# Parallel-opposed fields versus four fields, and two- versus three-dimensional radiotherapy planning in thin patients with gynecological malignancies

E. BEDNARUK-MŁYNSKI, E. SENKUS-KONEFKA, P. SZEWCZYK, A. BADZIO, J. JASSEM*

*Department of Oncology and Radiotherapy, Medical University of Gdańsk, Debinki 7 St, 80-211 Gdańsk, Poland, e-mail: jjassem@amg.gda.pl*

**Received May 10, 2007**

Conformal radiotherapy constitutes the standard management of pelvic malignancies, yet its role in thin patients remains debatable. This study compares dose distribution for 2D and 3D treatment techniques for cobalt ($^{60}Co$) and high energy photons from linear accelerator (LA) in cervical and endometrial cancer patients with antero-posterior diameter of less than 20 cm.

CT-based 3D treatment planning and 2D simulation were performed in 10 patients. Particular techniques were compared in terms of treatment portal areas, coverage of planning target volume (PTV) and sparing of critical organs.

For $^{60}Co$ beams**,** PTV was not covered adequately with 2D fields in nine patients and with conformal fields in seven. For LA, PTV was not adequately covered with 2D two-field and 2D four-field (“box”) technique in three and one patients, respectively. Mean bladder dose was comparable for all plans. Both 2D “box” and 3D “box” technique spared additional portion of the rectum volume included in 95% isodose, compared to two-field plan. 3D treatment planning better protected the small intestine.

Use of multiple field techniques and 3D planning allows for some improvement of PTV coverage and normal tissue sparing, although the magnitude of this benefit must be weighted against savings of time and labour related to use of simpler treatment techniques.

***Key words: gynecological malignancies, pelvic radiotherapy, radiation technique***

Pelvic radiotherapy is a commonly used treatment modality in cervical and endometrial cancer patients [6, 9]. The close anatomic relationship of the small bowel, bladder and rectum necessitates the application of advanced treatment techniques. The standard use of radiochemotherapy in cervical cancer may further increase the treatment toxicity. Up to 30% of patients may develop early or late bowel toxicity, and small bowel sequelae are among the most important acute and chronic toxicities [3, 8]. Therefore, decreasing the volume of organs at risk within the treated volume without jeopardising the adequate coverage of target lesion is of paramount importance. The introduction of CT-based conformal techniques has provided more precise definition and coverage of target volume and better sparing of organs at risk. The superiority of conformal (three-dimensional-3D) versus two-dimensional (2D) planning and the use of multiple versus two parallel beams is generally accepted [1, 2, 5, 7, 11]. In pelvic irradiation of thin patients, however, the optimal way of implementing radical radiotherapy has not been ultimately determined [4]. Irradiation of gynaecological malignancies, due to their high incidence and wide indications for radiotherapy, creates a considerable burden on radiotherapy facilities. Thus, omission in some patients of sophisticated and time-consuming planning, as well as a reduction in the number of treatment portals, might be of considerable value. Due to its economic and logistical benefits, some centres still use the two parallel-opposed fields technique, assuming that anatomical conditions allow for satisfactory dose distribution in this subgroup of patients. Others use 2D planning for the box technique and question the advantage of more sophisticated planning techniques.

To our knowledge, the subgroup of thin patients has not been analysed separately in the previous studies addressing dose distribution during pelvic radiotherapy. This study was designed to compare dose distribution of more sophisticated

* Corresponding author

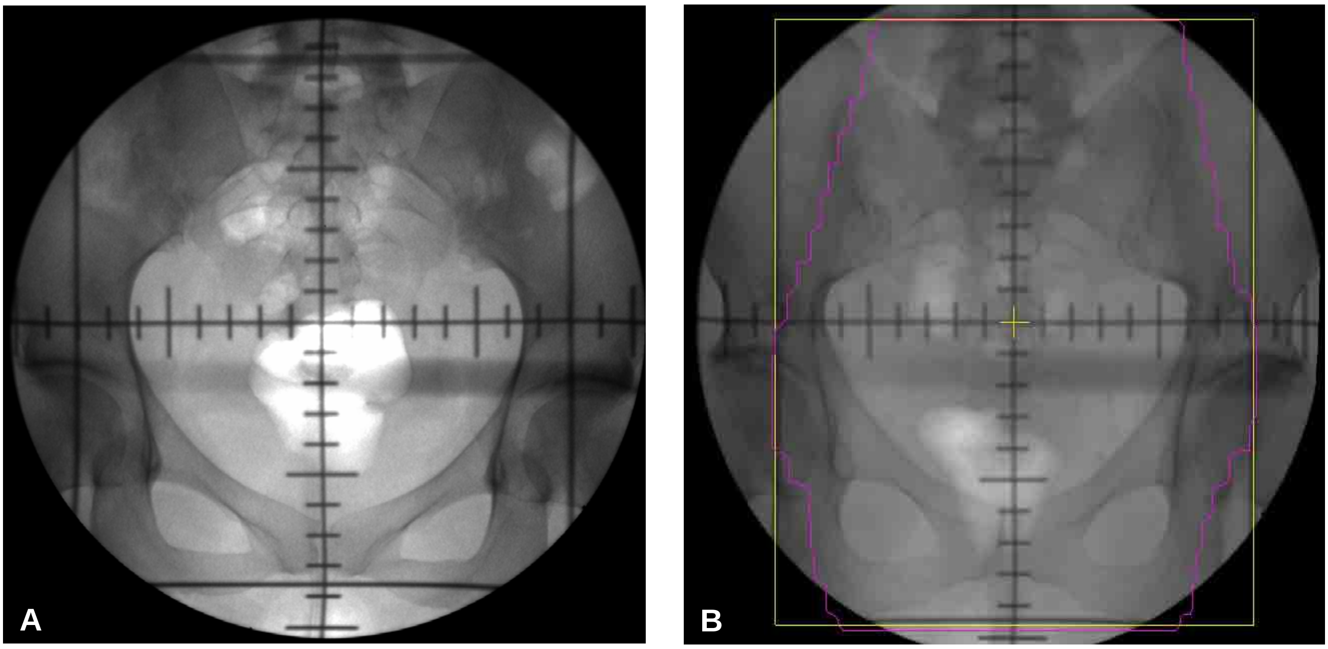


**Figure 1. Comparison of 2D (A) and 3D AP/PA (B) portals.**

conformal radiotherapy versus simpler and cheaper techniques: parallel-opposed fields and 2D box technique in thin patients irradiated for cervical or endometrial cancer. Our aim was to determine whether and to what extent 3D planning is superior to classical 2D method in these patients in terms of target volume coverage and protection of organs at risk. As brachytherapy was not a subject of this study, any information concerning this method was omitted.

## Material and methods

*Patient population.* Study group included ten gynaecological cancer patients with antero-posterior (AP) diameter at the level of beam axis of less than 20 centimetres (median: 17.9; range: 16.6-19.5 cm). There were eight cervical cancer patients; three, two and three in Federation Internationale de Gynecologie et d'Obstetrique (FIGO) stage I, II and III, respectively, and two endometrial cancer patients (both FIGO stage I C). The age of patients varied between 25 and 67 years (median 47 years). Seven patients were treated following a hysterectomy and three stage III cervical cancer patients underwent definitive radiotherapy.

*Imaging.* 2D radiotherapy planning was performed in the therapeutic position by the use of a Ximatron CX Simulator (Varian Oncology Systems, USA). Patients were positioned supine, with hands on the chest. For each patient, classical simulation portals were obtained. In the AP fields, superior margin was the upper border of the fifth lumbar vertebra, and the lower margin was 1 cm below the obturator foramen. The lateral borders were located 1-1.5 cm outside the bony pelvic walls. For the lateral fields, posterior border was the space between S2 and S3, and the anterior border was the anterior border of the pubic symphysis. For the purpose of 3D treatment planning, CT scans at a slice thickness of 1 centimetre were obtained in the same position through the true pelvis and abdomen (from the level of L1-L2 to the perineum). No contrast, either oral, intravenous or rectal was administered.

*3D volume definition.* Target volumes and critical structures, including urinary bladder, rectum and small bowel, were delineated on axial CT slices in accordance with International Commission of Radiation Units and Measurements (ICRU) report 50. The small bowel was defined as the entire peritoneal cavity, excluding major blood vessels and the rectum. We did not outline specific bowel loops. Clinical target volume (CTV) was defined as upper portion of the vagina, cervix, uterus (if present) and parametrial tissues, as well as obturator, external and internal iliac lymph nodes and blood vessels from the obturator region to bifurcation of common iliac vessels. The PTV area included CTV with 1 cm margin in all directions.

*Treatment planning.* Dose calculations were conducted using the Cadplan planning system (Version 3.1; Varian Oncology Systems, USA). The 2D portals were transferred into 3D planning system to assess dose distribution and the accuracy of PTV coverage. For 2D plans, in all cases the dose was calculated for two techniques, i.e. two parallel-opposed fields and box technique. 3D treatment plans using box technique were prepared based on the anatomical data from the CT slices in accordance with ICRU report 50. The plans for all three techniques were prepared for both $^{60}$Co and 18 MV photons generated by linear accelerator (LA).

The area of treatment portals and the dose-volume histograms for target volumes and critical organs, including bladder, rectum and small intestine, were compared for three treatment techniques and for both energies.

*Statistics.* Statistical analysis was performed using Stata 8 software. Differences between variables were assessed with the use of non-parametric Wilcoxon test. A $p$ value of 0.05 was assumed as the level of significance.

## Results

The median field areas for 2D AP/PA and lateral fields were 258 cm$^2$ and 176 cm$^2$, respectively. For 3D planning, median field areas for AP/PA and lateral fields were 298 cm$^2$ and 182 cm$^2$, respectively. On average, 3D AP/PA and lateral fields were respectively 40 cm$^2$ (15%) and 6 cm$^2$ (3%) larger than 2D portals.

*Target volume coverage.* Mean volume of PTV was 1161 cm$^3$. Mean values of PTV coverage by means of particular techniques are presented in Table 1. PTV was not covered effectively (less than 95% volume within 95% isodose) in all 2D $^{60}$Co plans but one, whereas conformal plans avoiding the excessive field size escalation resulted in inadequate coverage in seven patients. For LA, PTV was not adequately covered with 2D two-field and 2D "box" technique in three and one patients, respectively. In terms of adequate PTV coverage, $^{60}$Co two-field plans were inferior to 2D box plans (p=0.02), and the latter were inferior to 3D box plans (p=0.01). For LA, the difference between 2D two-field and box was not significant. However, 3D plans significantly better covered PTV compared to 2D techniques (p=0.005 and p=0.0002 for 2D two-field and 2D box technique, respectively). For particular techniques, all LA plans provided significantly better PTV coverage than $^{60}$Co plans (p=0.0005, p=0.0001 and p=0.0006 for 2D two-field, 2D box and 3D box technique, respectively).

The mean volumes of "geographical miss" defined as percentage of PTV outside the 90% isodose are shown in Table 1. More than 5% of PTV was missed in six 2D two-field and four 2D box $^{60}$Co plans. There was no statistical difference between two-field and 2D box $^{60}$Co plans according to "geographical miss", but 3D box plans offered significantly better PTV coverage (p=0.017 for two-field versus 3D box, and p=0.0002 for 2D box versus 3D box technique). For LA, two-field plans were inferior to 2D box plans (p=0.04), and the latter were as good as 3D box. Irrespective of particular technique, LA plans provided significantly less "geographical miss" than $^{60}$Co plans (p=0.01, p=0.0003 and p=0.04 for 2D two-field, 2D box and 3D box technique, respectively).

*Bladder doses.* Mean bladder volume encompassed by 95% isodose was comparable with all methods, with a median of

**Table 1. Mean values of PTV coverage for particular treatment techniques**

| Parameter | Technique | | | | | |
|---|---|---|---|---|---|---|
| | $^{60}$Co | | | LA | | |
| | two-field | 2D box | 3D box | two-field | 2D box | 3D box |
| Volume of PTV covered by the 95% isodose (range) | 71% (41-94%) | 80% (65-95%) | 86% (70-97%) | 93% (80-99%) | 95% (88-100%) | 99% (95-100%) |
| Volume of PTV missing the 90% isodose (range) | 8.8% (1-25%) | 6.7% (3-15%) | 2.9% (0-11%) | 1.7% (0-3%) | 1.0% (0-4%) | 0.3% (0-3%) |
| Minimum relative dose (range) | 51.0% (35.5-74.8%) | 72.0% (47.2-82.0%) | 87.2% (78.6-92.4) | 55.0% (43.0-81.2%) | 74.0% (49.8-89.8%) | 92.8% (68.8-94.4%) |
| Maximum relative dose (range) | 105.8% (102.0-109.6%) | 104.0% (102.0-107.6%) | 104.6% (103.0-109.0%) | 104.8% (100.7-107.0%) | 104.4% (100.5-106.3%) | 104.4% (101.7-106.3%) |
| Standard dose deviation (range) | 4.6 (3.1-7.2) | 4.4 (2.6-7.2) | 3.1 (2.6-4.3) | 3.0 (2.1-5.5) | 2.7 (1.4-5.5) | 1.6 (1.4-2.2) |

**Table 2.Mean bladder doses for particular treatment techniques**

| Parameter | Technique | | | | | |
|---|---|---|---|---|---|---|
| | $^{60}$Co | | | LA | | |
| | two-field | 2D box | 3D box | two-field | 2D box | 3D box |
| Mean relative dose (range) | 98.8% (94.8-104.0%) | 98.6% (93.8-99.0%) | 97.4% (94.4-100.4%) | 101.2% (98.4-103.2%) | 100.4% (97.8-102.0%) | 100.2% (97.0-103.0%) |
| Maximum relative dose (range) | 105.0% (101.4-108.2%) | 101.0% (98.4-103.6%) | 101.8% (98.0-104.6%) | 103.8% (101.2-106.6%) | 102.4% (101.0-103.6%) | 103.0% (101.2-106.2%) |
| Volume encompassed by the 95% isodose (range) | 88% (70-100%) | 81% (35-100%) | 84% (45-100%) | 99% (93-100%) | 98% (90-100%) | 96% (80-100%) |

148 cm$^3$ (91% of its volume; Table 2). The lowest and highest mean relative dose to the bladder was for $^{60}$Co 2D box technique and two-field LA technique (97.6% and 101.2% of the reference dose to the PTV, respectively).

*Rectum doses.* The mean volume of rectum encompassed by 95% isodose is shown in Table 3. For $^{60}$Co, the use of two-field technique resulted in significantly larger irradiated rectum volume compared to 2D box plans (p=0.003). There was no apparent gain for the 3D box compared to 2D technique. For LA, rectum was spared by means of both 2D box plans (p=0.009) and 3D box (p=0.01). The largest portion of the rectum was irradiated with 2D plans. When particular techniques were analysed with reference to energy used, the rectum volume was significantly smaller with $^{60}$Co than with LA plans (p=0.01, 0.001 and 0.02 for 2D two-field, 2D box and 3D box, respectively).

Mean rectum dose was comparable between 2D box and 3D box plans for both $^{60}$Co and LA. The dose for 2D two-field was higher than for 2D box for LA (p=0.008), but not for $^{60}$Co plans. Mean rectum dose did not differ between $^{60}$Co 3D and LA 3D plans, but there was a significant difference between mean rectum doses for $^{60}$Co two-field 2D and LA two-field 2D (p=0.004), and between $^{60}$Co 2D box and LA 2D box (p=0.02).

*Small bowel doses.* The mean small bowel volume covered by 95% isodose is shown in Table 4. The bowel volume covered by 95% isodose was not statistically different between 2D two-field and 2D box both for $^{60}$Co and LA plans. 2D box technique was inferior to 3D box for $^{60}$Co (p=0.003). There was also a significant difference favouring LA 3D box plans compared to two-field or 2D box plans (p=0.009 and p=0.002, respectively). The bowel volumes with conformal $^{60}$Co and LA plans were not significantly different. The use of LA two-field and 2D box techniques resulted in irradiation of significantly larger bowel volume (p=0.0004 and p=0.002, respectively) and higher mean bowel dose (p=0.0004 and p=0.002 for two-field and box, respectively) compared to $^{60}$Co plans.

There was no significant difference between the two energies when conformal radiotherapy was used. The use of conformal technique resulted in significantly lower mean small bowel dose compared to 2D box technique, for both $^{60}$Co and LA (p=0.01). The 2D box technique was significantly superior comparing to 2D two-field both for $^{60}$Co (p=0.005) and LA (p=0.0005).

The percentage of volume covered by 60% isodose ranged from 74.5 to 85.6% and was significantly smaller for two-field 2D versus 2D box plans for both energies (p=0.005 and p=0.04 for $^{60}$Co and LA, respectively). The difference between 2D box and 3D box favouring the latter technique was significant only for LA (p=0.03). LA plans tended to include slightly more small bowel volume compared to $^{60}$Co plans, but provided better target coverage.

## Discussion

Our data demonstrate better PTV coverage with conformal versus 2D radiotherapy in thin gynaecological patients. The risk of "geographical miss" (arbitrarily defined as 90%

**Table 3. Mean rectum doses for particular treatment techniques**

| Parameter | Technique | | | | | |
|---|---|---|---|---|---|---|
| | $^{60}$Co | | | LA | | |
| | two-field | 2D box | 3D box | two-field | 2D box | 3D box |
| Mean relative dose (range) | 96.8% (79.8-104.2%) | 90.6% (78.2-97.4%) | 93.6% (87.0-96.4%) | 98.6% (84.2-103.2%) | 93.0% (83.4-101.8%) | 94.2% (91.0-99.6%) |
| Maximum relative dose (range) | 105.6% (101.0-115.6%) | 101.6% (99.0-106.6%) | 101.8% (98.2-106.6%) | 103.8% (100.6-107.4%) | 102.8% (100.0-105.4%) | 102.2% (100.6-103.4%) |
| Volume encompassed by the 95% isodose (range) | 84% (43-100%) | 58% (23-90%) | 56% (18-75%) | 92% (67-100%) | 73% (45-100%) | 72% (33-99%) |

**Table 4. Mean small bowel doses for particular treatment techniques**

| Parameter | Technique | | | | | |
|---|---|---|---|---|---|---|
| | $^{60}$Co | LA | | | | |
| | two-field | 2D box | 3D box | two-field | 2D box | 3D box |
| Mean relative dose (range) | 79.4% (65.2-89.2%) | 87.2% (70.2-97.6%) | 83.4% (64.0-89.4%) | 81.8% (69.0-91.8%) | 88.6% (70.6-98.2%) | 81.0% (58.6-95.8%) |
| Maximum relative dose (range) | 108.0% (104.6-110.6%) | 105.0% (102.0-108.0%) | 104.0% (102.2-106.2%) | 104.4% (101.6-106.2%) | 104.6% (102.0-106.2%) | 103.8% (101.6-106.0%) |
| Volume encompassed by the 95% isodose (range) | 59% (40-76%) | 62% (26-87%) | 51% (14-63%) | 68% (50-84%) | 67% (32-87%) | 55% (15-81%) |
| Volume encompassed by the 60% isodose (range) | 78.7% (65-89%) | 85.6% (66-100%) | 81.4% (62-95%) | 80.0% (65-90%) | 83.3% (57-96%) | 74.5% (45-97%) |

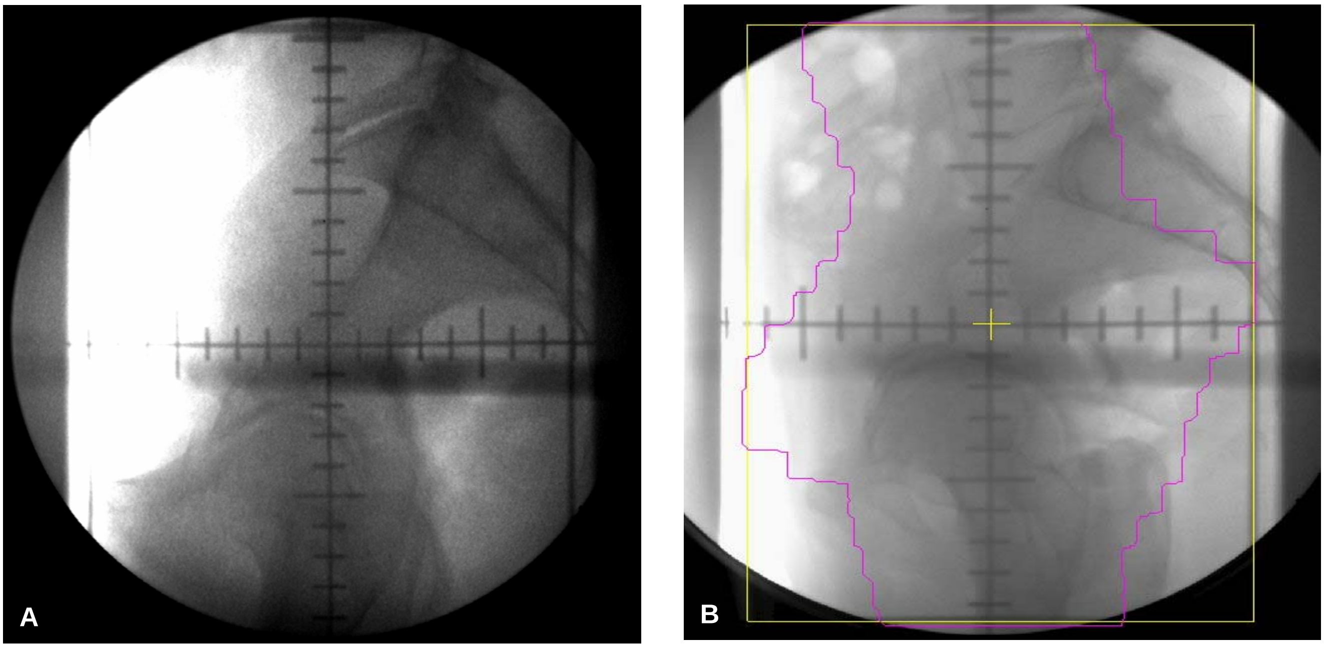


**Fig. 2. Comparison of 2D (A) and 3D (B) lateral portals.**

isodose missing >5% of CT-defined PTV) was 60% for $^{60}$Co 2D two-field and 40% for $^{60}$Co 2D box technique. It is possible that the extension of lateral borders of AP/PA fields beyond the classical 1-1.5 cm outside bony pelvis wall could result in better target coverage [4], yet such an analysis was not performed here. The minimal dose was less than 40 Gy in all patients but one planned with two-field technique, irrespective of beam energy. Among patients planned with 2D "box" technique, only three and four for $^{60}$Co and LA, respectively, would have received minimal PTV dose of at least 40 Gy. For comparison, the mean minimal doses for 3D $^{60}$Co and LA plans were 43.6 Gy and 46.4 Gy, respectively.

There was no clear advantage in bladder protection with conformal planning. In some patients this might have possibly resulted from inadequate bladder filling during CT planning. However, as the inclusion of external iliac nodes in the PTV requires anterior field extension, irradiation of significant portion of bladder wall and small bowel may be unavoidable, unless the intensity modulated radiotherapy (IMRT) planning is used [3, 10, 11].

We expected better rectal wall sparing with 3D box, but the actual dose distribution improvement in comparison to 2D box proved to be negligible. This may be explained by the anatomical position of the rectum, adjacent to the vagina. The need to add a sufficient margin (in this case 1 cm around the CTV) results in a marked posterior field extension. Comparing to two parallel opposed fields, all variants of "box" technique enabled sparing of additional 20-28% of the rectal volume. These results are comparable with the literature data. Apparently, worse rectal dose distribution for LA plans is the cost of superior PTV coverage by higher energies.

Whereas there was no additional gain from conformal technique compared to 2D box in reducing bladder and rectal dose, the dose to the small bowel was significantly lower with 3D plans. For LA, conformal planning reduced the small bowel volume by 11% compared to 2D box technique. The mean small bowel dose was reduced by 1.9 Gy compared to 2D box $^{60}$Co plans and by 3.8 Gy compared to 2D box LA plans. Although the anterior border of lateral conformal fields is often placed more anteriorly compared to 2D "box" technique, to secure adequate coverage of external iliac nodes, more precise bowel shielding is achieved using CT data, allowing for overally more favourable dose distribution.

In the present study patients were irradiated in the supine position, which has been widely used in gynaecological malignancies [7, 10, 11]. However, some authors claimed the superiority of the prone position [1, 5]. In thin patients, however, the estimated gain related to small bowel displacement with the prone position may be negligible. The same holds true for the use of belly boards.

Currently, better organ protection may be achieved with the use of IMRT [1, 2, 5, 7, 10-12]. This technique, when used for the whole pelvis, has to address the problem of organ motion within the irradiated area. To date, most studies regarding the bladder and rectum filling variation have focused on prostate cancer [13], whereas organ motion in the female pelvis has been less recognised. The research concerning pelvis organ motion and the problem of margin

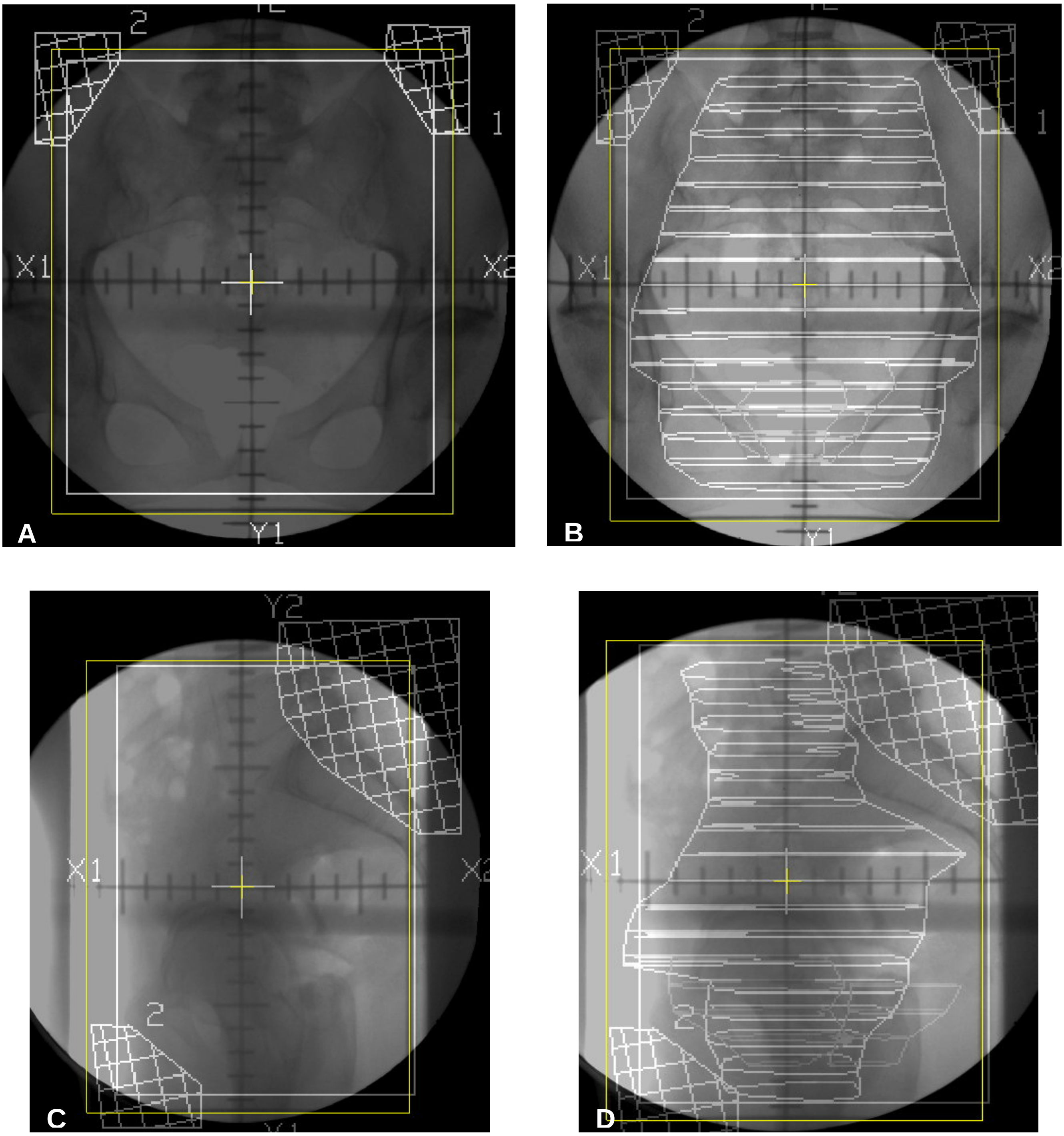


**Fig. 3. Image fusion of 2D and 3D portals: AP/PA and lateral view.**

optimisation is ongoing [11]. At present, IMRT technique in this application is promising, but still not ready for routine implementation. Institutional protocols designed to limit variations in organ motion need to be developed in order to minimise “geographical miss” and maximise the protection of organs at risk. For the time being, patients may still benefit from established, conventional radiotherapy, where the issue of organ motion is less crucial, the methodological basis well known, and the whole procedure less time- and resource-consuming.

In conclusion, we demonstrated the superiority of conformal planning compared to conventional box technique in terms of PTV coverage and small bowel protection in thin patients with gynaecological malignancies. Although there is a significant gain in rectum sparing with the 2D box compared to two parallel opposed fields, conformal planning further improves rectal dose distribution only for the LA irradiation. Neither 2D box technique nor 3D planning allow for better bladder protection. Our data suggest that the use of 2D technique carries a considerable risk of geographical miss with $^{60}Co$, especially with 2D two-field technique, but may be used relatively safely with LA. Overall, thin patients seem to benefit from 3D planning and the potential savings in terms of labour and machine time with 2D box and two-field techniques must be weighted against these benefits of 3D conformal therapy.

## References

[1] ALDI M, MAYR NA, KAISER HS, et al. Does prone position reduce small bowel dose in pelvic radiation with intensity-modulated radiotherapy for gynecologic cancer? Int J Radiat Oncol Biol Phys 2003; 57: 230–238

[2] DAS IJ, LANCIANO RM, MOVSAS B, et al. Efficacy of a belly board device with CT-simulation in reducing small bowel volume within pelvic irradiatin fields. Int J Radiat Oncol Biol Phys 1997; 39: 67–76

[3] HERON DE, GERSZTEN K, SELVARAJ RN, et al. Conventional 3D conformal versus intensity-modulated radiotherapy for the adjuvant treatment of gynecologic malignancies: a comparative dosimetric study of dose-volume histograms. Gynecol Oncol 2003; 91: 39–45

[4] KIM RY, MCGINNIES S, SPENCER SA., et al. Conventional four-field pelvic radiotherapy technique without computed tomography-treatment planning in cancer of the cervix: Potential geographic miss and its impact on pelvic control. Int J Radiat Oncol Biol Phys 1995; 31: 109–112

[5] KOELBL O, RICHTER S, FLENTJE M. Influence of patient positioning on dose-volume histogram and normal tissue complication probability for small bowel and bladder in patients receiving pelvic irradiation: a prospective study using a 3D planning system and a radiobiological model. Int J Radiat Oncol Biol Phys 1999;45: 1193–1198

[6] LANDONI F, MANEO A, COLOMBO A, et al. Randomized study of radical surgery versus radiotherapy for stage Ib-IIa cervical cancer. Lancet 1997; 350: 535–540

[7] MUNDT AJ, LUJAN AE, ROTMENSCH J, et al. Intensity-modulated whole pelvic radiotherapy in women with gynecological malignancies. Int J Radiat Oncol Biol Phys 2002; 52: 1330–1337

[8] PEREZ CA, BREAUX S, BEDWINEK JM, et al. Radiation therapy alone in the treatment of carcinoma of the uterine cervix. Analysis of complications. Cancer 1984; 54: 235–246

[9] PETERS WA III, LIU PY, BARRET RJ II, et al. Concurrent chemotherapy and pelvic radiation therapy compared with pelvic radiation therapy alone as adjuvant therapy after radical surgery in high-risk early stage cancer of the cervix. J Clin Oncol 2000; 18: 1606–1613

[10] PORTELANCE L, CHAO C, GRIGSBY PW, et al. Intensity-modulated radiation therapy (IMRT) reduces small bowel, rectum, and bladder doses in patients with cervical cancer receiving pelvic and para-aortic irradiation. Int J Radiat Oncol Biol Phys 2001; 51: 261–266

[11] ROESKE JC, LUJAN A, ROTMENSCH J, et al. Intensity modulated whole pelvic radiation therapy in patients with gynecological malignancies. Int J Radiat Oncol Biol Phys 2000; 48: 1613–1621

[12] SHANAHAN TG, MEHTA MP, BERTELRUD KL, et al. Minimization of small bowel volume within treatment fields utilizing customized "belly boards". Int J Radiat Oncol Biol Phys 1990; 19: 469–476

[13] Van HERK M, BRUCE A, KROES AP, et al. Quantification of organ motion during conformal radiotherapy of the prostate by three dimensional image registration. Int J Radiat Oncol Biol Phys 1995; 35: 1311–1320