# Impact of Organ Motion on IMRT Dose Distributions for Patients with Cancer of the Cervix

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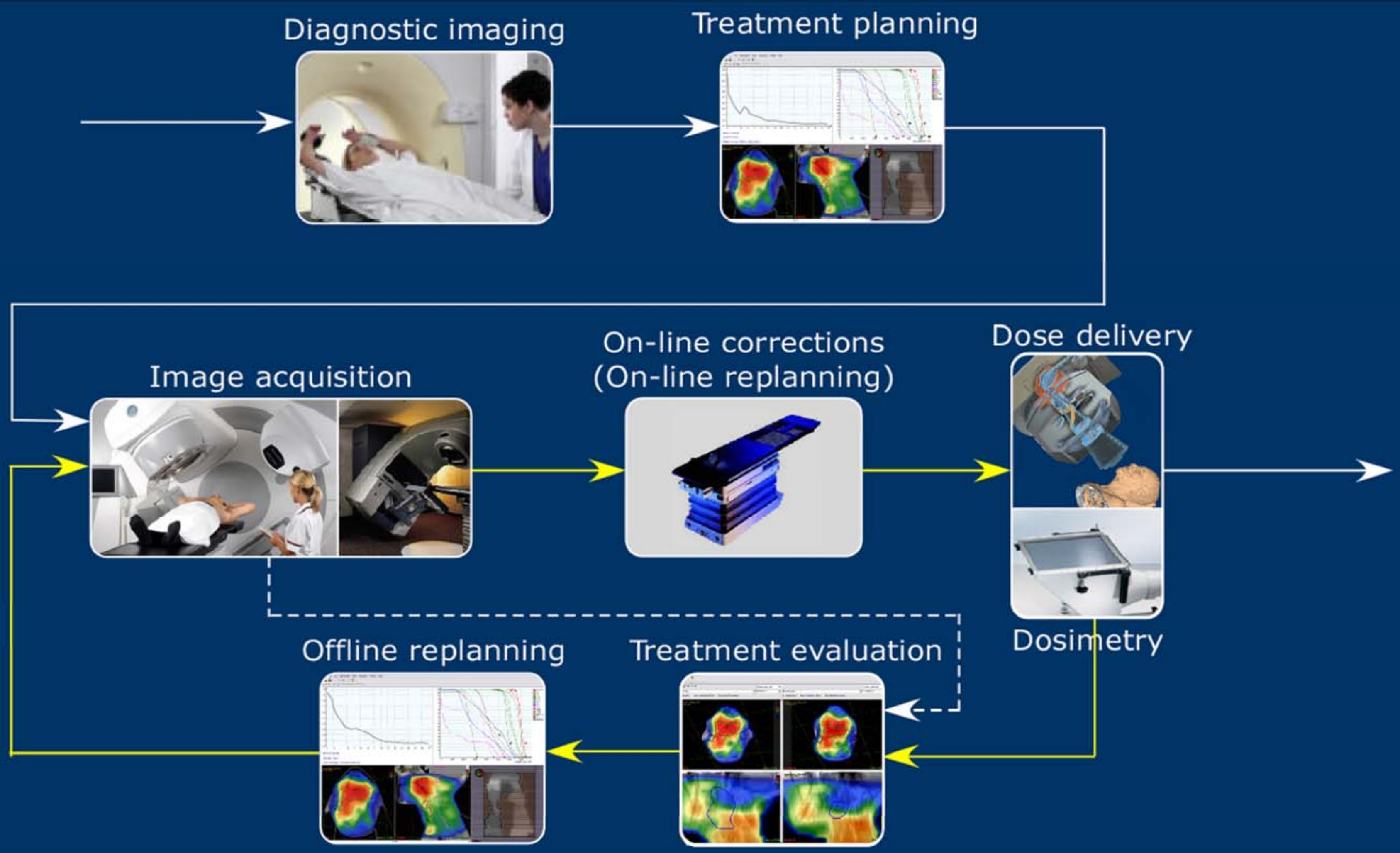
# Introduction

- Adaptive radiation therapy (ART) consists of
  - Monitoring
    - Organ motion and patient setup.
    - Dose delivered to changing patient geometry.
    - Tumor response and normal tissue acute damage.
  - Adaptation
    - Improved patient positioning.
    - Treatment replanning.

- Cancer of the cervix
  - Variable bladder and rectum filling induces
    - Tumor motion
    - Motion of the small bowel
  - Decrease in tumor volume.

- This study aims at quantifying the effect of organ motion on IMRT dose distributions
  - IMRT plans that were regarded as clinically acceptable
  - LargeMargin and SmallMargin plans
  - Part of effort to devise clinical protocols for IMRT treatments for cervical cancer.

# The ART process

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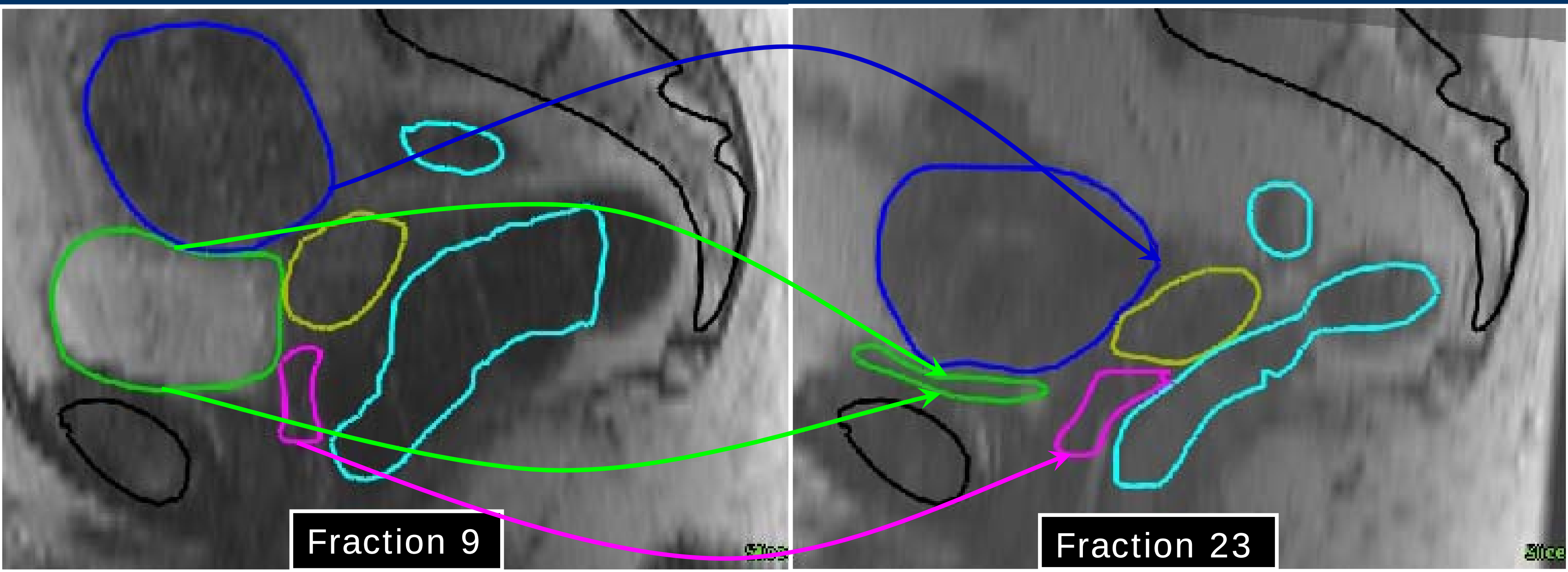
# Materials and Methods: Patient data

- 10 patients with cancer of the cervix
  - Stage IB-IVA disease.
  - Treatment:
    - Whole pelvis radiotherapy, concurrent cisplatin chemotherapy (RT-CT).
    - Intracavitary brachytherapy.
- Initial CT for planning.
- MR acquired before RT-CT and weekly during treatment.
- Organ motion reduction protocol
  - Mild laxative 12-24 hours before treatment
  - 500 ml water one hour before treatment after voiding
- Retrospective study:
  - Contours for each CT and MR dataset:
    - GTV
    - bladder, rectum plus sigmoid, cervix and uterus, upper vagina, bowel, parametrium
    - HRCTV (High-Risk): GTV + margins, excluding OAR
    - nodeCTV: pelvic nodes
  - IMRT treatment planned and deformable dose accumulation simulated.

# Example of organ motion

- Bladder filling varies.
- Large uterus motion.
- No obvious correlation between bladder filling and uterus position.
- Bone remains fixed between fractions.

Uterus
Cervix
Upper Vagina
Bladder
Rectum
Bone

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# Materials and Methods: Deformable dose accumulation

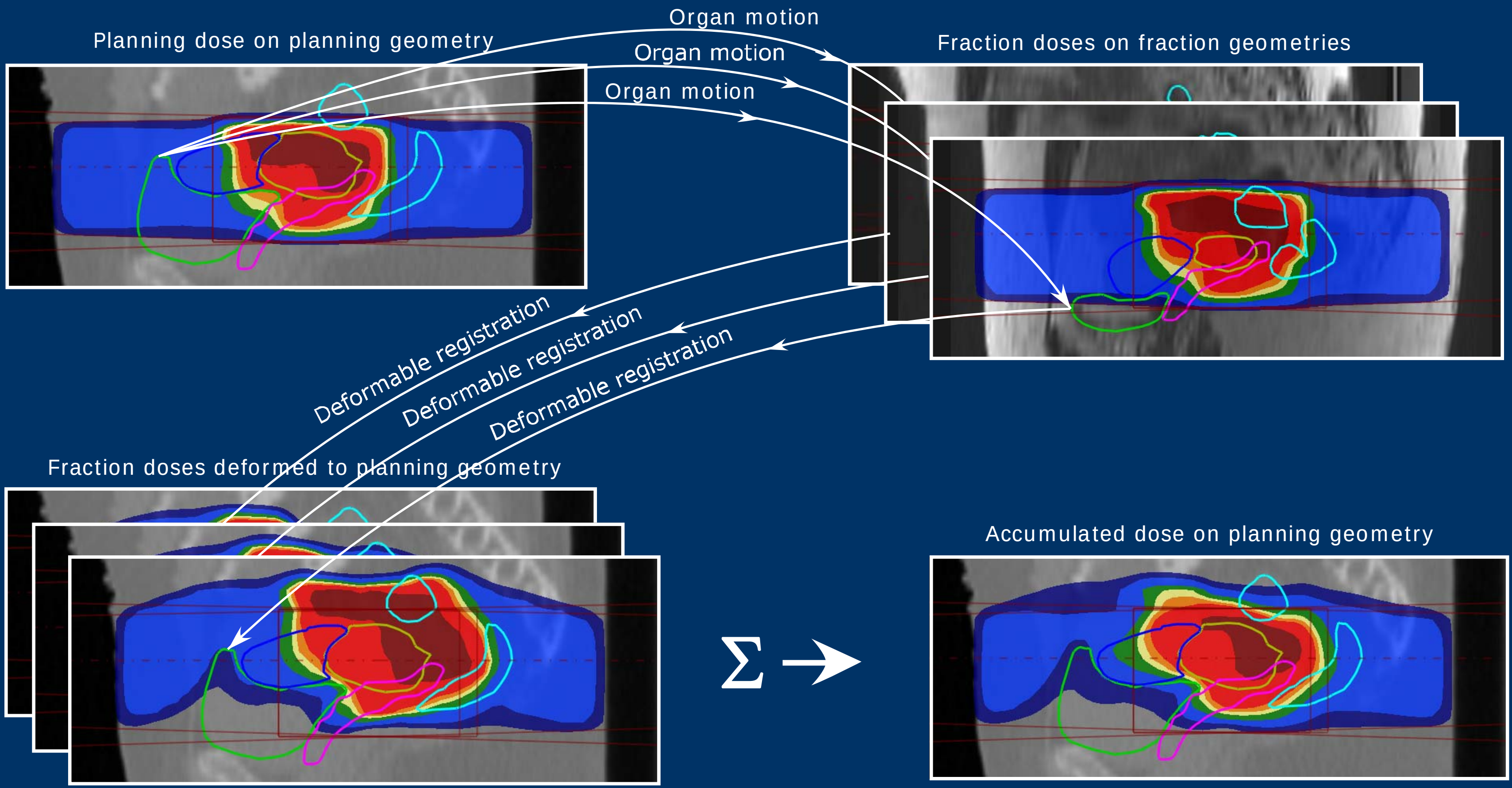



**Figure 3**: By deformable registration, fraction doses can be accumulated on the planning geometry. Data is courtesy of Princess Margaret Hospital, REB Approved Investigation.

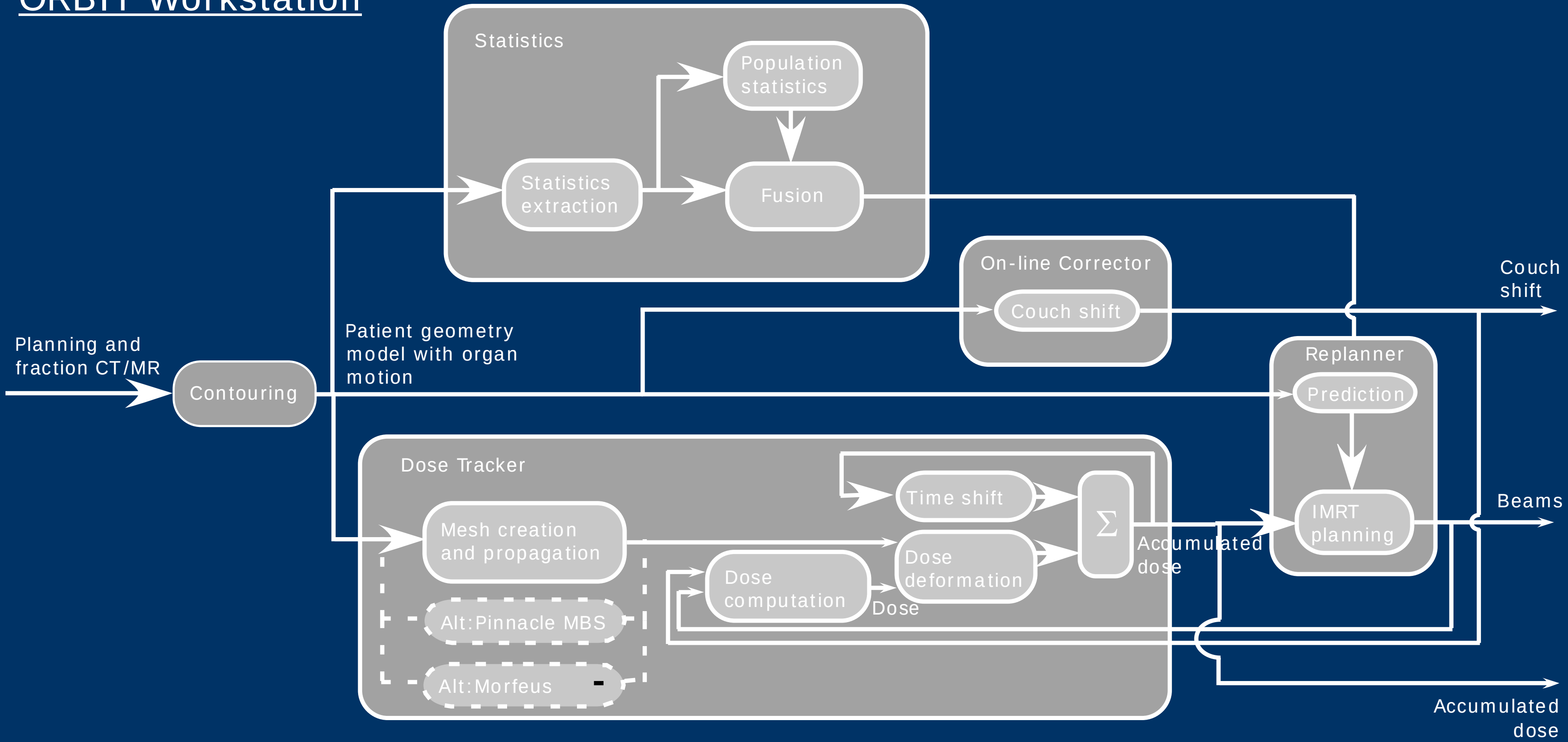
# Materials and Methods: Dose accumulation

- Organs delineated by contouring for every MR-data
- Meshes propagated over fractions.
  - Conforms to contours.
  - Using Morfeus*.
  - Establishes point-to-point correspondence for organ surfaces.
- Deformation of dose grid (mapping of fraction geometry to planning geometry)
  - Based on propagated meshes.
  - Using biomechanical deformation model.
  - Establishes point-to-point correspondence for patient volume.
- Dose is accumulated on planning geometry.

* Brock KK, et al. Feasibility of a novel deformable image registration technique… Int J Radiat Oncol Biol Phys. 2006 Mar 15;64(4):1245-54.

# Materials and Methods: Research software

ORBIT Workstation




ORBIT Workstation is developed by RaySearch Laboratories AB

# Materials and Methods: Delineation and planning

- PTV definitions: Two plans, LargeMargin (LM), SmallMargin (SM)

| | HRCTV (inferiorly) | nodeCTV |
|---|---|---|
| LM | 20 mm (10 mm) | 5 mm |
| SM | 5 mm (5 mm) | 5 mm |

- IMRT planning
  - Prescription dose: 50 Gy/25 fx.
  - Direct optimization of step-and-shoot segment shapes and weights.
  - ORBIT Workstation research software used.

| **Structure** | **Dose** | **Volume** | **Structure** | **Dose** | **Volume** |
|---|---|---|---|---|---|
| PTV | >47.5 Gy | 95% | Bladder, Rectum,Sigmoid | <45.0 Gy | 50% |
| PTV | <55.0 Gy | 100% | Small bowel | <35.0 Gy | 40% |
| Outside PTV | <47.5 Gy | 100% | Femoral head | <35.0 Gy | 10% |

# Results: Target coverage

- Target coverage was evaluated by computing $D_{98}$ to GTV and HRCTV
- Acceptance level was $D_{level}$=50 Gy for GTV and $D_{level}$=47.5 Gy for HRCTV.
- CTV
  - No underdoseage. Differs from submitted abstract due to the introduction of bony anatomy contours.
- GTV
  - For both the LM and SM plan, underdoseage was present for most patients, both in planned and accumulated dose (Table 1). (Not included in plan approval)
  - For both the LM and SM plan, coverage was compromised by organ motion (Table 2).

| | Min | Median | Max |
|---|---|---|---|
| LM | 0 | 0.4 | 1 |
| LM Acc | 0 | 0.4 | 1.7 |
| SM | 0 | 0.3 | 0.8 |
| SM Acc | 0 | 0.25 | 1.2 |

Table 1:
GTV Underdoseage($D_{98}$-$D_{level}$)

| | LM | | | SM | | |
|---|---|---|---|---|---|---|
| | Min | Median | Max | Min | Median | Max |
| GTV | -1.6 | 0.05 | 0.6 | -1.2 | 0.1 | 0.6 |
| HRCTV | -0.5 | 0.1 | 0.6 | -2.1 | -0.25 | 0.4 |

Table 2:
Change in $D_{98}$ (Accumulated-Plan)

# Results: Organ at risk protection

- Organ at risk dose was measured by
  - Rectum: D30
  - Sigmoid: D30
  - Bowel: D30
  - Bladder: D35
- Dose levels varied substantially over patients.
- Change in dose levels from planned dose to accumulated dose

| | LM | | | SM | | |
|---|---|---|---|---|---|---|
| | Min | Median | Max | Min | Median | Max |
| Rectum | -1.2 | 0.05 | 0.2 | -3.1 | 0.05 | 0.7 |
| Sigmoid | -0.3 | 0.05 | 1.2 | -0.4 | 0 | 0.9 |
| Bowel | -2.3 | 0.1 | 4.4 | -2.4 | 0.25 | 4.2 |
| Bladder | -1.3 | -0.15 | 0.8 | -3.2 | 0.7 | 1.8 |

Table 5: OAR dose $D_{\%}$ (Acc-Plan)

# Summary and discussion

- Aim at designing IMRT protocols for patients with cancer of the cervix.
- Expected outcome of study was
  - LM plan fulfills target coverage, SM does not.
  - SM plan has better OAR protection.
- Results show
  - no major difference in target coverage.
  - effect of organ motion on OAR dose varies over patients.
  - variable bladder filling, despite efforts to control.
  - what you see is not what you get when we approve IMRT plans.
- Implications for protocols - imperative to have daily image guidance to verify target position for IMRT. Perhaps US is sufficient.
- Further work:
  - Refine organ modelling.
  - Capture more image sets during treatment
  - Consider other strategies to minimize organ motion
  - Refine margin recipe
  - Explore various adapative strategies (ASTRO poster)