

# Effects of Lithotomy Position and External Compression on Lower Leg Muscle Compartment Pressure

Susanne D. Pfeffer, M.D.,\* John R. Halliwill, Ph.D.,† Mark A. Warner, M.D.‡

**Background:** Case reports have suggested that externally applied pressure from antithrombosis devices may contribute to the development of compartment syndromes during extended surgery in the lithotomy position. The purpose of this study was to assess the effects of a pneumatic compression device on directly measured intracompartment pressure in the lower leg with the leg positioned in the lithotomy position.

**Methods:** In 25 conscious, healthy men and women, the authors measured pressure within the tibialis anterior muscle compartment with the leg supine and in the lithotomy position with and without intermittent compression. Three different devices were used to keep the leg in the lithotomy position, supporting the leg either behind the knee, under the calf, or at the ankle.

**Results:** The lithotomy position with support behind the calf or knee increased intracompartment pressure to  $16.5 \pm 3.4$  versus  $10.7 \pm 5.8$  mmHg supine (mean  $\pm$  SD;  $P < 0.05$ ). The addition of intermittent compression decreased pressure to  $13.4 \pm 5.1$  mmHg during lithotomy ( $P < 0.05$ ) and to  $9.1 \pm 7.0$  mmHg in the supine position ( $P < 0.05$ ). In contrast, the lithotomy position with support near the ankle decreased intracompartment pressure to  $8.7 \pm 5.6$  versus  $13.3 \pm 5.1$  mmHg supine ( $P < 0.05$ ). The addition of intermittent compression decreased pressure to  $6.5 \pm 5.4$  mmHg during lithotomy ( $P < 0.05$ ) and to  $10.3 \pm 4.7$  mmHg in the supine position ( $P < 0.05$ ).

**Conclusions:** These results show that the lithotomy position is associated with changes in intracompartment pressure that are dependent on the method of leg support used. Furthermore, they indicate that intermittent external compression can reduce intracompartment pressure in the lower leg. Therefore, increases in intracompartment pressure during surgery in the lithotomy position with the calf or knee supported may be one of the factors that contribute to the development of compartment syndrome. Further, use of intermittent external compression may significantly reduce this pressure increase.

**COMPARTMENT syndrome** of one or both of the lower extremities is an infrequent but serious complication of procedures performed while the patient is in a lithotomy position.<sup>1-3</sup> The final common cause for compartment syndrome is that the circulation and function of tissues within a closed space are compromised by increased pressure within that space. Dense bony and fascial planes in extremities establish relatively unyielding

boundaries that divide groups of muscles, blood vessels, and nerves.

However, it is unclear what mechanism initially impairs compartment perfusion and precedes the final cause of increased intracompartment pressure.<sup>1</sup> For example, blood flow in the compartment can be impaired by perfusion failure of any kind, such as hypotension, vascular obstruction, or peripheral vascular disease or by increased resistance to blood flow in the compartment itself. Increased resistance to blood flow can be caused by external compression applied to the compartment, decreasing the size of the compartment and compressing its contents, or by an increased mass of compartment contents pressing against rigid walls and increasing tissue pressure in the compartment.

Many factors have been implicated in contributing to the development of compartment syndrome, such as patient positioning with obstruction of blood flow of either the femoral vessels at the hip or the popliteal vessels at the knee.<sup>1</sup> Another factor that has been implicated is the application of external pressure to the lower extremity. Case reports have suggested that externally applied pressure from antithrombosis devices may contribute to the development of compartment syndromes during extended surgery in the lithotomy position.<sup>4-5</sup> Therefore, the purpose of this study was to assess the effects of an antithrombosis device (intermittent external compression) on directly measured intracompartment pressure in the lower leg with the leg positioned in the lithotomy position.

## Methods

### Subjects

Twenty-five healthy volunteers (12 women and 13 men) between the ages of 20 and 36 yr were studied in the awake state. Subject demographics were as follows (mean  $\pm$  SD): weight,  $70.9 \pm 17.6$  kg; height,  $172 \pm 11$  cm; body surface area,  $1.83 \pm 0.27$  m<sup>2</sup>. This study was approved by the Institutional Review Board of the Mayo Clinic and Foundation (Rochester, MN). Each person gave written informed consent before participation.

### Experimental Protocol

All participants were positioned on a standard operating room table in the supine position while a pressure transducer (Coach 4-French transducer-tipped catheter; MIPM GmbH, Mammendorf, Germany) was inserted into the anterior muscle compartment of the right lower leg as fol-

\* Clinical Fellow, Mayo Graduate School of Medicine, † Assistant Professor of Anesthesiology, ‡ Professor of Anesthesiology, Department of Anesthesiology, Mayo Medical School.

Received from Department of Anesthesiology, Mayo Clinic and Foundation, Rochester, Minnesota. Submitted for publication December 20, 2000. Accepted for publication April 2, 2001. Supported by a grant from the Mayo Foundation, Rochester, Minnesota. This research was presented in preliminary form at the annual meeting of the American Society of Anesthesiologists, San Francisco, California, October 14-18, 2000.

Address reprint requests to Dr. Halliwill: Department of Anesthesiology, Mayo Clinic and Foundation, 200 First Street SW, Rochester, Minnesota 55905. Address electronic mail to: halliwill.john@mayo.edu. Individual article reprints may be purchased through the Journal Web site, www.anesthesiology.org.

lows.<sup>6</sup> The location for the insertion site was identified as 1.5 cm lateral of the tibial bone ridge and one-third the distance between the fibula head and the lateral malleolus. Under strict aseptic conditions, we infiltrated the skin and the subcutaneous tissue with 60 mg lidocaine, 1%, *via* a 30-gauge hypodermic needle. We then inserted a 14-gauge 5-cm intravenous catheter approximately 2.5 cm into the anterior tibial muscle at a 45–60° angle parallel to the muscle fibers, in the distal direction. The stylet was removed, and the pressure transducer was inserted until it was at the end of the plastic sheath of the catheter. The catheter was then pulled back, leaving the pressure transducer in place. The transducer was secured with sterile dressings and noncircumferential tape. The pressure cuff for a graduated intermittent pneumatic compression device (Venaflow Disposable Cuff, Venaflow system 30 A; Aircast, Inc., Summit, NJ) was applied to the right lower leg and in general extended from the fibular head to near the malleolus.

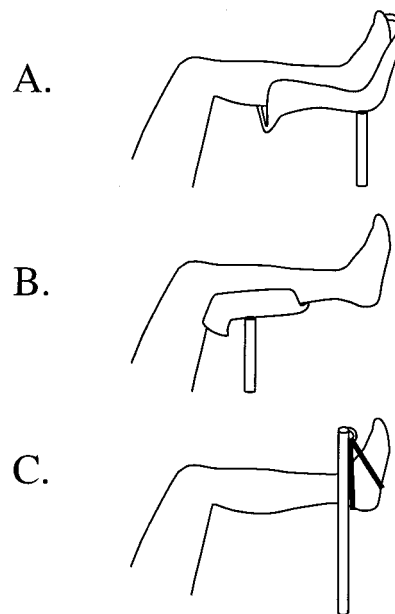
After instrumentation, the subject was allowed to rest supine for 30 min before measurements were performed. Subsequently, intracompartment pressure was measured for 30 min in each of the following positions (in random order):

1. supine position without intermittent external compression
2. supine position with intermittent external compression
3. standard lithotomy position without intermittent external compression
4. standard lithotomy position with intermittent external compression

Figure 1 illustrates this standard lithotomy position, using three different supports (see list). Joint angles were not specifically measured. During the two conditions in which intermittent external compression was applied, the pneumatic compressive device (Venaflow) was inflated every minute for 6 s. This device has a distal compartment that inflates to 52 mmHg, followed 0.3 s later by proximal compartment inflation to 45 mmHg.

Three different leg support devices were used to hold the leg in the lithotomy position during this study. Only one support device was used in a given subject. The following supports were used (fig. 1):

1. The first 10 subjects were measured with an Allen stirrup system (Allen Medical Systems, Cleveland, OH) supporting the calf in a boot-like device (fig. 1A).
2. The next five subjects were measured with a generic knee support, supporting the distal part of the thigh, the knee, and to a various degree in different patients the calf (fig. 1B). Only five subjects were studied with this support because results did not differ from the Allen stirrup system.
3. The last 10 subjects were measured with a cloth sling around the ankle and foot attached to a padded vertical “candy cane” (fig. 1C).



**Fig. 1.** Three different leg support devices were used to hold the leg in the lithotomy position during this study: (A) the Allen stirrup system, which supports the calf in a boot-like device; (B) a generic knee support, which supports the distal part of the thigh, knee, and calf; and (C) a cloth sling around the ankle and foot attached to a padded vertical “candy cane.”

#### Data Analysis

Intracompartment pressure was recorded continuously with a computer using a standard analog-to-digital data acquisition system (WinDaq; Dataq Instruments, Inc., Akron, OH). Data was analyzed off-line. During the 30-min data collection periods without application of external compression by the compressive device, intracompartment pressure was averaged over each 1-min interval. However, during the 30-min data collection periods with intermittent external compression, the intracompartment pressure was averaged over the approximately 50-s interval between cuff inflation cycles. This procedure was performed to exclude the brief (~6 s) period in which intracompartment pressure reflected the pressure in the pneumatic cuff system (fig. 2).

Because the results from subjects positioned with the Allen stirrup system (supporting the calf in a boot-like device) did not differ from those from the subjects positioned with the generic knee support (supporting the distal part of the thigh, knee, and calf), data were pooled across these 15 subjects. However, the results from subjects positioned with the cloth sling around the ankle and foot were qualitatively different from the first two groups, so this group of 10 subjects was analyzed separately.

#### Statistical Analysis

Intracompartment pressure was compared across conditions by two-way repeated-measures analysis of vari-

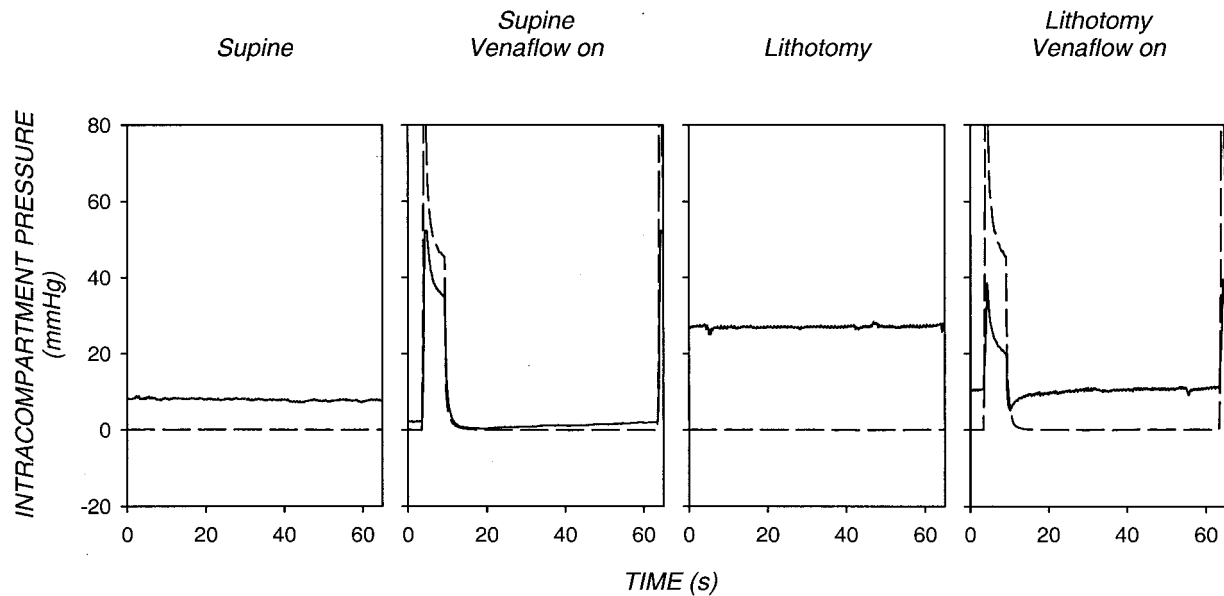


Fig. 2. A representative tracing showing the effect of transient compression on intracompartment pressure in the supine and lithotomy positions. The solid line represents directly measured intracompartment pressure, and the dashed line represents pressure applied by the external intermittent pneumatic cuff system (Venaflow; Aircast, Inc., Summit, NJ). As can be seen, external compression caused a transient increase in compartment pressure that quickly decreases below baseline when compression ends. The net result is that external compression results in lower average compartment pressures. This effect occurred regardless of leg position (supine *vs.* lithotomy).

ance. Tukey *post hoc* analysis was performed when the *P* value for the analysis of variance was less than 0.05. Values are reported as mean  $\pm$  SD, and *P* < 0.05 was the level of significance used.

## Results

A representative tracing showing the effect of transient compression on intracompartment pressure is shown in figure 2. Intermittent external compression caused a transient increase in compartment pressure that quickly decreased below baseline when compression ended. The net result is that external compression resulted in lower average compartment pressures. This effect occurred regardless of leg position (supine *vs.* lithotomy). Group average responses are shown in table 1.

Because the results from subjects positioned with the Allen stirrup system (supporting the calf in a boot-like device) did not differ from the subjects positioned with the generic knee support (supporting the distal part of the thigh, knee, and calf), results from subjects using these two supports were combined and are shown in table 1. In these subjects, the lithotomy position with support of the calf or knee increased intracompartment pressure *versus* supine (*P* < 0.05). The addition of intermittent compression decreased pressure during lithotomy (*P* < 0.05) and in the supine position (*P* < 0.05).

In contrast, responses from subjects positioned with the cloth sling around the ankle and foot were substantially different and so are presented separately from the other supports, in table 1. In these subjects, the lithotomy position with support near the ankle decreased

Table 1. Group Means for Intracompartment Pressure

	Group 1: Allen Stirrup (n = 10)	Group 2: Knee Support (n = 4)	Group 1 + 2: Allen and Knee (n = 14)	Group 3: Cloth Sling (n = 10)
Supine, without intermittent compression	10.5 $\pm$ 6.9	11.0 $\pm$ 1.2	10.7 $\pm$ 5.8	13.3 $\pm$ 5.1
Supine, with intermittent compression	9.0 $\pm$ 8.3*	9.3 $\pm$ 1.6*	9.1 $\pm$ 7.0*	10.3 $\pm$ 4.7*
Lithotomy, without intermittent compression	17.5 $\pm$ 2.6†	13.9 $\pm$ 4.1	16.5 $\pm$ 3.4†	8.7 $\pm$ 5.6†
Lithotomy, with intermittent compression	14.2 $\pm$ 5.4*†	11.2 $\pm$ 3.9*	13.4 $\pm$ 5.1*†	6.5 $\pm$ 5.4*†

\* *P* < 0.05 for with *versus* without intermittent compression. † *P* < 0.05 for lithotomy *versus* supine.

intracompartment pressure *versus* supine ( $P < 0.05$ ). The addition of intermittent compression decreased pressure during lithotomy ( $P < 0.05$ ) and in the supine position ( $P < 0.05$ ).

One subject showed a notable exception to the trends represented by the group averages. In the lithotomy position (generic knee support), pressure decreased from 20.3 mmHg to 15.5 mmHg with the addition of external compression, similar to other subjects. However, in the supine position, pressure increased from 11.3 to 34.8 mmHg supine with compression. It is unclear why this subject's response was divergent from others. The pressures generated by the intermittent compression device did not differ from those of other subjects, suggesting the device was functioning properly. We choose to exclude this subject from the group averages that are presented, but the statistical conclusions were not altered by inclusion or exclusion of this individual.

## Discussion

Our goal was to assess the effects of intermittent external compression on directly measured intracompartment pressure in the lower leg with the leg positioned in the lithotomy position. Our observations suggest that the simple act of placing the lower limb in the lithotomy position alters intracompartment pressure but that the direction of the response is linked to the manner in which the limb is supported. Furthermore, the results suggest that external compression, at least when it is applied intermittently, does not increase intracompartment pressure but decreases pressure.

Elevation of the limb into lithotomy position using the Allen stirrup and the knee support device consistently increased intracompartment pressure in all the volunteers. In contrast, elevating the leg with a sling support at the ankle consistently decreased intracompartment pressure. Therefore, it seems that resting the calf muscles on the leg support increases intracompartment pressure. Whether this is caused by applied pressure on the musculature by the support or by impairment of venous drainage out of or arterial inflow into the compartment has yet to be determined. Whether or not choice of leg support contributes to the development of compartment syndrome is unclear, but these findings suggest that support near the ankle compared with support under the knee or calf results in lower compartment pressures. However, this advantage of support near the ankle may be offset in clinical practice by the comparative instability of this support or other unforeseen adverse side effects.

The application of intermittent external compression may be beneficial in terms of decreasing intracompartment pressure. However, it must be noted that this effect is not likely to occur with application of constant

external compression as provided by compressive bandages or antithrombosis elastic stockings. This difference may be explained by the intermittent pressure application allowing for improved venous return and prevention of venous stasis while not significantly interfering with arterial perfusion.

What is the importance of the relatively small pressure changes we observed in intracompartment pressure throughout the course of these studies? We did not find steady-state pressures in the range considered necessary to cause a compartment syndrome ( $> 30$  mmHg).<sup>7</sup> However, our observation period in each condition was only 30 min, and in this relatively short period of time, we were able to observe an upward trend in intracompartment pressure in several individuals, independent of the leg support used. It is probable that duration of the lithotomy position might be an important cofactor in the development of compartment syndrome and that these relatively small pressure changes we observed reach critical levels during prolonged procedures. It also is possible that concomitant intraoperative events, such as hypotension, blood loss, use of vasoactive medications, externally applied pressure on the compartment by instruments or surgeons, or venous stasis, might lower the threshold for compartment syndrome such that it occurs at levels of intracompartment pressure similar in magnitude to what we observed in the current study.<sup>8</sup> We previously showed that perfusion pressure is reduced in the lithotomy position beyond the level predicted by elevation of the limb above heart level.<sup>9</sup> Therefore, small increases in intracompartment pressure may interact with decreased perfusion pressure or other factors to contribute to the development of compartment syndrome.

It is interesting that we occasionally observed greater increases in compartment pressure in slim volunteers in whom muscle mass was rather small. Although we do not have numerical data to support this observation statistically, it suggests that body habitus or gender might be a contributing factor for the development of compartment syndrome.

Our findings suggest that during procedures performed with patients in lithotomy positions, the use of equipment that supports the lower extremities at the calf or knee increases intracompartment pressure of the leg. We speculate that this pressure increase might contribute to the development of compartment syndrome, especially if sustained for a prolonged period. The pressure increase is dependent on the type of leg support used. The use of intermittent external compression seems to reduce this effect. These results need to be confirmed in anesthetized patients.

The authors thank Michael J. Joyner, M.D., and David O. Warner, M.D. (both at the Mayo Clinic, Rochester, MN), for their thoughtful review and suggestions during the development of this manuscript.

## References

1. Martin JT: Compartment syndromes: Concepts and perspectives for the anesthesiologist. *Anesth Analg* 1992; 75:275-83
2. Chase J, Harford F, Pinzur MS, Zussman M: Intraoperative lower extremity compartment pressures in lithotomy-positioned patients. *Dis Colon Rectum* 2000; 43:678-80
3. Warner ME, LaMaster LM, Thoeming AK, Marienau MS, Warner MA: Compartment syndrome in surgical patients. *ANESTHESIOLOGY* 2001; 94:705-708.
4. Lachmann EA, Rook JL, Tunkel R, Nagler W: Complications associated with intermittent pneumatic compression. *Arch Phys Med Rehabil* 1992; 73:482-5
5. Verdolin MH, Toth AS, Schroeder R: Bilateral lower extremity compartment syndromes following prolonged surgery in the low lithotomy position with serial compression stockings. *ANESTHESIOLOGY* 2000; 92:1189-91
6. Willy C, Gerngross H, Sterk J: Measurement of intracompartmental pressure with use of a new electronic transducer-tipped catheter system. *J Bone Joint Surg* 1999; 81-A:158-68
7. Hargens AR, Mubarak SJ: Current concepts in the pathophysiology, evaluation and diagnosis of compartment syndrome. *Hand Clin* 1998; 14:371-83
8. Styf J, Wiger P: Abnormally increased intramuscular pressure in human legs: Comparison of two experimental models. *J Trauma* 1998; 45:133-9
9. Halliwill JR, Hewitt SA, Joyner MJ, Warner MA: Effect of various lithotomy positions on lower-extremity blood pressure. *ANESTHESIOLOGY* 1998; 89:1373-6