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Original article

Prone left-sided whole-breast irradiation: Significant heart dose reduction using end-inspiratory versus end-expiratory gating

Irradiation du sein gauche en procubitus : le gating inspiratoire réduit significativement la dose cardiaque

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ABSTRACT

Purpose. – To quantify the influence on heart dose metrics of prone left-sided whole-breast irradiation in an end-inspiratory phase (Pr_{IN}) versus an end-expiratory phase (Pr_{EX}).
Patients and methods. – Twenty patients underwent CT-simulation in Pr_{IN} and Pr_{EX}. Dynamic intensity-modulated radiotherapy was planned for whole-breast irradiation with a median prescription dose of 40.05 Gy in 15 fractions and maximal sparing of the organs at risk. Dose–volume parameters were analyzed for heart, left anterior descending coronary artery, ipsilateral lung and both breasts.
Results. – Pr_{IN} consistently reduced ($P < 0.001$) heart and left anterior descending coronary artery dose metrics compared to Pr_{EX}. Population averages for maximum and mean heart dose were 6.2 Gy and 1.3 Gy for Pr_{IN} versus 21.4 Gy and 2.5 Gy for Pr_{EX}, respectively. Moreover, a maximum heart dose less than 10 Gy was achieved in 80% of patients for Pr_{IN}. Target dose distribution, ipsilateral lung and contralateral breast sparing by radiation dose were similar for both procedures.
Conclusions. – Inspiratory gating consistently reduced heart dose metrics pointing to a possible benefit of breathing-adapted radiotherapy for prone left-sided whole-breast irradiation.

RÉSUMÉ

Objectif de l'étude. – Quantifier les changements dosimétriques lors de l'irradiation du sein gauche en entier en procubitus entre la phase de fin d'inspiration et celle de fin d'expiration.
Patientes et méthodes. – Vingt patientes ont eu une scanographie de simulation en procubitus lors d'un *gating* inspiratoire puis expiratoire. Une radiothérapie conformationelle avec modulation de l'intensité a été planifiée, avec une dose de prescription médiane de 40,05 Gy en 15 fractions et une épargne maximale des structures saines. Les paramètres des histogrammes dose–volume ont été analysés pour le cœur, l'artère coronaire gauche antérieure, le poumon homolatéral et les deux seins.
Résultats. – En procubitus, les doses au cœur et à l'artère coronaire gauche antérieure étaient significativement réduites ($p < 0{,}001$) par le *gating* inspiratoire par rapport à la phase expiratoire. La moyenne pour la population des doses cardiaques maximum et moyennes étaient respectivement de 6,2 Gy et 1,3 Gy pour le *gating* inspiratoire contre 21,4 Gy et 2,5 Gy pour le *gating* expiratoire. De plus, une dose cardiaque maximale inférieure à 10 Gy a pu être obtenue chez 80 % des patientes avec le *gating* inspiratoire. La distribution de dose, l'épargne du poumon homolatéral et du sein contralatéral étaient similaires pour les deux procédures.

Mots clés :
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Conclusion. – Lors de l'irradiation du sein gauche en procubitus, le *gating* inspiratoire réduit significativement la dose cardiaque, indiquant un bénéfice potentiel de la radiothérapie asservie à la respiration dans cette position.

1. Introduction

Prone whole-breast irradiation might provide advantages compared to "the standard" supine position since it causes the breast to fall away from the chest wall enabling less intrathoracic irradiation. Recent data indeed support its superiority for lung sparing [1–8]. Moreover, Formenti et al. observed that 85% of left-sided patients benefited from prone whole-breast irradiation concerning heart sparing by individual prone-supine comparison [8].

Respiration causes a displacement of intrathoracic organs and chest wall/breast region. In supine position, inspiration compared to expiration expands the thoracic cavity and therefore shifts the anterior chest wall/breast region into an anterolateral direction; moreover, it contracts the diaphragm causing the heart to be displaced caudally. These anatomical modifications enlarge the distance between heart and the irradiated region, being the origin of breathing-adapted whole-breast irradiation in supine position [9–24].

The respiration-related effects on heart dose metrics of prone whole-breast irradiation are unknown. This trial aims to quantify dosimetric differences on heart dose metrics of prone whole-breast irradiation in end-inspiratory phase (Pr_{IN}) versus an end-expiratory phase (Pr_{EX}).

2. Patients and methods

2.1. Patients

The ethics committee of Clinique et maternité Sainte-Élisabeth (CMSE, Namur, Belgium) approved this study. Twenty early-stage left-sided breast cancer patients, addressed for radiation therapy after breast conserving surgery, were included after informed written consent. Patient characteristics are illustrated in Table 1.

2.2. Simulation

Demonstration and practicing of the oral repetitive breathing cycles was done before starting the procedure. Prone positioning was performed using a unilateral breast holder to retract the heterolateral breast from the treated site on a modified prone-breast board fabricated by Orfit Industries (Wijnegem, Belgium) [3]. A Varian Real-time Position Management system (RPM™) was positioned on the dorsum of the thorax to evaluate breathing cycles and to gate the CT scan acquisition. Fig. 1 shows the RPM™ placement in the prone position and windowing in the end-inspiratory phase. Since these RPM™ curves were visually too superficial in shallow breathing, the patients were asked to perform repetitive deeper breaths and verbal feedback was given to the patients. The patients had no tools to check their own breathing curves. The 75–80% breathing range was selected as the lower limit of the end-inspiratory phase and the 10–15% as the upper limit of the end-expiratory phase. First, the Pr_{IN} sequential CT-data acquisition was performed afterwards the Pr_{EX} using a dedicated LightSpeed® RT 16 large bore CT scanner (General Electric healthcare, Little Chalfont, Buckinghamshire, UK), with a slice thickness of 2.5 mm. Scan range, nor CT-parameters, nor patient positioning were altered between Pr_{IN} and Pr_{EX}; but only the gated window for CT-scanning. An additional free breathing scan in prone position was not performed to avoid supplemental radiation dose to these patients who already accepted this study with two prone CT-scans while treated in supine position. Fig. 2 demonstrates the anatomical modifications of the end-inspiratory versus the end-expiratory phase in prone position.

Table 1
Patient characteristics.
Caractéristiques des patients.

Patient	Age (years)	Body mass index	$V_{PTVoptim}$ (mL)		V_{lungs} (mL)	
			Pr_{EX}	Pr_{IN}	Pr_{EX}	Pr_{IN}
1	25	23	457	463	3313	4352
2	61	24	806	807	3261	4631
3	48	20	333	338	3400	5168
4	49	18	394	403	3720	4526
5	56	24	886	863	2914	3522
6	54	27	599	609	3077	4057
7	49	30	1129	1128	4418	5662
8	67	24	758	767	2640	3458
9	74	25	593	598	3444	3989
10	40	25	889	869	2371	4799
11	55	24	571	529	4149	5480
12	79	35	965	934	2294	3394
13	48	27	433	453	3900	5428
14	38	21	351	357	3162	4246
15	66	35	956	959	2632	3482
16	44	26	459	466	3705	4686
17	48	22	375	385	2401	3241
18	71	28	998	960	2707	4457
19	56	30	752	764	2575	2867
20	67	28	1316	1287	3934	5340

VPTVoptim: planning target for optimization volume; Vlungs: lungs volume; PrIN: prone postioning in the end-inspiratory phase; PrEX: prone positioning in the end-expiratory phase.