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Skin blood flow response to 2-hour repositioning in the long-term care residents: A pilot study

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Abstract

Purpose: The purpose of this non-invasive pilot study was to examine the changes in TcO_2, skin temperature, and hyperemic response in the heels, sacrum, and trochanters in a 2-hour loading unloading condition in nursing home residents who are positioned in supine and lateral positions.

Design: A one-group, prospective, repeated measures design was used.

Subjects and Setting: Nine subjects (5 males, 4 males) with a mean age of 85.3 ± 10.86 years (mean ± SD) who required help in turning and positioning at the skilled nursing facility participated in the study.

Methods: Oxygen and temperature sensors were placed on the heels, trochanters, and sacrum. The subject was 1) positioned lateral for 30 minutes (preload); 2) turned to supine position with head of bed at 30 degrees for 2 hours (both sacrum and heels were on the bed surface) (loading); 3) positioned lateral for 2 hours (unloading). Subjects were turned to either the right or the left side.

Results: Friedman Tests showed no statistical differences in TcO_2 or skin temperature on the sacrum, heels, or trochanters during preload, supine, and lateral positioning ($p > 0.5$). Individual data revealed that hyperemic response was seen in 6 of the 9 subjects when the position was changed from supine to lateral. Only 1/3 of the subjects attained a sacral TcO_2 of 40 mmHg or above at the end of the 2-hour lateral positioning. TcO_2 on both heels decreased within the first 30 minutes of loading.

Conclusion: Two hours of staying in the supine position lowered sacral oxygenation to below 40 mmHg, in some subjects, regardless of whether there was adequate TcO_2 at preload.

Repositioning to a lateral position after 2 hours of placement in a supine position did not cause the TcO_2 to return to preload level. The efficacy of a 2-hour repositioning schedule requires further investigation. Since heel TcO_2 was reduced after 30 minutes of loading, further work is needed to determine whether the heels should be offloaded with more frequent repositioning.

Introduction

Pressure ulcer (PU) incidence across healthcare settings is high, especially in adults aged 65 years and older.[1, 2] According to a 2008 and 2009 national survey, PU prevalence in long-term care facilities was 22%, the highest among all services in the United States.[3] Sustained external pressure results in reduced blood flow and decreased tissue oxygenation, causing subsequent tissue necrosis and PU developmen.[4] The most common sites of PU are the sacrum and the heels.[5,6] These anatomical sites are areas frequently subjected to external pressure with potentially decreased skin blood flow when a person lies in bed.

Skin blood flow has been measured using transcutaneous oxygen (TcO_2) and temperature.[7, 8] Decreased levels of TcO_2 are seen with increasing external loading pressure[9] and in areas over bony prominences such as the trochanters, [10] sacrum, [11] and heels.[8] Skin temperature fluctuates in response to pressure application [12] and may indicate changes in skin blood flow.

In healthy tissue, relief of external pressure leads to reactive hyperemia, a transient increase in blood flow.[13] Simultaneous changes in TcO_2 and skin temperature have been recorded during the period of reactive hyperemia.[14, 8] A blunted hyperemic response is related to subsequent PU development in patients undergoing lengthy surgeries[15] and this response has also been observed in persons with diabetes mellitus and persons undergoing amputation.[16]

Studies have shown that various turning schedules on special pressure- relieving bed surfaces reduced the incidence of PU.[17] While there is a lack of evidence concerning the most effective repositioning schedule,[18, 5, 19] most clinical experts advocate a 2-hour repositioning schedule to enhance skin blood flow over bony prominences.[20] The schedule usually involves alternatively turning the person to the two lateral sides and the back. The most recommended

side-lying position is a 30 degree lateral recumbent position.[21] However, it is questionable whether a person can be maintained in this position and whether the trochanters are still subjected to a high interface pressure. Other suggestions to redistribute pressure included small weight shifts, although the scientific basis for this suggestion is limited.

A recent study of 15 healthy adults showed that skin-bed interface pressures in the sacral, trochanter, and buttocks were ≥ 32 mmHg, when subjects were in the supine and lateral positions.[22] Subjects were all placed on a low air-loss bed and yet, repositioning did not reduce the interface pressure to below the capillary closing pressure of 32 mmHg.[23] Repositioning to the left and to the right took place within 10 minutes and there was no measurement of hyperemic response. Because PU prevalence remained significant despite the recommended use of a 2-hour turning schedule, researchers question whether the repositioning schedule was followed, especially at long-term care facilities.[24]

Studies on repositioning and PU prevention mostly examine factors such as repositioning frequency, type of support surface, bed-skin interface pressure, and score on the Braden Scale for Predicting Pressure Sore Risk. [5,17, 22, 25] The skin blood flow mechanism in response to external loading and unloading during repositioning has not been adequately explored. Thus, there remains a need to examine the effect of loading and unloading every 2 hours on skin blood flow, skin temperature, and hyperemic response. The overall aim of this pilot study was to identify the changes in TcO_2, skin temperature, and hyperemic response in the heels, trochanters, and sacrum in a 2-hour loading unloading condition in nursing home residents who were positioned in supine and lateral positions. The specific aims of the study were to: 1) determine whether there is a difference in heel, trochanter, and sacral TcO_2 and skin temperature over-time when the heels, trochanter, and sacrum are on the bed surface and when the heels, trochanter, and sacrum are off

the bed surface and 2) determine whether there is a hyperemic reaction when the subject is turned to the lateral position.

Methods

A one-group, prospective, repeated measures design was used for data collection. Subject recruitment began after obtaining IRB approval from San José State University and the Terraces of Los Gatos, both located in Northern California. Subjects were ≥ 18 years of age and required help in turning and positioning. Subjects who had changes in blood flow including those with spinal cord injury, those with disrupted innervations, and those with existing skin breakdowns on the heels, trochanters, and sacrum were excluded. The PI (V.W.) approached potential subjects and/or their surrogates, explained the study protocol, and screened the person for eligibility. Surrogates provided consent while subjects were enrolled with their assent.

Instruments

Mental status of the subjects was screened using the 10-question Mental Status Questionnaire (MSQ). MSQ provides a brief, objective, and quantitative assessment in mental orientation, remote memory, and general knowledge.[26] Cut-points are determined by the number of errors. Sensitivity (45% - 94%) and specificity (96% - 99%) varied according to different cut-points.[26] A surrogate decision-maker was approached if the error score was greater than 5. Demographic variables such as height and weight were collected from chart reviews. PU risk was assessed by using the Braden Scale for Predicting Pressure Sore Risk (Braden Scale). The Braden Scale has been shown to be reliable and valid in numerous studies. Ankle-brachial Index (ABI) was obtained by using a hand-held Doppler (Park Electronics Model 840) and sphygmomanometer to measure the systolic pressures in the brachial, dorsalis pedis and/or posterior tibial arteries. TcO_2 (transcutaneous oxygen tension) was measured using the Radiometer TCM400 transcutaneous

monitor. The device provides non-invasive continuous measurement of TcO_2 on six sites simultaneously. The accuracy is ± 2 mmHg or 0.2 kPa ± 0.1 % of reading at 25 °C (excluding electrode).[27] Tissue hypoxia was defined as TcO_2 < 40 mm Hg.[28] Patients with critical limb ischemia[29] and non-healing wounds[30] usually have a TcO_2 < 30 mm Hg.

Skin temperature was measured with the RSP Temperature Monitor with the 400 series Thermistors. Arterial oxygen saturation (SaO_2) was obtained with the portable pulse oximeter (Novametrix, model 512). The accuracy of this oximeter at 80-100% is ± 2% SpO_2 ± 1 standard deviation.[31]

Procedure

Subject's demographic and clinical data were obtained by chart review. Data collection started at bedtime to avoid any interruptions of the resident's daily activities. Two research assistants performed data collection procedure for all subjects.

Oxygen and temperature sensors were placed on heels, that is, the lower, plantar aspect of the sole of each foot. The sacrum placement site was distal to the coccyx and proximal to the anus (Figure 1A). For trochanteric placement, sensors were placed 2 inches perpendicular and medial to the greater trochanter (Figure 1B). All subjects lay on the same type of pressure-reduction mattress.

The subject was 1) positioned lateral for 30 minutes (preload); 2) turned to supine position with head of bed at 30 degrees for 2 hours (both sacrum and heels were on the bed surface) (loading); 3) positioned lateral for 2 hours (unloading). Subjects were positioned at a 30° angle when placed in either the right or the left side. The total duration of data collection was approximately 5 hours.

Data Analysis

Data were managed and analyzed using the PASW Statistics Base (SPSS) (Version 18). Categorical data were reported as frequencies and percentages. Since the sample size was small, continuous variables were reported in median values. Freidman Test was used to test the differences in TcO_2 and skin temperature in the heels, trochanters, and sacrum.

Results

Seventy-five residents were approached for participation in the study. Nine subjects (5 males, 4 males) were enrolled (Table 1). The mean age was 85.3 ± 10.86 years (mean ± SD), their age ranged from 68 to 100 years. All were White and non-smokers. Arterial oxygen saturation (SaO_2) was > 92%. Mean ankle-branchial index (ABI) of both legs was 1.15, ranging from 0.48 to 2.3. Most subjects had normal body mass index (BMI) (n = 5). The average score on the Braden Risk Assessment Scale was 15.6 ± 2.72, indicating subjects were at risk of developing PUs. The majority of the subjects had hypertension (78%) and 33% had coronary arterial disease.

The effects of changing positions (preload to supine, supine to lateral) on the left heel, right hip, and sacral were analyzed using non-parametric Friedman Test. When TcO_2 and skin temperature were evaluated in separate analyses, there was no statistically significant changes on TcO_2 and skin temperature across time ($p > 0.05$). As the median skin temperature on the trochanters, heels, and sacrum over time remained relatively constant, only changes in TcO_2 will be discussed.

There were five subjects who had a low baseline preload sacral TcO_2 (< 40 mmHg); all had a history of hypertension. One person had a history of stroke and resulting hemiplegia. When these subjects were in the supine position (loading at the sacral site), TcO_2 remained low at 15, 30, 60, 90, and 120 minutes of loading. Four of these subjects showed a hyperemic response at

the first minute when they were repositioned on the lateral position (unloading at the sacral site). The sensor came off on the fifth subject and subject refused to have it replaced. The increased TcO_2 continued at 15 and 30 minutes in the lateral position in three of the four subjects. Transcutaneous oxygen in the fourth subject fluctuated. After one hour in the lateral position, only one subject had a TcO_2 of above 40 mmHg. At the end of the 2-hour lateral position, two subjects had a TcO_2 of $\geq$ 40 mmHg.

The remaining four subjects had a sacral TcO_2 preload of 40 mmHg or above. When these subjects were in the supine position (loading), TcO_2 decreased but remained above 40 mmHg at 15, 30, and 60 minutes. At the end of 2 hours of supine position, all but one subject had a TcO_2 of 40 mmHg. With repositioning to the lateral side (unloading), a hyperemic response was noted in two subjects. After one hour in the lateral position, all four subjects had a low sacral TcO_2. At 90 minutes of unloading, all subjects had dropped their TcO_2 to below the preload level. After two hours of remaining in the lateral position, only one subject had a TcO_2 of 40 mmHg while other maintained a low TcO_2.

The hyperemic response was seen in 6 of the 9 subjects when the position was changed from supine to lateral (Figure 2). Those subjects with a preload sacral TcO_2 of less than 40 mmHg seemed to have a more lasting effect of increased TcO_2 during the two hours of lateral positioning than subjects with a preload sacral TcO_2 of 40 mmHg or higher.

Heel TcO_2

Five subjects were turned to the right lateral side for the subsequent 2 hours after lying in the supine position for the first 2 hours. Both the right heel (Figure 3) and the left heel (Figure 4) showed a reduction of median TcO_2 over time. Most subjects had a TcO_2 of less than 40 mmHg after one hour of supine positioning when both heels were on the bed surface. A hyperemic

response was not observed on the left heel when the subject was repositioned to the right lateral side. In fact, there was no increase in TcO_2 when the subject was turned.

Four subjects were repositioned to the left lateral position after 2 hours of supine positioning. Heels were all intact but there was variability in ABI values. Heel TcO_2 decreased in all subjects after 30 minutes in the supine position (loading) (Figures 5 & 6). At the end of the two hours of left lateral positioning, both heels showed inconsistent levels of TcO_2.

Trochanteric TcO_2

Neither the right trochanteric TcO_2 nor the left trochanteric TcO_2 decreased significantly when the subject was repositioned to the corresponding lateral position. The median right trochanteric TcO2 was 51 mmHg after 2 hours in the supine position (unloading). When turning to the right side (loading of the right hip) median right trochanteric TcO_2 decreased to 49.5 mmHg in the immediate minute but was increased to 56 mmHg at the end of the 2-hour side lying period. The median left trochanteric TcO_2 was 32 mmHg after 2 hours in the supine position (unloading) but decreased to 30.5 mmHg when subjects were turned to the left lateral side. An unusual increase of median left trochanteric TcO_2 of 63 mmHg was seen at the end of the 2-hour side lateral position (loading of the left hip).

Discussion

Hospitalized older adults are recognized as being at increased risk for developing PU. Aging reduces collagen synthesis, leading to decreased skin elasticity and decreased ability to redistribute external pressure.[32] Factors contributing to hospital acquired PU include dry skin, urinary and fecal incontinence, difficulty turning in bed, and nursing home residency.[6] The same factors are commonplace in residents of long-term care facilities and the prevalence of PU is high in long-term care, thus necessitating effective prevention strategies.

In subjects with low sacral TcO_2 at preload, the 2-hour supine position further reduced the TcO_2. Even in subjects with TcO_2 at or above 40 mmHg, the same transcutaneous oxygenation was not achieved in the second hour of supine positioning. Transcutaneous oxygenation fell after the first hour of loading. As seven of the nine subjects were classified as at-risk for developing PUs based on Braden score, it is possible that that some subjects had compromised sacral perfusion for some time when they experienced non-blanchable erythema.

The skin blood flow mechanism is complex and not well understood. A review of literature suggest that the increase in blood flow in response to external pressure provides protection against ischemia.[33, 15, 34] The dilatation and constriction of blood vessels are influenced by multiple factors including endothelial nitric oxide, metabolic waste, and oxygen demand.[35] In fact, a study measuring sacral capillary blood perfusion on young healthy adults (n = 10) showed that mean blood flow was at its minimum levels when the skin was subjected to an applied pressure between 15 mmHg and 20 mmHg.[35] However, as applied pressure increased to over 35 mmHg with the use of a computer-controlled indenter, capillary blood perfusion increased. In the aforementioned study, pressure application procedure took less than an hour and the authors postulated that there might be a myogenic response to incremental loading.

Our study occurred in a clinical environment and subject's own weight defined the loading pressure. Although not measured, the external pressure was probably above 32 mmHg in the supine position, as validated in another study.[22] In our study, subjects who had a preload sacral $TcO_2 \geq 40$ mmHg maintained the TcO_2 at or above 40 mmHg in the first hour of loading, reflecting the influence of a protective mechanism to maintain cutaneous perfusion. Extending the loading time to the second hour revealed a reduction of TcO_2 to below 40 mmHg in all but

one subject, who achieved a TcO_2 of only 40 mmHg by the end of 2 hours of loading. It is not known if sustained loading of over an hour can offset the protective myogenic effect.

The magnitude of loading may also contribute to the reduction in transcutaneous oxygenation. For instance, sacral TcO_2 in healthy volunteers (n = 16) decreased when the externally applied pressure was at 40 mmHg.[36] In our subjects whose sacral TcO_2 were below 40 mmHg at preload, there was no increase in TcO_2 in the first hour of loading. Therefore, it is doubtful if an increase in blood flow in response to loading occurs in less well-oxygenated tissue. Since PU may occur in subdermal tissues under bony prominences between the first hour and 4 to 6 hours when under constant external pressure,[37] additional research is needed to help us understand the relationship of loading duration and skin blood flow in the older at- risk population.

When being turned to the lateral side after 2 hours of supine positioning, an immediate increase in transcutaneous oxygenation occurred in 6 of the 9 subjects, showing the hyperemic response. At the end of the 2-hour lateral positioning, only one-third of all subjects achieved a sacral TcO_2 of 40 mmHg. It is not known how much more than 2 hours it would take for sacral TcO_2 to reach the preload level, if it ever did. The loading duration may have to be shortened and the unloading duration may have to be lengthened to ensure an adequate skin blood flow in the human sacrum.

Overall, heel TcO_2 decreased within the first 30 minutes of loading, regardless of when the subject was repositioned. Reduction of TcO_2 was apparent after only 15 minutes of loading in subjects after hip surgery.[8] Relieving heel pressure did not result in an increase in TcO_2 to preload level, reflecting a blunted hyperemic response. The optimal duration of placing heels on the bed surface may be very brief, especially in people with circulatory problems or restricted

mobility in the lower extremities. In this population, 2-hour repositioning will be inadequate to enhance heel skin oxygenation. When the body is turned to either the right or left side with a pillow placed in between the legs, the lateral side of heel is still subjected to external pressure. This continued pressure may help to explain the fluctuation in TcO_2 during the 2 hours of lateral positioning in our study. Numerous heel pressure reduction strategies and heel products are used by clinicians daily. However, the most effective heel pressure relief device has yet to be determined.[38] Keeping heels off the bed surface to prevent direct pressure, friction, and sheer is a priority in PU prevention.

No changes were observed in individual data on trochanteric TcO_2. A possible explanation is the less than optimal placement of the sensor. It is technically difficult to locate a site that is distal to trochanter blood flow but not over boney prominences. Further studies are needed to ensure the validity of sensor location in the trochanteric region.

Limitations

The sample size of this study limits the ability to generalize any findings. Even though all subjects had intact skin on the selected anatomical locations, some of them had non-blanchable erythema, which might have shown difference in skin blood flow. Also, since the transcutaneous oxygen sensor could not be placed directly under any bony prominence because lying on the sensor would obstruct blood flow, measurement reflected TcO_2 of distal blood flow rather than TcO_2 at the anatomical site.

Conclusions

Our findings suggest that the sacrum may sustain reduction in transcutaneous oxygenation when older adults lay on it for over an hour. Two hours of lying in the supine position lowered sacral oxygenation to below 40 mmHg, in some older subjects, regardless of

whether there was adequate TcO_2 at preload. Repositioning to lateral position after 2 hours of supine positioning did not result in the TcO_2 returning to preload level, even after 2 hours of pressure relief. The efficacy of 2-hour interval of repositioning in the older residents requires further investigation. Transcutaneous oxygenation in both heels was reduced after 30 minutes of loading, suggesting that tissue ischemia in the heels may occur earlier than in the sacrum. Further work is needed to determine whether the heels in older persons should be offloaded with more frequent repositioning. As the older population is increasing, the issue of PU development is anticipated to continue. Preventive strategies are more cost-effective than treatment. Understanding the mechanism of decreased blood flow resulting in ischemic changes is critical to development of such preventive protocols, including the repositioning schedule.

Key Points

- ✓ Reduced sacral TcO_2 occurs in most subjects when they are in supine position for 2 hours.
- ✓ Offloading the sacrum for 2 hours does not result in its return to preload levels, suggesting prolonged perfusion defect.
- ✓ Heel TcO_2 is reduced after only 30 minutes of loading, suggesting ischemia may occur sooner in the heels than in the sacrum.
- ✓ Older residents who undergo 2-hour repositioning are at risk of skin breakdown.

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Figure Legends

TABLE 1. Demographic data of the nine subjects

FIGURE 1. The sensor placement sites: distal to the coccyx but proximal to the anus (Diagram A) and at 2 inches perpendicular and medial to the greater trochanters (Diagram B).

FIGURE 2. Sacral TcO_2 in individual subjects over the study duration.

FIGURE 3. Median TcO_2 on the right heel with subjects in the right lateral position.

FIGURE 4. Median TcO_2 on the left heel with subjects in the right lateral position.

FIGURE 5. Median TcO_2 on the right heel with subjects in the left lateral position.

FIGURE 6. Median TcO_2 on the left heel with subjects in the left lateral positioning group

TABLE 1. Demographic data of the nine subjects

Subject	1	2	3	4	5	6	7	8	9
Age	100	81	97	87	70	90	89	87	68
Gender	M	M	F	M	M	F	F	M	F
Right ABI	1.46	1.45	1.0	1.50	1.02	1.0	1.34	0.92	N/A
Left ABI	1.0	2.30	1.25	1.20	0.93	0.48	0.84	N/A	1.08
Braden score	14	16	17	17	16	10	19	15	N/A
Baseline TcO_2 (mmHg)									
Sacral	51	40	95	73	37	40	10	26	39
Rt. Heel	54	70	104	79	100	80	68	77	68
Lt. Heel	55	N/A	98	73	67	82	38	101	93
Rt. Hip	27	27	65	80	32	56	22	87	45
Lt. Hip	13	82	90	74	N/A	18	18	31	N/A
Baseline Temp (°C)									
Sacral	34.7	35.2	21.0	35.4	36.8	35.8	35.2	37	33.9
Rt. Heel	27.4	30.6	22.8	34.6	34.4	32.6	25.6	34.5	27.2
Lt. Heel	28.2	30.9	32.7	33.4	34.8	30.4	21.9	36.4	N/A
Rt. Hip	35.7	34.1	22.7	34.8	35.1	32.7	32.6	30.8	34.0
Lt. Hip	36	34.9	35.1	35.2	33.7	34.1	32.5	33.9	33.6

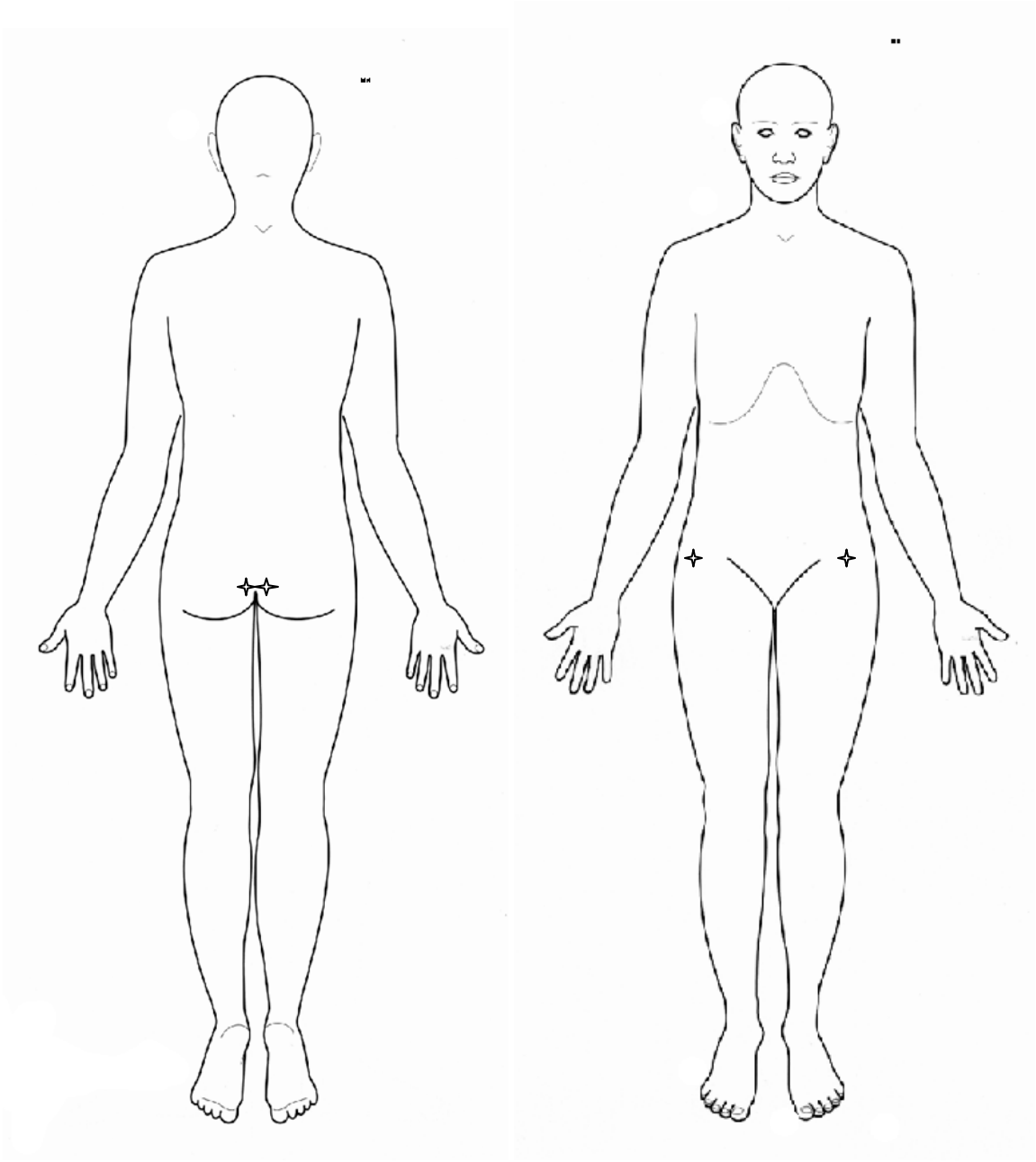

Diagram A Diagram B

FIGURE 1. The sensor placement sites: distal to the coccyx but proximal to the anus (Diagram A) and at 2 inches perpendicular and medial to the greater trochanters (Diagram B).

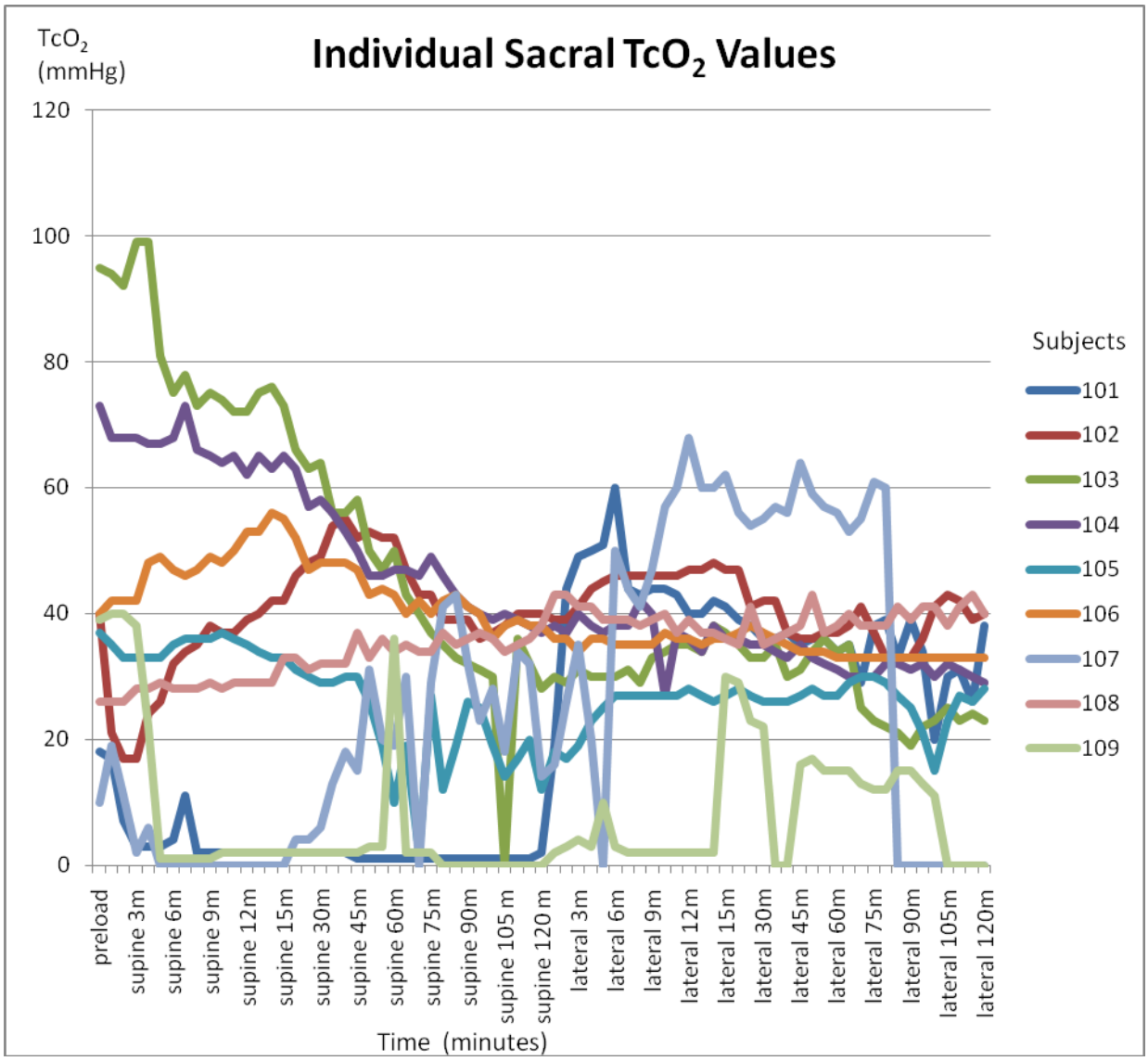

FIGURE 2. Sacral TcO_2 in individual subjects over the study duration.

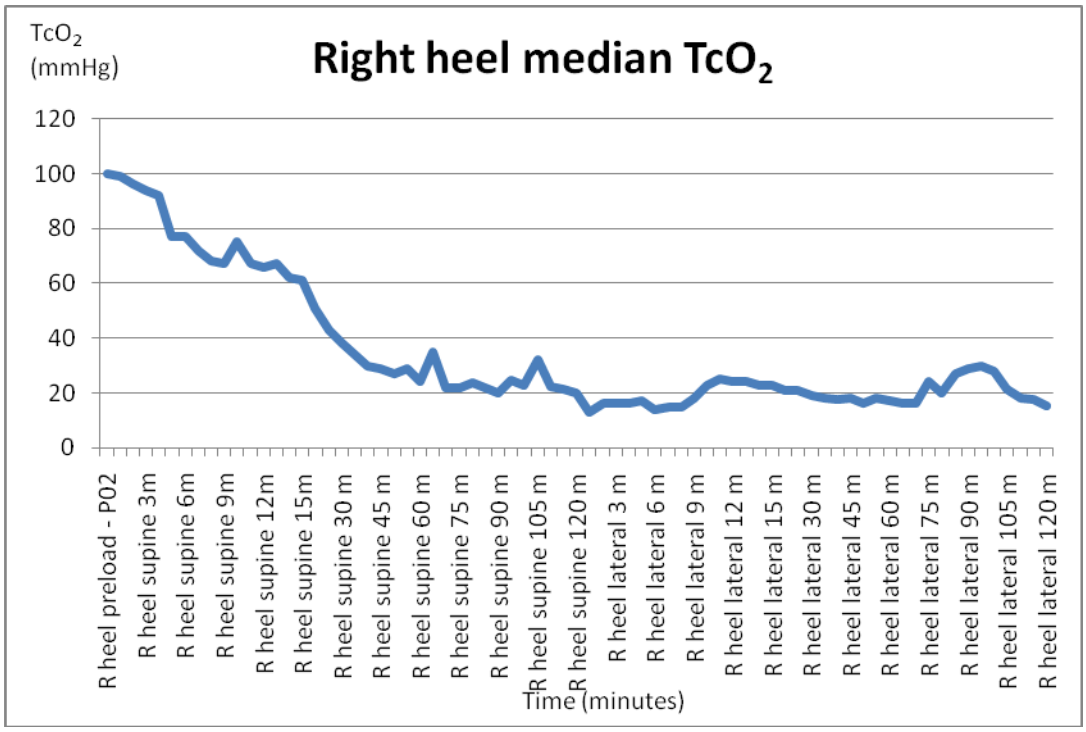

FIGURE 3. Median TcO_2 on the right heel with subjects in the right lateral position.

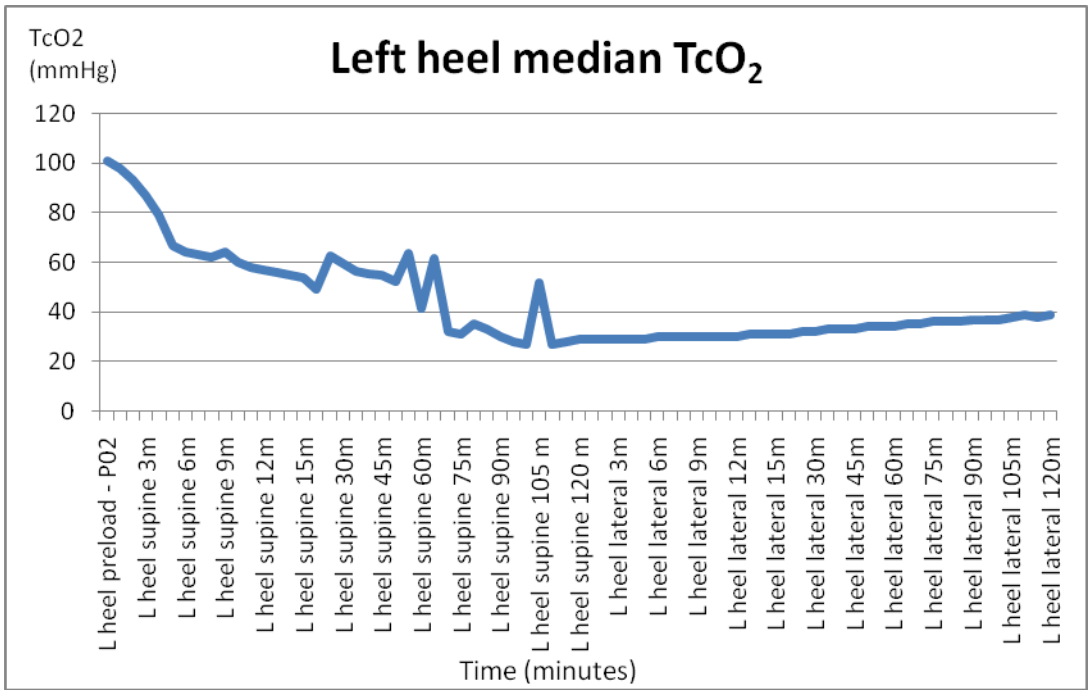

FIGURE 4. Median TcO_2 on the left heel with subjects in the right lateral position.

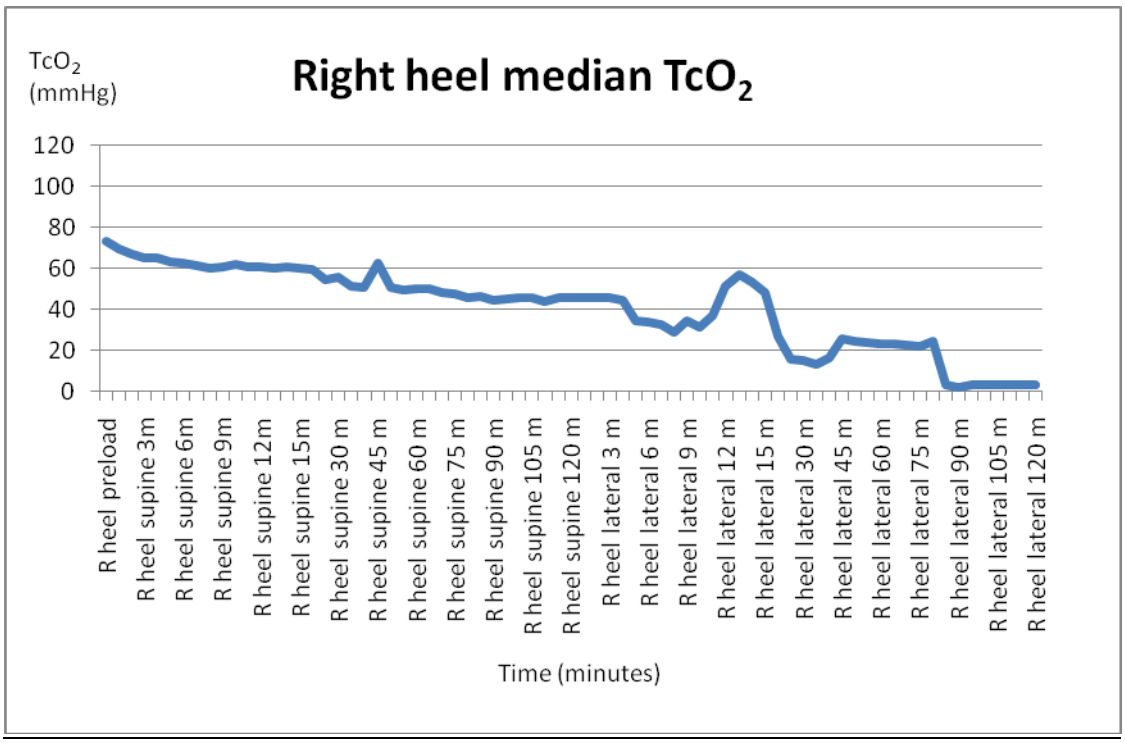

FIGURE 5. Median TcO_2 on the right heel with subjects in the left lateral position.

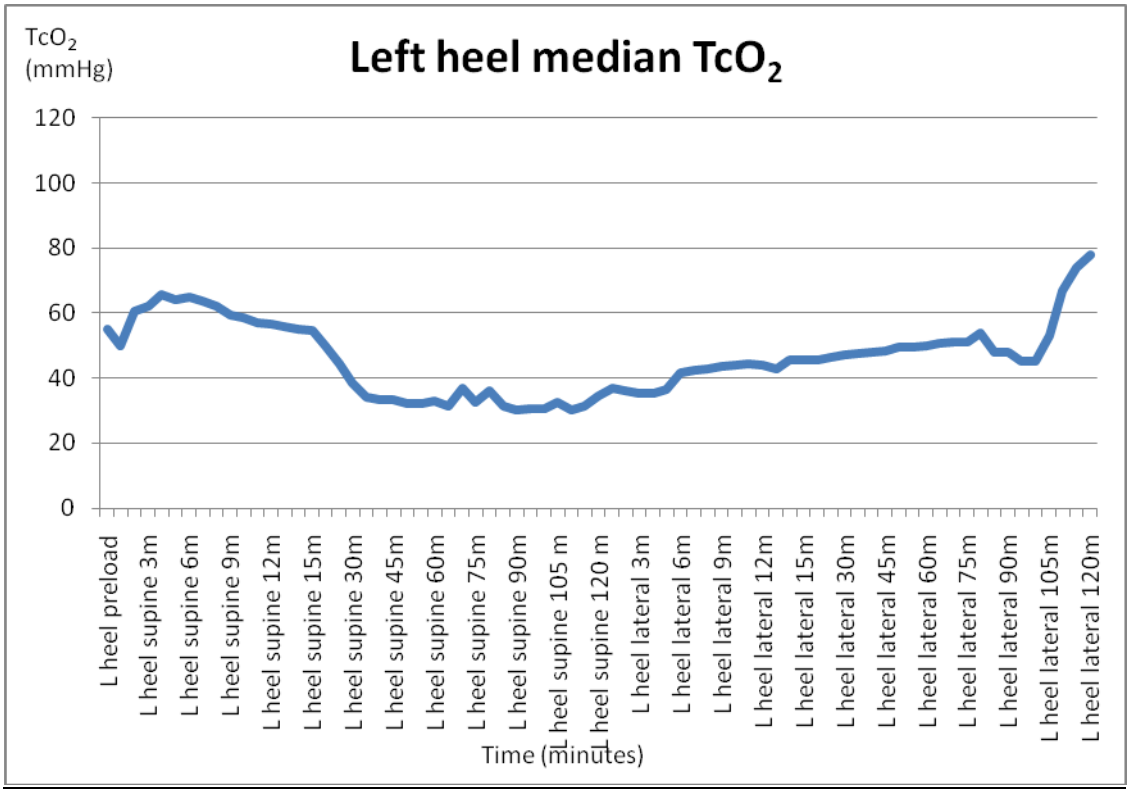

FIGURE 6. Median TcO_2 on the left heel with subjects in the left lateral positioning group.