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Technical Note

# Pancreatic tumor motion reduction by use of a custom abdominal corset

H.D. Heerkens [a,*], O. Reerink [b], M.P.W. Intven [a], R.R. Hiensch [c], C.A.T. van den Berg [a], S.P.M. Crijns [a], M. van Vulpen [a], G.J. Meijer [a]

[a] Department of Radiation Oncology, University Medical Center Utrecht, The Netherlands
[b] Department of Radiation Oncology, Isala Clinic, Zwolle, The Netherlands
[c] Department of Surgery, University Medical Center Utrecht, The Netherlands

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ABSTRACT

We studied the influence of a custom abdominal corset on cine MRI based pancreatic tumor motion. All patients were imaged twice; once without the corset, and once with the corset in place. Craniocaudal motion decreased on average by 4.1 mm, from 11.3 to 7.2 mm. No effects of the corset were observed in anteroposterior and lateral directions. The efficacy of the abdominal corset in combination with its simplicity, the low manufacturing costs and the good tolerance makes this an easy way to decrease motion. This might open the way to safer dose escalation when treating patients under free breathing conditions.



## 1. Introduction

Stereotactic radiotherapy (SBRT) has been explored for unresectable pancreatic cancer in several studies [1–6]. In these studies, a high dose was stereotactically delivered over a few fractions. Hence, accurate tumor positioning is essential. In pancreatic cancer patients this is hampered by the substantial breathing induced tumor motion. Particularly in craniocaudal direction, tumor motions of 15 mm to 24 mm have been observed [7–9]. By decreasing tumor motion, accuracy can be increased and this reduces the magnitude of motion induced treatment margins.

We developed a custom abdominal corset to reduce breathing induced tumor motion. The hypothesis is that the application of the corset decreases pancreatic tumor motion as a result of more shallow abdominal breathing. Therefore, the goal of this study was to investigate the pancreatic tumor motion reduction as measured with cine MRI with application of the custom abdominal corset.

## 2. Methods and materials

### 2.1. Patients

This study was part of a phase II trial investigating feasibility and safety of stereotactic radiotherapy for unresectable pancreatic cancer patients. Locally advanced pancreatic cancer was defined by the Dutch Pancreatic Cancer Group (DPCG, 2012). Patients without evidence of distant metastases, ECOG performance score ≤2, life expectancy of ≥3 months, age ≥18 years, no previous neoadjuvant chemotherapy or pancreatic surgery, and eligible for contrast enhanced CT and MRI imaging were included. The trial was approved by our local institutional review board and registered at www.clinicaltrials.gov (NCT01898741). All patients provided informed consent.

### 2.2. Corset

The Neofrakt® corset consists of a polyurethane soft foam and an elastic stocking as bandage surface (Neofrakt®, Spronken Orthopedie NV, Genk, Belgium), see also Fig. 1A. The abdominal corset was applied in soft condition. The corset was shaped in soft condition around the lumbar spine, where it will harden on the body. The lower ribs were left out to promote chest breathing and reduce abdominal breathing. No specific breathing instructions were provided to the patients, to obtain a reproducible, unaware and relaxed breathing pattern. Tightening to the patient was performed with the Velcro fasteners in a way that it was tight but still reasonable comfortable. The Velcro fastener settings were marked by pen. Distances from corset borders to tattoo points were noted.

Absorption of the corset was measured with a beam angle of 180 degrees and a field size of 10 by 10 cm. The effect of the corset on skin dose was quantified for a 10 MV photon beam calibrated at 20 mm depth.

* Corresponding author at: Department of Radiotherapy, University Medical Center Utrecht, Heidelberglaan 100, 3584 CX Utrecht, The Netherlands.
E-mail address: h.heerkens@umcutrecht.nl (H.D. Heerkens).

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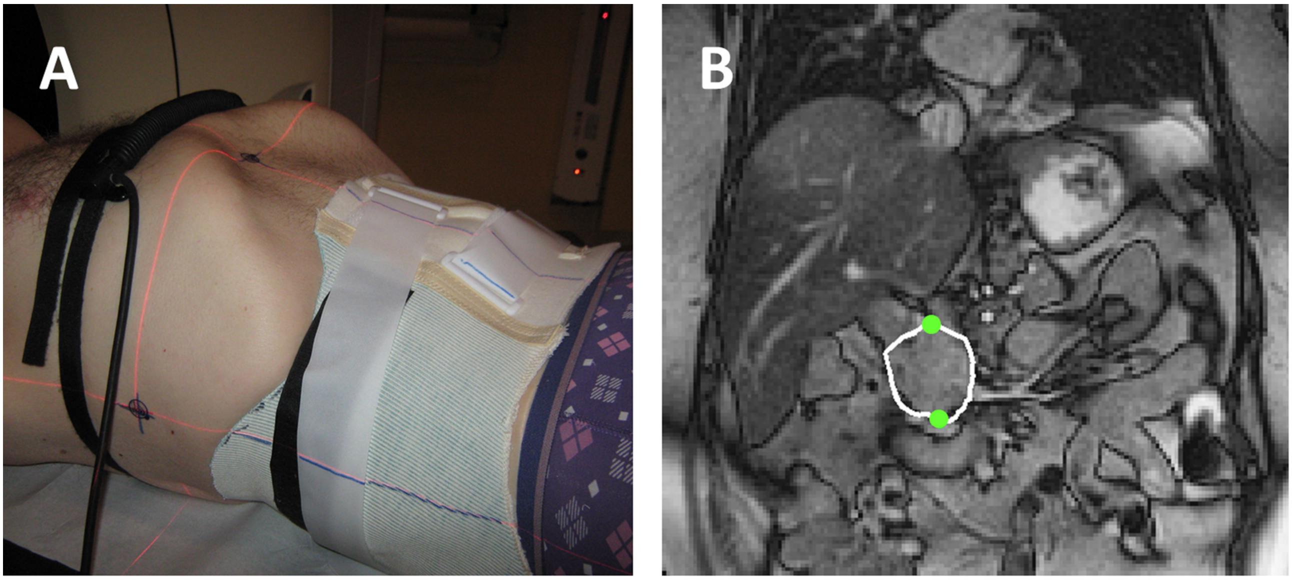


**Fig. 1.** A: patient positioning with corset in place. Note the aligning based on laser. B: example of coronal cine MRI image. The white line represents the tumor. The green dots are followed in time. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

### 2.3. Image acquisition

MRI scanning was performed on a 1.5 Tesla scanner (Achieva, Philips, Best, The Netherlands) using a 16 channel phased array torso coil. Patients drank 300 ml of tap water to increase contrast between pancreas and duodenum and to minimize upper intestinal air, directly prior to MRI scanning. All patients underwent cine-MRI scanning twice, the first scan without the corset in place and the second scan with the corset. The second cine-MRI was scheduled on the same day as the treatment planning CT and MRI. Both MRIs were scheduled before radiation treatment. Gold fiducial markers were placed in the tumor during an endoscopic ultrasound guided procedure between the two MRI scans ($0.4 \times 5$ mm gold fiducial marker, QLRAD Inc., Miami, USA or $0.35 \times 10$ mm Visicoil, IBA Dosimetry, Schwarzenbruck, Germany).

A respiratory triggered axial T2 weighted image was acquired. On this scan the single slice SSFP sequence cine MRI scans were planned. Cine MRI was performed in two directions through the center of the tumor, i.e. in the sagittal and coronal plane. To minimize out-of-plane motion in the coronal plane, this cine MRI was angulated in the main motion direction of the tumor, i.e. an angulation in the craniocaudal direction, relative to the left–right axis. Scan parameters were described previously [9]. The cine MRIs were collected at a rate of 2 Hz, over the course of one minute.

### 2.4. Motion characterization

The cine MRIs were analyzed with a minimum output sum of square errors (MOSSE) adaptive correlation filter, as described previously [9]. Tumor motion was characterized in craniocaudal (CC), lateral (LR) and anteroposterior (AP) directions. One point at the cranial edge of the tumor and one point at the caudal edge of the tumor were tracked in the sagittal and coronal scanning planes (Fig. 1B). The results of these two points were averaged to calculate the tumor motion.

Motion was described as the $M_{100\%}$ and $M_{95\%}$ . $M_{100\%}$ includes all data points, including outliers. The $M_{95\%}$ represents 95% of the bandwidth of all data points, and is a more robust measure. The 2.5 percentile most extreme data point on both inspiration and expiration were excluded.

The cine MRI motion was compared with 4D planning CT (4D CT) and 4D cone beam CT (4D CBCT) data. All patients underwent a 4D CT, containing 10 phases. If the pancreatic tumor motion on this 4D CT was smaller than 5 mm, we sufficed with 3D CBCTs during treatment. If this motion was larger than 5 mm, 4D CBCTs were performed. In these 10 patients, 4 patients had a tumor motion larger than 5 mm on the 4D planning CT. Motion on the 4D CTs was determined by assessing the difference in fiducial marker position between the two most extreme phases of breathing, i.e. inspiration and expiration. As the slice thickness was 3 mm, all values are a multiple of 3. Motion on the 4D CBCTs was determined by manual registration of the total inspiration and total expiration phases to the midventilation phase of the planning CT.

### 2.5. Statistics

A paired T-test was performed to assess differences in motion patterns with and without the corset. A *p*-value of 0.05 was considered statistically significant.

## 3. Results

### 3.1. Patients

Ten patients were included in this study, of whom 9 were locally advanced pancreatic cancer patients and one patient refused surgery due to severe comorbidities in combination with his age (86 years) (See Table A in electronic appendix for patient characteristics).

The two cine MRI scans were obtained with a median interval of 14 days (range 0–37 days). All patients tolerated the corset well during MRI scanning and radiotherapy.

An increase in skin dose of 34% was measured with application of the corset, equivalent to 3.5 mm water. The absorption of the corset was 0.95% at a perpendicular 10 by 10 cm beam. As the corset is place when acquiring the treatment planning CT, the absorption is taken into account during the treatment planning process.

### 3.2. Motion reduction

Without corset, the sagittal $M_{100\%}$ in CC direction was on average 11.3 mm (range 7.5–22.1 mm, Table 1). With the application of the corset, the average $M_{100\%}$ was 7.2 mm (range 4.1–12.1 mm). A