

# Supplementary material

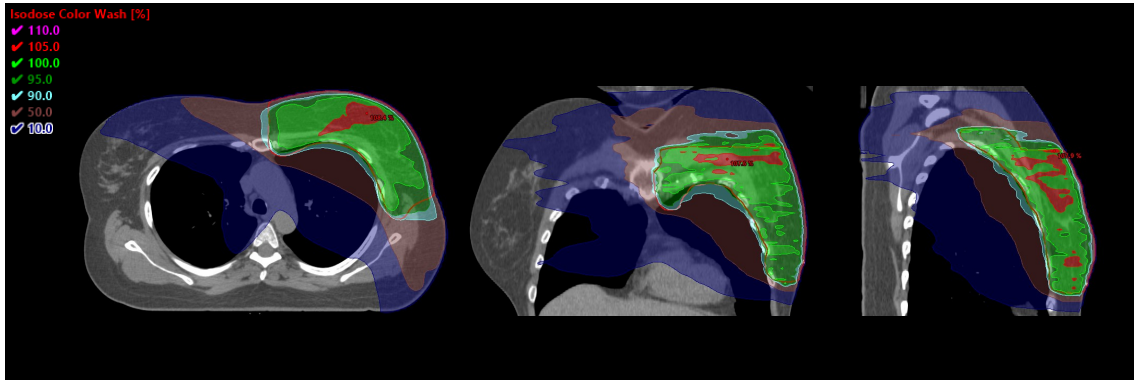
## A Planning goals

Table 1: Planning goals and acceptance limits that were used when optimising the treatment plans. The structures are ordered according to the priority that they had in the optimisation.

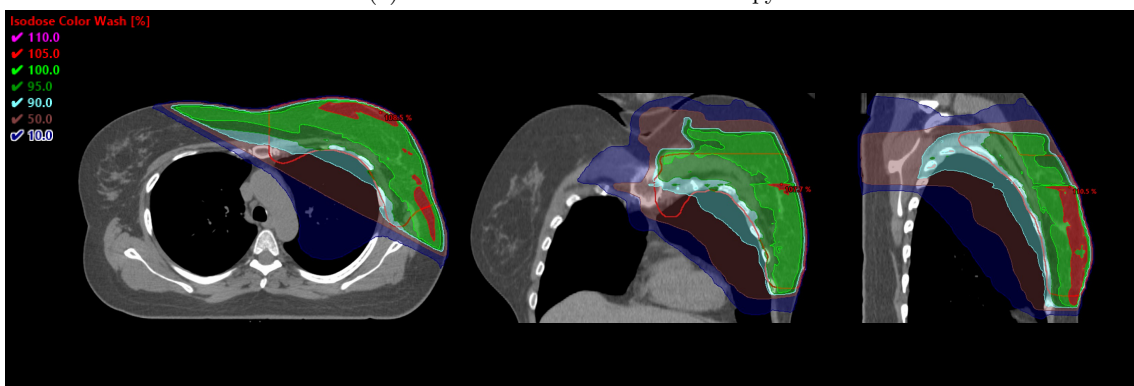
Structure	Parameter	Planning goal	Acceptance limit
Planning target volume	$V_{95\%}$	95%	90%
	$V_{107\%}$	1 cm <sup>3</sup>	3 cm <sup>3</sup>
Heart	Mean dose	2 Gy	4 Gy
	$D_{\max}$	20 Gy	40 Gy
Left anterior descending artery	Mean dose	5 Gy	10 Gy
Left lung	Mean dose	9 Gy	13 Gy
	$V_{16\text{Gy}}$	20 %	35 %
	$V_{4\text{Gy}}$	50 %	65 %
Right lung	Mean dose	1.5 Gy	2.5 Gy
Right breast	Mean dose	3 Gy	7 Gy
Spinal cord	$D_{\max}$	15 Gy	38 Gy
Brachial plexus	$D_{\max}$	42 Gy	43 Gy
Thyroid	Mean dose	17 Gy	20 Gy
Left humeral head	$V_{15\text{Gy}}$	30 %	50 %

Abbreviations:  $V_{X\text{Gy}}$  = the percentage volume receiving  $X$  Gy dose,  $V_{Y\%}$  = the percentage volume receiving  $Y$  % of the prescribed dose,  $D_{\max}$  = the maximum point dose.

## B Orthogonal views of the treatment plans



(a) Volumetric modulated arc therapy



(b) Field-in-field

Figure 1: Axial, sagittal and coronal views of the volumetric modulated arc therapy plan (a) and field-in-field plan (b) of a representative patient. The 100 % isodose level corresponds to 40.05 Gy.

## C Median dose-volume histograms

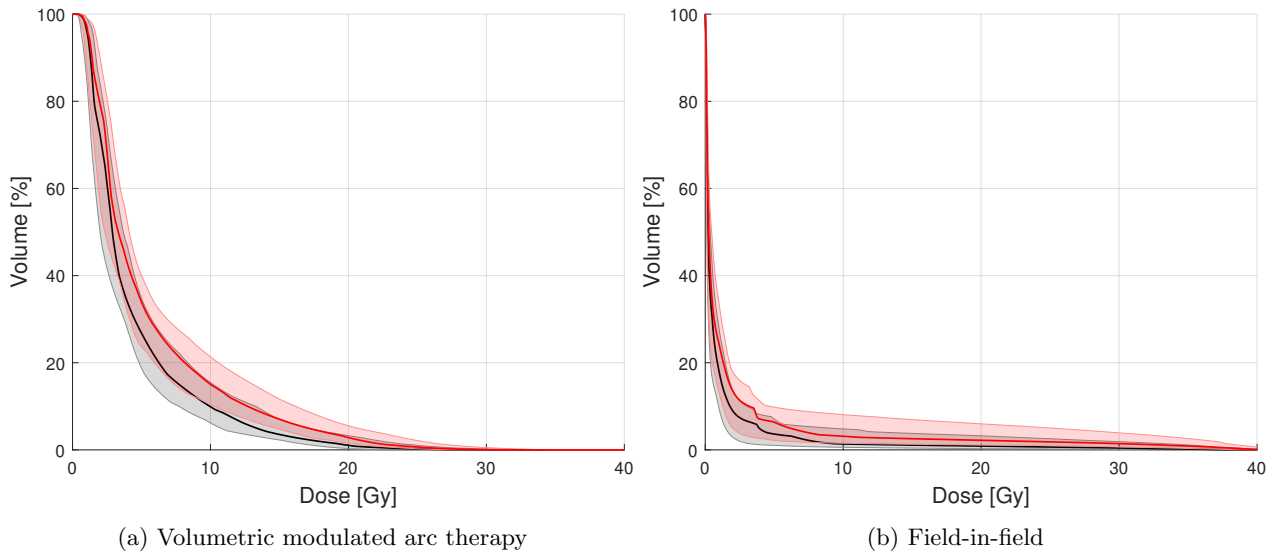


Figure 2: The median (25th percentile, 75th percentile) dose-volume histograms (DVHs) of the right breast in volumetric modulated arc therapy plans (a) and field-in-field plans (b). The original DVH (black line) and DVH after the rotation that caused the largest increase in the mean dose are plotted. Red line indicates rotation by 3° (-roll).

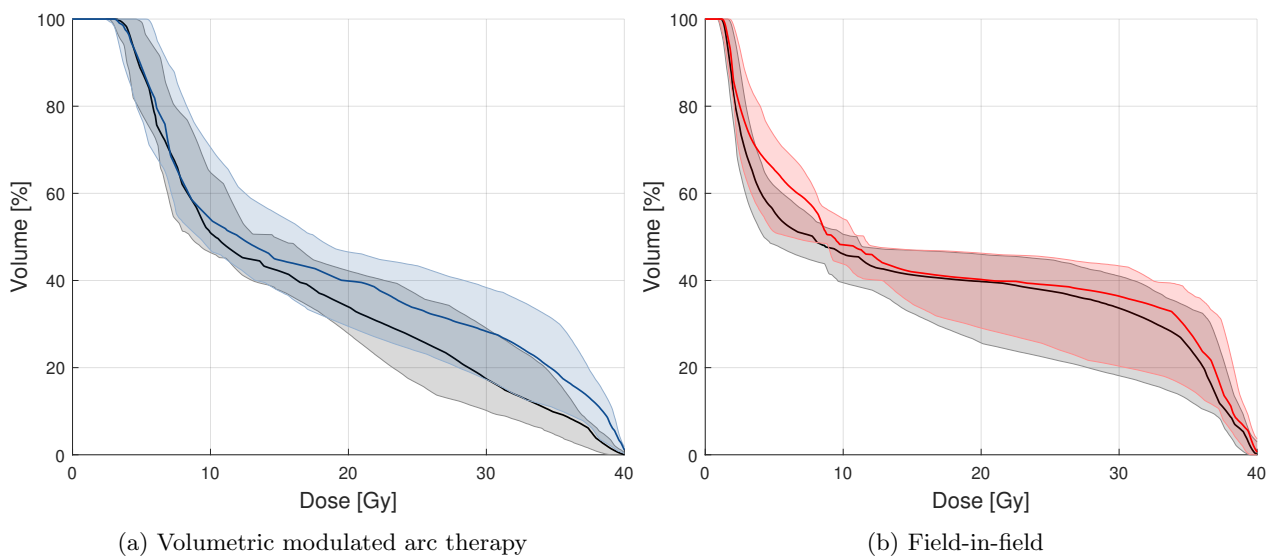


Figure 3: The median (25th percentile, 75th percentile) dose-volume histograms (DVHs) of the thyroid in volumetric modulated arc therapy plans (a) and field-in-field plans (b). The original DVH (black line) and DVH after the rotation that caused the largest increase in the mean dose are plotted. Yale blue line indicates rotation by 3° (-yaw) and red line rotation by 3° (+roll).

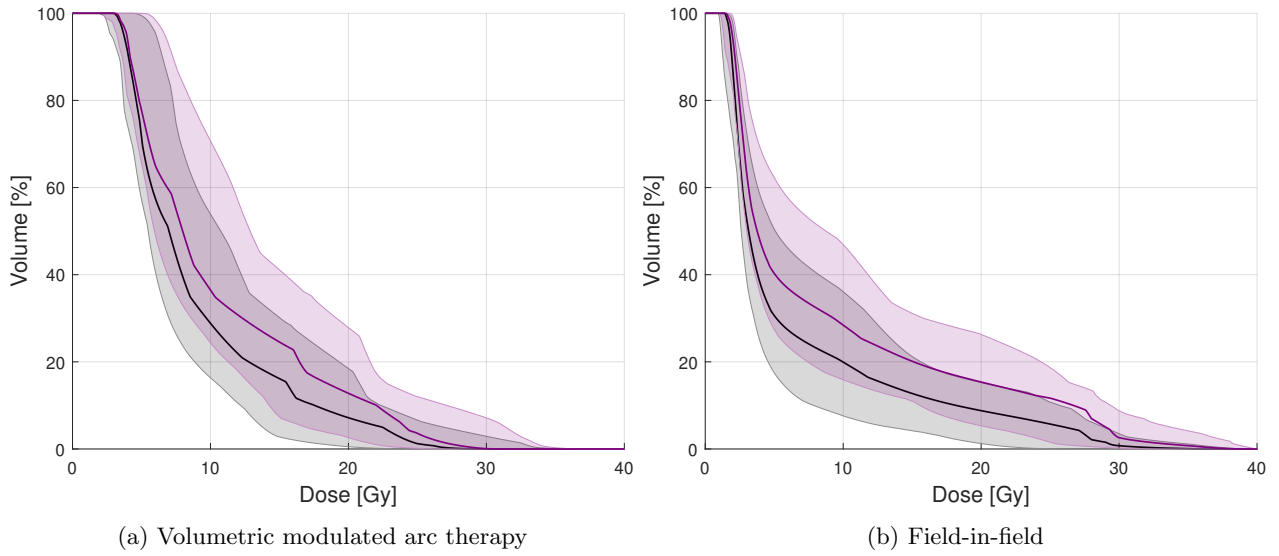


Figure 4: The median(25th percentile, 75th percentile) dose-volume histograms (DVHs) of the left humeral head in volumetric modulated arc therapy plans (a) and field-in-field plans (b). The original DVH (black line) and DVH after the rotation that caused the largest increase in the volume receiving more than 15 Gy are plotted. Purple line indicates rotation by  $3^\circ$  (+pitch).

## D Effect of rotations on dose-volume parameter values

Table 2: Absolute changes in the planning target volume (PTV) and clinical target volume (CTV) dose-volume parameters in volumetric modulated arc therapy plans caused by rotational setup errors. Values are expressed as median (25th percentile, 75th percentile) of 20 plans.

Parameter and original value		pitch	yaw	roll
PTV $V_{95\%}$ 93.50(92.96, 94.43)%	1°	-0.67(-1.03, -0.32) pp*	-0.31(-0.84, +0.05) pp*	-0.50(-1.15, -0.32) pp*
	-1°	-0.41(-0.79, -0.16) pp*	-0.61(-0.97, -0.38) pp*	-0.28(-0.73, -0.07) pp*
	2°	-1.53(-1.81, -0.94) pp*	-0.80(-1.23, -0.47) pp*	-1.15(-1.74, -0.74) pp*
	-2°	-1.69(-2.12, -1.18) pp*	-1.64(-2.07, -1.23) pp*	-0.63(-1.29, -0.36) pp*
	3°	-2.58(-2.76, -1.63) pp*	-1.40(-1.90, -0.89) pp*	-1.86(-2.82, -1.42) pp*
	-3°	-3.12(-3.54, -2.22) pp*	-2.63(-3.84, -2.14) pp*	-1.19(-2.22, -0.84) pp*
	CTV $V_{95\%}$ 95.54(95.23, 96.90)%	1°	-0.45(-0.74, -0.13) pp*	-0.32(-0.56, -0.02) pp*
-1°		-0.15(-0.35, +0.04) pp	-0.32(-0.56, -0.22) pp*	-0.21(-0.48, +0.02) pp*
2°		-0.51(-0.84, -0.30) pp*	-0.38(-0.56, -0.04) pp*	-0.56(-1.01, -0.34) pp*
-2°		-0.21(-0.42, -0.02) pp*	-0.44(-0.92, -0.36) pp*	-0.16(-0.46, +0.17) pp
3°		-0.64(-1.08, -0.16) pp*	-0.34(-0.88, -0.05) pp*	-0.78(-1.32, -0.45) pp*
-3°		-0.28(-0.80, +0.04) pp*	-0.57(-1.51, -0.27) pp*	-0.16(-0.79, +0.09) pp
PTV $D_{\min}(1\text{cm}^3)$ 34.21(33.97, 34.72) Gy		1°	-0.43(-0.54, -0.12) Gy*	-0.82(-1.09, -0.45) Gy*
	-1°	-0.77(-1.26, -0.34) Gy*	-0.42(-0.63, -0.10) Gy*	-0.24(-0.43, +0.07) Gy*
	2°	-1.09(-1.74, -0.50) Gy*	-2.40(-3.13, -1.18) Gy*	-2.74(-4.33, -1.59) Gy*
	-2°	-2.86(-3.77, -1.61) Gy*	-0.95(-1.95, -0.67) Gy*	-0.70(-1.28, -0.24) Gy*
	3°	-2.65(-4.20, -1.90) Gy*	-6.48(-7.47, -3.87) Gy*	-6.02(-7.57, -4.01) Gy*
	-3°	-6.12(-7.06, -4.50) Gy*	-2.39(-4.81, -1.80) Gy*	-2.09(-3.16, -1.07) Gy*
	CTV $D_{\min}(1\text{cm}^3)$ 35.06(34.78, 35.57) Gy	1°	-0.28(-0.58, -0.16) Gy*	-0.28(-0.46, -0.06) Gy*
-1°		-0.22(-0.36, +0.08) Gy	-0.22(-0.28, +0.07) Gy	-0.13(-0.30, -0.01) Gy*
2°		-0.27(-0.44, -0.13) Gy*	-0.32(-0.47, -0.16) Gy*	-0.41(-0.48, -0.03) Gy*
-2°		-0.27(-0.36, -0.11) Gy	-0.23(-0.31, -0.04) Gy	-0.09(-0.13, +0.03) Gy
3°		-0.23(-0.65, -0.09) Gy*	-0.35(-0.51, -0.21) Gy*	-0.46(-0.64, -0.11) Gy*
-3°		-0.23(-0.41, +0.05) Gy	-0.11(-0.33, +0.04) Gy	-0.05(-0.35, +0.14) Gy
PTV $D_{\max}(1\text{cm}^3)$ 42.65(42.41, 42.90) Gy		1°	+0.00(-0.07, +0.05) Gy	+0.08(-0.01, +0.13) Gy*
	-1°	+0.12(+0.05, +0.20) Gy*	+0.03(-0.03, +0.10) Gy	+0.01(-0.08, +0.08) Gy
	2°	-0.01(-0.13, +0.04) Gy	+0.17(+0.05, +0.21) Gy*	+0.21(+0.04, +0.34) Gy*
	-2°	+0.24(+0.09, +0.35) Gy*	+0.04(-0.07, +0.17) Gy	-0.02(-0.08, +0.09) Gy
	3°	-0.01(-0.15, +0.07) Gy	+0.25(+0.12, +0.37) Gy*	+0.36(+0.17, +0.71) Gy*
	-3°	+0.37(+0.12, +0.52) Gy*	+0.06(-0.09, +0.25) Gy	+0.00(-0.11, +0.19) Gy
	CTV $D_{\max}(1\text{cm}^3)$ 42.62(42.39, 42.82) Gy	1°	-0.01(-0.07, +0.05) Gy	+0.08(+0.01, +0.11) Gy*
-1°		+0.12(+0.07, +0.21) Gy*	+0.00(-0.04, +0.08) Gy	+0.02(-0.06, +0.06) Gy
2°		-0.03(-0.14, +0.05) Gy	+0.18(+0.08, +0.22) Gy*	+0.20(+0.02, +0.35) Gy*
-2°		+0.24(+0.12, +0.38) Gy*	+0.00(-0.07, +0.11) Gy	+0.02(-0.09, +0.08) Gy
3°		-0.04(-0.20, +0.09) Gy	+0.25(+0.15, +0.38) Gy*	+0.34(+0.12, +0.75) Gy*
-3°		+0.37(+0.16, +0.57) Gy*	+0.03(-0.08, +0.21) Gy	+0.04(-0.12, +0.12) Gy

\*Statistically significant change ( $p < 0.05$ )

Abbreviations:  $V_{Y\%}$  = the percentage volume receiving  $Y$  % of the prescribed dose,  $D_{\max/\min}(Z)$  = the minimum/maximum dose received by the volume  $Z$  that received the highest/lowest dose, pp = percentage point.

Table 3: Absolute changes in the planning target volume (PTV) and clinical target volume (CTV) dose-volume parameters in field-in-field plans caused by rotational setup errors. Values are expressed as median (25th percentile, 75th percentile) of 20 plans.

Parameter and original value		pitch	yaw	roll
PTV $V_{95\%}$ 90.25(89.96, 91.06) %	1°	+0.33(+0.14, +0.86) pp*	+0.63(+0.33, +1.26) pp*	+0.25(-0.07, +0.38) pp*
	-1°	-0.15(-0.46, +0.24) pp	-0.42(-0.62, +0.13) pp*	+0.03(-0.31, +0.64) pp
	2°	+0.28(-0.09, +0.79) pp*	+0.82(+0.55, +1.57) pp*	+0.01(-0.47, +0.50) pp
	-2°	-1.04(-1.40, -0.36) pp*	-1.08(-1.67, -0.73) pp*	-0.23(-0.99, +0.39) pp
	3°	+0.03(-0.68, +0.63) pp	+0.99(+0.70, +1.73) pp*	-0.49(-1.03, +0.12) pp*
	-3°	-1.83(-2.46, -0.75) pp*	-2.08(-2.87, -1.39) pp*	-0.60(-1.87, +0.08) pp*
CTV $V_{95\%}$ 95.60(95.01, 96.78) %	1°	-0.05(-0.22, +0.18) pp	+0.18(-0.02, +0.45) pp*	+0.09(-0.18, +0.39) pp
	-1°	+0.08(-0.10, +0.36) pp	-0.19(-0.25, +0.12) pp	-0.07(-0.27, +0.28) pp
	2°	-0.29(-0.64, -0.05) pp*	+0.09(-0.04, +0.53) pp*	-0.06(-0.43, +0.23) pp
	-2°	+0.02(-0.24, +0.39) pp	-0.44(-0.65, -0.11) pp*	-0.23(-0.66, +0.20) pp*
	3°	-0.74(-1.22, -0.29) pp*	+0.06(-0.07, +0.55) pp	-0.32(-0.75, +0.06) pp
	-3°	-0.16(-0.76, +0.04) pp	-0.69(-1.35, -0.39) pp*	-0.56(-1.27, -0.02) pp*
PTV $D_{\min}(1\text{cm}^3)$ 33.00(31.92, 33.70) Gy	1°	+0.15(+0.02, +0.55) Gy*	-0.06(-0.25, +0.09) Gy	-0.41(-1.15, -0.19) Gy*
	-1°	-0.80(-1.54, -0.50) Gy*	-0.45(-0.77, +0.01) Gy*	-0.12(-0.34, +0.20) Gy
	2°	+0.09(-0.10, +0.58) Gy	-0.34(-0.59, +0.03) Gy	-2.32(-5.71, -0.70) Gy*
	-2°	-4.30(-7.95, -2.03) Gy*	-1.63(-5.00, -0.31) Gy*	-0.71(-1.66, +0.10) Gy*
	3°	-0.01(-0.22, +0.71) Gy	-0.82(-1.50, -0.39) Gy*	-6.95(-12.13, -3.57) Gy*
	-3°	-11.87(-15.85, -8.22) Gy*	-5.91(-10.88, -1.66) Gy*	-2.36(-4.37, -0.50) Gy*
CTV $D_{\min}(1\text{cm}^3)$ 35.08(34.33, 35.62) Gy	1°	-0.10(-0.19, +0.05) Gy*	-0.19(-0.26, -0.09) Gy*	-0.22(-0.26, -0.12) Gy*
	-1°	-0.19(-0.33, -0.11) Gy*	-0.13(-0.26, -0.01) Gy*	-0.11(-0.22, -0.02) Gy*
	2°	-0.14(-0.30, -0.03) Gy*	-0.25(-0.33, -0.12) Gy*	-0.29(-0.47, -0.20) Gy*
	-2°	-0.30(-0.35, -0.16) Gy*	-0.15(-0.25, -0.03) Gy*	-0.17(-0.37, +0.00) Gy*
	3°	-0.18(-0.28, -0.03) Gy*	-0.24(-0.48, -0.18) Gy*	-0.43(-0.74, -0.26) Gy*
	-3°	-0.47(-1.17, -0.28) Gy*	-0.19(-0.29, -0.11) Gy*	-0.24(-0.59, +0.01) Gy*
PTV $D_{\max}(1\text{cm}^3)$ 43.47(43.32, 43.57) Gy	1°	+0.06(-0.04, +0.20) Gy	+0.14(+0.05, +0.21) Gy*	+0.07(+0.00, +0.18) Gy*
	-1°	+0.12(+0.04, +0.17) Gy*	+0.05(-0.07, +0.12) Gy	+0.11(+0.02, +0.34) Gy*
	2°	+0.07(-0.06, +0.36) Gy*	+0.24(+0.12, +0.41) Gy*	+0.06(+0.00, +0.25) Gy*
	-2°	+0.18(+0.09, +0.35) Gy*	+0.03(-0.10, +0.12) Gy	+0.20(+0.06, +0.52) Gy*
	3°	+0.10(-0.04, +0.44) Gy*	+0.38(+0.22, +0.57) Gy*	+0.12(+0.01, +0.33) Gy*
	-3°	+0.21(+0.11, +0.44) Gy*	+0.03(-0.18, +0.12) Gy	+0.25(+0.11, +0.72) Gy*
CTV $D_{\max}(1\text{cm}^3)$ 43.45(43.25, 43.54) Gy	1°	+0.05(-0.04, +0.20) Gy	+0.14(+0.05, +0.23) Gy*	+0.05(-0.03, +0.17) Gy*
	-1°	+0.13(+0.04, +0.21) Gy*	+0.02(-0.05, +0.13) Gy	+0.12(+0.02, +0.35) Gy*
	2°	+0.08(-0.05, +0.33) Gy*	+0.24(+0.13, +0.41) Gy*	+0.04(-0.04, +0.21) Gy
	-2°	+0.18(+0.08, +0.37) Gy*	+0.04(-0.10, +0.13) Gy	+0.21(+0.10, +0.52) Gy*
	3°	+0.11(-0.04, +0.42) Gy*	+0.35(+0.23, +0.54) Gy*	+0.07(-0.04, +0.28) Gy*
	-3°	+0.23(+0.11, +0.48) Gy*	+0.07(-0.18, +0.11) Gy	+0.27(+0.16, +0.72) Gy*

\*Statistically significant change ( $p < 0.05$ )

Abbreviations:  $V_{Y\%}$  = the percentage volume receiving  $Y$  % of the prescribed dose,  $D_{\max/\min}(Z)$  = the minimum/maximum dose received by the volume  $Z$  that received the highest/lowest dose, pp = percentage point.

Table 4: Absolute changes in the heart and left anterior descending artery (LAD) dose-volume parameters in volumetric modulated arc therapy plans caused by rotational setup errors. Values are expressed as median (25th percentile, 75th percentile) of 20 plans.

Parameter and original value		pitch	yaw	roll
Heart mean dose 2.84(2.29, 3.26) Gy	1°	+0.04(+0.04, +0.11) Gy*	+0.00(-0.03, +0.00) Gy	-0.07(-0.11, -0.04) Gy*
	-1°	-0.08(-0.11, -0.04) Gy*	+0.00(-0.04, +0.04) Gy	+0.04(+0.02, +0.08) Gy*
	2°	+0.13(+0.09, +0.23) Gy*	+0.00(-0.04, +0.01) Gy	-0.12(-0.15, -0.08) Gy*
	-2°	-0.12(-0.16, -0.08) Gy*	+0.00(-0.04, +0.04) Gy	+0.13(+0.06, +0.20) Gy*
	3°	+0.23(+0.16, +0.42) Gy*	+0.00(-0.04, +0.04) Gy	-0.16(-0.20, -0.11) Gy*
	-3°	-0.18(-0.20, -0.12) Gy*	+0.01(-0.03, +0.08) Gy	+0.21(+0.12, +0.31) Gy*
Heart $D_{\max}(1\text{cm}^3)$ 11.58(8.85, 16.70) Gy	1°	+1.45(+0.84, +2.47) Gy*	+0.27(+0.11, +0.66) Gy*	-1.14(-1.75, -0.59) Gy*
	-1°	-1.53(-2.55, -0.84) Gy*	-0.24(-0.51, +0.08) Gy*	+0.96(+0.50, +1.45) Gy*
	2°	+3.42(+2.06, +5.28) Gy*	+0.75(+0.35, +1.38) Gy*	-1.87(-2.39, -0.92) Gy*
	-2°	-2.36(-4.46, -1.49) Gy*	-0.32(-0.94, +0.18) Gy*	+2.05(+1.01, +3.36) Gy*
	3°	+5.94(+3.58, +8.50) Gy*	+1.26(+0.64, +2.43) Gy*	-2.53(-3.34, -1.24) Gy*
	-3°	-3.27(-5.80, -1.88) Gy*	-0.36(-1.34, +0.44) Gy	+3.37(+1.76, +5.35) Gy*
LAD mean dose 5.35(4.36, 6.69) Gy	1°	+0.38(+0.12, +0.63) Gy*	+0.16(+0.08, +0.31) Gy*	-0.20(-0.31, -0.09) Gy*
	-1°	-0.33(-0.45, -0.11) Gy*	-0.14(-0.26, -0.08) Gy*	+0.17(+0.07, +0.36) Gy*
	2°	+0.98(+0.33, +1.44) Gy*	+0.22(+0.05, +0.45) Gy*	-0.34(-0.55, -0.14) Gy*
	-2°	-0.60(-0.74, -0.21) Gy*	-0.16(-0.31, -0.05) Gy*	+0.37(+0.13, +0.75) Gy*
	3°	+1.80(+0.64, +2.66) Gy*	+0.38(+0.14, +0.80) Gy*	-0.46(-0.71, -0.18) Gy*
	-3°	-0.79(-0.96, -0.29) Gy*	-0.20(-0.48, -0.09) Gy*	+0.55(+0.21, +1.16) Gy*
LAD $V_{15\text{Gy}}$ 0.00(0.00, 0.33) %	1°	+0.03(+0.00, +2.51) pp*	+0.00(+0.00, +0.37) pp*	+0.00(-0.22, +0.00) pp*
	-1°	+0.00(-0.33, +0.00) pp*	+0.00(-0.23, +0.00) pp*	+0.00(+0.00, +0.30) pp*
	2°	+0.78(+0.00, +7.84) pp*	+0.01(+0.00, +1.17) pp*	+0.00(-0.30, +0.00) pp*
	-2°	+0.00(-0.33, +0.00) pp*	+0.00(-0.29, +0.00) pp*	+0.15(+0.00, +1.44) pp*
	3°	+5.19(+0.00, +15.07) pp*	+0.16(+0.00, +2.47) pp*	+0.00(-0.33, +0.00) pp*
	-3°	+0.00(-0.33, +0.00) pp*	+0.00(-0.33, +0.00) pp*	+0.63(+0.00, +4.67) pp*
LAD $D_{\max}(1\text{cm}^3)$ 7.17(6.07, 9.71) Gy	1°	+0.57(+0.16, +1.30) Gy*	+0.19(+0.10, +0.58) Gy*	-0.31(-0.61, -0.15) Gy*
	-1°	-0.47(-0.97, -0.24) Gy*	-0.30(-0.57, -0.16) Gy*	+0.20(+0.09, +0.68) Gy*
	2°	+1.30(+0.57, +3.11) Gy*	+0.30(+0.05, +0.97) Gy*	-0.47(-1.10, -0.27) Gy*
	-2°	-0.78(-1.74, -0.45) Gy*	-0.36(-0.67, -0.12) Gy*	+0.49(+0.23, +1.41) Gy*
	3°	+2.53(+1.34, +5.78) Gy*	+0.45(+0.19, +1.66) Gy*	-0.62(-1.52, -0.36) Gy*
	-3°	-1.03(-2.17, -0.59) Gy*	-0.46(-0.97, -0.17) Gy*	+0.80(+0.45, +2.26) Gy*

\*Statistically significant change ( $p < 0.05$ )

Abbreviations:  $V_{X\text{Gy}}$  = the percentage volume receiving  $X$  Gy dose,  $D_{\max}(Z)$  = the minimum dose received by the volume  $Z$  that received the highest dose, pp = percentage point.

Table 5: Absolute changes in the heart and left anterior descending artery (LAD) dose-volume parameters in field-in-field plans caused by rotational setup errors. Values are expressed as median (25th percentile, 75th percentile) of 20 plans.

Parameter and original value		pitch	yaw	roll
Heart mean dose 1.56(1.30, 2.99) Gy	1°	+0.22(+0.13, +0.24) Gy*	+0.12(+0.08, +0.16) Gy*	-0.08(-0.14, -0.04) Gy*
	-1°	-0.15(-0.23, -0.12) Gy*	-0.08(-0.12, -0.04) Gy*	+0.08(+0.04, +0.12) Gy*
	2°	+0.48(+0.33, +0.55) Gy*	+0.22(+0.16, +0.28) Gy*	-0.12(-0.26, -0.08) Gy*
	-2°	-0.24(-0.42, -0.20) Gy*	-0.16(-0.23, -0.09) Gy*	+0.18(+0.09, +0.31) Gy*
	3°	+0.78(+0.61, +0.91) Gy*	+0.38(+0.25, +0.48) Gy*	-0.16(-0.40, -0.12) Gy*
	-3°	-0.34(-0.60, -0.28) Gy*	-0.24(-0.31, -0.12) Gy*	+0.26(+0.16, +0.46) Gy*
Heart $D_{\max}(1\text{cm}^3)$ 25.43(16.74, 33.88) Gy	1°	+2.94(+0.32, +5.47) Gy*	+2.17(+0.38, +3.18) Gy*	-0.54(-1.88, -0.11) Gy*
	-1°	-3.57(-6.07, -0.32) Gy*	-2.02(-2.75, -0.18) Gy*	+0.81(+0.15, +1.86) Gy*
	2°	+4.53(+0.78, +9.36) Gy*	+3.60(+0.65, +5.71) Gy*	-1.77(-4.22, -0.27) Gy*
	-2°	-5.93(-11.93, -0.61) Gy*	-4.14(-5.36, -0.58) Gy*	+1.21(+0.30, +3.91) Gy*
	3°	+5.44(+1.24, +11.24) Gy*	+4.68(+0.89, +7.94) Gy*	-2.79(-6.47, -0.39) Gy*
	-3°	-7.81(-15.82, -0.86) Gy*	-5.45(-8.00, -0.80) Gy*	+1.57(+0.46, +5.76) Gy*
LAD mean dose 10.25(4.38, 16.49) Gy	1°	+1.56(+0.67, +2.11) Gy*	+1.08(+0.61, +1.84) Gy*	-0.48(-1.03, -0.26) Gy*
	-1°	-0.90(-2.26, -0.35) Gy*	-0.50(-0.85, -0.08) Gy*	+0.50(+0.25, +0.94) Gy*
	2°	+3.44(+1.66, +4.43) Gy*	+1.60(+0.86, +2.43) Gy*	-0.94(-1.90, -0.42) Gy*
	-2°	-1.41(-4.31, -0.92) Gy*	-1.08(-2.34, -0.69) Gy*	+0.90(+0.58, +1.89) Gy*
	3°	+4.95(+2.13, +6.97) Gy*	+2.52(+1.36, +3.71) Gy*	-1.36(-2.72, -0.56) Gy*
	-3°	-2.25(-5.94, -1.26) Gy*	-1.50(-3.73, -0.89) Gy*	+1.50(+0.78, +2.97) Gy*
LAD $V_{15\text{Gy}}$ 26.14(2.28, 58.23) %	1°	+5.16(+1.82, +8.14) pp*	+3.13(+2.21, +7.11) pp*	-1.84(-3.63, -0.94) pp*
	-1°	-3.91(-7.94, -0.62) pp*	-1.81(-3.81, +0.00) pp*	+1.65(+0.71, +3.73) pp*
	2°	+10.49(+5.05, +19.20) pp*	+5.60(+1.63, +10.48) pp*	-3.54(-7.54, -1.54) pp*
	-2°	-6.09(-18.23, -1.60) pp*	-4.61(-8.32, -1.03) pp*	+3.72(+1.38, +6.92) pp*
	3°	+14.32(+5.60, +27.20) pp*	+10.26(+2.14, +15.08) pp*	-5.06(-11.42, -1.93) pp*
	-3°	-6.68(-28.11, -2.28) pp*	-5.48(-14.00, -1.74) pp*	+6.64(+1.65, +10.53) pp*
LAD $D_{\max}(1\text{cm}^3)$ 16.53(5.97, 29.64) Gy	1°	+1.35(+0.21, +4.41) Gy*	+0.69(+0.11, +2.71) Gy*	-0.72(-1.64, -0.24) Gy*
	-1°	-1.53(-4.72, -0.41) Gy*	-1.12(-3.12, -0.32) Gy*	+0.32(+0.11, +1.61) Gy*
	2°	+3.63(+0.38, +7.91) Gy*	+1.46(+0.18, +4.95) Gy*	-1.18(-3.31, -0.51) Gy*
	-2°	-3.12(-7.62, -0.82) Gy*	-2.19(-5.16, -0.62) Gy*	+0.84(+0.14, +2.85) Gy*
	3°	+6.04(+0.68, +11.90) Gy*	+2.35(+0.41, +6.98) Gy*	-1.68(-4.60, -0.65) Gy*
	-3°	-4.30(-9.94, -1.23) Gy*	-3.20(-6.16, -0.75) Gy*	+1.50(+0.19, +4.66) Gy*

\*Statistically significant change ( $p < 0.05$ )

Abbreviations:  $V_{X\text{Gy}}$  = the percentage volume receiving  $X$  Gy dose,  $D_{\max}(Z)$  = the minimum dose received by the volume  $Z$  that received the highest dose, pp = percentage point.



Table 6: Absolute changes in the lung dose-volume parameters in volumetric modulated arc therapy plans caused by rotational setup errors. Values are expressed as median (25th percentile, 75th percentile) of 20 plans.

Parameter and original value		pitch	yaw	roll
Left lung mean dose 9.61(8.87, 10.33) Gy	1°	-0.04(-0.11, +0.00) Gy*	+0.08(+0.04, +0.08) Gy*	+0.04(+0.04, +0.08) Gy
	-1°	+0.04(+0.01, +0.09) Gy*	-0.04(-0.07, +0.00) Gy*	-0.04(-0.08, -0.04) Gy*
	2°	-0.06(-0.16, -0.02) Gy*	+0.12(+0.05, +0.16) Gy*	+0.12(+0.08, +0.16) Gy*
	-2°	+0.10(+0.05, +0.16) Gy*	-0.08(-0.14, +0.00) Gy*	-0.08(-0.15, -0.08) Gy*
	3°	-0.10(-0.23, -0.04) Gy*	+0.16(+0.12, +0.26) Gy*	+0.16(+0.15, +0.24) Gy*
	-3°	+0.16(+0.07, +0.21) Gy*	-0.10(-0.20, -0.03) Gy*	-0.12(-0.23, -0.08) Gy*
Right lung mean dose 2.14(1.51, 2.74) Gy	1°	+0.00(+0.00, +0.00) Gy	-0.04(-0.08, -0.04) Gy*	-0.08(-0.08, -0.04) Gy*
	-1°	+0.00(+0.00, +0.00) Gy*	+0.04(+0.04, +0.08) Gy*	+0.08(+0.04, +0.08) Gy*
	2°	+0.00(+0.00, +0.00) Gy	-0.12(-0.15, -0.08) Gy*	-0.16(-0.19, -0.12) Gy*
	-2°	+0.00(-0.01, +0.00) Gy*	+0.12(+0.08, +0.12) Gy*	+0.16(+0.11, +0.19) Gy*
	3°	+0.00(+0.00, +0.01) Gy	-0.16(-0.20, -0.12) Gy*	-0.24(-0.24, -0.16) Gy*
	-3°	+0.00(-0.02, +0.00) Gy	+0.17(+0.12, +0.20) Gy*	+0.24(+0.17, +0.31) Gy*
Left lung $V_{5Gy}$ 51.66(46.17, 58.29)%	1°	-0.25(-0.51, -0.17) pp*	+0.42(+0.29, +0.55) pp*	+0.61(+0.41, +0.85) pp*
	-1°	+0.23(+0.16, +0.50) pp*	-0.42(-0.61, -0.29) pp*	-0.65(-0.94, -0.42) pp*
	2°	-0.48(-0.89, -0.34) pp*	+0.79(+0.49, +1.06) pp*	+1.27(+0.85, +1.89) pp*
	-2°	+0.46(+0.33, +0.90) pp*	-0.78(-0.99, -0.57) pp*	-1.24(-1.76, -0.86) pp*
	3°	-0.69(-1.31, -0.52) pp*	+1.20(+0.70, +1.60) pp*	+1.92(+1.28, +2.83) pp*
	-3°	+0.70(+0.49, +1.36) pp*	-1.16(-1.45, -0.83) pp*	-1.79(-2.55, -1.28) pp*
Left lung $V_{20Gy}$ 16.40(14.21, 18.66)%	1°	-0.08(-0.22, +0.01) pp*	+0.12(+0.00, +0.20) pp	+0.07(-0.09, +0.14) pp
	-1°	+0.10(-0.01, +0.22) pp*	-0.01(-0.16, +0.05) pp	-0.04(-0.15, +0.05) pp
	2°	-0.16(-0.38, -0.02) pp*	+0.15(-0.02, +0.35) pp*	+0.14(-0.12, +0.28) pp
	-2°	+0.19(+0.02, +0.37) pp*	-0.03(-0.28, +0.12) pp	-0.09(-0.26, +0.09) pp
	3°	-0.27(-0.50, -0.07) pp*	+0.22(+0.02, +0.55) pp*	+0.20(-0.14, +0.45) pp
	-3°	+0.27(+0.06, +0.53) pp*	-0.04(-0.41, +0.20) pp	-0.14(-0.36, +0.15) pp

\*Statistically significant change ( $p < 0.05$ )

Abbreviations:  $V_{XGy}$  = the percentage volume receiving  $X$  Gy dose, pp = percentage point.

Table 7: Absolute changes in the lung dose-volume parameters in field-in-field plans caused by rotational setup errors. Values are expressed as median (25th percentile, 75th percentile) of 20 plans.

Parameter and original value		pitch	yaw	roll
Left lung mean dose 11.35(9.38, 13.35) Gy	1°	+0.12(+0.08, +0.19) Gy*	+0.16(+0.12, +0.23) Gy*	+0.04(+0.04, +0.11) Gy*
	-1°	-0.08(-0.12, -0.04) Gy*	-0.08(-0.12, -0.04) Gy*	+0.00(-0.08, +0.04) Gy
	2°	+0.22(+0.12, +0.32) Gy*	+0.28(+0.20, +0.43) Gy*	+0.10(+0.04, +0.16) Gy*
	-2°	-0.20(-0.27, -0.08) Gy*	-0.20(-0.31, -0.12) Gy*	-0.04(-0.15, +0.04) Gy*
	3°	+0.34(+0.20, +0.44) Gy*	+0.42(+0.32, +0.63) Gy*	+0.14(+0.05, +0.24) Gy*
	-3°	-0.30(-0.40, -0.16) Gy*	-0.32(-0.50, -0.20) Gy*	-0.08(-0.23, +0.03) Gy*
Right lung mean dose 0.58(0.49, 0.80) Gy	1°	+0.00(+0.00, +0.00) Gy	-0.04(-0.04, +0.00) Gy*	+0.00(+0.00, +0.00) Gy
	-1°	+0.00(+0.00, +0.00) Gy	+0.04(+0.00, +0.04) Gy*	+0.00(+0.00, +0.04) Gy
	2°	+0.00(+0.00, +0.03) Gy	-0.04(-0.07, -0.04) Gy*	+0.00(-0.03, +0.00) Gy
	-2°	+0.00(+0.00, +0.00) Gy	+0.04(+0.04, +0.08) Gy*	+0.00(+0.00, +0.04) Gy
	3°	+0.00(+0.00, +0.03) Gy	-0.08(-0.08, -0.04) Gy*	+0.00(+0.00, +0.04) Gy
	-3°	+0.00(+0.00, +0.03) Gy	+0.08(+0.04, +0.12) Gy*	+0.00(+0.00, +0.08) Gy*
Left lung $V_{5\text{Gy}}$ 44.06(38.89, 48.76) %	1°	+0.13(+0.04, +0.25) pp*	+0.37(+0.30, +0.49) pp*	+0.28(+0.20, +0.36) pp*
	-1°	-0.13(-0.28, -0.03) pp*	-0.33(-0.48, -0.20) pp*	-0.28(-0.36, -0.19) pp*
	2°	+0.28(+0.11, +0.49) pp*	+0.69(+0.57, +0.94) pp*	+0.53(+0.36, +0.69) pp*
	-2°	-0.25(-0.61, -0.06) pp*	-0.59(-0.90, -0.45) pp*	-0.55(-0.72, -0.40) pp*
	3°	+0.43(+0.14, +0.76) pp*	+1.07(+0.85, +1.46) pp*	+0.79(+0.51, +1.04) pp*
	-3°	-0.35(-0.94, -0.13) pp*	-0.89(-1.33, -0.63) pp*	-0.82(-1.07, -0.61) pp*
Left lung $V_{20\text{Gy}}$ 25.83(20.64, 31.54) %	1°	+0.37(+0.18, +0.48) pp*	+0.37(+0.23, +0.54) pp*	+0.02(-0.02, +0.17) pp
	-1°	-0.35(-0.45, -0.17) pp*	-0.25(-0.42, -0.16) pp*	+0.03(-0.13, +0.09) pp
	2°	+0.72(+0.35, +0.91) pp*	+0.65(+0.40, +0.98) pp*	+0.03(-0.05, +0.27) pp
	-2°	-0.70(-0.91, -0.37) pp*	-0.54(-0.84, -0.32) pp*	+0.00(-0.25, +0.17) pp
	3°	+1.04(+0.49, +1.39) pp*	+1.00(+0.60, +1.48) pp*	+0.02(-0.08, +0.37) pp
	-3°	-1.00(-1.38, -0.58) pp*	-0.81(-1.28, -0.50) pp*	+0.01(-0.39, +0.23) pp

\*Statistically significant change ( $p < 0.05$ )

Abbreviations:  $V_{X\text{Gy}}$  = the percentage volume receiving  $X$  Gy dose, pp = percentage point.

Table 8: Absolute changes in the right breast, spinal cord, left brachial plexus, thyroid and left humeral head dose-volume parameters in volumetric modulated arc therapy plans caused by rotational setup errors. Values are expressed as median (25th percentile, 75th percentile) of 20 plans.

Parameter and original value		pitch	yaw	roll
Right breast mean dose 4.17(3.54, 5.72) Gy	1°	-0.04(-0.07, +0.00) Gy*	-0.12(-0.17, -0.08) Gy*	-0.26(-0.39, -0.20) Gy*
	-1°	-0.04(-0.08, -0.01) Gy*	+0.07(+0.01, +0.12) Gy*	+0.24(+0.20, +0.32) Gy*
	2°	+0.00(-0.04, +0.04) Gy	-0.24(-0.30, -0.12) Gy*	-0.53(-0.67, -0.37) Gy*
	-2°	-0.08(-0.15, -0.04) Gy*	+0.16(+0.12, +0.27) Gy*	+0.60(+0.48, +0.67) Gy*
	3°	+0.01(-0.03, +0.08) Gy	-0.32(-0.42, -0.20) Gy*	-0.71(-0.92, -0.50) Gy*
	-3°	-0.10(-0.13, -0.04) Gy*	+0.28(+0.20, +0.40) Gy*	+0.94(+0.77, +1.08) Gy*
Right breast $V_{2Gy}$ 72.21(49.88, 84.03)%	1°	-0.36(-0.87, +0.02) pp*	-1.38(-1.70, -0.74) pp*	-2.54(-3.16, -1.64) pp*
	-1°	-0.37(-0.78, +0.01) pp*	+0.64(-0.01, +0.94) pp*	+1.58(+1.25, +2.31) pp*
	2°	-0.21(-0.57, -0.02) pp*	-2.09(-3.10, -1.42) pp*	-4.79(-6.14, -3.27) pp*
	-2°	-0.68(-1.10, +0.03) pp*	+1.26(+0.59, +1.79) pp*	+3.64(+2.88, +4.62) pp*
	3°	-0.08(-0.53, +0.05) pp	-2.85(-4.50, -1.69) pp*	-6.92(-8.84, -4.37) pp*
	-3°	-0.56(-1.13, +0.00) pp*	+2.27(+1.36, +3.48) pp*	+5.83(+4.14, +7.55) pp*
Spinal cord $D_{max}(1cm^3)$ 15.55(11.89, 17.52) Gy	1°	-0.11(-0.19, -0.02) Gy*	-0.36(-0.45, -0.26) Gy*	+0.13(-0.03, +0.24) Gy*
	-1°	+0.04(-0.02, +0.17) Gy*	+0.30(+0.22, +0.46) Gy*	-0.15(-0.25, -0.03) Gy*
	2°	-0.19(-0.34, -0.03) Gy*	-0.75(-0.85, -0.54) Gy*	+0.25(-0.05, +0.56) Gy*
	-2°	+0.11(+0.03, +0.35) Gy*	+0.61(+0.42, +0.94) Gy*	-0.31(-0.48, -0.07) Gy*
	3°	-0.28(-0.51, +0.01) Gy*	-1.07(-1.25, -0.80) Gy*	+0.32(-0.08, +0.78) Gy*
	-3°	+0.17(+0.04, +0.57) Gy*	+0.85(+0.64, +1.41) Gy*	-0.40(-0.73, -0.19) Gy*
Brachial plexus $D_{max}(1cm^3)$ 40.81(40.45, 41.04) Gy	1°	+0.16(+0.09, +0.21) Gy*	+0.22(+0.19, +0.25) Gy*	+0.01(-0.07, +0.13) Gy
	-1°	-0.07(-0.13, +0.00) Gy*	-0.16(-0.22, -0.14) Gy*	+0.05(-0.03, +0.10) Gy
	2°	+0.33(+0.16, +0.45) Gy*	+0.45(+0.38, +0.55) Gy*	+0.02(-0.07, +0.33) Gy
	-2°	-0.19(-0.29, -0.02) Gy*	-0.34(-0.42, -0.22) Gy*	+0.09(-0.04, +0.17) Gy
	3°	+0.43(+0.22, +0.67) Gy*	+0.65(+0.56, +0.86) Gy*	+0.05(-0.12, +0.54) Gy
	-3°	-0.29(-0.43, -0.09) Gy*	-0.51(-0.62, -0.35) Gy*	+0.14(-0.05, +0.23) Gy*
Thyroid mean dose 16.27(14.24, 18.45) Gy	1°	+0.10(-0.03, +0.36) Gy	-0.64(-0.99, -0.36) Gy*	+0.30(+0.12, +0.55) Gy*
	-1°	-0.06(-0.35, +0.04) Gy	+0.62(+0.37, +0.86) Gy*	-0.28(-0.56, -0.12) Gy*
	2°	+0.30(+0.01, +0.89) Gy*	-1.32(-1.96, -0.83) Gy*	+0.60(+0.21, +1.20) Gy*
	-2°	-0.08(-0.75, +0.22) Gy	+1.38(+0.76, +1.78) Gy*	-0.54(-1.12, -0.19) Gy*
	3°	+0.50(-0.08, +1.42) Gy*	-1.98(-2.67, -1.15) Gy*	+1.02(+0.41, +1.83) Gy*
	-3°	-0.18(-1.13, +0.31) Gy	+1.96(+1.06, +2.58) Gy*	-0.70(-1.65, -0.22) Gy*
Left humeral head $V_{15Gy}$ 16.14(2.76, 30.15)%	1°	+2.58(+1.37, +3.63) pp*	-0.13(-1.17, +0.12) pp	-0.36(-0.90, -0.12) pp*
	-1°	-2.59(-3.71, -1.07) pp*	+0.22(-0.20, +1.29) pp	+0.46(+0.16, +1.24) pp*
	2°	+5.31(+2.56, +6.46) pp*	-0.78(-2.73, -0.26) pp*	-0.65(-1.54, -0.21) pp*
	-2°	-4.31(-5.74, -1.40) pp*	+1.53(+0.86, +2.99) pp*	+0.94(+0.40, +2.83) pp*
	3°	+8.03(+4.86, +10.36) pp*	-0.88(-3.54, -0.29) pp*	-0.92(-2.18, -0.28) pp*
	-3°	-6.26(-8.96, -1.69) pp*	+2.21(+0.72, +5.09) pp*	+1.43(+0.62, +4.93) pp*

\*Statistically significant change ( $p < 0.05$ )

Abbreviations:  $V_{XGy}$  = the percentage volume receiving  $X$  Gy dose,  $D_{max}(Z)$  = the minimum dose received by the volume  $Z$  that received the highest dose, pp = percentage point.

Table 9: Absolute changes in the right breast, spinal cord, left brachial plexus, thyroid and left humeral head dose-volume parameters in field-in-field plans caused by rotational setup errors. Values are expressed as median (25th percentile, 75th percentile) of 20 plans.

Parameter and original value		pitch	yaw	roll
Right breast mean dose 1.34(0.49, 1.92) Gy	1°	+0.04(+0.00, +0.08) Gy*	-0.04(-0.04, +0.00) Gy*	-0.14(-0.35, -0.08) Gy*
	-1°	-0.08(-0.16, -0.04) Gy*	+0.00(-0.03, +0.00) Gy	+0.14(+0.08, +0.28) Gy*
	2°	+0.12(+0.04, +0.19) Gy*	-0.04(-0.11, +0.00) Gy*	-0.26(-0.59, -0.12) Gy*
	-2°	-0.12(-0.27, -0.05) Gy*	+0.00(-0.03, +0.04) Gy	+0.32(+0.16, +0.67) Gy*
	3°	+0.20(+0.08, +0.32) Gy*	-0.04(-0.15, +0.00) Gy*	-0.32(-0.76, -0.13) Gy*
	-3°	-0.16(-0.36, -0.09) Gy*	+0.00(-0.03, +0.07) Gy	+0.58(+0.29, +1.11) Gy*
Right breast $V_{2Gy}$ 8.92(2.88, 13.72) %	1°	+0.19(+0.02, +0.38) pp*	-0.26(-0.42, -0.02) pp*	-1.07(-1.72, -0.49) pp*
	-1°	-0.60(-0.94, -0.32) pp*	-0.15(-0.31, +0.09) pp	+0.67(+0.47, +1.21) pp*
	2°	+0.63(+0.27, +1.11) pp*	-0.30(-0.43, +0.03) pp*	-1.85(-2.86, -0.85) pp*
	-2°	-1.11(-1.37, -0.55) pp*	-0.10(-0.35, +0.13) pp	+1.81(+1.09, +3.02) pp*
	3°	+1.11(+0.54, +1.95) pp*	-0.30(-0.61, +0.06) pp*	-2.51(-3.64, -1.07) pp*
	-3°	-1.58(-1.81, -0.65) pp*	-0.05(-0.45, +0.19) pp	+3.19(+1.91, +4.84) pp*
Spinal cord $D_{max}(1cm^3)$ 10.73(9.91, 11.87) Gy	1°	+0.00(-0.06, +0.03) Gy	-0.16(-0.29, -0.09) Gy*	+0.37(+0.16, +0.90) Gy*
	-1°	-0.01(-0.04, +0.01) Gy	+0.20(+0.07, +0.46) Gy*	-0.25(-0.56, -0.14) Gy*
	2°	+0.01(-0.08, +0.07) Gy	-0.33(-0.53, -0.17) Gy*	+1.11(+0.32, +2.49) Gy*
	-2°	-0.01(-0.08, +0.05) Gy	+0.39(+0.17, +0.82) Gy*	-0.45(-0.92, -0.24) Gy*
	3°	+0.00(-0.12, +0.12) Gy	-0.48(-0.73, -0.26) Gy*	+2.43(+0.54, +5.15) Gy*
	-3°	-0.02(-0.13, +0.08) Gy	+0.66(+0.28, +1.40) Gy*	-0.60(-1.17, -0.32) Gy*
Brachial plexus $D_{max}(1cm^3)$ 40.73(39.91, 41.27) Gy	1°	+0.03(-0.03, +0.11) Gy	+0.01(+0.00, +0.03) Gy	+0.00(-0.04, +0.02) Gy
	-1°	-0.04(-0.10, +0.00) Gy*	-0.02(-0.04, +0.00) Gy*	+0.00(-0.02, +0.05) Gy
	2°	+0.08(+0.01, +0.23) Gy*	+0.03(-0.02, +0.05) Gy	-0.03(-0.08, +0.03) Gy
	-2°	-0.09(-0.22, +0.05) Gy*	-0.02(-0.08, +0.02) Gy	+0.01(-0.04, +0.11) Gy
	3°	+0.12(-0.02, +0.36) Gy*	+0.01(-0.05, +0.08) Gy	-0.04(-0.12, +0.05) Gy
	-3°	-0.09(-0.33, +0.04) Gy	-0.01(-0.11, +0.03) Gy	+0.03(-0.07, +0.18) Gy
Thyroid mean dose 16.72(12.90, 19.26) Gy	1°	+0.12(+0.06, +0.24) Gy*	-0.30(-0.56, -0.07) Gy*	+0.32(+0.21, +0.39) Gy*
	-1°	-0.16(-0.23, -0.08) Gy*	+0.16(-0.03, +0.49) Gy	-0.36(-0.47, -0.21) Gy*
	2°	+0.36(+0.16, +0.47) Gy*	-0.52(-1.01, -0.15) Gy*	+0.70(+0.38, +0.91) Gy*
	-2°	-0.32(-0.47, -0.16) Gy*	+0.40(+0.05, +0.79) Gy*	-0.64(-0.79, -0.40) Gy*
	3°	+0.50(+0.23, +0.72) Gy*	-0.68(-1.45, -0.29) Gy*	+1.04(+0.74, +1.50) Gy*
	-3°	-0.46(-0.84, -0.29) Gy*	+0.48(-0.04, +1.31) Gy*	-0.96(-1.22, -0.63) Gy*
Left humeral head $V_{15Gy}$ 12.74(2.57, 21.21) %	1°	+2.64(+1.40, +3.55) pp*	-0.51(-0.94, -0.06) pp*	-0.62(-1.35, -0.28) pp*
	-1°	-2.41(-3.71, -1.05) pp*	+0.39(+0.00, +1.10) pp*	+0.64(+0.19, +1.30) pp*
	2°	+4.21(+2.43, +6.45) pp*	-1.70(-3.48, -0.42) pp*	-1.22(-2.56, -0.50) pp*
	-2°	-3.63(-5.41, -1.67) pp*	+1.93(+0.76, +3.74) pp*	+1.36(+0.45, +2.69) pp*
	3°	+6.83(+4.50, +9.73) pp*	-1.96(-4.49, -0.57) pp*	-1.71(-3.85, -0.68) pp*
	-3°	-5.34(-9.36, -2.14) pp*	+2.87(+0.99, +5.27) pp*	+2.22(+0.70, +4.18) pp*

\*Statistically significant change ( $p < 0.05$ )

Abbreviations:  $V_{XGy}$  = the percentage volume receiving  $X$  Gy dose,  $D_{max}(Z)$  = the minimum dose received by the volume  $Z$  that received the highest dose, pp = percentage point.