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High buttocks supine position to reduce small bowel exposure in gynecological radiotherapy

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Abstract

Purpose To minimize radiation exposure to the small bowel (SB) in patients undergoing treatment for gynecological tumors by adopting a comfortable positioning method.

Methods and patients All 76 women undergoing Intensity-Modulated Radiation Therapy (IMRT) were included in this study. Patients were immobilized in a supine position using a vacuum bag and thermoplastic cast formation. In the trial group ($n=36$), patients raised their buttocks and a solid foam pad was placed under the sacral tail before immobilization. The control group ($n=40$) received treatment in the standard supine position. The SB was delineated from the pubic symphysis to the total iliac bifurcation in computed tomography (CT) scans.

Result In the trial group, a significant reduction in SB volume within the pelvic cavity was observed (mean 399.17 ± 158.7 cc) compared to the control group (mean 547.48 ± 166.9 cc), with a p-value less than 0.001. The trial group showed a statistically significant reduction in the absolute volume of irradiated SB at each dose, ranging from the low dose (10 Gy) to the high dose (45 Gy). In the control group, a negative correlation was found between SB and bladder volumes (R = -0.411, P = 0.008), whereas in the trial group, this correlation was weaker (R = -0.286, P = 0.091), with no significant relationship observed between bladder volume and SB.

Conclusion The high buttocks supine position effectively reduces SB radiation exposure without the need for bladder distension. This positioning method holds promise for reducing SB irradiation in various pelvic tumors.

Keywords High buttocks supine position, Small bowel, Gynecological tumor, IMRT

Introduction

It is widely acknowledged that the SB is highly susceptible to radiation, especially in the context of abdominal and pelvic cancer treatments. There exists a direct correlation between the volume of SB exposed to radiation and the likelihood of complications such as diarrhea, strictures, and perforations [1–3]. Given the SB's pivotal role in nutrient absorption, its radiation exposure significantly impacts patient quality of life. Radiation oncologists(ROs) face the challenge of balancing effective doses with the risk of subsequent issues, as pelvic radiotherapy is prevalent for cancers like rectal, cervical, and prostate cancer. Gynecological tumors, in particular, often necessitate larger therapy volumes, thereby elevating the risk of SB

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exposure. While acute bowel reactions typically subside within three months post-radiotherapy, addressing late sequelae remains a challenging aspect [3]. Furthermore, a noteworthy connection has been established between radiotherapy, radiation enteritis, microbiota, and treatment outcomes [4, 5]. Therefore, the imperative to minimize SB radiation exposure is underscored, not only to reduce the incidence of late sequelae but also to enhance the overall effectiveness of therapeutic interventions.

Minimizing the volume of the bowel exposed to radiation in patients with pelvic tumors remains a persistent challenge for ROs. Numerous studies have attempted to address this issue, including altering the patient's position during treatment [6–9] or employing invasive methods such as surgery [10]. However, the findings from these studies are contradictory. While some research suggests that the prone position can reduce the volume of SB exposed to radiation, others have found no significant difference between the prone and supine positions [11, 12]. It is worth noting that the prone position may also lead to increased setup errors [11, 13] and cause greater discomfort for patients [14].

R. J. Caspers, W. C. Hop, et al. conducted a study that revealed an inclined position could spare the SB in the pelvic region, although the effectiveness was limited [15]. However, there may be a way to enhance the effectiveness of reducing the volume of SB by using an inclined position that takes into account the effects of height and gravity. So our study aims to evaluate the effectiveness of a supine position with elevated buttocks to minimizes SB volume in the pelvis.

Materials and methods

Patients positioning and method

Our research adheres to the Helsinki Declaration and the recommended guidelines of the International Committee of Medical Journal Editors (ICMJE). This study obtained approval from the Ethics Committee of our hospital (NO. 20200901) and commenced in October 2020, based on promising preliminary results involving the use of a high buttocks supine position (HBSP) during pelvic radiotherapy. Consequently, all patients who provided consent and were undergoing pelvic radiotherapy were treated using this approach, prompting the conduct of a retrospective study. Between October 2020 and February 2022, the trial group comprised 38 patients, whereas the control group consisted of 47 patients, they were all the patients from October 2018 to October 2020. The inclusion criteria are (1) Eastern Cooperative Oncology Group (ECOG) 0–1. (2) age between 18 and 70 years. (3) The pathological confirmation indicates cervical malignancy or endometrial cancer. The exclusion criteria are ① age over 70 years. ② lower limb issues. ③prior gastrointestinal surgery. ④ a history of pelvic or abdominal radiotherapy. Among them, 76 patients had cervical cancer, and the remaining 9 had endometrial cancer, with staging determined using the FIGO classification. 9 patients were excluded due to exclusion criteria. All patients underwent IMRT at the Department of Oncology in Sanming Second Hospital, with nearly all also receiving concurrent chemotherapy using cisplatin or carboplatin. Among the 76 patients, four received single radiotherapy, three discontinued treatment, and two declined concurrent chemoradiotherapy. During simulation, patients were immobilized in the supine position using a vacuum bag and thermoplastic cast formation, with orthogonal tattoos serving as skin markers.

Table 1 The characteristics of patients

	Normal SP	High buttocks SP	*P*
NO. patients	40	36	
Age(mean)	57.8 ± 8.2	56.3 ± 10.3	0.5
Tumor site			
Cervix	37	30	0.294
endometrium	3	6	
FIGO stage			
I-II	28	19	0.123
III-IV	12	17	
BMI (mean)	24 ± 3.9	23 ± 2.6	0.615
Bladder (mean cc)	136 ± 130	148 ± 110	0.665
hysterectomy			
Yes	17	16	0.864
No	23	20	

Abbreviation: SP: supine position. BMI: Body Mass Index

For the trial group, consisting of 36 patients, the study initiation took place in October 2020, with informed consent obtained before immobilizing the patients. Prior to immobilization, a piece of solid foam (measuring 10 cm x 10 cm x 5 cm in length, width, and height) was positioned beneath the patient's feet, aligned in the direction of the vacuum pad. Patients were then instructed to place their sacrum atop the foam and assume a flat lying position, securing the position using thermoplastic cast formation. During this process, patients performed a glute bridge action, raising their buttocks as high as possible by flexing their lower limbs. This specific position was designated as the HBSP.

In contrast, the control group comprised 40 patients who underwent immobilization in the normal supine position (NSP). Similar to the trial group, immobilization involved the use of a vacuum bag and thermoplastic cast formation; however, the control group did not undergo the lifting action and make use of the hard foam. Table 1 presents the characteristics of both groups for comparison.

Planning CT: Patients underwent CT (GE Revolution) scans with 3 mm slices, covering the region from the tops of their diaphragms to their ischial tuberosities. An hour before the CT scan, patients were instructed to empty their bladder and consume 500mL of gastrographin solution. Intravenous contrast enhancement was administered to enhance delineation accuracy. The acquired imaging data were imported into the Monaco 5.0 treatment system by Elekta AB, based in Stockholm, Sweden.

Target and Delineation: Patients with gynecological tumors for the study, including those undergoing radical radiotherapy or post-gynecologic resection, the prescribed dose ranged from 45 Gy to 60 Gy. Some patients had delineated gross tumor volume (GTV), while others did not, potentially impacting the irradiated volume of the SB. Nevertheless, the irradiated volume of the pelvic cavity remained consistent between positions. The upper border ranged from the aortic bifurcation to the paraaortic region, while the lower border was set at 1/2 or 1/3 of the vagina. Contoured targets encompassed GTV, positive lymph nodes, clinical target volume (CTV), and regional lymphatics. The plan target volume (PTV) was expanded by 0.8 cm in the superior-inferior and anterior-posterior directions, and by 0.5 cm in the left-right direction for comprehensive coverage. SB loops and peritoneal space (PS) in the pelvic cavity were delineated from the pubic symphysis to the iliac bifurcation. The PS included all pelvic cavity organs (large bowel, bladder, SB, mesenteric structures, large blood vessels, and uterus), excluding the muscle. All target structures and organs at risk (OARs) underwent meticulous contouring by an experienced radiation oncologist (with over 15 years of experience) and were rigorously reviewed by a second senior radiologist (with over 15 years of experience). Dose-volume histograms (DVHs) were calculated for the target volume and SB in the pelvic region for all patients. Additionally, the volume of the SB in the pelvic cavity was recorded at 5 Gy dose intervals within the range of 10 Gy to 45 Gy.

Statistical analysis

To statistically compare the means of two samples, we applied the formula δ (μ1-μ2)/σ=70%, with a one-sided alpha of 0.05 and beta of 0.1. We deemed a *P*-value less than 0.05 as statistically significant.

Based on these calculations, we determined that a sample size of 36 was required for each group. Patient baseline characteristics, including clinicopathological factors, tumor site, stage, and whether surgery was performed, were compared using the chi-squared test. The means of two samples were analyzed using Student's t-test, the means of three samples were analyzed using one-way ANOVA, and the relationship between the bladder and SB was explored through linear regression.

All statistical analyses were conducted using IBM SPSS 22, with a significance threshold set at *P*-value less than 0.05.

Result

This study involved 76 women who underwent IMRT for radiotherapy. In the normal supine position, the average age of patients was 53, ranging from 35 to 70, while in the HBSP, the average age was 54, ranging from 23 to 70. The prescribed doses ranged from 45 Gy to 60 Gy. Table 1 presents a comprehensive overview of all patient characteristics, revealing a comparable baseline between both positions. The findings also demonstrated a statistically significant difference in the mean volume of the SB between the two positions. The trial group, utilizing the raised buttocks position, exhibited a decreased volume of SB in the pelvic cavity (mean 399.17 ± 158.7 cc) compared to the normal group (mean 547.48 ± 166.9 cc) ($p<0.001$) (Fig. 1A).

Furthermore, the trial group showed a statistically significant reduction in the absolute volume of irradiated SB at each dose, ranging from the low dose (10 Gy) to the high dose (45 Gy), as depicted in Fig. 2A. This reduction is further illustrated in the physical plans outlined in Table 2. The examination of the PS, where the SB can move, revealed no significant difference in the average volume of the PS between the two positions. The mean volume was 2066 ± 370 cc in the normal supine position and 2030 ± 276 cc in the high buttocks supine position, indicating no discernible difference, as depicted in Fig. 1B. However, aside from the 40 Gy dose ($p=0.041$), there was no notable variation in the volume of irradiated PS within the pelvic cavity between the two positions, as detailed in Table 3; Fig. 2B.

Furthermore, we examined the correlation between bladder volume and the volume of the SB in the pelvic cavity. In the NSP, the *P*-value was 0.008, and the correlation coefficient was −0.411 (Fig. 3A). Conversely, in the HBSP, the *P*-value was 0.091, and the correlation coefficient was −0.286 (Fig. 3B).

Patients were stratified into three groups based on their body mass index (BMI): the underweight group (BMI ≤ 19), the normal weight group (BMI 20 to 24), and the overweight group (BMI ≥ 25). The results revealed a significant impact of the underweight group on the volume of SB, which was the largest among the three groups, with a mean volume of 650 ± 95 cc. A statistically significant difference was observed between the underweight group and the normal weight group, with a mean volume of 458 ± 177 cc ($p=0.002$), as well as between the underweight group and the overweight group, with a mean volume of 447 ± 173 cc ($p=0.006$). However, no significant difference was noted between the normal weight and overweight groups, ($p=0.704$) (Fig. 1C).

Additionally, patients were categorized into two groups based on whether they underwent hysterectomy. The group without hysterectomy comprised 43 patients, while the group with hysterectomy comprised 33 patients.

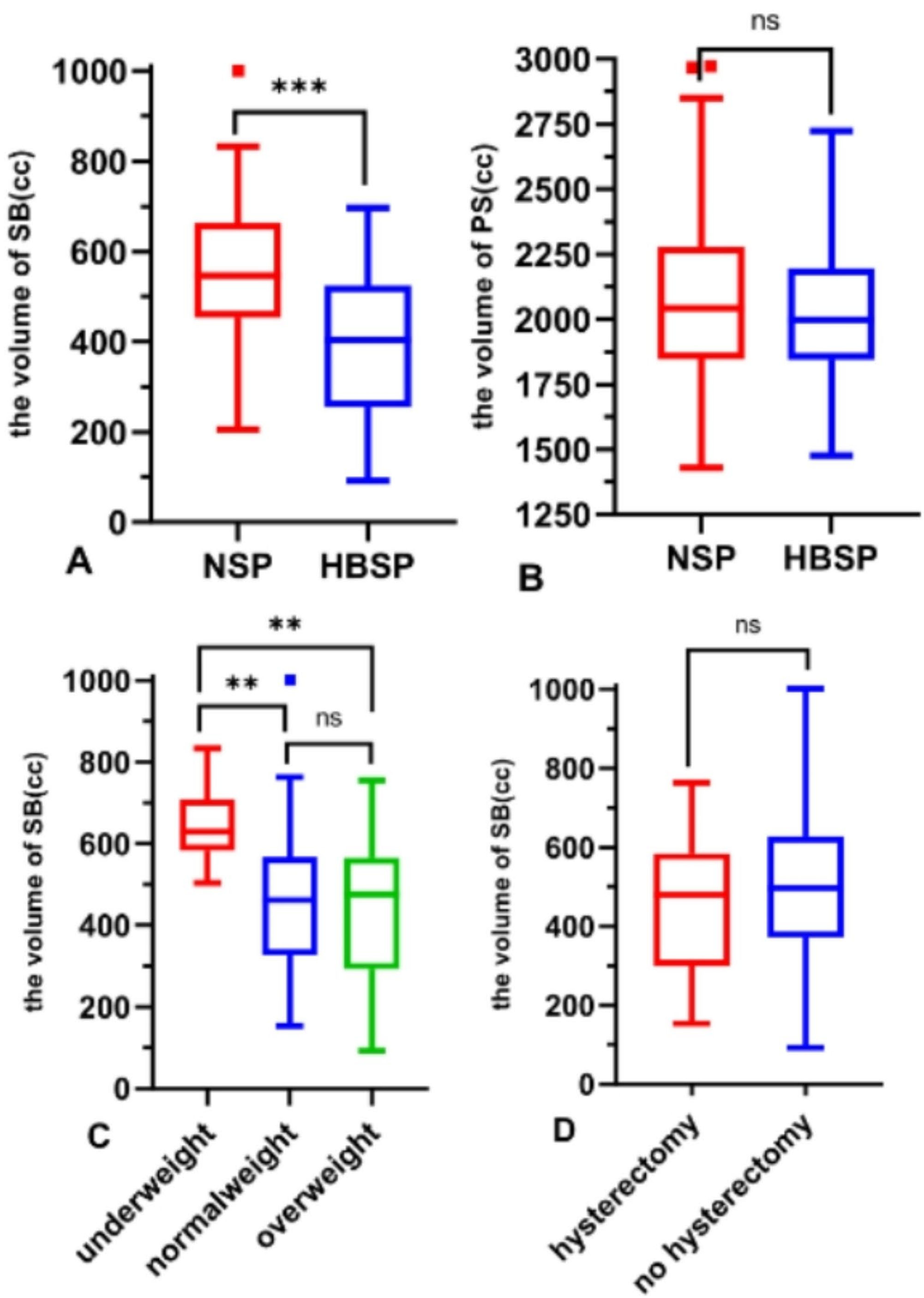

Fig. 1 Box plot of volume between different groups. Panel A illustrates the variance in small bowel (SB) volumes between the normal supine position (NSP) and the high buttocks supine position (HBSP); Panel B portrays the disparity in pelvic space volumes between NSP and HBSP; Panel C showcases the discrepancies in SB volumes among different Body Mass Index (BMI) categories; Panel D displays the distinctions in SB volumes between patients who underwent hysterectomy and those who did not

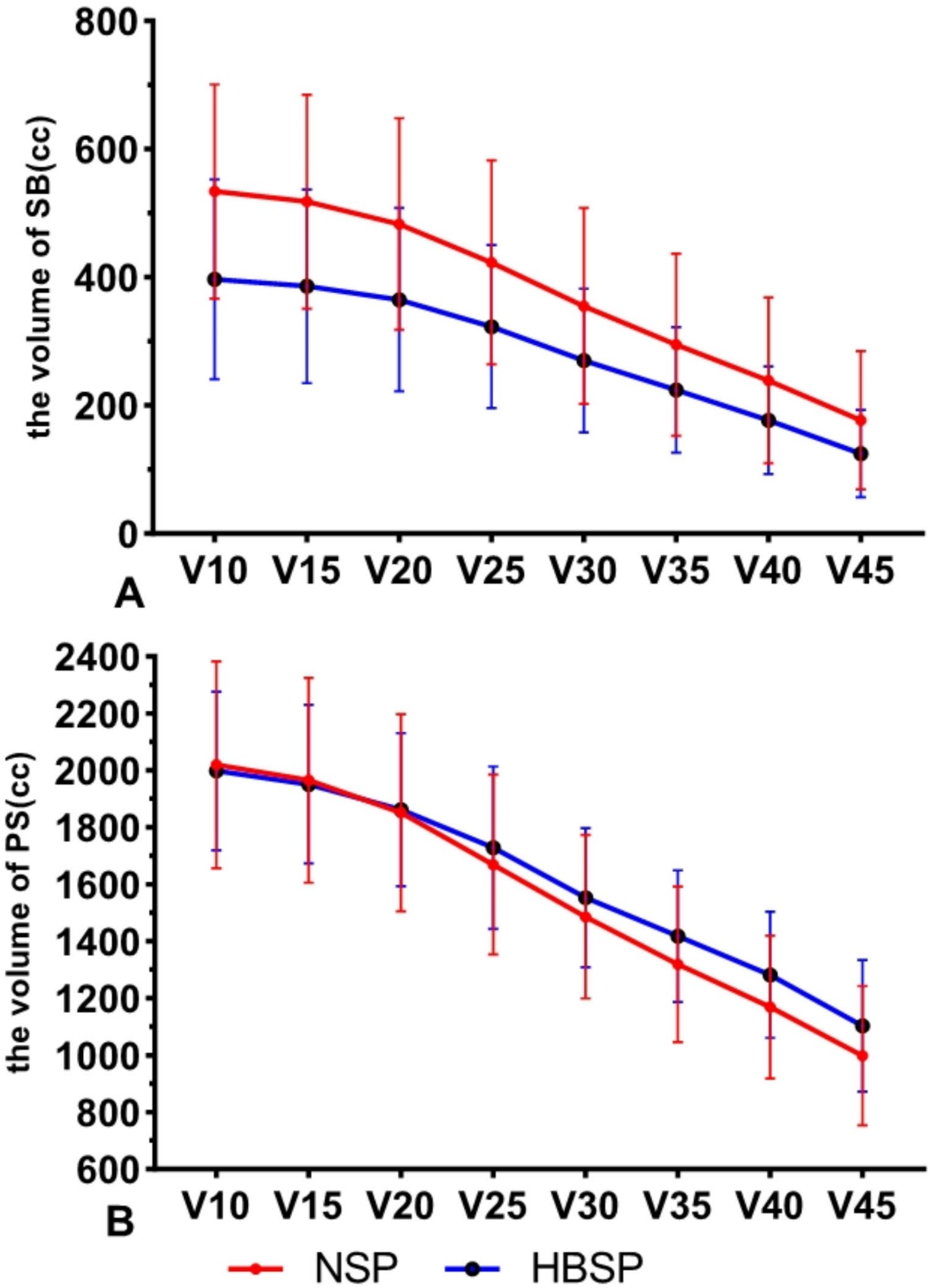

Fig. 2 The volume-averaged radiation doses received in the conventional position (shown in red) and the high hip position (shown in blue) are illustrated. Panel **A** depicts the volume of the small intestine, while Panel **B** displays the pelvic space volume

Table 2 Contrast between irradiated SB volumes in the normal supine position and the high buttocks supine position

	Normal supine position (mean)	High buttocks SP (mean)	*P*
V_{10}	534 ± 167	397 ± 156	< 0.001
V_{15}	518 ± 167	386 ± 151	0.001
V_{20}	483 ± 165	365 ± 143	0.001
V_{25}	423 ± 159	323 ± 127	0.004
V_{30}	355 ± 153	270 ± 112	0.007
V_{35}	295 ± 142	224 ± 98	0.014
V_{40}	239 ± 129	177 ± 84	0.016
V_{45}	177 ± 108	125 ± 68	0.016

Table 3 Contrast between irradiated pelvic space volumes in the normal supine position and the high buttocks supine position

	Normal supine position (mean)	High buttocks SP (mean)	*P*
V_{10}	2019 ± 363	1998 ± 278	0.781
V_{15}	1965 ± 359	1951 ± 278	0.844
V_{20}	1851 ± 346	1862 ± 268	0.871
V_{25}	1669 ± 316	1729 ± 285	0.394
V_{30}	1486 ± 287	1553 ± 245	0.277
V_{35}	1319 ± 273	1418 ± 231	0.095
V_{40}	1169 ± 251	1282 ± 221	0.041
V_{45}	998 ± 245	1103 ± 231	0.059

The volume of SB in these two groups was comparable, with means of 492.94±184.7 cc and 456.88±170.4 cc, respectively, resulting in a non-significant *p*-value of 0.387(Fig. 1D).

Discussion

IMRT stands as the primary modality for treating gynecological tumors, offering superior protection for the SB compared to three-dimensional conformal radiation therapy (3D-CRT) [16]. Despite its advantages, the SB remains a limiting organ in terms of radiation dosage during pelvic tumor radiotherapy, posing a challenge for ROs. Our study uncovered that assuming a supine position with elevated buttocks can effectively diminish the volume of SB within the pelvic cavity compared to the standard supine position. In the elevated buttocks position, the average bowel volume is significantly lower than in the normal position. As a result, the irradiated volume of SB also decreased in contrast to the normal position. Noteworthy reductions were observed at each 5 Gy interval ($P<0.05$). This study introduces an innovative approach to minimize the irradiated volume of the bowel in the pelvic region across a range of radiation doses.

In our study, we harnessed the force of gravity to displace the SB from the pelvic cavity. In the NSP, as patients sat on the therapist's treatment bed, their pelvic cavity occupied the lowest level in the body, causing the SB to be compressed within the pelvic cavity due to the gravitational effect. To address this issue, patients were instructed to raise their buttocks, elevating the pelvic cavity to a higher position within the body and causing the SB to shift into the upper abdomen. To ensure that the SB remained in its elevated position, a solid foam pad was placed under the sacral tail. The results of our study validated the effectiveness of this approach.

In the realm of radiotherapy, there is a persistent endeavor among ROs to minimize the presence of the SB within the pelvic cavity [8, 10, 17], particularly considering that this area typically receives the highest radiation dose. This objective is paramount in preventing adverse effects associated with high doses of radiation in the pelvic region. However, the current methods employed to achieve this goal, such as invasive techniques and the use of belly boards in prone positions, come with inherent limitations, including discomfort and setup errors. Previous studies have suggested that adopting prone positions with belly boards can effectively reduce the volume of the SB within the treatment field [18–20]. For instance, in a study by Olofsen-van Acht et al. [19], it was observed that employing prone positions resulted in a noteworthy 64% reduction in the volume of irradiated SB compared to supine positions. It is essential to recognize that this conclusion was drawn based on the use of orthogonal radiographs, which may not provide accurate estimations of SB volume.

In contrast, conflicting conclusions have been presented in other studies. For example, a study involving rectal cancer patients reported that the median volume of SB in the prone position was higher within the longitudinal PTV extension, measuring 983.5 cm^3, compared to the supine position, which measured 806.0 cm^3 ($p<0.005$) [20]. Martin J et al. [7] also found that the prone position led to a reduction in the volume of SB exposed to high doses of radiation but increased the volume of SB exposed to low doses (≤50% isodose). These findings raised concerns regarding setup errors and reproducibility.

In the study conducted by Koeck et al., the utilization of IMRT in conjunction with a prone position was found to effectively reduce the radiation dose received by the SB. However, their findings revealed no significant difference in the mean volume of the SB between the prone and supine positions, with mean volumes of 662.29±189.60 cc and 652.08±163.17 cc, respectively [6]. Similarly, the study conducted by Kim et al. produced analogous results, indicating no statistically significant difference in SB volumes between the prone and supine positions. The mean volumes were 489±211 cc and 521±226 cc, respectively [17]. Notably, all patients included in these studies were diagnosed with rectal cancer, and the irradiated field was relatively smaller compared to that of gynecological tumors. Conversely,

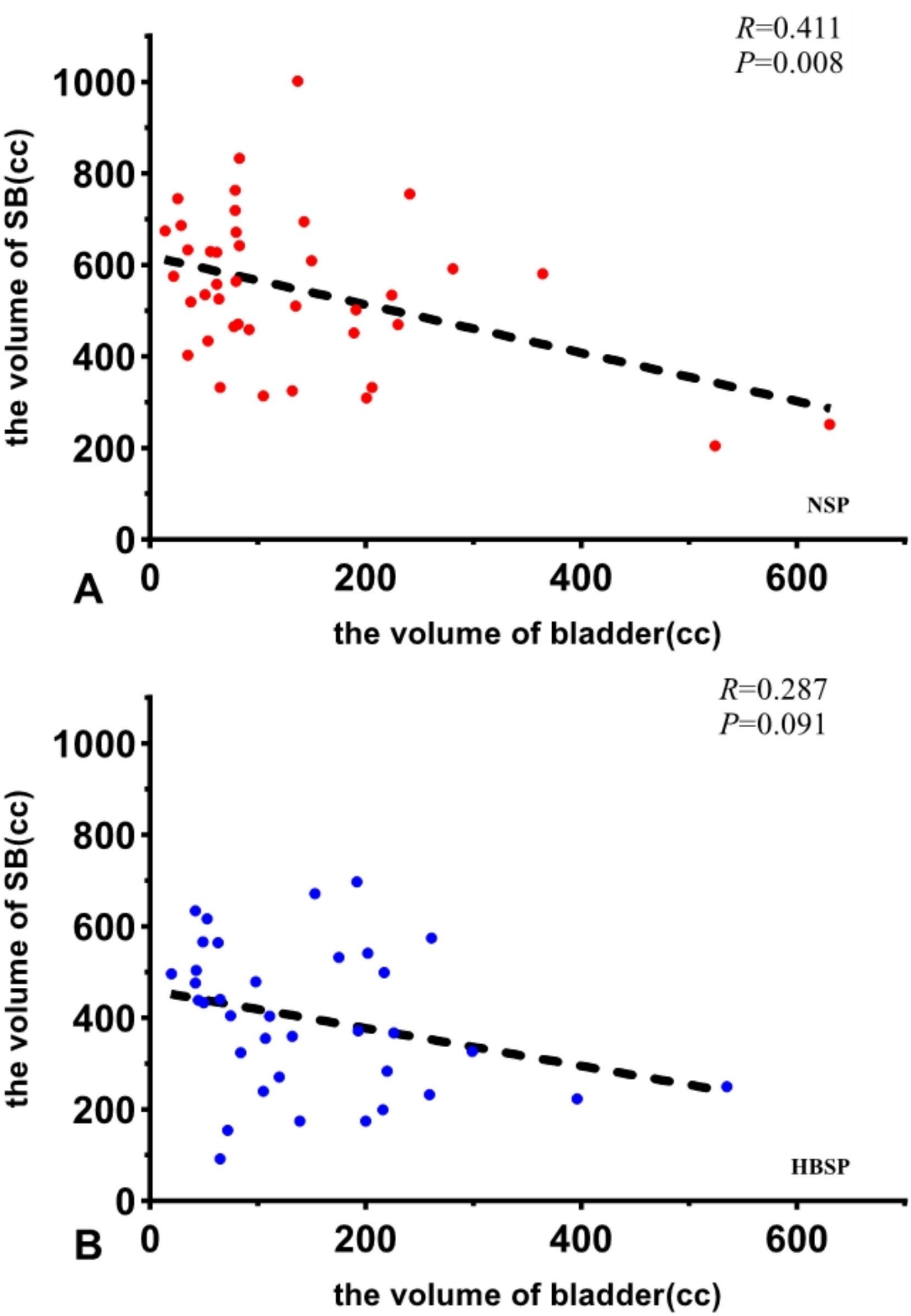

Fig. 3 The dots on the graph illustrate the relationship between the volume of the small intestine in the pelvic region and the volume of the bladder in different positions. Panel A represents the normal supine position (NSP), while Panel B represents the high buttocks supine position (HBSP)

Weiss et al. found that while the difference in SB volumes between the supine and prone positions was minimal, the supine position demonstrated better protection for organs at risk, such as the liver and kidneys [21].

The findings from various studies exploring the impact of prone versus supine positions on the irradiated volume of the SB have yielded inconsistent results. Some studies reported a notable decrease in the irradiated SB volume [18], while others did not observe such a significant reduction [22]. This variability might be attributed to discrepancies in the definition of the SB, with some studies delineating individual SB loops and others outlining the perineal cavity. Another factor contributing to these disparities is the potential difference in the volume of the perineal cavity between the prone position with a belly board and the supine position. In the prone position, the perineal cavity volume can be larger [23], leading to the actual SB in the pelvic region moving forward and away from the irradiated zone. Additionally, the placement of the belly board [22] may influence the results. Researchers have explored alternative non-invasive methods to reduce the SB volume within the treatment area. For instance, Muren LP and Nijkamp J et al. [24] discovered that by combining bladder distension with the use of a belly board, the average volume of the SB can be significantly reduced. In clinical practice, it is customary for patients undergoing pelvic tumor radiotherapy to be advised to consume oral fluids and avoid urination before treatment, aiming for bladder distension. The bladder volume significantly influences the size of the SB within the pelvic region, displaying a negative correlation, as supported by our findings in patients positioned supine. We observed a linear correlation coefficient (R) of -0.411 and a *P*-value of 0.008, indicating a statistically significant negative correlation. However, bladder distension may induce discomfort and a strong urge to urinate, potentially causing involuntary body movements during treatment. Kim TH et al. [25] acknowledged that this approach carries the potential for increased discomfort and setup errors, requiring absolute patient cooperation. While their study demonstrated a 10% reduction in the average volume of the SB, decreasing from 396 cc to 214 cc using different combined methods, it's noteworthy that their study specifically focused on rectal cancer patients. In our study, in the HBSP group, we observed no significant correlation between the volume of the SB and the bladder volume, as indicated by a linear correlation coefficient (*R*) of -0.286 and a *P*-value of 0.091. We hypothesized that the difference between the two groups lies in the HBSP, where gravitational forces may shift the SB from the pelvic cavity to the upper abdomen. Consequently, the SB is no longer in close proximity to the bladder. Based on these findings, we can conclude that patients with pelvic tumors undergoing radiotherapy in the high buttocks supine position may not necessarily need to retain urine to distend the bladder. Patients can maintain a natural position during radiotherapy, potentially reducing setup errors and minimizing body movement during treatment, thereby helping to decrease significant inter-fractional errors.

Various factors can impact the volume of the SB in the pelvic region, including BMI and surgical procedures. In our study, we meticulously considered these factors and categorized patients into three groups. Our findings affirm the correlation between BMI and the volume of SB in the pelvic region, with underweight patients exhibiting a larger volume. This phenomenon may be attributed to enteritis and inflammation in the perineal area, resulting in reduced absorption and a smaller volume of the great omentum, subsequently leading to weaker peristaltic movement. The influence of surgery in our study was relatively constrained, diverging from prior research. This discrepancy could be attributed to advancements in surgical techniques that effectively minimize bleeding and harm to the peritoneum.

Our study is subject to certain limitations that warrant acknowledgment. Owing to financial constraints, all patients underwent treatment in a single position, thereby restricting our capacity to compare two positions within the same patient. A more informative approach would have involved assessing two plans in two positions, allowing us to examine the optimal placement of the solid foam and determine the degree to which patients should raise their buttocks. Additionally, implementing the HBSP demands effective cooperation between patients and radiation therapists; therefore, an auxiliary device should be designed to better assist patients during the procedure.

Conclusion

Our study unveiled that adopting a supine position with elevated buttocks significantly reduces the irradiated volume of the SB during radiotherapy for gynecological tumors. Importantly, this effect was observed independently of bladder volume. Moreover, considering these benefits, this position could be contemplated for application in the treatment of other pelvic malignancies.

Abbreviations

HBSP	High buttocks supine position
SB	Small bowel
IMRT	Intensity-modulated radiation therapy
ROs	Radiation oncologists
OAR	Organs at risk
ICMJE	International Committee of Medical Journal Editors
ECOG	Eastern Cooperative Oncology Group
NSP	Normal supine position
CT	Computed tomography
GTV	Gross tumor volume
CTV	Clinical target volume
PTV	Plan target volume

DVHs Dose-volume histograms
PS Peritoneal space
3D-CRT three-dimensional conformal radiation therapy

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Author contributions
Su-Fang Qiu conceptualized the study. Chao Li, and You-Ping Xiao performed methodology and wrote the manuscript. Lin Huang, Wang Jing and Bin Zhang, helped to analyze data. Song-Hua Huang, and Li-Bao Yang supervised the manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
The study was approved by the Human Research Ethics Committees of Second Hospital of Sanming City, Fujian Province, China.

Consent for publication
All authors agree to publish.

Competing interests
The authors declare no competing interests.

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