

Indigenous Groin Board Immobilization Reduces Planning Target Volume Margins in Groin Radiotherapy

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Abstract

Purpose: To quantify the relative motion of pelvic and groin lymph nodes (PLN and GLN) and define indicative margins for image-guided radiotherapy based on bony anatomy for the frog-leg position (FLP) and groin immobilization board (GIB). **Materials and Methods:** Twenty patients with planning computed tomography (CT) scan and on treatment cone beam CTs (median = 8) for groin and pelvic radiotherapy were included in the study. Of these nine were treated with FLP and eleven with GIB. The PLN and GLN regions on the left and right were outlined in each scan. Systematic and random uncertainties were determined along with correlations between the motions of these regions. The clinical target volume to planning target volume (PTV) margins required to take motion into account was calculated for each immobilization. **Results:** The mean shifts for PLN and GLN were lesser but not statistically lower using GIB over FLP. There was significant concordance in the vertical, longitudinal and lateral motion of the pelvis and right groin ($P = 0.015, 0.09$ and 0.049 , respectively), pelvis and left groin ($P = 0.001, 0.048$, and 0.006 , respectively) and between left and right groin ($P = 0.013, 0.01$ and 0.07 , respectively) for FLP and not GIB. The PTV margins required by Van Herk and Stroom's formula were reduced from 11 mm and 9 mm to 6 mm and 5 mm for pelvis; 12 mm and 11 mm to 7 mm and 6 mm for groin, respectively, using FLP over GIB. **Conclusions:** GIB brings concordance in shifts between pelvis and groin and between bilateral groins, thereby reducing the required PTV margins.

Keywords: Groin immobilization board and frog-leg position, groin radiotherapy, penile neoplasm, planning target volume

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INTRODUCTION

Groin radiotherapy is generally required for rare malignancies of the perineal region such as penile or vulvar cancer and other rare malignancies such as melanomas of genital tracts, sarcoma of groin or thighs representing <5% of malignancies in males and females, respectively.^[1,2] The treatment generally consists of surgery followed by adjuvant radiation therapy (RT) to the groin in the presence of high-risk features or definitive RT alone.^[2-4] The target volume would include treatment of the groin nodal region with or without pelvis nodal regions.

The local toxicities of the groin with or without pelvic RT include radiation dermatitis, gastrointestinal, genitourinary toxicity, and increased lymphedema.^[4-7] Advances in RT technology such as intensity-modulated radiation therapy (IMRT) and image-guided radiotherapy (IGRT) may help in reducing some of these toxicities with similar or better control rates. IMRT would create a sharp dose gradient between the target volumes and organs at risk (OAR), while

IGRT would ensure accurate delivery. A review of previous IGRT data can help to estimate the required margins (planning target volumes [PTV]), reduction of PTV margins if feasible, and proper IGRT schedules which may be necessary to cover the PTV adequately at all times and minimize doses to the nearby normal tissue or OARs.^[8-10]

However, this mandates rigid immobilization to ensure the reproducibility of set up at each fraction. Conventionally, the patients needing groin with or without pelvic RT were simulated in "frog-leg position" (FLP) using knee support, to avoid skin folds between groin and thigh as well as between thigh and scrotum in males, and similarly for skin folds between thigh and labia majora in female perineum malignancies such

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as vulvar cancers.^[11,12] The separation of skin folds is believed critical in reducing groin skin reactions. However, FLP is an uncomfortable position and may not be always accurately reproducible due to varying degrees of thigh abduction and knee flexion at each setup. This may compromise coverage with a serious impact on target coverage and normal tissue avoidance.

In today's modern era of high precision radiation oncology practice, setup with immobilization device and PTV margins estimation play a critical role. Along with this, there are challenges to meet the technological advances in most remote places. Nonavailability of modern set-up devices such as alpha cradle, vacLocs can be detrimental in the treatment of certain sites such as groin using IG-IMRT. In scopes of this, the development of low-cost indigenous immobilization boards and their clinical validation with PTV margin calculations cannot be overemphasized. Other than the cost, they present evidence for avoiding conventional methods (such as frog leg) which may be less accurate and time-efficient. To overcome these difficulties and uncertainties, we designed a groin immobilization board (GIB). The primary objective of the study was to retrospectively determine the setup errors and PTV margins required for groin radiotherapy with traditional FLP versus GIB in previously treated patients at our institution.

MATERIALS AND METHODS

Patients

We identified penile cancer patients who were simulated, planned, and treated with RT to the groin with or without pelvis using either FLP or GIB with at least 5 onboard cone-beam computed tomographs (CBCTs) between January 2016 and September 2019. Twenty such consecutive patients were identified and were included in the study.

Immobilization using frog-leg position

During conventional FLP immobilization, the patient is placed with arms over the chest and a pillow beneath their head. The hips are externally rotated and abducted with knees mid-flexed and internally rotated supported and fixed by wedge support under the thighs. Three lead markers are kept at the level of the pubic symphysis and inter-knee distance (distance between the medial condyles of the femur) is measured that helps in alignment of the patient for daily treatment.

Immobilization using groin immobilization board

The GIB was made from styrofoam material with attenuation similar to air. It consisted of a triangular body with the apex at the scrotal area which would fix in the perineum and would generate 60° abduction at the thigh, and the base at the level of the bilateral knee joint with supporting wedges to rest thigh with slope and flexion at the knee joint. The slope, height, and position of thigh-knee rest are fixed rigidly to the central triangular body against the perineum and the baseplate of the board, as shown in Figure 1. There were two longitudinal markings A and B on the board one inch apart to align one of

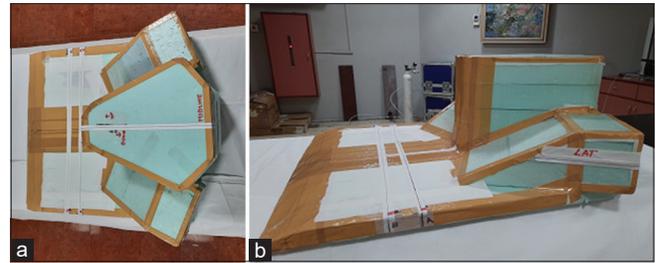


Figure 1: The groin immobilization board, top view (a) showing central triangular body for fixing against the perineum of the patient with midline marked, two lateral fixed wedges for resting thigh and knee, two horizontal lines A, B for matching patient tattoo and horizontal room laser; Lateral view (b) showing the horizontal line on knee supports to match with patient tattoo and in-room vertical lasers

them with the patient vertical axis through tattoos, midline line on board to align with patient midline tattoo, and lateral shift laser. The vertical line on knee wedges is to align with the patient lateral tattoo with vertical lasers in the room. This way, patient tattoos, board markings, and room lasers would be aligned together at each setup.

For the GIB immobilization, patients were positioned supine with arms over chest and a pillow beneath their head. The board was placed such that the patient's scrotal sac rested on the apex of the triangular body of the board with both hips externally rotated, bilateral knees mid-flexed, and slightly internally rotated such that both the heels approximate each other. The wedge-like support adjacent to the triangular body helped to rest the thighs and increase the comfort of the patient [Figure 1a and b]. The alignment of the patient was done with the help of room lasers, and patient tattoos with board markings. We assumed that the rigid fixation of the triangular body and wedges along with the alignment on board and patient will help to decrease the set-up uncertainty by reproducing the same position each day.

Simulation

For simulation, contrast-enhanced computerized tomography scans were taken from the upper border of the second lumbar vertebrae to 5 cm below the lesser trochanter of femurs and images were pushed to the planning station. Contouring of the nodes along the vessels and OAR was done. Clinical target volume (CTV) to PTV margin of 5 mm isotropically was prescribed and IMRT plans were generated. During the treatment, CBCTs were taken on the first three treatment days followed by once weekly. The patients were scanned in the treatment position, with superior-inferior coverage from the cranial boundary of the sacroiliac joints to 4 cm caudal to the pubis.

Matching

Matching of the CBCT with the planning computed tomography (CT) was done by both radiation oncologist and technologist before actual treatment delivery. Initially, automatic bone-to-bone matching was done followed by manual matching to desirable treatment position and shifts were noted and

treatment was delivered. Only vertical (x), longitudinal (y), and lateral (z) shifts were considered and no rotational shift was corrected and applied. For the purpose of study, the external iliac, internal iliac constituting pelvic lymph node (PLN), and inguinal/groin lymph node (GLN) lymph nodes were contoured separately on the left and right with vessels as a surrogate on the planning CT and each CBCTs. We assumed that the motion of the bony anatomy is a surrogate for the motion of the nodes as they are rarely visible on CBCT. Pelvis to pelvis bone and pelvic nodal region (PLN) matching was done on CBCTs and planning CT noting shifts in vertical (x1), longitudinal (y1), and lateral (z1) axes. Similarly, both right and left femurs were matched and groin nodes were matched (GLN) noting shifts. This gave us the corresponding shifts in each direction (right- x2, y2, z2 and left- x3, y3, z3). In the three matching scenarios, the mean translation shifts were calculated for each patient. The standard deviation (SD) of these measurements across all patients quantifies the systematic positional errors (Σ). The SD of the translations for each patient across the repeated CT scans was also calculated, and the root mean square of these values across all patients quantifies the random position errors (σ). The PTV margins were calculated using Van Herk's^[13] and Stroom's formula^[14] and compared between setup on FLP and GIB. For Van Herk's formula, the PTV margin = $2.5\Sigma + 0.7\sigma$ and for Stroom's formula the PTV margin = $2\Sigma + 0.7\sigma$.

Statistical analysis

All the analyses were done on IBM SPSS v 23 (NewYork, US). Patients' baseline characteristics were analyzed using descriptive statistics. Mean shifts in vertical, longitudinal, and lateral direction were calculated using descriptive statistics and compared with an independent *t*-test. The following hypotheses were tested with two setup methods of FLP and GIB: (1) The mean shifts for pelvic (PLN) and groin (GLN) nodal matching will be lesser using GIB as compared to FLP. (2) The motion of the pelvis is in concordance with the motion of the groin. Comparisons between shifts required for pelvis and groin matching will be done. (3) The motion of the left groin is in concordance with the right groin. Comparisons between shifts required for both groin matching will be done. Correlation of motion between pelvic and groin region with different setup positions was calculated using Pearson's correlation test and significance was noted keeping $P < 0.05$. (4) The motion of the pelvis will be lesser as compared to the motion of groin nodes. PTV margins for the respective matching protocol will be estimated. The PTV margins required for different matching scenarios with two different immobilizations were calculated.

RESULTS

Twenty patients were included in the study; nine were treated using FLP while 11 with GIB. The median age of the patients was 59 years and 56 years, respectively ($P > 0.05$). In both types of immobilization, the majority had included bilateral inguinal with or without pelvic nodes in target volumes ($P > 0.05$). The median number of CBCTs per patient was 7.7 in FLP and 8.5 in GIB ($P > 0.05$).

Hypothesis 1

The mean shifts for pelvic (PLN) and groin (GLN) nodal matching will be lesser using GIB as compared to FLP.

The mean shifts for PLN matching vertical were 0.57 mm (SD 2.29) and -0.33 (SD 1.72), $P = 0.324$ in vertical direction; -1.71 (SD 4.59) and 0.18 (SD 1.49), $P = 0.211$ in longitudinal direction; and -1.61 (SD 2.87) and 0.21 (SD 1.46), $P = 0.175$ in lateral direction, respectively for FLP and GIB. The mean shifts for right GLN matching in were 2.57 (SD 2.82) and 0.81 (SD 1.94), $P = 0.117$ in vertical direction; -1.15 (SD 3.79) and 0.899 (SD 1.51), $P = 0.158$ in longitudinal direction; and -0.609 (SD 3.28) and 1.24 (SD 2.18), $P = 0.148$ in lateral direction, respectively, for FLP and GIB. The mean shifts for left GLN matching were 2.00 (SD 1.24) and 1.09 (SD 2.32), $P = 0.305$ in vertical direction; -1.44 (SD 5.03) and 0.93 (SD 1.55), $P = 0.154$ for longitudinal; and 0.79 (SD 4.47) and 0.22 (SD 2.71) $P = 0.54$ for lateral direction for FLP and GIB, respectively, as shown in Figure 2. Hypothesis 1 was rejected as there was no statistically significant difference between the PLN and GLN shifts with respect to two types of immobilization.

Hypothesis 2

The motion of the pelvis is in concordance with the motion of the groin.

The motion of the pelvis was in concordance with the right groin for only longitudinal direction (Pearson's correlation score (r) 0.853 ; $P = 0.03$) for FLP while for vertical and lateral direction for GIB [Table 1]. The concordance for the motion of the pelvis and left groin was noted in all three directions for GIB [$P < 0.05$; Table 1] but only in vertical and longitudinal direction for FLP [Table 1]. Hypothesis 2 was better supported for GIB but not for FLP.

Hypothesis 3

The motion of the left groin is in concordance with the right groin.

The motion of the left and right groin was concordant in patients with GIB in all three directions [$P < 0.05$; Table 1], whereas with FLP, the only concordance was in the lateral direction [all r and P values in Table 2]. Hypothesis 3 was again supported for GIB but not for FLP.

Hypothesis 4

The motion of the pelvis was lesser as compared to the groin.

The mean shifts for PLN and GLN matching using FLP were 0.57 (SD 2.29) and 2.57 (SD 2.82), $P = 0.034$ in vertical; -1.71 (SD 4.59) and -1.15 (SD 3.79), $P = 0.501$ in longitudinal and -1.61 (SD 2.87) and -0.60 (SD 3.28), $P = 0.429$ in lateral direction. Similarly, with GIB were -0.33 (SD 1.72) and 0.81 (SD 1.94), $P = 0.023$ in vertical; 0.18 (SD 1.49) and 0.89 (SD 1.51), $P = 0.148$ in longitudinal; and -0.21 (SD = 1.46) and 1.24 (SD 2.18), $P = 0.022$ in lateral direction. There was a systematic reduction in both systematic and random error in all three directions for using GIB over FLP in the pelvis and

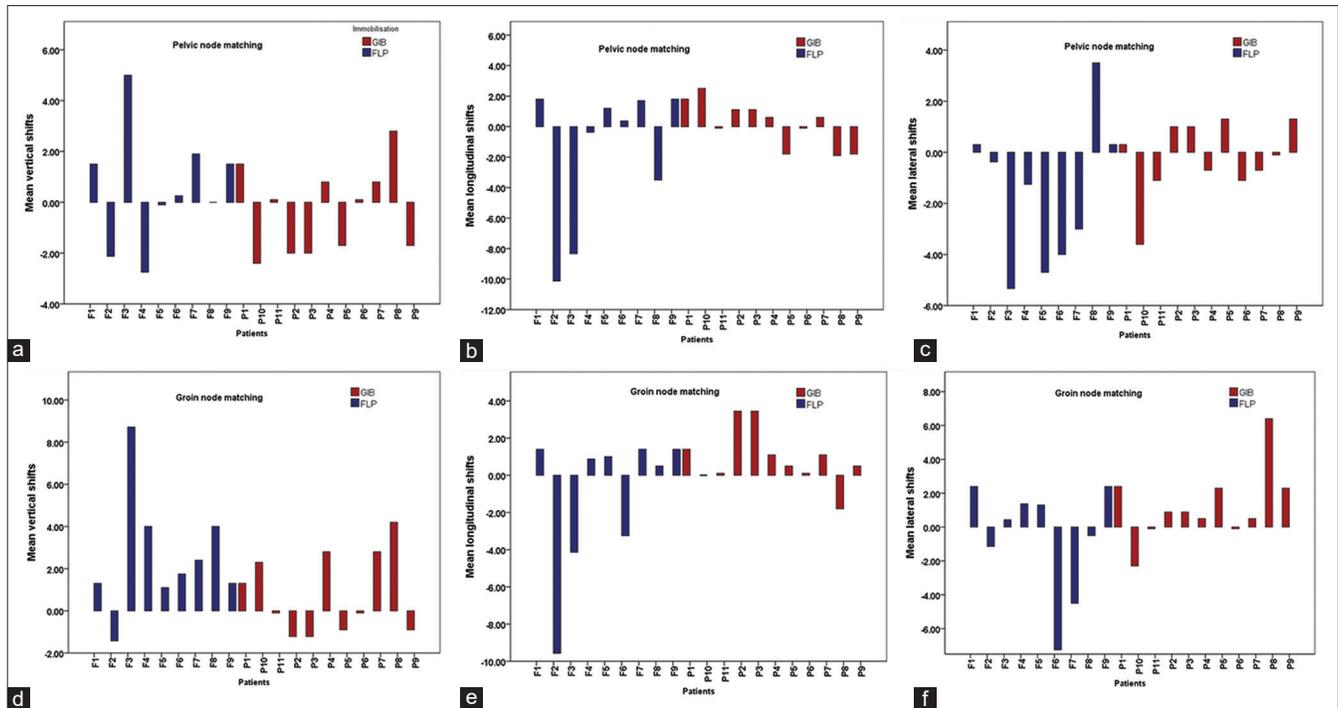


Figure 2: Pelvic lymph node mean shifts in the vertical (a), longitudinal (b) and lateral (c) directions and groin node mean shifts in the vertical (d), longitudinal (e) and lateral (f) directions using frog-leg position and groin immobilization board

Table 1: Pearson’s correlation of motion in vertical, longitudinal, and lateral direction using frog-leg position and groin immobilization board

	FLP		GIB	
	Pearson`s correlation	P	Pearson`s correlation	P
Pelvis to right groin motion				
Vertical (X)	0.598	0.089	0.706	0.015
Longitudinal (Y)	0.853	0.03	0.601	0.09
Lateral (Z)	0.313	0.413	0.684	0.049
Pelvis to left groin motion				
Vertical (X)	0.678	0.045	0.833	0.001
Longitudinal (Y)	0.803	0.009	0.606	0.048
Lateral (Z)	-0.218	0.573	-0.762	0.006
Right to left groin motion				
Vertical (X)	0.597	0.09	0.884	0.013
Longitudinal (Y)	0.906	0.01	0.887	0.01
Lateral (Z)	0.329	0.388	-0.565	0.07

FLP: Frog-leg position, GIB: Groin immobilization board

for groin [Table 2]. The corresponding minimum PTV margin required for FLP for pelvis by Van Herk and Stroom’s formula would be 11 and 9 mm, respectively (rounded to 1 mm). With GIB, they were reduced to 6 and 5 mm, respectively. Similarly, the required PTV margins (Van Herk/Stroom’s) were reduced from 12/10 to 7/6 mm from FLP to GIB, respectively. Hypothesis 4 was supported by both FLP and GIB.

DISCUSSION

To the best of our knowledge, this is the first study to evaluate the concept and quantification of the target-specific motion in

groin radiotherapy. In this study, we have quantified the motion around the pelvis and groin with two setups determining the adequate margins required to ensure target coverage.

In our study, we assumed that the mean shifts would be lower in GIB as compared to FLP, although numerically lesser, they were not statistically different. The motion of the pelvis was much more time concordant with motion in the groin with GIB as compared with FLP. More robustly the left and right groin motion was concordant in GIB and not in FLP. Both systematic and random errors were reduced in groin and pelvis using GIB over FLP. Finally, the PTV margins were

Table 2: Systematic, random errors and the required planning target volume margins (mm) in pelvis and groin matching using frog-leg position and groin immobilization board

	Pelvis to pelvis matching					
	FLP			GIB		
	Vertical (X)	Longitudinal (Y)	Lateral (Z)	Vertical (X)	Longitudinal (Y)	Lateral (Z)
Systematic error	2.8	3.1	2.9	2.0	1.8	1.7
Random error	2.6	4.1	3.1	1.6	2.3	1.5
PTV margin by Van Herk's formula	8.9	10.6	9.4	6.2	6.2	5.2
PTV margin by Stroom's formula	7.4	9.1	7.9	5.2	5.3	4.4

	Groin matching					
	FLP			GIB		
	Vertical (X)	Longitudinal (Y)	Lateral (Z)	Vertical (X)	Longitudinal (Y)	Lateral (Z)
Systematic error	2.9	3.9	3.85	2.01	1.3	1.9
Random error	2.7	3.6	2.1	1.8	1.8	3.5
PTV margin by Van Herk's formula	9.2	12.2	10.9	6.3	4.7	7.2
PTV margin by Stroom's formula	7.7	10.3	9.2	5.3	3.9	6.3

FLP: Frog-leg position, GIB: Groin immobilization board, PTV: Planning target volume

also reduced from FLP to GIB for both pelvis and groin by 4–5 mm.

As defined in ICRU 50^[15] and 62^[16] the CTV to PTV margins includes all the possible geometrical variations and inaccuracies (may be intrafractional or interfractional) such as movements of tissue, variation in size and shape of the tissue, variation in beam and machines such as noncongruency of the laser while setup, and couch sag. It is well known that standard isotropic margins from CTV to generate PTV are often chosen for ease of use and are population-based margins. Conventionally, a 5–7 mm isotropic margin is considered adequate. The current study suggests that these margins would be largely inadequate in FLP and would be best suited with GIB.

The main advantage of the GIB is the markings on the board, which when matched with anatomic landmarks of the patient, helps in better immobilization; also it can be patient-specific and thus reproducible. This GIB can provide adequate immobilization of the pelvis and groin and can be used in the positioning of patients in treating several perineal malignancies such as vulvar cancer, melanomas of genital tracts, and sarcoma of groin or thighs which mandates treatment of pelvic and/or groin region. Other methods of immobilization are using a vacuum bag (e.g. CIVCO's Vac-Lok) which is patient-specific and more flexible but is costly, requires expertise in making them. They also bring logistic challenges for storage and preservation during the planning phase (2–4 weeks) and treatment phase (4–6 weeks) to retain shape and form avoiding leakage, etc.

Further patient-specific patient individualization may be possible for outliers who are unable to fit on the board due to bulky built or inability to abduct thigh adequately. Although we did not experience any such patient until now, such possibilities cannot be excluded from the study. Other options

for PTV reduction can also be explored in these patients. These include adaptive planning techniques such as “multiple adaptive plans” where multiple plans are created at the outset and a plan of the day is selected based on best matching PTV on the day of treatment. Such an approach has been a success in bladder cancer.^[17] Furthermore, the library of plans strategy for rectal cancer based on population statistics was feasible and resulted in a considerably reduced average rectum PTV volume compared to conventional radiotherapy.^[18]

Other than usual limitations associated with retrospective studies, were the availability of less than daily imaging and nonavailability of patients of other perineum malignancies treated using GIB. In the current study, we cannot comment on the required IGRT schedule and its influence on the required margins.^[19] Our study did not investigate rotational errors.

CONCLUSIONS

The indigenous groin board improved the concordance between the pelvis and groin motion than using conventional frog-leg position. This helped in reducing the PTV margins to be needed and may help in much better target coverage while avowing dose unnecessary normal tissue. These boards can be developed in any department easily with low cost and have definite advantage in low middle-income countries like India.

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Conflicts of interest

There are no conflicts of interest.

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