7	97.6	−38.3	−0.1	0.5 ± 0.5	1.9	−1.8
Rectum	−4.3	20.0 ± 20.8	69.0	−75.7	−0.1	0.8 ± 0.8	1.8	−3.3
Bowel (including sigmoid)	−12.5	57.9 ± 56.9	110	−249.7	0.2	0.6 ± 0.5	2.1	−1.5

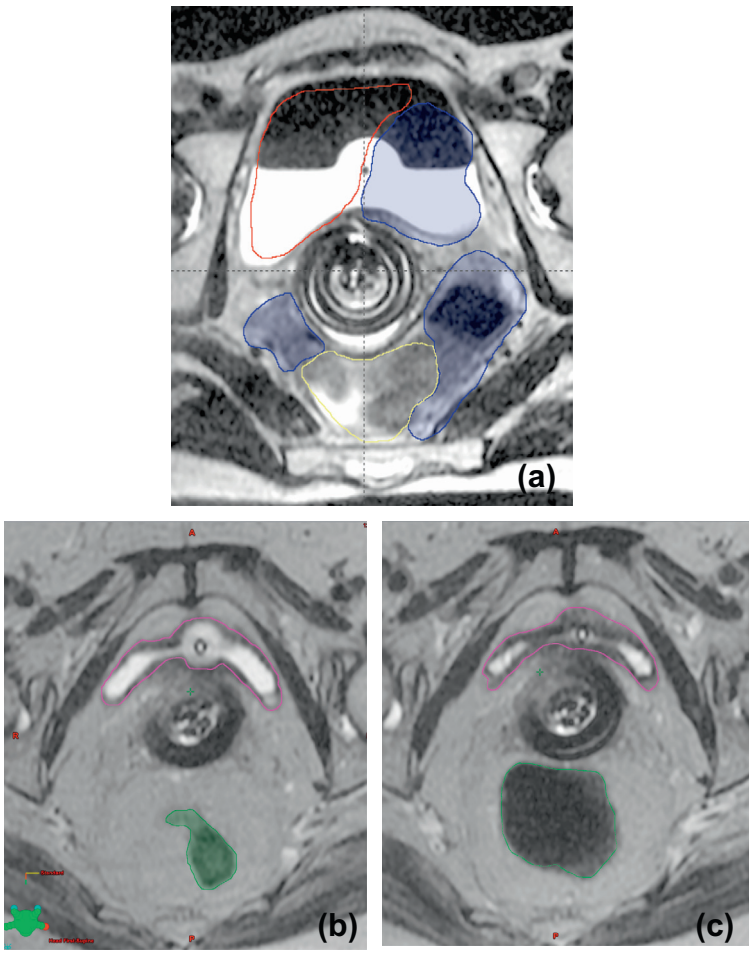

Fig. 1. (a) Planning image with overlaid pre-treatment contours. The non-functioning urinary catheter was resolved before pre-treatment imaging; bowel, including sigmoid (blue) was observed to enter the volume occupied by bladder (red) on the planning image. (b) and (c) show variation in rectum (green) and bladder (magenta) contours between planning (b) and pre-treatment (c) MR scans.

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