

# Contact-Thermography - response to queries

Prepared by:

Luis Vitetta<sup>1</sup>

Marilyn Johnson<sup>2</sup>

Fernando Cortizo<sup>3</sup>

Avni Sali<sup>4</sup>

Graduate School of Integrative Medicine,  
Swinburne University

<sup>1</sup> Director of Research

<sup>2</sup> Research Assistant

<sup>3</sup> Senior Lecturer and Research Supervisor

<sup>4</sup> Professor and Head of School



**Contact-Thermography - response to queries**

Graduate School of Integrative Medicine  
Swinburne University  
9 Frederick Street  
Hawthorn Vic 3122

Telephone: + 61 3 9214 5296  
Facsimile: + 61 3 9214 8009  
Email: [lvitetta@swin.edu.au](mailto:lvitetta@swin.edu.au)  
Website: [www.swin.edu.au/gsim](http://www.swin.edu.au/gsim)



© 2003

## Overall Summary:

We have been asked to comment in the form of an official scientific report on three separate screening techniques used by Australian Biologics - Testing Services Pty Ltd.

The screening technique in question is:

1. contact thermography

For this review of the scientific evidence we have utilised the rating system that is recommended by the Quality of Care and Health Outcomes Committee and has been adapted from the system developed by the US Preventive Services Task Force, which has also been adopted by the National Health and Medical Research Council of Australia. The rating system consists of the following:

- **Level I Evidence** is obtained from a systematic review of all relevant randomised controlled trials - meta analyses.
- **Level II Evidence** is obtained from at least one properly designed randomised controlled clinical trial.
- **Level III Evidence** is obtained from well designed controlled trials without randomisation or from well designed cohort or case control analytic design studies, preferably from more than one centre or research group or from multiple time series with or without an intervention.
- **Level IV Evidence** represents the opinions of respected authorities based on clinical experience, descriptive studies or reports of expert committees.

As far as contact thermography is concerned there is ample level II, III and IV evidence to show that this is a most important modality that can be considered to be most useful in determining peripheral blood flow in numerous disease states.

We refer you to our previously prepared document.<sup>1</sup> Further, the evidence to date demonstrates that contact thermography has applications which have been successfully applied in the diagnosis and treatment of various disease states that include breast cancer, cardiovascular disease, diabetes, and general blood flow problems. Contact thermography has general adjuvant diagnostic properties that need to be fully exploited by the medical profession. Moreover, contact thermography has been advocated as a rapid, non-invasive diagnostic modality in evaluating patients at risk for breast cancer.<sup>91</sup> In that study which was conducted approximately twenty years ago it was reported that thermograms should be reported as either being normal or abnormal, criteria that would allow the modality to show a high degree of reliability.

## Responses to Queries:

1. thermography does not provide assessment of the degree of illness (slight to serious) (*"thermography does not provide an assessment of the degree of **all** illness"*)

We have reviewed this screening technique in a previous report that has been delivered to Australian Biologics.

In Summary: from our interpretation of the evidence of this technique we believe contact thermography to be a most useful adjuvant screening procedure for a number of different medical problems.

At no time has there been an interpretation that this screening technique would provide an assessment of the degree of all illness. Moreover there is no current medical test/procedure that was or is currently available, that provides an assessment or measure of the degree of ALL illness.

Excerpt from our review:<sup>1</sup> In terms of breast pathology we conclude in our report that from the evidence that is currently available that contact thermography may constitute a low cost adjuvant screening intervention that could be a yearly evaluation as part of a routine physical assessment for women who find mammography a painful and difficult procedure. Therefore

as soon as a suspicious (positive) breast thermal examination is performed, the appropriate follow-up diagnostic and clinical testing can be ordered. This would include mammography and other imaging tests, clinical laboratory procedures, nutritional and lifestyle evaluation and training in breast self examination. Thermography is a simple, non-invasive, highly accurate, inexpensive form of screening imaging technique as well as being a 'breast friendly' procedure.

Moreover, as thermography is capable of measuring changes in temperature that can reflect blood supply and inflammation which are general physiological changes, it is then possible to envisage its adaptation to screen other physiological changes that are associated with blood flow. An additional search of the current medical literature showed that contact thermography has been applied to other medical conditions. Namely, cardiovascular disease, comorbidities associated with diabetes and as an adjuvant method to better define cancer diagnoses.

We have identified numerous studies from the medical literature that hence emphasize the importance of this technique in medical practice.<sup>1-175</sup>

In addition to breast screening studies we have identified other peer reviewed studies that have employed contact thermography in other areas of medicine and these include:

**cardiovascular disease and circulation/blood flow**

- Coloured contact thermography has been employed as an additional method for the diagnosis of diseases of the abdominal aorta and its major branches.<sup>171</sup>

- Thermography has been used to study myocardial temperature during infusion of cold cardioplegic solutions. Slow cooling was recorded distal to coronary stenosis or occlusions, thereby indicating insufficient protection of the myocardium in these areas<sup>169, 171-173</sup>
- In a recent study of thermograms in army personnel regional hothermia was investigated with thermograms.<sup>160</sup> Further, in another recent study of thermograms in army personnel by the same group of researchers investigated thermograms during and after basic military training evaluating the temperature changes in thermograms whilst differentiating between those with normal foot parameters, those with musculoskeletal stress and others with foot stress. The thermograph showed that normal foot cooling differed between the three groups. In conclusion thermography did not reveal an exact diagnosis however it was of greatest benefit monitoring severity and healing of the foot.<sup>160</sup>
- Liquid Crystal contact Thermography has been shown to be very reliable for as a method of investigating skin blood flow and for a screening method in the diagnosis of deep venous thrombosis.<sup>59,164</sup>
- The use of thermography has been used to evaluate the peripheral circulatory function in the diagnosis of diabetic complications.<sup>163</sup> Thermography has been employed to observe wound temperature and hence monitor healing in surgical patients.<sup>162, 163</sup> Contact thermography in conjunction with Doppler sonograph resulted in the highest diagnostic accuracy when investigating retrograde blood flow in the internal spermatic vein.<sup>152</sup>

## Diabetic neuropathy

- Contact thermography has been successfully employed to investigate and identify diabetic patients who are at increased risk for neuropathic foot ulceration.<sup>16</sup>

### 2. thermography can only assess some aspects of peripheral blood flow and it does provide an assessment of the circulation, disturbances of cerebral and/or peripheral blood circulation and vascular occlusion.

There is substantial scientific evidence that thermography can assess various aspects of peripheral blood flow.<sup>1, 8-165</sup> That is, that microcirculatory disturbances can be clinically assessed by thermography. Further, the patho-physiological analysis of the peripheral circulation using thermography has been investigated as an example of functional body imaging. Moreover, since vascular damage is the main complication of diseases such as diabetes, in studies with lower limb amputations for diabetic foot have shown that the amputation level of the limb was determined by skin thermography. Thermography was useful in avoiding deep and systemic circulatory problems which are commonly associated with diabetic limb amputations. Hence, any interpretation that thermography is only useful for some aspects of peripheral blood flow and that it does not provide an assessment of the circulation of the blood as a whole is without merit as there are numerous peer reviewed studies indicating its successful employment.



3. thermography does not provide assessment of the strain a person is able to bear before he be subject to an operation or vaccination  
Thermography provides a useful assessment of peripheral blood flow abnormalities. Therefore when combined with medical expertise these results may have a useful adjuvant and indirect application in the assessment of the surgical patient.
4. thermography does not provide an assessment of the success of therapies.

As an example of thermography providing success of a therapy can be seen in a recent study<sup>121</sup> that assessed temporary stellate ganglion block thermographically and its effectiveness during cardio-surgical procedures. The assumption behind this method was that the increase in the temperature of the upper extremity on the side of the blockade was due to the broadening of the arterial bed. It was shown that thermography was a useful method for the assessment of stellate blockade effectiveness. Effective blockade resulted in increased blood flow in the radial artery.

Further, low temperature is an important factor in protecting the myocardium during an operation on the heart. This can be difficult to accomplish if the cold cardioplegic solution is hindered by occlusions or stenosis of the coronary arteries. Thermography has been used to study myocardial temperature during infusion of cold cardioplegic solution. Slow cooling was recorded distal to coronary stenosis or occlusions, thereby indicating insufficient protection of the myocardium in these areas.<sup>162-165</sup>

5. thermography is not suitable for diagnostic purposes in the cardiac field

Thermography has been employed extensively in the cardiac field. Namely, thermography has been used to study myocardial temperature during infusion of cold cardioplegic solutions. Slow cooling was recorded distal to coronary stenosis or occlusions, thereby indicating insufficient protection of the myocardium in these areas.<sup>162-165</sup> Further, in order to understand, treat, and prevent acute coronary syndromes it has been reported that there is a need to improve the ability to identify the rupture-prone, vulnerable atherosclerotic coronary plaque. In a recent review it was noted that thermography used in clinical trials provided useful results.<sup>176</sup> Moreover, it has also been recently reported that an atherosclerotic plaque is considered vulnerable when it is at higher risk of inducing acute cardiac events. The early detection and follow-up of the vulnerable plaque are crucial to prevent these events from happening. Arterial wall thermography, which traces the heat signature of the activated macrophages, is a new and promising method in this direction.<sup>177</sup>

6. thermography is not suitable for analytical purposes in the cardiac field

Thermography is a very suitable analytical technique in the cardiac field. The identification of vulnerable plaque is one of the primary goals in cardiology during the last years. Several techniques have been developed for the anatomic and functional assessment of atherosclerotic plaques. Thermography is a new method for the evaluation of the inflammatory process locally within the atherosclerotic plaque. Several animal and clinical studies demonstrated the value of thermography not only for the detection of inflamed atherosclerotic plaques, but its use in new fields like in the evaluation of inflammation in the coronary vascular bed and the

cardiovascular system. A recent article has reviewed the developments and the clinical implications of thermography.<sup>178</sup>

7. thermography does not represent true preventative medicine :

To claim outright that contact thermography has no preventative medicine benefits is both unsubstantiated and erroneous given the current peer reviewed literature that is available. To claim that it is a technique that prevents people from becoming ill is further erroneously misrepresented. Contact thermography is a very useful adjuvant technique that can assist the clinician to provide guidance to the patient with breast cancer or a suspicious breast lump.<sup>1</sup> Further, it has been shown that contact thermography has other useful applications in medicine as has been pointed previously in points 4 and 5.

8. thermography does not provide an indication of unrecognised disease, hidden cause and dangerous sequelae (complications).

From the available evidence it has already been shown that contact thermography has been successfully used to monitor newly developing breast disease.<sup>1</sup> These results support contact thermography as being useful in detecting previously unrecognised disease. Therefore contact thermography does provide some evidence for previously undiagnosed disease with serious sequelae (eg. Breast cancer).

9. thermography does not provide a valuable aid in monitoring the restoration of health.

This statement is inaccurate. Refer further to points 1, 2, 3, 4, and 8 previously.

## References

1. Vitetta L, Johnson M, Sali A. Contact Thermography - a scientific evaluation. Report 2002.
2. Berliner S., Shapira I., Rogowski O., Sadees N., Rotstein R., et al Combined leukocyte and erythrocyte aggregation in the peripheral venous blood during sepsis. A clue to the presence of a commonly shared adhesive protein(s). *International Journal of Clinical and Laboratory Research*, 2000; 30: 27-31.
3. Fabry T.L. Mechanism of erythrocyte aggregation and sedimentation. *Blood* 1987; 70: 1572-1576.
4. Fusman R., Zeltser D., Rotstein R., et al. INFLAMET: an image analyzer to display erythrocyte adhesiveness/aggregation. *European Journal of Internal Medicine*, 2000; 11: 271-276
5. Rogowski O., Zeltzer D., Rotstein R., et al. Correlated Expression of Adhesive Properties for Both White and Red Blood Cells During In ammation. *Biorheology*, 2000; 37: 361-70
6. Rotstein R., Zeltzer D., Fusman R., et al. The in ammation meter (INFLAMET): a new diagnostic approach to reveal the presence of an in amatory response and for the assessment of its intensity. *Israel Medical Association Journal* 2000; 2, 476-477.
7. Rotstein R, Landau T, Twig A, Rubinstein A, et al. The erythrocyte adhesiveness/aggregation test (EAAT). A new biomarker to reveal the presence of low grade subclinical smoldering inflammation in individuals with atherosclerotic risk factors. *Atherosclerosis* 2002; 165(2):343-51.

## Skin Thermography and Blood Flow

8. Abbot, N. C.; Beck, J. S.; Harrison, D. K., and Wilson, S. B. Dynamic thermographic imaging for estimation of regional perfusion in the tuberculin reaction in healthy adults. *J Immunol Methods*. 1993 Jun 4; 162(1):97-107.
9. Aberg, G. and Adler, R. Thermographic registrations of some vascular effects of a local anaesthetic compound. *Sven Tandlak Tidskr*. 1970; 63(10):671-8.
10. Aoyama, Y.; Ueda, Y.; Kurita, M.; Ohashi, H.; Torigata, C., and Maejima, K. [Biological effects of exposure to high frequency electromagnetics on rabbits and guinea pigs]. *Jikken Dobutsu*. 1992; 41(4):421-35.
11. Astrup, A. Thermogenesis in human brown adipose tissue and skeletal muscle induced by sympathomimetic stimulation. *Acta Endocrinol Suppl (Copenh)*. 1986; 278:1-32.

12. Austin, J. H. and Sajid, M. H. Direct thermometry in ophthalmic-internal carotid blood flow. *Arch Neurol.* 1966; 15(4):376-92.
13. Barnett, R. I. and Ablarde, J. A. Skin vascular reaction to standard patient positioning on a hospital mattress. *Adv Wound Care.* 1994; 7(1):58-65.
14. Baudet, J.; LeMaire, J. M., and Guimberteau, J. C. Ten free groin flaps. *Plast Reconstr Surg.* 1976; 57(5):577-95.
15. Beinder, E.; Huch, A., and Huch, R. Peripheral skin temperature and microcirculatory reactivity during pregnancy. A study with thermography. *J Perinat Med.* 1990; 18(5):383-90.
16. Benbow SJ, Chan AW, et al. The prediction of diabetic neuropathic plantar foot ulceration by liquid crystal contact thermography. *Diabetes Care* 1994; 17(8):835-839.
17. Birklein, F.; Riedl, B.; Neundorfer, B., and Handwerker, H. O. Sympathetic vasoconstrictor reflex pattern in patients with complex regional pain syndrome. *Pain.* 1998; 75(1):93-100.
18. Birklein, F.; Sittl, R.; Spitzer, A.; Claus, D.; Neundorfer, B., and Handwerker, H. O. Sudomotor function in sympathetic reflex dystrophy. *Pain.* 1997; 69(1-2):49-54.
19. Bornmyr, S. and Svensson, H. Thermography and laser-Doppler flowmetry for monitoring changes in finger skin blood flow upon cigarette smoking. *Clin Physiol.* 1991; 11(2):135-41.
20. Bovenzi, M. Finger thermometry in the assessment of subjects with vibration-induced white finger. *Scand J Work Environ Health.* 1987; 13(4):348-51.
21. Broseta, J.; Garcia-March, G.; Sanchez, M. J., and Goncales, J. Influence of spinal cord stimulation on peripheral blood flow. *Appl Neurophysiol.* 1985; 48(1-6):367-70.
22. Buchwald, W.; Habighorst, L. V., and Hulse, R. [Thermography in blood circulation disorders of the extremities]. *Radiologe.* 1973; 13(8):329-34.
23. Chan, A. W.; MacFarlane, I. A., and Bowsher, D. R. Contact thermography of painful diabetic neuropathic foot. *Diabetes Care.* 1991; 14(10):918-22.
24. Chant, A. D. Hypothesis: why venous oedema causes ulcers and lymphoedema does not. *Eur J Vasc Surg.* 1992; 6(4):427-9.
25. Cole, R. P.; Shakespeare, P. G.; Chissell, H. G., and Jones, S. G. Thermographic assessment of burns using a nonpermeable membrane as wound covering. *Burns.* 1991; 17(2):117-22.

26. Curri, S. B. [Microvascular anatomy of the skin and its appendages]. *Phlebologie*. 1990 Jul-1990; 43(3):407-30.
27. De Leve, L. D.; Parnham, M. J., and Saxena, P. R. Redistribution of cardiac output during localized granulomatous inflammation and the effect of methysergide in anesthetized rats. *Inflammation*. 1980; 4(4):359-69.
28. Dereymaeker, A.; Lams-Cauwe, V., and Fobelets, P. Frontal dynamic thermometry. Improvement in diagnosis of carotid stenosis. *Eur Neurol*. 1978; 17(4):226-32.
29. Deshayes, P.; Lauret, P.; Menard, J. F.; Carpentier, P.; Piton, J. L.; Le Loet, X.; Phelip, X., and Samson, D. [Current methods of vascular exploration: Doppler, thermography, capillaroscopy]. *Rev Rhum Mal Osteoartic*. 1982; 49(11):835-40.
30. Deumer, J.; de Haan, F.; Tulp, M. T., and van den Hoven, R. Effect of an isoxsuprine-resin preparation on blood flow in the equine thoracic limb. *Vet Rec*. 1991; 129(19):427-9.
31. Devulder, J.; Duprez, D.; De Laat, M., and Rolly, G. Epidural spinal cord stimulation does not improve microvascular blood flow in neuropathic pain. *Angiology*. 1996; 47(12):1145-9.
32. Diagnostic thermography. *Vet Clin North Am Equine Pract*. 2001; 17(1):95-113.
33. Doutreleau, S.; Gautherie, M.; Lonsdorfer, E.; Rouyer, O.; Epailly, E.; Eisenmann, B.; Piquard, F., and Geny, B. Usefulness of finger thermography to assess cyclosporine toxicity after heart transplantation. *Transplant Proc*. 2001; 33(7-8):3318-9.
34. Dover, H.; Pickard, W.; Swain, I., and Grundy, D. The effectiveness of a pressure clinic in preventing pressure sores. *Paraplegia*. 1992; 30(4):267-72.
35. Drummond, P. D. and Lance, J. W. Facial temperature in migraine, tension-vascular and tension headache. *Cephalalgia*. 1984; 4(3):149-58.
36. Duteil, L.; Czernielewski, J., and Schaefer, H. [Cutaneous microcirculation: focus on exploratory methods]. *Ann Dermatol Venereol*. 1987; 114(8):1011-22.
37. Evans, A. L.; James, W. B., and Forrest, H. Thermography in lower limb arterial disease. *Clin Radiol*. 1976; 27(3):383-8.
38. Fischer, H. [Measure technics in blood circulation disorders]. *Arztl Forsch*. 1967; 21(9):340-7.
39. Fogdestam, I.; Jensen, F. T., and Nilsson, S. K. Delayed primary closure. Blood-flow in healing rat skin incisions. *Scand J Plast Reconstr Surg*. 1981; 15(2):81-5.
40. Forck, G. [Blood circulation disorders of the skin as a cosmetic and measuring technical problem]. *Cosmetologica*. 1970; 19(10):367-82.

41. Fraunhofer, S.; Henzler, M.; Strotzer, M., and von Sommoggy, S. [Measuring regional blood flow in evaluating CT-controlled lumbar sympathetic neurolysis in arterial occlusive disease]. *Vasa Suppl.* 1991; 33:160-1.
42. Friedlander, A. H. and Gratt, B. M. Panoramic dental radiography as an aid in detecting patients at risk for stroke. *J Oral Maxillofac Surg.* 1994; 52(12): 1257-62.
43. Fujimasa, I. Pathophysiological expression and analysis of far infrared thermal images. *IEEE Eng Med Biol Mag.* 1998 Jul-1998; 17(4):34-42.
44. Fushimi, H.; Kubo, M.; Inoue, T.; Yamada, Y.; Matsuyama, Y., and Kameyama, M. Peripheral vascular reactions to smoking--profound vasoconstriction by atherosclerosis. *Diabetes Res Clin Pract.* 1998; 42(1):29-34.
45. Gautherie, M. Thermopathology of breast cancer: measurement and analysis of in vivo temperature and blood flow. *Ann N Y Acad Sci.* 1980; 335:383-415.
46. Gautherie, M.; Bourjat, P.; Grosshans, E., and Quenneville, Y. [Vasodilator effect of *Gingko biloba* extract determined by skin thermometry and thermography]. *Therapie.* 1972 Sep-1972 Oct 31; 27(5):881-92.
47. Gautherie, M.; Qenneville, Y., and Gros, C. H. [Thermogenesis of mammary epitheliomas. III. Study, by means of fluvography, of the termal conductivity of mammary tissue and of the influence of tumor vascularization]. *Biomedicine.* 1975 May; 22(3):237-45.
48. Goriainova, L. K.; Anton'ev, A. A., and Kulish, B. D. [Thermography in the complex diagnosis of skin lesions of the lower extremities in Donbass miners (a preliminary report)]. *Vestn Dermatol Venerol.* 1981 May; (5):51-5.
49. Gottstein, U.; Felix, R.; Flad, H. D., and Sedlmeyer, I. [Studies on the effect of nicotinic acid and adenosine monophosphate on skin and muscle circulation in healthy subjects and patients with peripheral circulatory disorders]. *Z Kreislaufforsch.* 1966 Oct; 55(10):970-87.
50. Graf, P.; Hofmeister, F.; Schaff, J., and Biemer, E. [Morbidity of the donor site of the dorsalis pedis flap]. *Handchir Mikrochir Plast Chir.* 1992 Sep; 24(5):239-42.
51. Gush, R. J.; Taylor, L. J., and Jayson, M. I. Acute effects of sublingual nifedipine in patients with Raynaud's phenomenon. *J Cardiovasc Pharmacol.* 1987 May; 9(5):628-31.
52. Haake, M.; Willenberg, T.; Sauer, F., and Griss, P. [Effect of extracorporeal shockwave therapy on vascular regulation. Infrared thermography in epicondylitis humeri radialis]. *Swiss Surg.* 2002; 8(4):176-80.

53. Habler, H. J.; Stegmann, J. U.; Timmermann, L., and Janig, W. Functional evidence for the differential control of superficial and deep blood vessels by sympathetic vasoconstrictor and primary afferent vasodilator fibres in rat hairless skin. *Exp Brain Res.* 1998; 118(2):230-4.
54. Hanssler, L.; Roll, C., and Breukmann, H. [Laser Doppler flowmetry in newborn infants with low birth weight. The effect of differences in humidity on peripheral circulation]. *Klin Padiatr.* 1992; 204(5):359-61.
55. Harkins, J. D.; Mundy, G. D.; et al. Character and duration of pharmacological effects of intravenous isoxsuprine. *Equine Vet J.* 1996; 28(4):320-6.
56. Harrison, D. K.; Abbot, N. C.; Beck, J. S., and McCollum, P. T. Laser Doppler perfusion imaging compared with light-guide laser Doppler flowmetry, dynamic thermographic imaging and tissue spectrophotometry for investigating blood flow in human skin. *Adv Exp Med Biol.* 1994; 345:853-9.
57. Hassan, M. and Togawa, T. Observation of skin thermal inertia distribution during reactive hyperaemia using a single-hood measurement system. *Physiol Meas.* 2001 Feb; 22(1):187-200.
58. Hauer, J. L.; Boland, O. M.; Ewing, D. J., and Clarke, B. F. Hand skin blood flow in diabetic patients with autonomic neuropathy and microangiopathy. *Diabetes Care.* 1991 Oct; 14(10):897-902.
59. Hirata, K.; Nagasaka, T., and Noda, Y. Venous return from distal regions affects heat loss from the arms and legs during exercise-induced thermal loads. *Eur J Appl Physiol Occup Physiol.* 1989; 58(8):865-72.
60. Hofferberth B, Gottschaldt M, Dykan S. Comparison of Doppler sonography and plate thermography for the detection of carotid artery stenosis.
61. Hoffmann, R.; Brutsch, H. P.; Largiader, F., and Tittel, R. [Liquid-crystal-contact-thermography (LCCT) a new diagnostic method for determination of skin circulation. Results of 300 studies]. *Helv Chir Acta.* 1989; 56(1-2):263-6.
62. Hohn, H. [Effect of thermoregulation on drug-induced increase of blood circulation]. *Arzneimittelforschung.* 1970 Apr; 20(4):524-7.
63. Holm, J.; Johnsen, C., and Schersten, T. Thermography in vascular surgery. A preliminary report based on a study in 12 cases. *Acta Chir Scand.* 1974; 140(6):445-8.
64. Hornstein, O. P.; Boissevain, F., and Wittmann, H. Non-invasive measurement of the vascular dynamics of dermographism comparative study in atopic and non-atopic subjects. *J Dermatol.* 1991 Feb; 18(2):79-85.



65. Hornstein, O. P.; Keller, J., and Boissevain, F. Abnormalities of cutaneous microcirculation in atopic eczematous. *Acta Derm Venereol Suppl (Stockh)*. 1992; 176:86-9.
66. Hsieh, J. C.; Chan, K. H.; Lui, P. W., and Lee, T. Y. Clinical application of infrared thermography in diagnosis and therapeutic assessment of vascular ischemic pain. *Ma Zui Xue Za Zhi*. 1990 Dec; 28(4):493-501.
67. Huang, J. and Togawa, T. Measurement of the thermal inertia of the skin using successive thermograms taken at a stepwise change in ambient radiation temperature. *Physiol Meas*. 1995 Nov; 16(4):213-25.
68. Hundhausen, E. and Theves, B. [Calculation of thermally caused blood flow changes in a finger using thermographic skin temperature measurements (author's transl)]. *Eur J Appl Physiol Occup Physiol*. 1979 Mar 1; 40(4):235-44.
69. Hunold, S.; Mietzsch, E., and Werner, J. Thermographic studies on patterns of skin temperature after exercise. *Eur J Appl Physiol Occup Physiol*. 1992; 65(6):550-4.
70. Ippolito, F.; Di Carlo, A.; Carducci, M.; Leone, G., and Frascione, P. Cyclosporin A and psoriasis: a thermographic study. *Acta Derm Venereol Suppl (Stockh)*. 1989; 146:155-8.
71. Ishizaki, F. [Thermographic studies on the relationships between the nasal skin temperature and nasal airway resistance]. *Nippon Jibiinkoka Gakkai Kaiho*. 1987 Apr; 90(4):547-54.
72. Jacobs, A. M.; Esper, R.; O'Leary, R.; Duda, Z. M., and Yorzyk, W. Thermographic evaluation of the autonomic effects of nerve blocks in the foot. *J Am Podiatr Med Assoc*. 1989; 79(3):107-15.
73. Jaeger-Denavit, O.; Lacert, P.; Pannier, S., and Grossiord, A. [Study of cutaneous blood flow as a function of local skin temperature in paraplegia and quadriplegia due to spinal cord lesions]. *Rev Eur Etud Clin Biol*. 1972; 17(5):518-24.
74. Kakuta, N.; Yokoyama, S., and Mabuchi, K. Human thermal models for evaluating infrared images. *IEEE Eng Med Biol Mag*. 2002; 21(6):65-72.
75. Kamada, T.; Sato, N.; Kakubari, N.; Yoda, K.; Kawano, S.; Schichiri, M., and Abe, H. Noninvasive assessment of microcirculation of living organs and tissues using laser. *Lasers Surg Med*. 1983; 2(3):275-80.
76. Kanai, S.; Okano, H., and Abe, H. Efficacy of toki-shigyakuka-gosyuyu-syokyo-to (danggui-sini-jia-wuzhuyu- shengjiang-tang) on peripheral circulation in autonomic disorders. *Am J Chin Med*. 1997; 25(1):69-78.

77. Karpman, H. L.; Kalb, I. M., and Sheppard, J. J. The use of thermography in a health care system for stroke. *Geriatrics*. 1972; 27(2):96-105.
78. Kent, P.; Wilkinson, D.; Parkin, A., and Kester, R. C. Comparing subjective and objective assessments of the severity of vibration induced white finger. *J Biomed Eng*. 1991; 13(3):260-2.
79. Khizhli, K. h. A. [Potentials of noninvasive methods for assessing disordered blood supply to the lower extremities]. *Khirurgiia (Sofiiia)*. 1983; 36(3):256-62.
80. Kimura, T.; Goda, Y.; Kemmotsu, O., and Shimada, Y. Regional differences in skin blood flow and temperature during total spinal anaesthesia. *Can J Anaesth*. 1992; 39(2):123-7.
81. Kistler, A.; Mariauzouls, C., and von Berlepsch, K. Fingertip temperature as an indicator for sympathetic responses. *Int J Psychophysiol*. 1998; 29(1):35-41.
82. Kivikoski, A.; Laaksa, L.; Viitanen, S. M., and Jaykka, S. The influence of risk factors upon changes in the skin temperature of newborn. *Acta Obstet Gynecol Scand Suppl*. 1971; 9:Suppl 9:62.
83. Kopsa, H. [Diagnostic relevance of contact thermography in renal transplantation (author's transl)]. *Wien Klin Wochenschr Suppl*. 1980; 112:1-18.
84. Koradecka, D. [The use of thermographic method and of <sup>133</sup>Xe clearance in diagnostic studies of peripheral blood circulation disturbances under effect of vibration (author's transl)]. *Przegl Lek*. 1981; 38(8):629-32.
85. Lance, J. W.; Anthony, M., and Somerville, B. Facial thermography in cerebral vascular insufficiency and migraine. *Proc Aust Assoc Neurol*. 1973; 9:31-8.
86. Langauer-Lewowicka, H. [Effect of peripheral thermoregulation on the results of various studies used in the diagnosis of the vibration syndrome]. *Med Pr*. 1987; 38(5):352-6.
87. Langer, L.; Fagerberg, S. E., and Johnsen, C. Peripheral circulation in diabetes mellitus a study with infrared thermography. *Acta Med Scand*. 1972 Jan-1972 Feb 28; 191(1-2):17-20.
88. Lecerof, H.; Bornmyr, S.; Lilja, B.; De Pedis, G., and Hulthen, U. L. Acute effects of doxazosin and atenolol on smoking-induced peripheral vasoconstriction in hypertensive habitual smokers. *J Hypertens Suppl*. 1990; 8(5):S29-33.
89. Lee, B. Y.; Trainor, F. S.; Kavner, D.; McCann, W. J., and Madden, J. L. Noninvasive hemodynamic evaluation in selection of amputation level. *Surg Gynecol Obstet*. 1979; 149(2):241-4.

90. Lefaix, J. L. and Daburon, F. Diagnosis of acute localized irradiation lesions: review of the French experimental experience. *Health Phys.* 1998; 75(4):375-84.
91. Lindorf, H. H. Investigation of the vascular effect of newer local anesthetics and vasoconstrictors. *Oral Surg Oral Med Oral Pathol.* 1979; 48(4):292-7.
92. Lokhvitskii, S. V.; Kovalenko, V. I.; Bogomolov, A. D., and Afanas'ev, A. N. [Functional electrothermometry in the diagnosis of vascular diseases of the extremities]. *Kardiologiia.* 1980; 20(10):105-7.
93. London RS, Murphy L, et al. Reliability of contact thermogram reading services. *Reprod Med.* 1984; 29(9): 686-688.
94. Loreck, D.; Ihle, E.; Schmidt, P.; Apostoloff, E.; Heerdegen, I., and Buhler, G. [Liquid crystal thermography of the hands in patients with visceral lupus erythematosus]. *Dermatol Monatsschr.* 1987; 173(3):113-22.
95. Love, T. J. Thermography as an indicator of blood perfusion. *Ann N Y Acad Sci.* 1980; 335:429-37.
96. Lovisatti, L.; Mora, L., and Pistolesi, G. F. Thermographic patterns of lower limb arterial disease. *Bibl Radiol.* 1975; (6):107-114.
97. Lynch, P. R.; Mottram, R. F.; Owen, O., and Smale, B. F. Results of studies using two radiological methods in investigating the circulation of exercising human arms. *J Physiol.* 1971 Mar; 213(2):41P-42P.
98. Maksimova, A. L. and Ryzhenkov, A. A. [The thermal imaging assessment of peripheral vascular reactions during local cold exposure in subjects with differing hypoxic resistances]. *Fiziol Cheloveka.* 1999 Jan-1999 Feb 28; 25(1):109-14.
99. Mannara, G.; Salvatori, G. C., and Pizzuti, G. P. Ethyl alcohol induced skin temperature changes evaluated by thermography. Preliminary results. *Boll Soc Ital Biol Sper.* 1993 Oct; 69(10):587-94.
100. Marszalek, A. [The use of selected methods in assessing peripheral circulation of blood]. *Med Pr.* 2000; 51(3):299-309.
101. McCollum, P. T.; Spence, V. A., and Walker, W. F. Amputation for peripheral vascular disease: the case for level selection. *Br J Surg.* 1988; 75(12):1193-5.
102. McCollum, P. T.; Spence, V. A.; Walker, W. F., and Murdoch, G. A rationale for skew flaps in below-knee amputation surgery. *Prosthet Orthot Int.* 1985; 9(2): 95-9.
103. McEwan, A. J. and Ledingham, I. M. Blood flow characteristics and tissue nutrition in apparently ischaemic feet. *Br Med J.* 1971; 3(768):220-4.

104. Merla, A.; Di Donato, L.; Di Luzio, S.; et al. Infrared functional imaging applied to Raynaud's phenomenon. *IEEE Eng Med Biol Mag.* 2002 Nov-2002; 21(6):73-9.
105. Mitchell, W. S.; Winocour, P. H.; Gush, R. J.; Taylor, L. J.; Baker, R. D.; Anderson, D. C., and Jayson, M. I. Skin blood flow and limited joint mobility in insulin-dependent diabetes mellitus. *Br J Rheumatol.* 1989; 28(3):195-200.
106. Moller, U. and Bojsen, J. Temperature and blood flow measurements in and around 7,12- dimethylbenz(a)anthracene-induced tumor and Walker 256 carcinosarcomas in rats. *Cancer Res.* 1975; 35(11 Pt 1):3116-21.
107. Musaeov, A. V.; Nasrullaeva, S. N., and Namazov, D. Z. [A clinico-thermographic assessment of the efficacy of naphthalan therapy in patients with diabetic microangiopathies of the lower extremities]. *Vopr Kurortol Fizioter Lech Fiz Kult.* 1998 Jul-1998; (4):26-9.
108. Ng, E. Y. and Sudharsan, N. M. Numerical uncertainty and perfusion induced instability in bioheat equation: its importance in thermographic interpretation. *J Med Eng Technol.* 2001; 25(5):222-9.
109. Nilsson, G.; Lindblom, P.; Palmer, B.; Vernersson, E., and Aberg, M. The effect of triglycyl-lysine-vasopressin (terlipressin INN, Glypressin) on skin blood flow, measured with laser Doppler flowmetry, thermography and plethysmography. A dose-response study. *Scand J Plast Reconstr Surg Hand Surg.* 1987; 21(2):149-57.
110. Nilsson, S. K.; Gustafsson, S. E., and Torell, L. M. Skin temperature over a heat source: experimental studies and theoretical calculations. *Ann N Y Acad Sci.* 1980; 335:416-28.
111. Normell, L. A. Recording of normal and impaired cutaneous thermoregulatory vasomotor responses by infra-red thermography: a methodological study. *Scand J Clin Lab Invest Suppl.* 1974; 138:1-24.
112. Ohashi, S.; Iwatani, M.; Hyakuna, Y., and Morioka, Y. Thermographic evaluation of the hemodynamic effect of the antithrombotic drug cilostazol in peripheral arterial occlusion. *Arzneimittelforschung.* 1985; 35(7A):1203-8.
113. Okumura, Y.; Asakawa, K.; Ogasahara, Y.; Muramatu, A.; Wada, S.; Tamaru, S., and Nagai, M. [Bathing in bed accelerates the recovery of skin temperature after ethanol-loading]. *Ann Physiol Anthropol.* 1994; 13(1):49-54.
114. Otsuka, K.; Okada, S.; Hassan, M., and Togawa, T. Imaging of skin thermal properties with estimation of ambient radiation temperature. *IEEE Eng Med Biol Mag.* 2002; 21(6):49-55.
115. Patil, K. D. and Williams, K. L. Thermographic study of heat flow in the detection of incompetent perforating veins. *Surg Gynecol Obstet.* 1971; 132(3):396-402.

116. Pavlidis, I. and Levine, J. Thermal image analysis for polygraph testing. *IEEE Eng Med Biol Mag.* 2002 Nov-2002; 21(6):56-64.
117. Pomerance, J. J.; Lieberman, R. L., and Ukrainski, C. T. Neonatal thermography. *Pediatrics.* 1977; 59(3):345-51.
118. Pye, G. and Bowker, P. Skin temperature as an indicator of stress in soft tissue. *Eng Med.* 1976; 5(3):58-60.
119. Rusch, D.; Follmann, M.; Boss, B., and Neeck, G. Dynamic thermography of the knee joints in rheumatoid arthritis (RA) in the course of the first therapy of the patient with methylprednisolone. *Z Rheumatol.* 2000; 59 Suppl 2:II/131-5.
120. Rutka, J.; Jung, A.; Zuber, J., and Kalicki, B. [Changes of kidney parenchyma in children with nephrolithiasis after ESWL treatment in ultrasonography, power Doppler and thermovision monitoring]. *Pol Merkuriusz Lek.* 2000; 8(46):206-8.
121. Salmi, A. M.; Tukiainen, E., and Asko-Seljavaara, S. Thermographic mapping of perforators and skin blood flow in the free transverse rectus abdominis musculocutaneous flap. *Ann Plast Surg.* 1995; 35(2):159-64.
122. Samuel, E. Thermography-some clinical applications. *Biomed Eng.* 1969; 4(1):15-9.
123. Sarin, S.; Shami, S.; Shields, D. A.; Scurr, J. H., and Smith, P. D. Selection of amputation level: a review. *Eur J Vasc Surg.* 1991; 5(6):611-20.
124. Schurmann, M.; Gradl, G.; Wizgal, I.; Tutic, M.; Moser, C.; Azad, S., and Beyer, A. Clinical and physiologic evaluation of stellate ganglion blockade for complex regional pain syndrome type I. *Clin J Pain.* 2001; 17(1):94-100.
125. Seifalian, A. M.; Stansby, G.; Jackson, A.; Howell, K., and Hamilton, G. Comparison of laser Doppler perfusion imaging, laser Doppler flowmetry, and thermographic imaging for assessment of blood flow in human skin. *Eur J Vasc Surg.* 1994; 8(1):65-9.
126. Shawket, S.; Dickerson, C.; Hazleman, B., and Brown, M. J. Prolonged effect of CGRP in Raynaud's patients: a double-blind randomised comparison with prostacyclin. *Br J Clin Pharmacol.* 1991; 32(2):209-13.
127. Sherman, R. A.; Karstetter, K. W.; Damiano, M., and Evans, C. B. Stability of temperature asymmetries in reflex sympathetic dystrophy over time and changes in pain. *Clin J Pain.* 1994; 10(1):71-7.
128. Shevelev, I. A. Temperature topography of the brain cortex: thermoencephalography. *Brain Topogr.* 1992 Winter; 5(2):77-85.
129. Spence, V. A. and Walker, W. F. The relationship between temperature isotherms and skin blood flow in the ischemic limb. *J Surg Res.* 1984; 36(3):278-81.

130. Spence, V. A.; McCollum, P. T.; Walker, W. F., and Murdoch, G. Assessment of tissue viability in relation to the selection of amputation level. *Prosthet Orthot Int.* 1984; 8(2):67-75.
131. Steketee, J. and van der Hoek, M. J. Thermal recovery of the skin after cooling. *Phys Med Biol.* 1979; 24(3):583-92.
132. Sterns EE, Zee B, et al. Thermography. Its relation to pathologic characteristics vascularity proliferation rate and survival of patients with invasive ductal carcinoma of the breast. *Cancer* 1996; 77(7):1324-1328.
133. Stevens, J. D. and Rogers, W. Liquid crystal thermography of transplantable mouse tumors. *Vasc Surg.* 1971; 5(4):186-92.
134. Stuttgen, G. and Eilers, J. Reflex heating of the skin and telethermography. *Arch Dermatol Res.* 1982; 272(3-4):301-10.
135. Stuttgen, G. Thermographic evaluation of the benign diseases and reactive changes of the skin. *Prog Clin Biol Res.* 1982; 107:397-411.
136. Stuttgen, G.; Flesch, U.; Witt, H., and Wendt, H. Thermographic analysis of skin test reaction using AGA thermovision. *Arch Dermatol Res.* 1980; 268(2):113-28.
137. Swain, I. D. and Grant, L. J. Methods of measuring skin blood flow. *Phys Med Biol.* 1989; 34(2):151-75.
138. Swanson Beck, J. and Spence, V. A. Patterns of blood flow in the microcirculation of the skin during the course of the tuberculin reaction in normal human subjects. *Immunology.* 1986; 58(2):209-15.
139. Takazawa, K.; Iketani, T., and Ibukiyama, C. [Pulse wave velocity, thermography in the diagnosis of arteriosclerosis]. *Nippon Rinsho.* 1993; 51(8):2074-9.
140. Temperature and blood flow patterns in breast cancer during natural evolution and following radiotherapy. *Prog Clin Biol Res.* 1982; 107:21-64.
141. Toms, S. L. and Cooke, E. D. A comparison of the functioning of arteriovenous anastomoses in secondary Raynaud's phenomenon and control subjects in response to local hand warming. *Int Angiol.* 1995; 14(1):74-9.
142. Trandel, R. S.; Lewis, D. W., and Verhonick, P. J. Thermographical investigation of decubitus ulcers. *Bull Prosthet Res.* 1975 Fall; (10-24):137-55.
143. Tsuchida, Y. Rate of skin blood flow in various regions of the body. *Plast Reconstr Surg.* 1979; 64(4):505-8.

144. Turner, T. A. Thermography as an aid to the clinical lameness evaluation. *Vet Clin North Am Equine Pract.* 1991; 7(2):311-38.
145. Turner, T. A.; Fessler, J. F.; Lamp, M.; Pearce, J. A., and Geddes, L. A. Thermographic evaluation of horses with podotrochlosis. *Am J Vet Res.* 1983; 44(4):535-9.
146. Usuki, K.; Kanekura, T.; Aradono, K., and Kanzaki, T. Effects of nicotine on peripheral cutaneous blood flow and skin temperature. *J Dermatol Sci.* 1998; 16(3):173-81.
147. Valtonen, E. J.; Lilius, H. G., and Svinhufvud, U. Effect of timing and duration of the syncardial pressure pulses of skin temperature and plethysmogram of the legs. *Am J Phys Med.* 1973; 52(2):59-64.
148. van den Berg, J. W. Thermal conductivity and heat transfer of the human skin. *Bibl Radiol.* 1975; (6):166-77.
149. Volgin, E. G.; Mel'nikova, V. P.; Stroev, I. u. I., and Zakalinskii, I. A. [Thermography in the evaluation of peripheral blood flow in patients with diabetes mellitus]. *Vestn Khir Im I I Grek.* 1983; 130(1):56-62.
150. Wanklyn, P.; Ilsley, D. W.; Greenstein, D.; et al. The cold hemiplegic arm. *Stroke.* 1994; 25(9):1765-70.
151. Wilson, S. B. and Spence, V. A. Dynamic thermographic imaging method for quantifying dermal perfusion: potential and limitations. *Med Biol Eng Comput.* 1989; 27(5):496-501.
152. Winsor, T. Instrumental methods for studying the peripheral arterial circulation. *Cardiovasc Clin.* 1971; 3(1):17-35.
153. Woodcock, A. H.; Taylor, P. N., and Ewins, D. J. Long pulse biphasic electrical stimulation of denervated muscle. *Artif Organs.* 1999; 23(5):457-9.
154. World Health Organization. Comparison among different methods for the diagnosis of varicoceles. *Fertil. Steril.* 1985; 43(4): 575-582.
155. Wouda, A. A. The significance of photoelectric plethysmography, thermography and venous occlusion plethysmography in the investigation of the peripheral circulation. *Pflugers Arch.* 1970; 314(2):172-3.
156. Zhang, D.; Xue, L.; Wei, Z.; Gao, H.; et al. [Analysis of the relationship between the facial skin temperature and blood flow]. *Sheng Wu Yi Xue Gong Cheng Xue Za Zhi.* 1999; 16(1):81-5.

157. Zhang, X.; Tong, B.; Gu, H.; et al. [Comparison of evaluation methods on changes of facial microcirculation during induction of motion sickness]. *Space Med Med Eng (Beijing)*. 1997; 10(3):182-6.
158. Zontak, A.; Sideman, S.; Verbitsky, O., and Beyar, R. Dynamic thermography: analysis of hand temperature during exercise. *Ann Biomed Eng*. 1998; 26(6): 988-93.

### Skin thermography and central blood flow

159. Abbot, N. C.; Beck, J. S.; Harrison, D. K., and Wilson, S. B. Dynamic thermographic imaging for estimation of regional perfusion in the tuberculin reaction in healthy adults. *J Immunol Methods*. 1993; 162(1):97-107.
160. Birklein, F.; Riedl, B.; Neundorfer, B., and Handwerker, H. O. Sympathetic vasoconstrictor reflex pattern in patients with complex regional pain syndrome. *Pain*. 1998; 75(1):93-100.
161. Di Benedetto M, Huston CW, et al. Regional hypothermia in response to minor injuries. *Amer J Phys Med Rehabil* 1996; 75(4):270-277.
162. DiBenedetto M, Yoshida M, et al. Foot evaluation by infrared imaging. *Mil Med* 2002; 167(5):384-392.
163. Hanssler, L.; Roll, C., and Breukmann, H. [Laser Doppler flowmetry in newborn infants with low birth weight. The effect of differences in humidity on peripheral circulation]. *Klin Padiatr*. 1992; 204(5):359-61.
164. Horzic M, Bunoza D, Maric K. Contact thermography in a study of primary healing of surgical wounds. *Ostomy Wound Manage*. 1996; 42(1):36-38; 40-42; 44.
165. Horzic M, Bunoza D, Maric K. Three dimensional observation of wound temperature in primary healing. *Ostomy Wound Manage*. 1996; 42(8): 38-40; 42-44; 46-47.
166. Kohler A, Hoffmann R, et al. Diagnostic value of duplex ultrasound and liquid crystal contact thermography in preclinical detection of deep vein thrombosis after proximal femur fractures. *Arch Orthop Trauma Surg* 1998; 117(1-2):39-42.
167. Mabuchi K. Clinical significance of thermography - a non invasive and non contact method to evaluate peripheral circulatory function in the diagnosis of diabetic complications. *Nippon Rhinso* 1990; 48 (suppl): 580-587.
168. Mohammadian, P.; Andersen, O. K., and Arendt-Nielsen, L. Correlation between local vascular and sensory changes following tissue inflammation induced by repetitive application of topical capsaicin. *Brain Res*. 1998; 792(1):1-9.



169. Salmi, A. M.; Tukiainen, E., and Asko-Seljavaara, S. Thermographic mapping of perforators and skin blood flow in the free transverse rectus abdominis musculocutaneous flap. *Ann Plast Surg.* 1995; 35(2):159-64.
170. Tham, T. C.; Silke, B., and Taylor, S. H. Comparison of central and peripheral haemodynamic effects of dilevalol and atenolol in essential hypertension. *J Hum Hypertens.* 1990; 4 Suppl 2:77-83.

### Thermography in cardiovascular Diagnoses

171. Ekroth R, Berggren H, Sudow G et al. Thermographic demonstration of uneven myocardial cooling in patients with coronary lesions. *Ann Thorac Surg.* 1980; 29(4):341-5.
172. Moiseenko MD, Kitsal TA, et al. Use of color thermography for diagnosing aortic and iliac artery disease. *Vestn Khir Im I I Grek* 1986; 136(1):60-64.
173. Rogowski J, Mrozinski P, Jagielak D, et al. Thermographic assessment of stellate ganglion block effectiveness during cardiosurgical procedures. *Med Sci Monit.* 2000; 6(2):407-10.
174. Szabo T, Fazekas L, Geller L, et al. Cardiothermographic assessment of arterial and venous revascularization. *IEEE Eng Med Biol Mag.* 2000; 19(3):77-82.
175. Szabo T, Horkay F, Fazekas L, et al. Thermographic evaluation of myocardial protection. *IEEE Eng Med Biol Mag.* 2000; 19(3):83-6.
176. Stefanadis C, Vavuranakis M, Toutouzas P. Vulnerable plaque: the challenge to identify and treat it. *J Interv Cardiol.* 2003; 16(3):273-80. Review.
177. Diamantopoulos L. Arterial wall thermography. *J Interv Cardiol.* 2003; 16(3): 261-6. Review.
178. Stefanadis C, Toutouzas K, Vaina S, et al. Thermography of the cardiovascular system. *J Interv Cardiol.* 2002; 15(6):461-6. Review.