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Prevention of well-leg compartment syndrome following lengthy medical operations in the lithotomy position

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ABSTRACT

Purpose: Compartment syndrome that occurs after lengthy surgery in the lithotomy position is known as well-leg compartment syndrome. It has serious consequences for patients, including amyotrophic renal failure, limb loss, and sometimes even death. This study aimed to identify effective preventive measures against well-leg compartment syndrome using a retrospective cohort study of 1,951 patients (985 and 966 in the prevention and control groups, respectively).

Material and methods: The following preventive interventions were analyzed: (1) changing from the lithotomy position to the open-leg position, (2) removing lower leg pressure caused by the lithotomy position, (3) limiting leg elevation based on the height of the right atrium, (4) horizontally repositioning the operating table every 3 hours, and (5) decompressing the contact area of the lower leg in the lithotomy position during operation.

Results: Eight cases of well-leg compartment syndrome occurred in the control group, whereas no well-leg compartment syndrome occurred in the prevention group.

Conclusion: These findings suggest that the five interventions assessed can prevent the development of well-leg compartment syndrome.

INTRODUCTION

Compartment syndrome occurs when excessive pressure builds up inside a muscle space enclosed by fascia and is usually caused by factors such as edema and bleeding; this condition results in a microcirculation disorder that affects the muscles and nerves [1]. Although compartment syndrome is commonly associated with blunt trauma, it can also occur because of an abnormal physical position that results in compression of the lower leg, such as the lithotomy position. In 1979, Leff and colleagues [2] reported compartment syndrome due to the lithotomy position adopted for cystectomy and urethroplasty patients and coined the term “well-leg compartment syndrome” (WLCS). WLCS has since been reported as a rare postoperative complication [3–6].

The incidence of WLCS has been reported as 1 in 3,500 lithotomy patients and 1 in 500 cystectomy patients [7,8]. WLCS has serious consequences for patients, including metabolic acidosis, amyotrophic renal failure, Volkmann's contracture, limb loss, and sometimes even death [9,10]. The risk factors of WLCS have been identified as follows: surgery time over 4 hours, assumption of the lithotomy position, peripheral vascular disorder, obesity, diabetes mellitus, use of intermittent air oppression equipment, intravascular volume shortage, traction and oppression of the blood vessels by intrapelvic manipulation, and oppression of the leg [8,11–14].

The prevention of WLCS is one of the most critical challenges in lithotomy-position surgery. Although several risk factors of WLCS have been reported, there have not yet been any reports on systemic preventive interventions. Therefore, this study aimed to identify effective preventive measures against WLCS. WLCS is an iatrogenic complication. Therefore, we hypothesized that WLCS could be prevented by appropriate interventions by health care providers. We conducted five interventions for patients with potential WLCS. Proving that the five interventions are effective leads to the prevention of WLCS. We hypothesized that our interventions could completely prevent WLCS.

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MATERIAL And METHODS

Study Setting and Population. All participants were patients scheduled for lithotomy-position surgery under general anesthesia from April 2013 to March 2019 at the National Hospital Organization Nagasaki Medical Center. The inclusion criteria for patients were a minimum age of 20 years and a minimum operation time of 3 hours. Emergency surgery patients were excluded, as the general condition of patients may vary according to scheduled or emergency surgery. Upon patients' arrival in the operation room, they underwent routine monitoring of noninvasive arterial blood pressure, electrocardiogram, and oxygen saturation (Spo_2). A device for spreading the lower limbs apart was used to absorb compressive forces (Levitator, MIZUHO, Japan) to achieve the lithotomy position.

Ethical Considerations. The study received ethical approval from the ethics committee of the National Hospital Organization Nagasaki Medical Center (approval no. 30017). In this study, we did not obtain written or oral consent from participants, as we analyzed existing information and did not recruit new participants or solicit additional information. Information about the study was made available to the participants, and the opportunity to deny permission for their information to be used in the study was guaranteed. We published a research plan and guaranteed the opportunity to opt out online on our hospital's homepage, according to the instructions from the institutional review board. We chose a retrospective study design because intervention studies may create groups that do not take WLCS prevention. WLCS is a serious complication for patients. This study is aimed at patients who actually underwent surgery, and we, as medical professionals, are obliged to provide safe and secure medical care to patients who undergo surgery. We therefore chose a retrospective study to prove the intervention effectiveness.

Design. We retrospectively reviewed the medical records of patients who underwent lithotomy-position surgery from April 2016 to March 2019 and for whom five interventions for the prevention of WLCS were implemented (prevention group). For the control group, we retrospectively reviewed the medical records of patients who underwent lithotomy-position surgery without any intervention for WLCS prevention from April 2013 to March 2016.

The primary endpoint was the occurrence of WLCS. The diagnosis of WLCS was made by an orthopedist when patients fulfilled one or more criteria based on puff, pain, paresthesia, paralysis, and pulselessness [15]. The secondary endpoint was the presence or absence of sacral dermatopathy or neuropathy in an area other than the lower legs.

Patient background information included age, sex, height, weight, body mass index, and medical history (ie, diabetes mellitus, hypertension, and ischemic heart disease). Anesthesia risk included all American Society of Anesthesiologists' physical classifications. Intraoperative risk factors reported within the literature include operation time, lithotomy position time, anesthesia time, intraoperative blood loss, and presence of blood transfusion. Postoperative complications included sacral dermatopathy and neuropathy other than in the lower leg. We used the National Pressure Injury Advisory Panel pressure ulcer staging system to evaluate postoperative sacral dermatopathy [16] and the Seddon classification for the evaluation of postoperative neuropathy [17].

Interventions for the Prevention of WLCS

Several variables are thought to contribute to the risk of developing WLCS in lithotomy-position surgeries. Currently, prophylaxis for WLCS is not established. We performed interventions designed to address these WLCS risk factors. Selection of the interventions for the prevention of WLCS was determined with a DELPHI method performed by an operating room nurse, surgeon, urologist, and gynecologist [18–20]. WLCS countermeasures were discussed, and the implementation of interventions 1–5 was determined for all lithotomy-position surgeries scheduled to last more than 3 hours (Table 1).

Intervention 1: Changing From the Lithotomy Position to the Open-Leg Position. The open-leg position does not involve the lithotomy position. As most cases of WLCS have been reported in procedures in the lithotomy position, we deemed it necessary to change the lithotomy position. Thus, surgeons should avoid prolonging the lithotomy position by repositioning the patient when the surgical technique allows it. When possible, the change from the lithotomy position to the open-leg position (without using the lithotomy position table) was carried out. In this alternative position, the lower part of the operating table was opened without using the instrument for position fixation.

Intervention 2: Relieving Excessive Pressure on the Lower Leg Contact Area in the Lithotomy Position and Measuring the Lower Leg Pressure. After the fixation of the operating position, the clearance of one finger was confirmed to prevent the oppression of the lower leg contact area in the lithotomy position. We considered the high risk of surgery for uterine and bladder malignancies as per case reports in Japan and other countries [21] indicating that these patients appear to constitute a high-risk group for WLCS, particularly in case of lymphadenectomy and hypoperfusion of the lower extremities due to a lower positioning of the head. The sensor PREDIA (Molten, Japan) was used to measure the pressure of the lower leg, adjusted to 40 mm Hg or less as per reports on lower leg compartment pressure that becomes the adaptation of the hypotonic incision [22,23]. The measurement of lower leg pressure was carried out quickly by the perioperative nurse.

Intervention 3: Limiting Leg Elevation Based on Height of the Right Atrium. Blood pressure during surgery should be maintained within the normal range. The maximum height of leg elevation was limited when the operating position was fixed during surgery to prevent ischemia due to leg elevation. After fixation of the operating position, the surgeon, perioperative nurse, and anesthesiologist confirmed that the elevation of the leg did not exceed that of the right atrium.

Intervention 4: Horizontally Repositioning the Operating Table Every 3 Hours. The falling horizontal position was altered to maintain the blood flow of the leg. The interval time (ie, time returning the operating table rotation to horizontal) was set to 5 minutes every 3 hours after consultation with the perioperative nurse, surgeon, urologist, and gynecologist.

Intervention 5: Decompressing the Contact Area of the Lower Leg in the Lithotomy Position by the Nurse During the Operation. During surgery, pressure on the patients' legs should be avoided. We determined that the perioperative nurse should ensure the intraoperative decompression of the contact area of the lower leg with the lithotomy table. The perioperative nurse inserted a hand in the contact point between the

Table 1
Interventions to prevent postoperative well-leg compartment syndrome

Interventions	*Details*
Intervention 1	Changing from the lithotomy position to the open-leg position
Intervention 2	Relieving excessive pressure on the lower leg contact area in the lithotomy position and measuring the lower leg pressure
Intervention 3	Limiting leg elevation based on the height of the right atrium
Intervention 4	Horizontally repositioning the operating table every 3 h
Intervention 5	Decompressing the contact area of the lower leg in the lithotomy position by the nurse during the operation

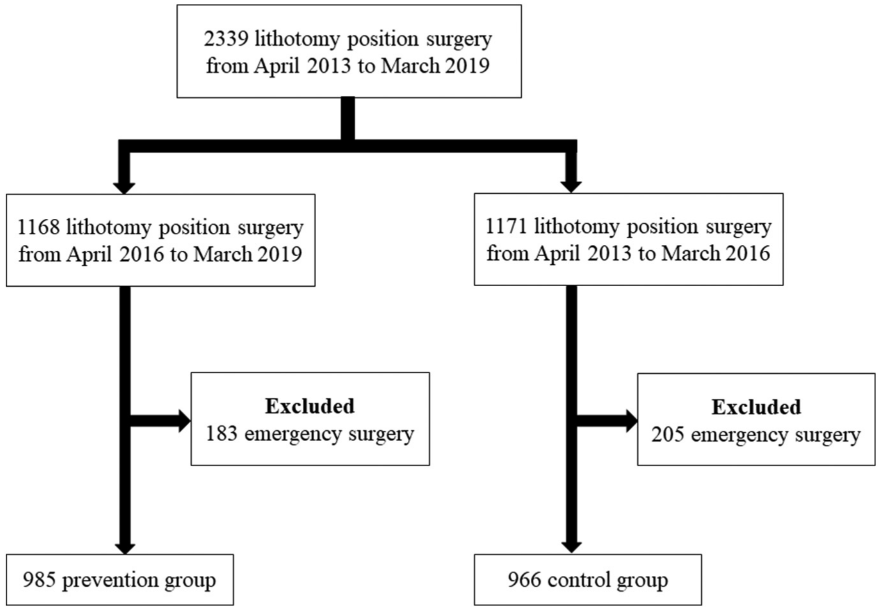

Fig 1. Flow diagram for study participants.

lithotomy table and the patient's body once every hour after the start of the operation, ensuring the release of body pressure. This decompression, performed by the perioperative nurse after confirming the operative field, should not interfere with the surgical procedure.

When intervention 1 was applied, interventions 2–5 were not applied because the patient was in the open-leg position. Clinical data were collected from the patients' charts.

Statistical Analysis. We performed a retrospective analysis of the prevention and control groups. Student's *t* tests or Mann-Whitney *U* tests were used to compare continuous variables among the patients' background and intraoperative factors between lithotomy-necessary cases and lithotomy-unnecessary cases in the prevention and control groups. χ^2 or Fisher exact tests were used to compare categorical variables, blood transfusion, and postoperative factors. *P* values were two-sided. All statistical analyses were carried out using JMP 14 (SAS Institute Inc, Cary, NC, USA).

RESULTS

A total of 2,339 patients underwent lithotomy-position surgery with reconstruction during the study period, and 1,951 patients fit the inclusion criteria. The prevention group included 985 participants, and the control group included 966 participants. In the prevention group, 526 patients (general surgery: $n = 134$; gynecology: $n = 323$; urology: $n = 69$) were changed from the lithotomy position to the open-leg position according to intervention 1. Patients receiving intervention 1 included those undergoing upper gastrointestinal surgery in general surgery, total hysterectomy in gynecology, and prostate surgery in urology. There was no extension of the postural fixation time with intervention 1. Interventions 2 to 5 were applied to 459 patients in the prevention group who were not eligible for shifting to the open-leg position (Figs 1 and 2).

The pressure of the lower leg contact point of 30 lithotomy patients was measured. The mean of the left lower leg pressure was 24.4 (SD =

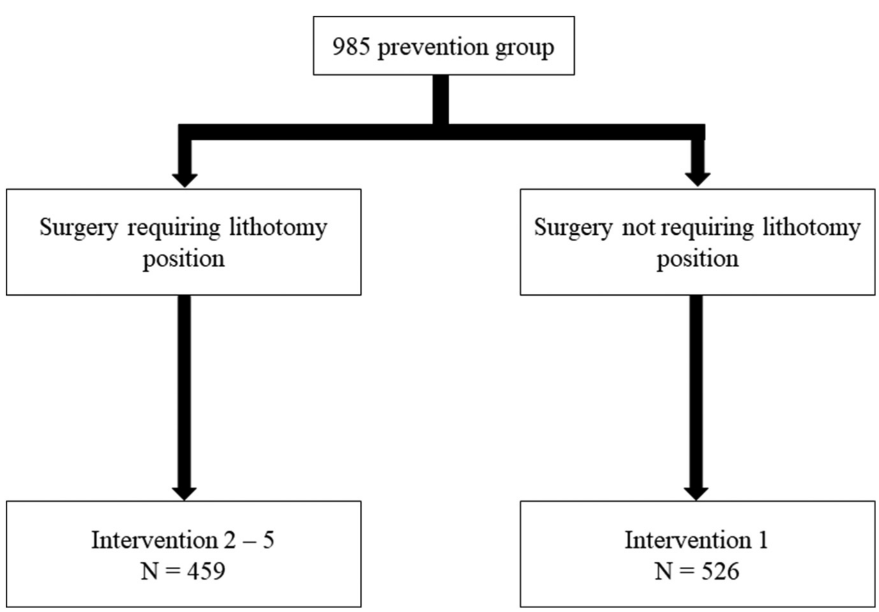

Fig 2. Flow diagram for intervention 1–5.

Table 2
Patients' demographic and clinical characteristics ($N = 1{,}951$)

Variable	Prevention group (n = 985)	Control group (n = 966)	P value
Clinical department			
Surgery	482	579	
Gynecology	420	367	
Urology	83	20	
Age (y)[a]	64.7 (13.7)	64.1 (14.1)	.85
Sex[b*]			.81
Male	359	358	
Female	626	608	
Height (cm)[a]	160.1 (9.2)	159.9 (9.4)	.92
Weight (kg)[a]	58.1 (11.1)	57.7 (10.9)	.45
BMI[a]	22.4 (4)	22.6 (3.2)	.63
Laparoscopic surgery[b]	387 (39.3%)	407 (42.1%)	.21
Operation time (min)[a]	301.2 (131.7)	278.3 (129.1)	.07
Lithotomy position time (min)[a]	316.8 (133.3)	296.4 (124.9)	.06
Anesthesia time (min)[a]	396.4 (164.2)	369.9 (143.2)	.06
Amount of bleeding (mL)[a]	222.6 (453.5)	200.6 (423.4)	.38
Blood transfusion[b]	59 (5.9%)	63 (6.5%)	.64
Hypertension[b]	114 (11.6%)	91 (9.2%)	.12
Diabetes mellitus[b]	53 (5.4%)	39 (4.0%)	.16
Ischemic heart disease[b]	16 (1.6%)	11 (1.1%)	.43

Values are mean (SD) or number of patients (%).
BMI, body mass index.
[a] Student's *t* test.
[b] χ^2 test.
[*] $P < .05$.

14.6) mm Hg, and that of the right lower leg pressure was 24.1 (SD = 11.5) mm Hg. Based on these results, the urologist and gynecologist determined that measuring lower leg pressure was unnecessary in conjunction with other interventions and was subsequently discontinued.

The background characteristics of patients in the prevention and control groups are shown in Table 2. Robot-assisted surgeries were not included in the preventive and control groups. There were no significant differences in patient background between the prevention and control groups.

Postoperative patient conditions are summarized in Table 3. No WLCS occurred postoperatively in the prevention group. Eight patients in the control group (0.83%) experienced postoperative WLCS. Postoperative sacral dermatopathy was reactive hyperemia in all cases, and its prevalence was significantly lower in the prevention group than in the control group ($P < .01$). The postoperative neurological diagnosis was neurapraxia of the arm in all cases, which was observed to improve on postoperative day 1. No significant differences were recorded in postoperative neurological disorders between prevention and control groups. The background characteristics of WLCS cases are shown in Table 4. In gynecology, all patients underwent surgery for uterine malignancy.

DISCUSSION

Although the occurrence of WLCS is rare, it is a serious complication after lithotomy-position surgery. Typical clinical symptoms of WLCS include crural pain. In the present study, none of the participants in the prevention group complained of lower leg pain or was diagnosed with WLCS, which suggests that the WLCS prevention intervention in this study was effective. In addition, based on the background of WLCS cases that occurred during the study period, there is a possibility of WLCS occurring in the lithotomy position, and preventive interventions should thus be implemented.

WLCS is considered to develop postoperatively owing to the assumption of the lithotomy position during surgery. The fixed lithotomy position may lead to WLCS by increasing muscle pressure in the lower leg as well as decreasing arterial pressure and Spo_2 [24,25]. We attempted to increase oxygenation by reducing the pressure on the lower extremities and increasing arterial pressure. We then incorporated the exclusion of risk factors as part of the interventions. The avoidance of unnecessary lithotomy positioning during surgery has been reported as a possible preventive measure against WLCS [26,27]. We changed the lithotomy position to the open-leg position (intervention 1) in operations such as upper digestive tract surgery, simple hysterectomy, and prostatic surgery, which constituted 53.4% of the prevention group. Because no cases of WLCS occurred after surgery performed in the open-leg position, it can therefore be assumed that changing from the lithotomy position to the open-leg position is an effective prevention intervention for WLCS. However, performing the surgery without the patient being in the lithotomy position for the remaining 46.6% of the prevention group was challenging. For these patients, it was necessary to implement the other interventions [2–5] during the operation. However, according to the results of the prevention and control groups comparing the open-leg and lithotomy positions, intervention 1 was effective in preventing postoperative sacral dermatopathy.

We attempted to prevent WLCS by maintaining the blood flow in the lower legs. For each 1 cm of elevation of the ankle above the right atrium, the arterial pressure in the lower extremities has been reported to decrease by approximately 0.78 mm Hg [28]. Because a decrease in arterial pressure is a risk factor for WLCS and elevation restriction is considered to prevent blood flow failure in the legs, the height of the lower limbs was fixed below the right atrium to

Table 3
Status of occurrence of well-leg compartment syndrome ($N = 1{,}951$)

Variable	Prevention group (n = 985)	Control group (n = 966)	P value
WLCS[a]	0 (0%)	8 (0.8%)	<.01[**]
Postoperative sacral dermatopathy[b]	64 (6.5%)	87 (9.0%)	.04[*]
Postoperative neurological disorders[a]	4 (0.4%)	1 (0.1%)	.37

Values are mean (SD) or number of patients (%).
[a] Fisher exact test.
[b] χ^2 test.
[*] $P < .05$.
[**] $P < .01$.

Table 4
Patients' background characteristics (WLCS cases)

Variable	WLCS cases N = 8
Clinical department	
Surgery	3
Gynecology	5
Urology	0
Age (y)	43 (35–62)
Sex	
Male	2
Female	6
Height (cm)	165.3 (154.9–171.3)
Weight (kg)	76.9 (37.2–87.2)
BMI	27 (15.5–29.4)
Laparoscopic surgery	3 (37.5%)
Site of gastrointestinal surgery	
Colon	1
Rectum	2
Operation time (min)	456 (366–532)
Lithotomy position time (min)	470 (425–550)
Anesthesia time (min)	513 (439–602)
Amount of bleeding (ml)	995 (660–2185)
Blood transfusion	5 (62.5%)
Hypertension	0 (0%)
Diabetes mellitus	3 (37.5%)
Ischemic heart disease	0 (0%)
Postoperative sacral dermatopathy	0 (0%)
Postoperative neurological disorders	0 (0%)

Median (min–max) or number of patients (%).
WLCS, well-leg compartment syndrome; *BMI*, body mass index.

maintain the blood flow in the lower limbs during surgery (intervention 3). In addition, the prevention of ischemia was attempted by adjusting the lithotomy table to minimize the pressure on the leg contact area. Experiments with human sacral skin have shown that the pressure at which the oxygen partial pressure gradually recovers is 30 mm Hg [29]. In the first 30 patients in the prevention group, the measurement of the lower leg pressure showed a mean value under 30 mm Hg (intervention 2). We assumed that although the pressure measurement in this study was not in the sacral region, it was similar in terms of maintaining the blood flow without compressing the peripheral blood vessels. It can therefore be assumed that the adjustment of the leg position on the lithotomy position table is an effective means of doing so.

Finally, during surgery, the ankle must be positioned higher than the right atrium with the pelvis elevated to ensure an adequate visual field. Periodically returning to the operating table's horizontal positioning reportedly increases the arterial pressure in the ankle joint and restores the blood flow to the lower leg [30,31]. In this study, the operating table was periodically returned to the horizontal position for 5 minutes every 3 hours to maintain the blood flow in the lower extremities (intervention 4). As no WLCS occurred within the prevention group with the restoration of the horizontal position for short periods of time, it can be assumed that the return to the horizontal positioning of the pelvic elevation effectively improved the blood flow in the legs. However, there have been no reports of lower leg pressure changes due to pelvic elevation. Therefore, it was hypothesized that the pressure of the lower leg contact area with the lithotomy position table might increase with pelvic elevation. The decompression once every hour by the perioperative nurse can be assumed to be an effective strategy for preventing the oppression of the lower leg contact area. In the future, clarifying the pressure change in the lower leg contact area when the pelvis is elevated is necessary.

The prevention group in this study included no cases of postoperative WLCS. In addition, a significant reduction in postoperative sacral dermatopathy cases was considered one of the effects of the WLCS prevention interventions. Based on the results of this study, patients who undergo lithotomy-position operations should consider the potential risk of WLCS and seek appropriate countermeasures. The approach presented here can serve as a theoretical framework for WLCS prevention.

Limitations. This study has some limitations, which represent research opportunities for future studies. First, there was a difference in the incidence of WLCS compared with previous studies by Halliwill and Simms [7,8]. We speculate that the main reason for this is their inclusion of laparoscopic surgeries. During laparoscopic surgery, the operating table is rotated to secure the operative field compared with open surgery [14]. This reduces blood flow to the lower extremities and increases the risk of WLCS. We, therefore, believe that WLCS incidence may have been higher among Halliwill and Simms's patients than in previous studies. However, this is only a conjecture and has not yet clarified yet, so we plan to conduct a multi-institutional joint study and increase the number of analyzed cases in the future. Second, we observed that WLCS can be prevented with the implementation of interventions and determined that five interventions could be combined to prevent WLCS. However, it was difficult to determine which of the interventions employed here was the most effective or preferable. Therefore, since the effectiveness of WLCS prevention has thus far only been assessed for all five interventions simultaneously, the most effective approach currently available is to integrate and implement all five interventions together as one unified WLCS prevention intervention. However, this issue is open to debate, and additional data are needed in the future.

In conclusion, although several risk factors of WLCS after lithotomy-position surgery have been identified, preventive interventions have not yet been established. In this study, we demonstrated that WLCS can be prevented by common interventions that can be implemented by the medical team.

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Author Contribution

Contributor K. Hara was responsible for the organization and coordination of the study. K. Hara was the chief investigator and also responsible for the data analysis. Dr Kuroki, Dr Kaneko, Dr Taniguchi, Dr Fukuda, and Dr Onita provided the study data. Dr Sawai revised it critically for important intellectual content. All authors contributed to the writing of the final manuscript.

Conflict of Interest

The authors have no conflicts of interest to declare and received no financial support for this work.

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