

## SKIN BLOOD FLOW IN AN AREA AT RISK FOR PRESSURE SORE

Anna-Christina Ek, David H. Lewis, Hans Zetterqvist  
and Per-Gunnar Svensson

*From the Clinical Research Center, Clinic of Long-term Care,  
University Hospital, S-581 85 Linköping, Sweden*

**ABSTRACT.** The aim of this study was to measure skin blood flow in patients with pressure sore in a long-term care unit. For comparison, measurements were also carried out on in-patients at risk of developing pressure sores and on healthy individuals in the same age groups as the in-patients. Skin blood flow was measured in the morning, using a laser-Doppler flowmeter. Measurements were made over the lateral part of the hip and over the lateral part of the upper arm. Measurements were carried out first at ambient temperature. The flow was then followed as the local skin region was heated to 40°C. The results indicate that in healthy individuals the heat stimulus increased skin blood flow over the lateral part of the hip more than in in-patients in the same age group. Individuals below the age of 60 have a greater response than those over the age of 60. This impairment in the ability of the older in-patients to increase skin blood flow in response to thermal stimulus may be a factor in the development of pressure sores.

*Key words:* Skin blood flow, pressure sore, laser-Doppler flowmeter, nursing care, thermal stimulus

In February 1980 a study was carried on the prevalence of pressure sores on acute and long-term wards and the characteristics of those patients within a Public Health Services area.

The criteria for pressure sores were: skin discoloration or epithelial damage, or damage to the full thickness of the skin. There were 71 patients with pressure sores (4%); 25 of them had more than one such sore. The total number of sores was 109 and approximately 80% were situated on the caudal part of the body (5).

The nursing staff usually place great emphasis on the colour of the skin, and especially the effect of the various treatment methods for pressure sores on the colour of the skin. This is felt to give information on skin blood flow, which is considered important for survival of the tissue. Skin blood flow is clearly of importance for nutrition of the skin, but it has other functions including temperature regulation, the distribution of blood flow and blood volume, and the regulation of blood pressure (17). At

rest and at normal ambient temperature the skin receives 5-10% of cardiac output, which exceeds that needed for its nutrition. The blood flow increases with temperature and can reach 50-70% of cardiac output at high body temperatures. In a study of rats, Song et al. (21) found that blood flow to normal skin increases 3-4-fold at 43°C local heat stimulus.

Immobilization and bedrest influence central circulatory function (19). To investigate the effect of immobilization and bedrest on peripheral circulatory function, Friman & Hamrin (7) studied reactive hyperaemia in 14 healthy young men before and after 7 days of clinical bedrest. They found a significantly decreased reactive hyperaemia in the calf muscle.

It is widely accepted that the prime causal factor in the development of pressure sores is ischemia caused by prolonged pressure (4, 6). The observations of Bennett et al. (1) suggest that the age of the patient is a very important factor in the response of peripheral blood flow to external pressure. Investigations have shown that skin tolerates normothermic ischemia for a long period of time (13, 22). Animal experiments have shown that the tissue changes seen after 2 hours of ischemia are reversible, but that they are irreversible after 4 hours of ischemia (16). The time limit between reversible and irreversible changes is not known. It may be individual and can also depend upon a number of factors (12).

The purposes of this study were:

- to measure the blood flow in the skin which is normally exposed to pressure in the bed and in the wheelchair,
- to measure blood flow in normal skin at room temperature and at increased temperature (40°C) in healthy individuals and in in-patients, and
- to measure blood flow in skin in both caudal and cranial parts of the body

Table I. Age, body temperature, skin temperature, ambient temperature and systolic blood pressure (Mean±SD).

F = females M = males p.s. = pressure sore

	Age	Temperature			Ambient	Systolic blood pressure	M	F
		Body	Skin					
			Leg	Arm				
Healthy people below 60 years of age	34.7±13.8	36.9±0.1	29.5±1.5	30.3±1.0	22.8±1.6	120±11	10	9
Healthy people over 60 years of age	78.7±2.4	36.7±0.3	30.9±1.0	30.5±0.4	23.4±0.5	145±8	5	5
Patients in long-term care over 60 years of age, without p.s.	79.4±10.5	36.6±0.4	31.7±1.0	31.1±1.0	22.5±1.7	140±18	4	14
Patients in long-term care over 60 years of age, with p.s.	76.3±10.0	36.9±0.3	31.7±1.3	31.0±1.0	22.6±0.8	140±24	3	7
Patients in long-term care below 60 years of age, with and without p.s.	43.2±16.5	36.7±0.3	30.8±1.7	30.9±0.9	22.8±0.7	130±25	4	2

## METHODS AND MATERIALS

The skin temperature was measured with a thermistor temperature probe (Yellow Springs Instrument Co., Yellow Springs, Ohio). The skin blood flow was measured with a laser-Doppler flowmeter (9, 10, 11). With this method all blood flow values are expressed in millivolts and not in ml/min/tissue weight as usually applied to blood flow measurement. Healthy people younger than 60 years of age and out-patients older than 60 years of age rested supine during preparation and information in order to stabilize the peripheral blood flow (3, 15). The skin blood flow was measured in the morning before breakfast, at ambient temperature (20–24°C) and continuously during heating of the skin to 40°C and until no further increase in blood flow could be observed. In addition date of birth, sex, diagnosis, drugs, body temperature, blood pressure and room temperature were noted.

The skin blood flow was measured over the lateral part of the hip (representing skin on the caudal part of the body) and on the lateral part of the upper arm (representing skin on the cranial part of the body). Measurements were carried out on normal skin. Sixty-three individuals were studied in five different groups. The number of individuals in each group and their characteristics are shown in Table I. Healthy people younger than 60 years of age were persons who were either taking no drugs or with drugs of no consequence for the skin blood flow. Healthy people older than 60 years of age were persons who annually consult a doctor at the clinic for long-term treatment and who were either taking no drugs or whose drugs were of no consequence for the skin blood flow.

In-patients younger and older than 60 with and without pressure sores were patients who could lie relatively quietly during the period of measurement of about 30 min. In-patients younger than 60 were patients with para- or tetra-

plegia. In-patients older than 60 were patients with diagnosis according to previous studies, para- and tetraplegia, cerebral haemorrhage, rheumatoid arthritis, arteriosclerosis, disseminated sclerosis, cancer, fractures, and senile dementia (5, 14). The patients were divided into groups with vs. without pressure sores, on the basis of skin discoloration, epithelial damage, or damage to the full thickness of the skin (13).

Skin blood flow values at ambient temperature and maximum blood flow at 40°C were aspects noted on the blood flow curve. From these measurements, percentage increase, arithmetic mean, standard deviation and Spearman's coefficient of rank order correlation were calculated. Wilcoxon test and  $\chi^2$ -test were used to reveal differences in blood flow between groups. No statistical test has been made with the group of patients younger than 60 years of age because of their small number ( $n=6$ ) except for their increase in blood flow of more vs. less than 100% (Table II). Students' *t*-test was used to reveal differences in skin temperature between groups.

## RESULTS

The skin temperature measured over the lateral part of the hip in connection with the skin blood flow measurement varied significantly between the group of healthy people below 60 years of age and the groups over 60 years of age ( $p<0.05$ ) (Table I). All subjects were afebrile. The mean ambient temperature was 22.8°C±0.8.

Regression analysis indicates that the differences in skin blood flow observed over the lateral part of the hip are not due to ambient temperature, skin

Table II. Effect of increasing skin temperature to 40°C on skin blood flow over the lateral part of the hip and over the lateral part of the upper arm

The percentage increase in skin blood flow (%)	Healthy individuals		In-patients		
	Less than 60 years <i>n</i> =19	More than 60 years <i>n</i> =10	Less than 60 years <i>n</i> =6	More than 60 years <i>n</i> =28	
Lateral part of hip	<100	2	2	3	16
	100-200	4	2	2	10
	200-300	3	3	0	1
	>300	10	3	1	1
Lateral part of upper arm	<100	3	4	1	8 <sup>a</sup>
	100-200	3	3	0	1
	200-300	2	1	1	8
	>300	11	2	4	10

<sup>a</sup> Technically unsatisfactory measurement in one patient, *n*=27.

temperature, body temperature, systolic blood pressure, age or sex.

The differences in skin blood flow between in-patients older than 60 with and without pressure sores are not statistically significant. In further analysis they are therefore taken together. In-patients had statistically significant higher blood flow in the skin over the lateral part of the hip at ambient temperature, compared with healthy people ( $p<0.01$ ) (Fig. 1).

In-patients over 60 years of age had a significantly lower maximum skin blood flow over the lateral part of the hip than had healthy people older than 60 ( $p<0.05$ ) (Fig. 1). The difference could also be seen when comparing percentage increase ( $p<0.001$ ) (Table II). In the skin over the lateral part of the upper arm the reverse was the case (Fig. 2). The patients undergoing long-term treatment who were older than 60 years had a higher maximum skin blood flow than the healthy people over 60 years of age, but the difference was not statistically significant ( $p<0.10$ ).

All the groups, except healthy people older than 60 years of age had a greater percentage increase over the lateral part of the upper arm than over the lateral part of the hip (Fig. 2).

The majority of the in-patients older vs. younger than 60 years of age had an increase in the skin over the lateral part of the hip equal to or less than 100% and more than 100% increase in the skin over the lateral part of the upper arm. Most of the healthy people had a more than 100% increase in both

measurements (Table II). The differences are statistically significant, using the  $\chi^2$ -test ( $p<0.01$ ).

Significant correlations between skin blood flow and skin temperature at ambient temperature were found in the group of in-patients, older than 60 years and without pressure sores, in the group of healthy people below 60 years of age ( $p<0.01$ ), and in the whole material ( $p<0.01$ ).

## DISCUSSION

In the present study we found a significant impairment in the ability of the older in-patients to increase their skin blood flow in response to local thermal stimulus over the lateral part of the hip. The majority of the in-patients older than 60 years of age had an increase in skin blood flow at 40°C over the lateral part of the hip which was less than 100%, but the majority of the healthy people older than 60 years of age had more than 100% increase. The same changes in peripheral blood flow as demonstrated in this study have been found in a study of reactive hyperaemia after immobilization and bedrest (7).

Many indirect techniques have been used to study the cutaneous circulation, such as skin temperature and thermal conductance (23). Recent studies have measured the skin-capillary perfusion by the intradermal <sup>133</sup>Xenon clearance technique (3, 8). The method used in the present study was the laser-Doppler flowmeter. This technique measures the velocity of moving red cells; it does not

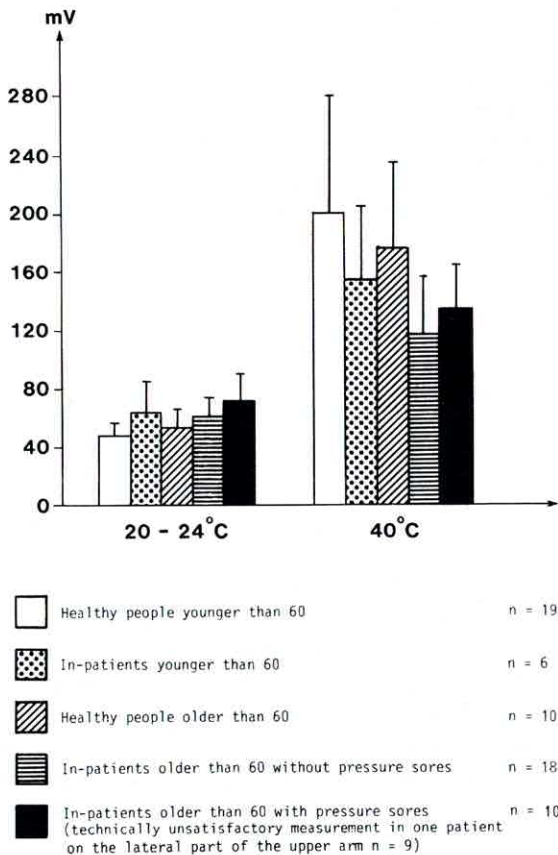


Fig. 1. Skin blood flow as measured with laser-Doppler flowmeter, expressed in millivolts, over the lateral part of the hip. Basal blood flow at room temperature (20-24°C) and maximum blood flow at 40°C (Mean±SD)

give a direct measure in ml/min/tissue weight, but rather in millivolts. The laser-Doppler flowmeter that measures to a depth of 1 to 1.5 mm, is a non-invasive technique and can be recorded continuously under changing conditions, in this case during heating of the skin to 40°C. Studies have shown a close correlation between <sup>133</sup>Xenon clearance technique and laser-Doppler technique (8). When measuring skin blood flow in patients at risk of developing pressure sores it is important to use a technique that can be used without causing trauma and which can be used several times on the same patients and on the same region.

Skin blood flow varies over the body, depending upon the vascularization in the papillae (18). The skin becomes thinner with age due to a decreased vascularization in the papillae (18). It is believed that this vascular atrophy is the result of inadequate

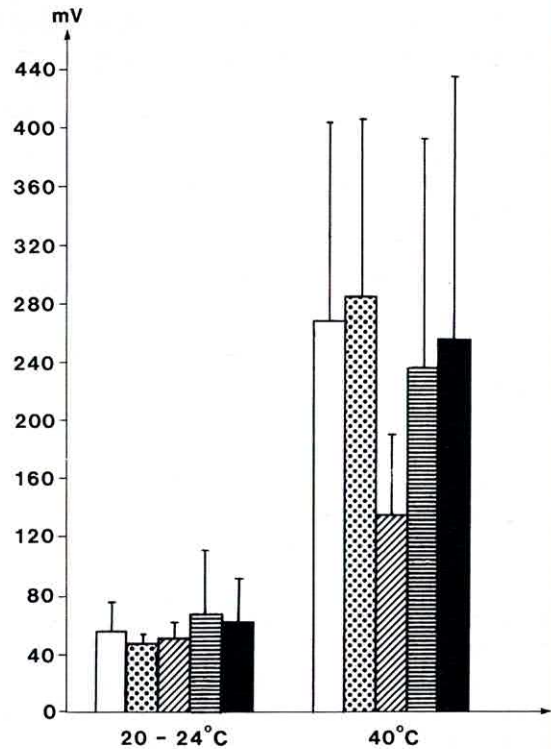


Fig. 2. Skin blood flow as measured with laser-Doppler flowmeter, expressed in millivolts, over the lateral part of the upper arm. Basal blood flow at room temperature (20-24°C) and maximum blood flow at 40°C (Mean±SD)

stimulus, since atrophic skin can be stimulated to vascularization during the process of healing after an injury (18). Is this impairment in the ability of older in-patients to increase blood flow in response to local thermal stimuli due to a decreased vascularization in the papillae? Could the difference between in-patients and out-patients be due to less physical activity in hospital compared with living at home?

The skin area in contact with the mattress on a bed or with the seat of a chair is subjected to higher temperature conditions, compared with other skin areas on the body, due to heat accumulation (2, 20). This higher temperature is a thermal stimulus to increase the blood flow, but the impaired ability of older in-patients to increase their blood flow may lead to insufficient blood flow and ischemia which, in turn, can cause a pressure sore.

Most pressure sores are to be found on the caudal part of the body. Comparison between skin blood flow at 40°C on the lateral part of the hip and

on the lateral part of the upper arm of the older in-patients showed a significantly greater increase in the skin on the lateral part of the upper arm. It is conceivable that this difference in blood flow could be one of the factors causing fewer pressure sores on the cranial part of the body.

### ACKNOWLEDGEMENTS

Grants from the Swedish Medical Research Council (B82-17X-02042-16A), the National Defence Research Institute (H 170), the research fund of the County of Östergötland from the Regional Council of Östergötland, the Regional Hospital at Linköping and the University of Linköping, as also advice and assistance from the Department of Bio-medical Engineering, University of Linköping, are gratefully acknowledged.

### REFERENCES

- Bennett, L., Kavner, D., Lee, B. Y., Trainor, F. S. & Lewis, J. M.: Skin blood flow in seated geriatric patients. *Arch Phys Med Rehabil* 62:392, 1981.
- Brattgård, S. O., Carlsöö, S. & Severinsson, K.: Temperature and humidity in the sitting area. *In Bed Sore Biomechanics* (ed. R. M. Kenedi, J. M. Cowden & J. T. Scales), pp. 185-188. Macmillan Press, London, 1976.
- Daly, M. J. & Henry, R. E.: Quantitative measurement of skin perfusion with Xenon-133. *J Nucl Med* 21:156, 1980.
- Dinsdale, S. M.: Decubitus ulcers: Role of pressure and friction in causation. *Arch Phys Med Rehabil* 55:147, 1974.
- Ek, A.-C. & Boman, G.: A descriptive study of pressure sores: The prevalence of pressure sores and the characteristics of patients. *J Adv Nurs* 7:51, 1982.
- Fisher, S. V. & Kosiak, M.: Pressure distribution and skin temperature effect of the ROHO wheelchair balloon cushion. *Arch Phys Med Rehabil* 60:70, 1979.
- Friman, G. & Hamrin, E.: Changes of reactive hyperaemia after clinical bed rest for seven days. *Ups J Med Sci* 81:79, 1976.
- Holloway, G. A. & Watkins, D. W.: Laser Doppler measurement of cutaneous blood flow. *J Invest Dermatol* 69:306, 1977.
- Lewis, D. H., Holmström, A., Nilsson, G., Tenland, T., Skogh, M. & Öberg, P. Å.: Measurement of microcirculatory blood flow with a new non-invasive laser-Doppler technique. II. Experimental and clinical applications. *Microvasc Res* 17:163, 1979.
- Nilsson, G. E., Tenland, T. & Öberg, P. Å.: A new instrument for continuous measurement of tissue blood flow by light beating spectroscopy. *IEEE Trans Biomed Eng* 27:12, 1980.
- Nilsson, G. E., Tenland, T. & Öberg, P. Å.: Evaluation of a laser Doppler flowmeter for measurement of tissue blood flow. *IEEE Trans Biomed Eng* 27:597, 1980.
- Norton, D., MacLaren, R. & Exton-Smith, A. N.: *An Investigation of Geriatric Nursing Problems in Hospital*. 3rd edn. Churchill Livingstone, London, 1979.
- Nylén, B.: Bedsores—origin, prophylaxis as well as conservative and surgical treatment. SPRI report No. 4, pp. 122-137. Stockholm, Sweden, 1979.
- Petersen, N. C. & Bittman, S.: The epidemiology of pressure sores. *Scand J Plast Reconstr Surg* 5:62, 1971.
- Roberts, M. F. & Wenger, B. C.: Control of skin blood flow during exercise by thermal reflexes and baroreflexes. *J Appl Physiol* 48:717, 1980.
- Romanus, M.: *Microcirculatory Reactions to Local Pressure Induced Ischemia*. Thesis, University of Gothenburg, Sweden, 1977.
- Rowell, L. B.: Reflex control of the cutaneous vasculature. *J Invest Dermatol* 69:154, 1977.
- Ryan, T. J.: Structure, pattern and shape of the blood vessels of the skin. *In The Physiology and Pathophysiology of the Skin* (ed. A. Jarrett), pp. 577-651. Academic Press, Inc., London, 1973.
- Saltin, B., Blomqvist, G., Mitchell, J. H., Johnsson, R. L., Wildenthal, K. & Chapman, C. B.: Response to exercise after bed rest and after training. *Circulation* 38; Suppl. VII, 1968.
- Shishoo, R.: *Studies about comfort in the patients' bed with regards to microclimatological conditions and physical environments*. STU report No. 80-3025 (TEFO PO17) Gothenburg, Sweden, 1983.
- Song, C. W., Rhee, J. G. & Lewitt, S. H.: Blood flow in normal tissues and tumors during hyperthermia. *JNCI* 64:119, 1980.
- Willms-Kretschmer, K. & Majno, G.: Ischemia of the skin. *Am J Pathol* 54:327, 1969.
- Wright, H. M.: Measurement of the cutaneous circulation. *J Appl Physiol* 20:696, 1965.

#### Address for offprints:

Anna-Christina Ek  
Clinical Research Center  
University Hospital  
S-581 85 Linköping, Sweden