Heart and coronary artery doses from breast radiotherapy

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Background

Long-term follow-up of women irradiated for breast cancer has shown that past breast radiotherapy regimens have increased the risk of death from heart disease. The relationship between this risk and radiation dose to the heart can be assessed using detailed dosimetry. This can be used to derive a dose-response relationship.

Methods

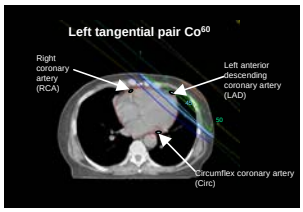
1. A technique based on virtual simulation and CT-based 3-dimensional treatment planning has been used to reconstruct a large number of breast radiotherapy regimens used since the 1950s on one representative patient. Manual planning techniques have been used to derive dose distributions for 250 keV regimens and iridium wire implants. For each treatment plan, dose-volume histograms were generated. Estimations of dose to the heart and to each of the three main coronary arteries were performed.
2. Sources of variability associated with these methods were identified and quantified.
3. These cardiac doses have been applied to women irradiated in the Early Breast Cancer Trialists' overview of individual patient data. This includes around 30,000 women in 64 trials of radiotherapy for early breast cancer for whom cause of death is known. This has enabled characterization of the relationship between radiation dose to the heart and death from heart disease.
4. For comparison with contemporary breast radiotherapy, heart and coronary artery doses were assessed for 55 patients who received left tangential irradiation in Leeds, UK in 2006.

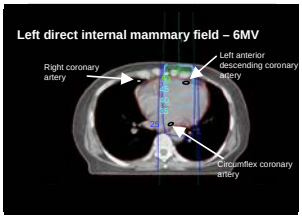
Results

1. Breast radiotherapy techniques from 1950s onwards

Radiation fields that were used to treat the internal mammary lymph nodes generally gave rise to the highest heart doses, particularly for photon irradiation. The table below summarises doses from two commonly used breast radiotherapy techniques, for left-sided irradiation. Dose distributions for megavoltage left tangential and left direct internal mammary irradiation are also illustrated by CT plans (isodoses refer to dose in Gray).

Target	Field arrangement	Beam energy	Typical dose	Mean dose (Gy)			
				Heart	LAD	RCA	Circ
Left chest wall/ breast	Tangential pair	6MV	50 Gy in 25	4.7	21.9	2.0	2.8
		Co-60	50 Gy in 25	4.7	21.8	1.7	2.7
		250 kev	42 Gy in 20	14	51	11	8
Left IMC	Direct anterior	6MV	50 Gy in 25	16.7	25.1	6.2	15.5
		Co-60	50 Gy in 25	15.0	22.7	6.5	13.5
		Elec (10 Mev)	50 Gy in 25	2.7	6.4	4.6	0.8
		250 kev	50 Gy in 25	13	23	7	10

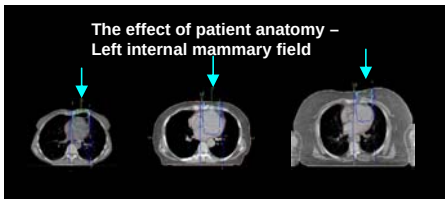




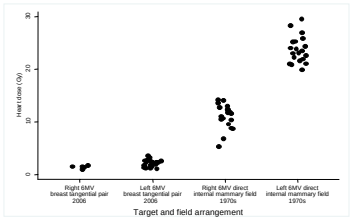
2. Assessment of uncertainties in the dosimetry methods

The following sources of uncertainty were assessed:

- Variability in patient anatomy.
- Patient position.
- Difficulty identifying skin and bony landmarks on virtual simulator.
- Variability in the use of bolus.
- FSD and SSD variability.
- Uncertainties involved in hand planning.
- CT planning and virtual simulator inaccuracies.

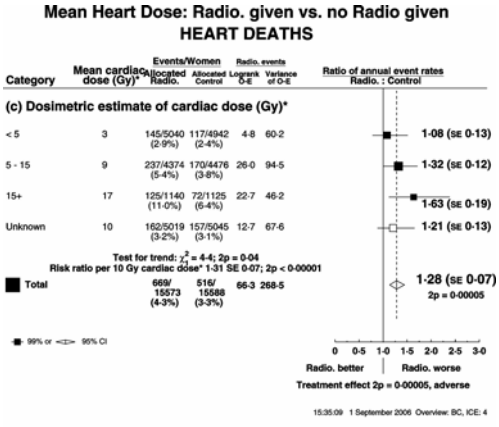


In order to quantify the effect of patient anatomy on heart dose, two techniques were set up on 20 different patients.



3. Dose-response relationship

For each woman in the Early Breast Cancer Trialists' overview, mean dose to the heart was calculated. Women were divided into high (15+ Gy), medium (5-15 Gy) and low (<5 Gy) dose categories. There is a significant relationship between increasing dose to the heart and risk of death from heart disease. The relative risk of cardiac death per 10 Gy, from these data, is 1.31 (see forest plot opposite).



4. Heart dose from contemporary radiotherapy

Year	Mean dose (Gy)			
	Heart	Left anterior descending artery	Right coronary artery	Circumflex coronary artery
1970s	13.3	31.8	9.1	6.9
1990s	4.7	21.9	2.0	2.8
2006	2.3	7.6	2.0	1.2

Dose to the heart has reduced over the past four decades. This table shows the difference in heart and coronary artery doses from 1970s, 1990s and 2006 left tangential pair radiotherapy.

Conclusions

- Virtual simulation and CT planning enable the measurement of detailed, accurate estimates of radiation dose to the heart and coronary arteries
- The main source of variability in these dose estimates concerns the effect of patient anatomy, however there is greater variation in heart dose between between different regimens than between individual patients
- Application of these doses to patients treated in the Early Breast Cancer Trialists' overview has demonstrated a significant relationship between mean radiation dose to the heart and risk of death from heart disease, with a risk ratio of 1.31 per 10 Gy mean heart dose.
- Radiation dose to the heart from left tangential pair radiotherapy has reduced over the past four decades