SACRAL SKIN BLOOD PERFUSION: A FACTOR IN PRESSURE ULCERS?

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Pressure ulcers occur over the sacrum but are rare over the gluteus maximus. This predilection is partly explained by pressure concentration effects, but other factors may be involved. The authors hypothesized that if resting sacral skin blood flow was greater than in surrounding tissues, a decrease or stoppage of blood flow during loading might represent increased risk because relative tissue deficits would be greater. Because information on sacral skin blood flow is scarce yet important to the plausibility of this hypothesis, the objective was to determine if actual sacral skin resting blood flow is, in fact, different than flow in other nearby posterior areas. Thus, skin blood flow was measured with laser Doppler imaging in 15-cm² areas overlying the sacrum in 30 subjects (15 male) and compared to skin blood flow in other posterior sites (gluteus maximus and lower back) and to remote sites (hand and fingers). Results showed that average sacral skin blood flow (59.1 ± 1.4 arbitrary profusion units) was significantly ($P < 0.001$) greater than other posterior sites (48.7 ± 2.5 a.u.) and was significantly ($P < 0.01$) greater in females (63.0 ± 1.6 vs. 55.2 ± 1.8). These findings provide the first systematic characterization of resting sacral skin blood flow. The data are consistent with the tentative hypothesis, but more direct evidence of a linkage is clearly needed. Large spatial variability in skin blood flow (40%) suggests that comparisons of skin blood flow among sites are best done with laser Doppler imaging in contrast to standard laser Doppler monitoring.

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Certain sites of bony prominence are known to be at particular risk for skin breakdown and pressure ulcer development as compared with soft tissue sites under similar loading conditions. For example, pressure ulcers occur over the sacrum but are rare over the gluteus maximus.[1] To a large measure, this predilection is explainable on the basis of pressure concentration and other mechanical effects on tissue overlying the sacrum. Differences in response to short-term pressure loading of skin, overlying sacrum, and gluteus regions have been reported. Differential microvascular flow regulation involvement has been suggested.[2] A possible additional contributing factor that has not been widely considered is that tissue sites with greater resting levels of blood flow might be at greater risk of breakdown when weighted to levels that significantly decrease blood flow. The authors hypothesized that if resting sacral skin blood flow (SBF) was greater than in surrounding tissues, a decrease or stoppage of blood flow during loading might represent increased risk because relative tissue deficits would be greater. This hypothesis is based on the concept that for equal loading durations, the resulting tissue "flow-debt" and subsequent injury potential would be greater in more highly perfused tissue. The possible validity of this hypothesis depends, in part, on whether breakdown-prone regions do, in fact, tend to have greater resting perfusion than nearby surrounding regions.

Data describing resting blood flow in the breakdown-prone sacral region are scarce. One study of 11 healthy people suggests no significant difference exists in single point laser-Doppler measurements between sacrum and gluteus maximus.[3] Data from two other

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studies — one including 10 young and another including 10 older healthy patients — also indicate a lack of resting perfusion difference between sacrum and gluteus maximus.[4,5] However, the combination of the small sample size and small tissue sampling area of single point laser-Doppler (~ 1 mm^2) used in these studies may have obscured the presence of true differences in SBF between these sites. Because such a differential in SBF, if present, may increase understanding about the etiology of pressure ulcers, the purpose of this study was to compare ulcer-prone sacral region SBF to other less-at-risk tissue SBF using laser Doppler imaging[6-13] of larger spatial samples.

Methods

Sacral SBF with simultaneously determined resting SBF at the gluteus maximus and lower back were measured using laser Doppler imaging (LDI) to allow a large tissue area (15 cm^2) to be sampled and studied for each site. Measurements were performed in 30 subjects (15 male) with an age range of 21 to 56 years (37.1 ± 2.1 years). In one subset of this group (N = 8), localized sacral skin heating to 44° C for 5 minutes was used to ascertain maximal SBF responses. In another separate subset (N = 13), SBF response of hand areas were determined to provide reference comparisons for sacral perfusion levels. In a third subset (N = 6), repeat measurements within the sacral region were performed 6 weeks after the first set of measurements to determine reproducibility. Institutional Review Board approval was obtained and all patients provided informed consent.

Experimental. Thirty subjects (15 male) with an age range of 21 to 56 years participated in the study. No subject reported a history of cardiac or vascular disease and none had a history of diabetes mellitus. In all 30 subjects, the lower back, sacrum, and gluteus maximus areas were scanned with LDI, which yields both image and quantitative information on SBF as has been previously described.[6-15] All laser Doppler images were obtained with subjects in a prone position on an examining table using a 633 nm wavelength instrument (Moor Instruments, Model LDI-VR, Wilmington, Del.), which was positioned at a 50-cm vertical distance above the sacral area. The scan pattern was rectangular (19 cm x 24 cm) with a total scan area of 456 cm^2 (see Figures 1a and 1b and 2a and 2b). The scan was started after the subject had been resting in the prone position for 15 minutes. Each scan took 250 seconds to complete. Skin temperatures were recorded at the midsacrum, gluteus maximus, and lower back near the midline at the level of L2 using a small thermocouple thermometer. In addition to the single baseline back scans, a second scan was performed in 13 of the subjects after heating the midsacral area with a 1.9-cm diameter contact heater raised to a set temperature of 44° C for 5 minutes. In eight other subjects, the dorsal surface of the dominant hand was scanned immediately after the back scan. Six of the 30 subjects were re-scanned 6 weeks after their initial back scans.

Data analyses. The mean skin blood perfusion rates within standardized 15-cm^2 triangular regions overlying the sacrum, gluteus, and lower back (see Figures 1a and 1 b and 2a and 2b) were calculated and compared. Tests for differences within sites (sacrum, gluteus, and low back) and between genders were performed using a full general linear model (GLM) for repeated measures with gender as a between-subjects factor using the Statistical Package for the Social Sciences (SPSS version 6.1). For the heated area, the region corresponding to the heater dimensions was used as the analytical region of interest (see Figures 3a and 3b). For the dorsal hand SBF measurements, two regions were selected for comparison with the SBF in the sacral area. One was the

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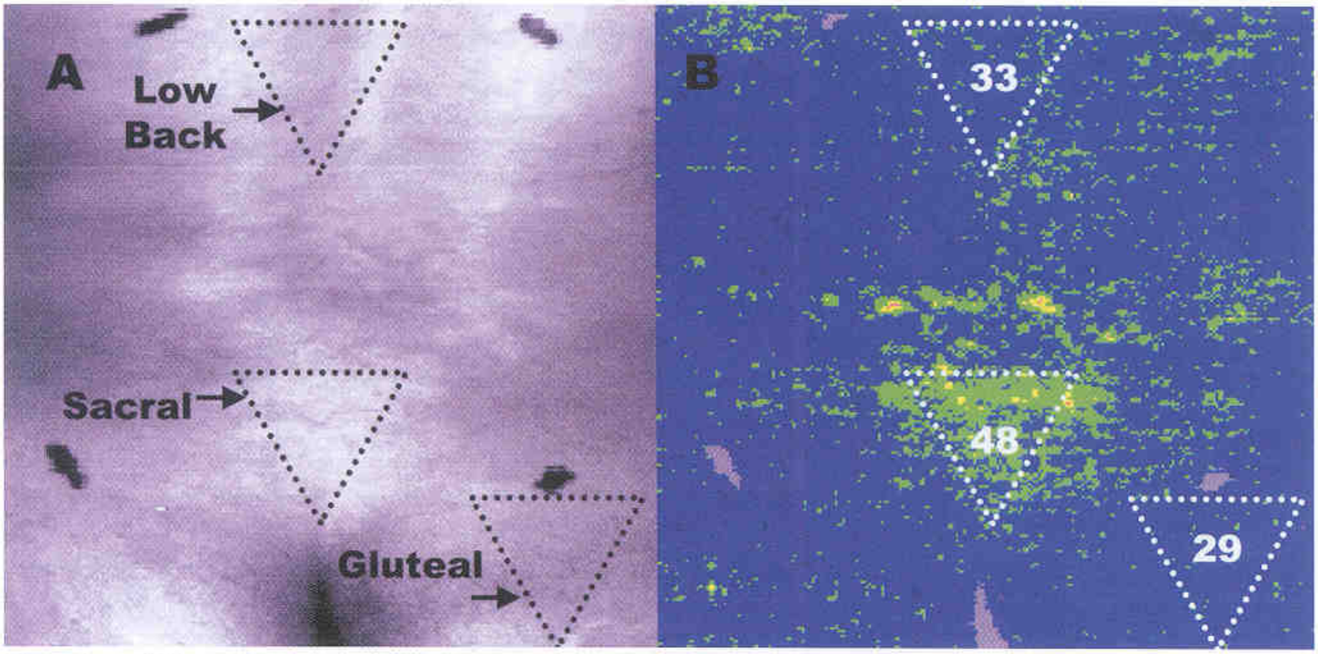
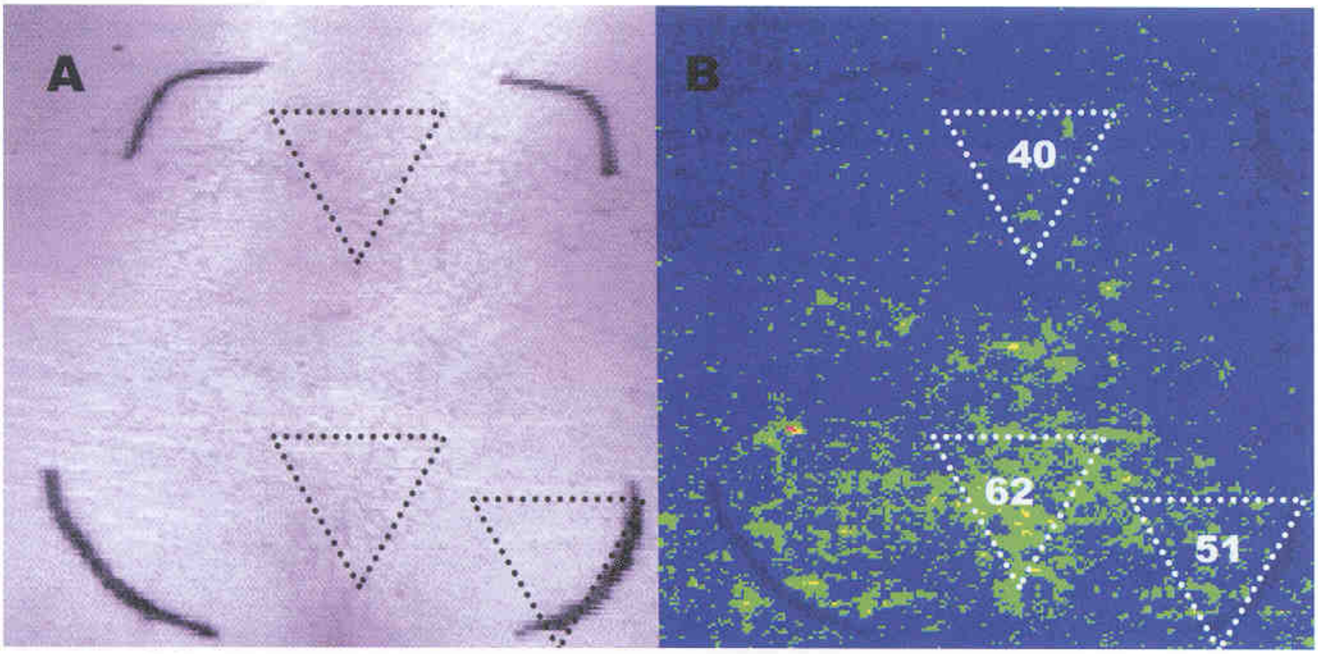
KEY POINTS

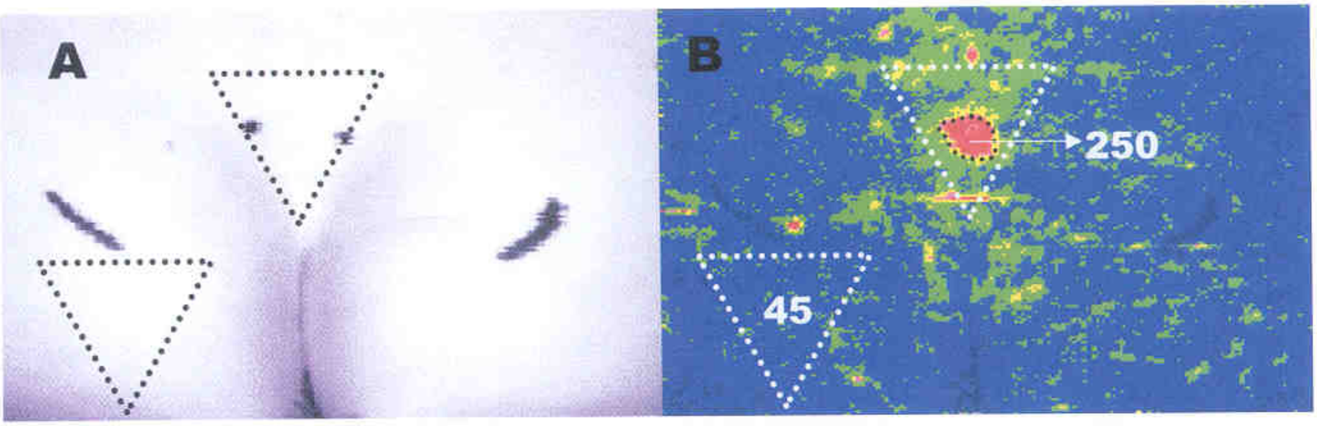
- The presence of a bony prominence and its mechanical effects is often used to explain the high incidence of pressure ulcers in the sacral area.
- Because differences in response to short-term pressure loading on different areas of the skin have been reported, the authors measured blood flow and skin temperatures in 30 healthy volunteers.
- Average skin blood flow was found to be significantly higher in the sacral region than in adjacent areas and higher in women than in men. These findings suggest that relative, rather than absolute, blood flow deficits may increase the risk of pressure ulcer formation.
- The results of this study warrant further research to help clinicians understand the etiology of pressure ulcers and prevent them.



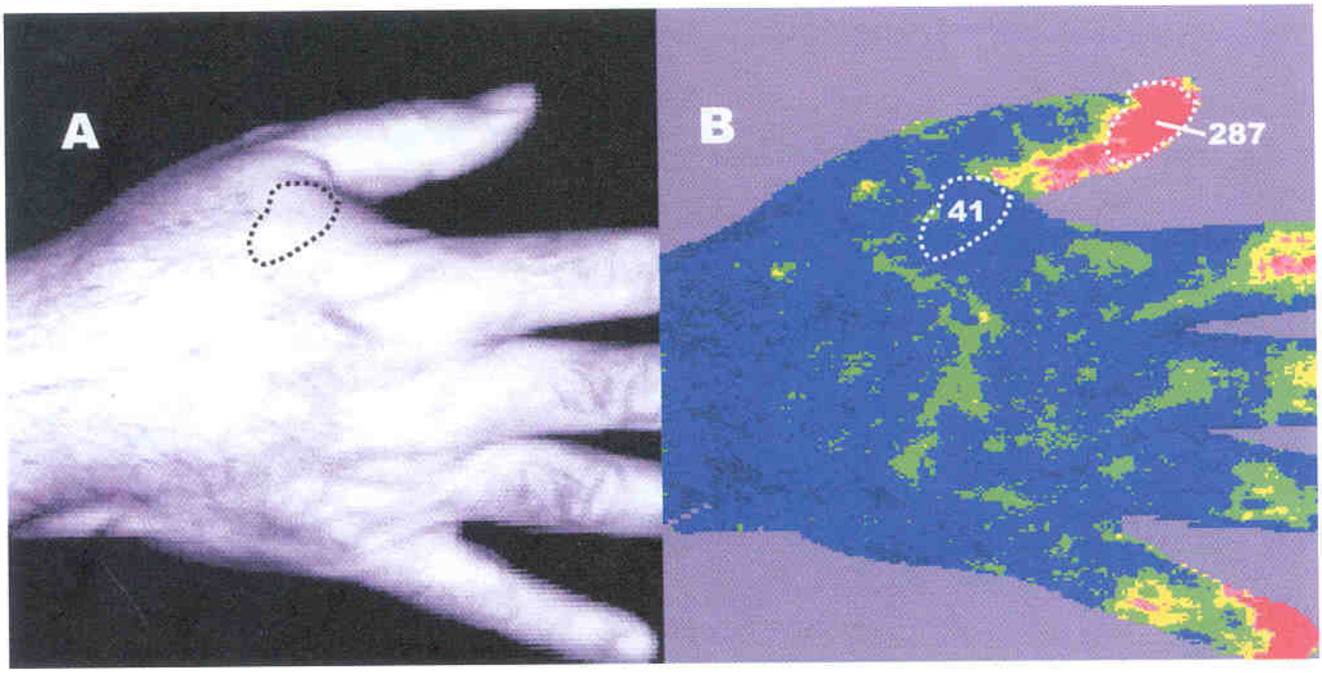
Figures 1a and 1b
LDI scan region and blood perfusion method. Figure 1a: Photo image of scanned region with superimposed 15-cm^2 triangular regions for skin blood perfusion measurement. Figure 1b: Perfusion scan corresponding to photo image with median values of perfusion superimposed. In all images red, yellow, green, light blue, and dark blue represent the highest to lowest SBF progression. In this subject, all regions except the sacral area were relatively low.



Figures 2a and 2b
LDI scan of a subject. Figure 2a: Photo image of scanned region with superimposed 15-cm^2 triangular regions for skin blood perfusion measurement. Figure 2b: Perfusion scan corresponding to photo image with median values of perfusion superimposed. In this subject, all perfusion values are higher than those shown in Figure 1, but for this subject, the sacral SBF is still relatively larger than either the lower back or gluteal areas.



Figures 3a and 3b
Increased SBF due to localized heating of the sacral region. Figure 3a: Photo image of region of the scanned area. Figure 3b: Perfusion scan showing the normally higher SBF within the sacral region (green) and the superimposed SBF increase caused by localized heating to 44° C (red). Numbers indicate the median SBF in the gluteal region (45 a.u.) and within the heated sacral area (250 a.u.).



Figures 4a and 4b
LDI scanning of the hand. Figure 4a: Photo image. Figure 4b: Perfusion image comparing the SBF in the hand web with the thumb. Values are the median SBF within the equal dotted areas of interest.

web area, posterior to the thenar eminence, and the other was the distal part of a digit (see Figures 4a and 4b).

Results

Site average SBF. Mean and SEM summary SBF data are shown in Table 1. All SBF are presented as arbitrary perfusion units (a.u.) as is standard for laser Doppler measurements.[14,15] Results of the GLM repeated measures analysis for the full data set showed an overall significant difference in SBF within sites ($P < 0.001$). Sacral SBF was significantly greater than either gluteus or low back sites ($P < 0.001$) with no significant difference between gluteus and low back SBF ($P = 0.190$). Median SBF values for sacrum, gluteus, and lower back were 59.6, 51.3, and 46.9 a.u., respectively. Individual average sacral SBF varied among patients from a minimum of 43.6 a.u. to a maximum of 75.8 a.u.

TABLE I
RESULTS OF SKIN BLOOD PERFUSION (SBF) AND TEMPERATURE MEASUREMENTS (N = 30)

	Male (N=15)	Female (N=15)	Total Group (N=15)
SBF (a.u.)			
Sacrum	55.2 ± 1.8[*]	63.0 ± 1.6[*,†]	59.1 ± 1.4[*]
Gluteus	49.7 ± 2.4	54.2 ± 2.6	52.0 ± 1.8
Low back	44.6 ± 1.8	52.8 ± 2.4	48.7 ± 2.5
Age (years)	38.5 ± 2.6	35.3 ± 3.5	37.1 ± 2.1
Temperature (centigrade)			
Sacrum	31.2 ± 0.3	31.9 ± 0.8	31.5 ± 0.4
Gluteus	30.6 ± 0.3	30.3 ± 0.5	30.5 ± 0.4
Low back	32.1 ± 0.2[*]	32.5 ± 0.8[*]	32.2 ± 0.4[*]

Values are given as mean ± sem

[*] *Sacral SBF and low back temperatures significantly different from other two sites*

[†] *Sacral SBF in women significantly higher than in men*

Gender differences in SBF. A significant overall difference between genders was present, with sacral SBF for females being greater than for males ($P < 0.001$). This gender difference, confined to sacral SBF, was confirmed by one-way analysis of variance with gender as a factor ($P = 0.003$). Age was not significantly different between genders ($P = 0.480$).

Skin temperatures. An overall significant difference in temperature within sites was present, with the low back region being greater than either the sacrum or the gluteus ($P < 0.001$), which were not significantly different from each other. No gender difference was noted in skin temperatures by site and no correlation between SBF at any site and subject age was observed.

Intrasite variability in SBF. On average, 1,500 individual 1-mm^2 pixels were sampled within each site. A summary measure of intrasite SBF variability is the coefficient of variation (CV) which is calculated as the ratio of the intrasite SBF standard deviation to the mean SBF of all 1,500 pixels. Intrasite CV was nearly identical in each of the three sites, with an overall composite value of 0.41 ± 0.01.

Sacral SBF heat response. For the subjects undergoing the heat response protocol (N = 8), the average SBF within the heated area (1.1 ± 0.1 cm^2) increased from a baseline level of 54.5 ± 3.6 a.u. to 186.6 ± 21.8 a.u. This represents a heat-induced increase in SBF by a factor of 3.5 ± 0.5.

Hand SBF reference values. For subjects undergoing the hand scan protocol (N = 13), sacral SBF (57.2 ± 1.7 a.u.) was slightly higher than the SBF of the web of the hand (50.7 ± 4.0 a.u., $P < 0.05$). Both were significantly less than SBF of the finger tip dorsum (240 ± 26 a.u., $P < 0.001$). As ratios, sacral SBF was 1.19 ± 0.08 a.u. that of the hand web and 0.32 ± 0.07 a.u. of the finger tip SBF.

Two-visit comparisons. For subjects with follow-up measurements 6 weeks after the first visit (N = 6), sacral SBF at the second visit (64.2 ± 2.9 a.u.) did not significantly differ from that obtained on the first visit (58.3 ± 2.6 a.u.).

Discussion

Methodology. Literature searches did not identify other reports of the use of LDI to characterize the skin blood perfusion features of the sacral and lower back regions. The main advantage of this technique, as compared with single-point laser Doppler methods, is its ability to sample large areas of skin within target regions of interest. In the present study, each sacral, gluteal, and lower back scan included approximately 1,500 individual 1-mm^2 pixels, with each pixel approximately corresponding to the sampling area of a standard, single-point laser Doppler probe. Thus, one LDI scan was roughly equivalent to using 1,500 probes. Each scan allows an assessment of average perfusion within the target areas and also provides information on the spatial variability within that region. In the sites studied, this variability was considerable, having a coefficient of variability slightly more than 40%. The presence of this amount of spatial variability creates a serious sampling problem for single-point measurements, especially if comparing resting skin blood perfusion among different sites. This problem is significantly less, although not absent, when using the LDI approach.

Primary findings. Several features of sacral skin blood perfusion in comparison to other nearby tissue regions and with respect to other skin areas were observed. First, in contrast to previous data[3-5] obtained with single-point laser Doppler methods, the LDI method has revealed that resting sacral SBF is greater than SBF overlying the gluteus maximus and is also greater than in nearby lower back skin. On average, sacral SBF was found to be 13.7% greater than gluteal SBF and 21.3% greater than low back SBF. These differences are not explainable on the basis of skin temperature differences, as the low back site had a significantly higher temperature than either of the other two sites.

Second, the average perfusion within the sacral region of the present subject group was found to be close to but somewhat greater than that in the hand web but is, as expected, significantly less than the high flow normally found in the fingertips. These comparisons help place the resting sacral skin perfusion levels in perspective; combined with the heat induced responses at the sacrum, they show a hyperemia potential at the sacrum near that of resting digit perfusion.

Third, the present results indicate a gender difference in resting sacral SBF, with SBF being significantly greater in females. No previous reports uncovering this difference have been published — perhaps due to methods employed.

The higher SBF over the sacrum found using the LDI method is at least consistent with the hypothesis that regions of higher resting SBF may be at greater risk of injury when exposed to external forces that cause a substantial reduction in this resting blood flow. Although the relative importance of this finding, as compared to other factors that predispose the sacrum to pressure ulcers, has not yet been investigated, speculating possible implications may be useful. The average resting sacral SBF among the people studied varied by a factor of about 1.7; in patients that often have varying superimposed conditions affecting skin blood flow, a considerable person-to-person difference in sacral SBF is likely.

A relevant question is whether resting flow variations among patients represents a factor that influences sacral ulcer predilection. For similar sacral loading conditions, expecting that a person with a higher resting blood flow would be more at risk for a sacral ulcer than one who has a lower blood flow seems almost counterintuitive. However, if resting flow is reduced to zero or near zero for a sufficient duration, the relative deficit would actually be greater in the person with the higher resting flow. If blood flow is restored by offloading the sacral forces, either mechanically (with pressure relief surfaces) or by turning the patient, the deficit needs to be repaid via the normal hyperemic response. For people with higher resting flows, this response needs to be more vigorous and sustained. Hence, a differentiating factor as to ulcer risk may be whether an optimal amount of hyperemia can occur.

Conclusion

The present findings indicate that a substantial flow reserve is normally present in the sacrum. Based on the localized heat responses, a peak hyperemia that was, on average, 3.5 times the resting SBF was observed. However, at least two broad categories of conditions exist in which hyperemia in relation to prior flow deprivation might be inadequate. One is the category in which a person's vasodilatory capacity is blunted due to microvascular or other deficits. This includes people with diabetes, the elderly, and those with systemic hypotension. The other category includes people who have experienced an abnormal increase in resting blood flow attributable to prior bed lying, skin heating, or other skin-related conditions such as localized irritation. These people may have a vasodilatory blood flow capacity adequate to meet their normal reperfusion needs following intervals of flow deprivation, but the blood flow may not be adequate to meet the imposed increased blood flow demands. Based on these considerations, it would seem prudent to at least consider the possible role of resting SBF as a potential added risk component and to consider factoring this concept into patient care strategies. However, more investigative work is needed to provide further direct evidence for or against this concept. - OWM

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