

Does thermal imaging provide extra information in patients suffering from headache ?

Kurt Ammer

Austrian Society of Thermology, Vienna, Austria

Introduction

Primary headache disorders are now regarded as many discrete entities, although the view that primary headache disorders is a continuum of which each is part, is still a not uncommon idea of some headache experts (1). However, the international classification of headache disorders available since 1988 in the first version contributed a lot to the definition and understanding of headache disorders. The second edition of this classification is based on evidence that slightly different symptoms of distinct disorders are caused by a different pathophysiology (2). This is definitely true for the primary headache forms classified with the code 1. migraine and code 3: cluster headache and other trigeminal cephalgias.

Pathophysiological models of migraine

Big progress has been made in the last 50 years in understanding the pathophysiology of migraine and other primary headaches. The vascular hypothesis of migraine developed by Wolff in the 1930s and 1940s proposed that migraine was simply a vasospastic disorder, initiated by vasoconstriction in the cranial vasculature (3). In 1969, Heyck suggested that opening of the cranial arteriovenous anastomoses, which is reflected by a sudden reduction in the difference between arterial and jugular venous blood oxygen saturation, characterizes the onset of a migraine attack. Some animal models for migraine are based on the view that cranial extracerebral vasodilatation is an integral part of the pathophysiology of migraine. The involvement of arteriovenous anastomoses in the primary headache migraine is mainly based on the findings that 1.. antimigraine agents decrease carotid blood flow by a vasoconstrictor action exclusively on arteriovenous anastomoses; 2. during migraine, the oxygen saturation difference between arterial and jugular venous blood decreases and this is normalised after treatment-induced or spontaneous alleviation of the attack (5). Pain is generated in this model due to the increased vascular pulsation which may activate mechanical receptors within the vessel wall. This would, release neuropeptides, mainly calcitonin gene-related peptide (CGRP) from the perivascular nerves which may ultimately cause pain and other associated symptoms Lance stated in 1970 (6) that “the present of migraine is that of an hereditary vascular instability which renders the individual susceptible to alteration in the level of humoral vasoactive substances, particularly serotonin, which can be in turn affected by a variety of circumstances“. Consequently he used infrared thermography for research in the vascular disorder migraine.

Another phenomenon associated with changes in cerebral bloodflow goes back to the animal experiments of the the Brazilian physiologist Leão (3). He observed that the application of noxious stimulus on to the exposed cerebral cortex of an animal depressed the electrical activity at the point of application and that over time this depression spread in a wave to adjacent areas of the cortex. This phenomenon known as cortical spreading depression (CSD). CSD begins with a brief wave of excitation, followed by a prolonged period of neuronal depression, which is associated with disturbances in nerve cell metabolism. Coupled with this electrical phenomenon are cerebral blood flow (CBF) changes which consisted of four phases: a brief hypoperfusion before the direct current (DC) shift; a marked CBF rise during the DC shift; followed by a smaller, but protracted increase of CBF; and a prolonged CBF reduction, the oligemia..(7). Two magnetic resonance imaging studies may be used as strong arguments, that CSD and the associated changes of CBF are the physiological processes underlying the aura and other prodromal symptoms of migraine patients (8,9).

However, the current understanding of migraine (10) favours a different pathogenesis of migraine. There is agreement with the relationship between aura and cortical spreading depression and the occurrence of cerebral blood flow is not denied. The main concern is the mechanism of pain generation in migraine and other primary headaches which can not fully explained by solely vascular changes. Three candidates may be involved in migraine pain: the cranial blood vessels, the trigeminal innervation of the vessels, and the reflex connections of the trigeminal system with the cranial parasympathetic outflow. As the substance of the brain is insensate due to the lack of pain fibers; pain can be generated by large cranial vessels, proximal intracranial vessels, or by the dura mater. These vessels are innervated by branches of the ophthalmic division of the trigeminal nerve, whereas the structures of the posterior fossa are innervated by branches of the C₂ nerve roots. The involvement of the first branch of the trigeminal nerve and the overlap with the innervation area of the first two spinal nerves explain the common distribution of migraine pain over the frontal and temporal regions. In migraine patients it seems very likely, that activation of the brainstem observed by functional imaging is involved in the pain process in a permissive or triggering manner rather than simply as a response to nociception in the ophthalmic division of the trigeminal nerve (11). The pain may be a combination of an altered perception as a result of peripheral or central

sensitization of craniovascular input that is not usually painful (12) and the activation of feed-forward neurovascular dilator mechanism that is functionally specific for the first division of the trigeminal nerve.

It is also clear, that a number of neuropeptides is involved in the pathomechanism of primary headaches. Calcitonin-gene-related-peptide (CGRP) and substance P (SP) play a major role in the pathogenetic process of migraine. The function of CGRP as a strong vasodilator and of SP as a compound inducing extravasation and the interaction of both mediators to promote neurogenic inflammation seems to be similar in cerebral blood vessels as observed in the skin (13).

Thermography and Headache Research

Wood recorded thermal images of the face thermography in the mid of the nineteensixties for the assessment of cerebrovascular disease (14,15), but Lance was probably the first who used this technique in headache patients (6). He reported the influence of intramuscular reserpine and, intravenous serotonin on the facial thermogram. The effect of serotonin injected in the external carotid artery was documented with thermography and angiograms recorded 2 minutes after the injection. He also showed a low temperature on the affected side of the forehead in 80% of patients with acute migraine attacks.

After this first thermographic headache reports (6,16), few other papers appeared in the nineteenseventies. The pioneer of facial thermography published a paper on cluster headache (17) and Kudrow showed that higher temperatures were correlated with increased blood flow velocities measured by Doppler flow in patients successfully treated for cluster headache (18). A series of case reports of patients suffering from various kinds of headache and facial pains were published from Liverpool (19). Spierings quotes three papers in which thermography was applied in headache patients, but unfortunately with unclear description of the methods used. Therefore, pooled data from thermography could not be compared with the results of other techniques which have been measured hemodynamic changes in patients with vascular headache (20). A study from Italy found asymmetric facial temperature distribution in 58 % of patients during migraine attack and in 15% between attacks. More frequently than thermal asymmetry they observed a hot spot at the internal angle of the orbita (21).

The highest interest for thermal imaging as a research tool for headache investigations was during the eighties of the 20th century. Drummond and Lance concluded from thermographic findings on the contribution of dilatation of the superficial temporal artery and its branches to pain generation in migraine headache (22). Kudrow described a typical thermal pattern in patients suffering from cluster headache (23) He described two warm vertical lines contralateral to the painful side, mainly in the interval between the pain attacks. Drummond and Lance described the thermal pattern in cluster headache as an area of low temperature in the affected orbital region, which may spread above and below the eye, down the nose, and to the affected temple in

some patients (24). Inhalation of 100% oxygen reduced or abolished cluster pain in 22 of 25 patients, and temperature asymmetry then disappeared. The same authors reported the thermographic findings of 186 patients during 209 separate attacks of headache affecting the anterior part of the head (25). The analysis of thermal imaging did not obtain a clear relationship between clinical symptoms and temperature changes. Throbbing headaches were associated with low temperatures over the affected frontotemporal region and cheek. In addition, the supra-orbital region was cooler on the affected side in patients who felt nauseated, while the opposite was observed in patients who had vomited. Thermal asymmetry in other regions was unrelated to clinical diagnosis, symptoms, severity or time course of headache. De Marinis et al induced headache with histamine in 12 healthy controls and 37 patients who had surgical treatment for trigeminal neuralgia. (26). Smaller changes of skin temperature were observed during the induced headache on the operated side than on the side of undisturbed trigeminal nerve. The authors interpreted the decreased vasomotor response on the operated side as possible pathogenetic relationship between vasomotor response and perception of headache. Drummond reported temperature changes in case of chronic paroxysmal hemiparesis which have been similar to the findings in cluster headache i. e. the temperature over the frontotemporal region was lower on the habitually-affected left side by 0.5°C, but cooler by 1°C from the cheek (27). Another case reported the treatment effect of repeated stellate ganglion blocks in a patient posttraumatic dystonia tonic headache (28). A retrospective study on thermograms of 120 consecutive patients of a headache clinic found temperature asymmetries in 100% of patients with cluster headache and in 64% of migraine patients. A cold nose was a predominant finding in two thirds of migraine patients, but only in 18% of sufferers from cluster headache (29).

In 1986 a paper from Swerdlow and Dieter was the onset of the discussion on the validity of the "cold patch" in chronic headache (30). An associated editorial speculated about the utility of thermography as a marker for vascular headache (31). Swerdlow and Dieter concluded from their statistical analysis of thermograms from 275 patients and 45 controls without headache, that vascular headache patients displayed a significantly greater number of "cold patches" than did normal individuals, or patients having secondary headaches. Mixed headaches involving a vascular component also displayed a significantly greater number of "cold patches," as did cluster disorders and post-traumatic headaches.

Swerdlow and Dieter reported thermal patterns in the posterior cervical-thoracic region from 30 headache patients randomly selected from a total patient sample of 438 (32). These subjects were followed for 5 months to investigate the persistence of three predominate patterns in the cervical-thoracic region of the back. The authors concluded that the temperature distribution over the upper back may be consistent over time, but that patterns on cervico-thoracic region fluctuate and do not correlate with chronic headaches. Drummond studied scalp tenderness in 102 patients with headache and 35 nonheadache control subjects

(33). Pressure-pain threshold at the site of unilateral headache was unrelated to thermographic findings. However, tenderness in the occiput and neck was greater in 17 patients with low temperatures over the symptomatic frontotemporal region. Swerdlow and Dieter investigated the effect of hyperoxia on the temperature distribution of the forehead of headache 30 patients and 20 controls (34). The study demonstrated that a significant portion of the migraine headache population investigated exhibited a paradoxical response to hyperoxia which resulted in vasodilatation. The response to hyperoxia did not differ if the patient was experiencing a headache, nor did oxygen significantly reduce pain. Hyperoxia increased migraine "cold patch" size. Regardless of temperature fluctuations, facial patterns remained stable across conditions. S Govindan, who had stimulated Swerdlow's study on hyperoxia, used the oxygen inhalation (35) and hypercarbia (36, 37) to increase the temperature response to antimigraine drugs or to enhance the vascular reactivity in patient with narcolepsy. (37).

The discussion on "cold patches" was stimulated by a paper by Dalla Volta and Anzola (38). The authors reported that prior to treatment, eighteen from 22 vascular headache patients presented with a "cold patch" in the external carotid territory, ipsilateral to the prevailing side of pain. After six months of treatment the "cold patch" had disappeared or was attenuated in all the patients, who had clinical improvement. Swerdlow and Dieter, who had the opinion that the thermal pattern of the forehead is stable over the time, were concerned about these results from Italy and assumed that poor standards in conducting this study might have caused these findings (39). Subsequently they published a study, which indicates that in migraine patients with improved condition after treatment 46.7% of subjects exhibited an increase in cold patch size, 40% of cold patches remained stable, 6.7% of cold patches reduced in size, and zero cold patches disappeared with successful treatment (40). Within the group with worsened condition 20% of cold patches decreased in size, 40% increased in size, and 40% remained stable. Swerdlow and Dieter concluded from their findings, that vascular cold patch is independent of treatment effects and a permanent element of a vascular headache sufferer's facial thermal pattern.

The answer of Dalla Volta's group was a report on a sample of 246 consecutive migraine patients (41). Among the 136 patients who experienced complete or substantial relief from headache the cold patch disappeared or markedly reduced size in 85% of the cases. In the 46 patients with partial relief the thermogram showed an improved pattern in 48% of patients, characterised by smaller hot patches compared to extent prior to treatment. No clinical improvement was observed in 24 patients with unchanged thermal images in 85% of cases. Finally, Swerdlow and Dieter accepted, that thermal imaging can be used as outcome measure in headache patients (42) as proposed by Dalla Volta (38, 1), Govindan (35,36,37) and Drummond (24). Drummond reported a case series of nine patients with atypical facial pain whose thermograms indicated

that vascular changes accompany atypical facial pain in at least 50% of cases (43).

The number of publications on thermal imaging in headache patients decreased rapidly since 1990. Mongini et al were interested in the thermal image of cranio-facial pain. They used a clenching test to increase temperature asymmetry caused by tense muscles (44). This group showed also that thermal imaging can be used successfully as outcome measure in an analgetic drug trial (45). The responsiveness of thermography to drug effects was also shown in two trials applying sumatriptan in migraine patients (46,47). A retrospective study including thermograms from 993 patients with various headache found abnormal thermograms in 855 patients (86.1%) characterized by low temperatures in the supraorbital region (48). The most recent thermographic headache publication closes the circle as this is like the first publication by Lance a case report with unknown impact for the diagnosis or management of patients (49).

Headache-Thermography in the current issue

In this issue of *Thermology international* appear three papers dealing with thermal imaging in patients suffering from headache. S. Govindan presents two case reports. In one patient the effects of betablocker medication becomes visible by the help of hyperoxia. (50). The second case demonstrates clearly, that the vasoconstrictive effect can be imaged by infrared thermography (51). The third paper evaluates the diagnostic utility of thermal imaging for headache in children (52). Headache in children is a difficult issue due to less clear diagnostic criteria. This publication from the Pediatric Neurology Department of the University Hospital in Katowice, Poland, provides evidence that different thermal patterns exist in children with various forms of headache. Perhaps, this focus on thermal imaging in headaches may stimulate further research in this field.

References

1. Wöber-Bingöl C, Wöber C, Karwautz A, Auerth A, Serim M, Zebenholzer K, et al. Clinical features of migraine: A cross-sectional study in patients aged three to sixty-nine. *Cephalalgia*. 2004;24:12-17.
2. Olesen J, Steiner TJ. The international classification of headache disorders, 2nd edn (ICHD-II). *J Neurol Neurosurg Psychiatry* 2004, 75; 808-811
3. Silberstein SD. Migraine pathophysiology and its clinical implications. *Cephalalgia* 2004, 24 (Suppl. 2): 2-7
4. Heyck H. Pathogenesis of migraine. *Res Clin Stud Headache* 1969; 2:1-28.
5. De Vries P, Villalon CM, Saxena PR. Pharmacological aspects of experimental headache models in relation to acute antimigraine therapy. *Eur J Pharmacol* 1999; 375: .61-74
6. Lance JW, Anthony M, Somerville B. Thermographic, hormonal and clinical studies in migraine. *Headache*. 1970; 10(3): 93-104.
7. Lauritzen M. Cortical spreading depression in migraine. *Cephalalgia*. 2001; 21(7):757-60.
8. Cao Y, Welch KM, Aurora S, Vikingstad EM. Functional mBOLD of visually triggered headache in patients with migraine. *Arch Neurol* 1999; 56 (5):548±54.
9. Hadjikhani N, Sanchez R, Wu O et al. Mechanisms of migraine aura revealed by functional MRI in human visual cortex. *Proc Natl Acad Sci USA* 2001; 98 (8):4687-4692.

10. Goadsby PJ, Lipton RB; Ferrari MD. Migraine- Current Understanding and Treatment. *N Engl J Med* 2002, 346:257-270
11. May A. Headache: lessons learned from functional imaging. *Br Med Bull* 2003; 65: 223-234
12. Burstein, R., Cutrer, M.F., Yarnitsky, D., The development of cutaneous allodynia during a migraine attack clinical evidence for the sequential recruitment of spinal and supraspinal nociceptive neurons in migraine. *Brain* 2000; 123, 1703- 1709.
13. Holzer P. Neurogenic Vasodilation and Plasma Leakage in the Skin. *Gen Pharmac* 1998, 30(1): 5-11
14. Wood EH. Thermography in the diagnosis of cerebrovascular disease: Preliminary report. *Radiology* 1964; 83: 540-6.
15. Wood EH. Thermography in the diagnosis of cerebrovascular disease. *Radiology* 1965; 85: 207-15.
16. Lance JW, Anthony M. Thermographic studies in vascular headache. *Med J Aust.* 1971; 1(5):240-3
17. Wood EH, Friedman AP. Thermography in cluster headache. *Res Clin Stud Headache.* 1976;4:107-11.
18. Kudrow L. Thermographic and Doppler flow asymmetry in cluster headache. *Headache.* 1979;19(4):204-8.
19. Mumford JM, Miles JB. Thermography and orofacial pain. *Acta thermographica* 1977, 2: 155-161
20. Spierings LH. Headache. Craniovascular accompaniments of the vascular headache of the migraine type. 1979;19(7):397-9.
21. Perrone P, Porazzi D, Carnaghi PL, Landi G. Thermographic patterns in migraine. *Acta thermographica*, 1980, 5: 129-132
22. Drummond PD, Lance JW. Extracranial vascular changes and the source of pain in migraine headache. *Ann Neurol.* 1983; 13(1):32-7.
23. Kudrow L. A Distinctive Facial Thermographic Pattern in Cluster Headache the "Chai" Sign. *Headache* 1985; 25:33-36.
24. Drummond PD, Lance JW. Thermographic changes in cluster headache. *Neurology.* 1984;34(10):1292-8.
25. Drummond PD, Lance JW. Facial temperature in migraine, tension-vascular and tension headache. *Cephalalgia.* 1984; 4(3): 149-58
26. De Marinis M, Martucci N, Gagliardi FM, Feliciani M, Agnoli A. Trigeminal control of cranio-facial vasomotor response: I. Histamine test in patients with unilateral gasserian ganglion lesions. *Cephalalgia* 1984;4:243-51.
27. Drummond PD. Thermographic and pupillary asymmetry in chronic paroxysmal hemicrania. A case study. *Cephalalgia.* 1985; 5(3): 133-6.
28. Swerdlow B. Thermographic Documentation in a Case of Post-traumatic Dysautonomic Cephalalgia. *Thermology*, 1985, 1: 102-105
29. Rapoport AM, Sheftel FD, Altemus M. Correlations of Facial Thermographic Patterns and Headache diagnosis. In: Abernathy M, Uematsu S (eds) *Medical Thermology*, American Academy of Thermology, Georgetown, Washington D.C, 1986, p-56-61
30. Swerdlow B, Dieter JN. The validity of the vascular "cold patch" in the diagnosis of chronic headache. *Headache.* 1986; 26(1):22-6
31. Edmeads J. Is Thermography a Marker for Vascular Headaches? *Headache* 1986, 26: 47
32. Swerdlow B, Dieter JN. Posterior cervical-thoracic thermograms: pattern persistence and correlation with chronic headache syndromes. *Headache.* 1987;27(1):10-5.
33. Drummond PD. Scalp Tenderness and Sensitivity to Pain in Migraine and Tension Headache. *Headache* 1987, 27:45-50.
34. Swerdlow B, Dieter JN. The thermographically observed effects of hyperoxia on vascular headache patients and non-headache individuals. *Headache.* 1987;27(10):533-9.
35. Govindan S. Thermography During Induced Hyperoxia. *Thermology* 1987, 2: 587-589
36. Govindan, S. Effect of Sansert on the facial thermogram. *Thermology* 3:139-140, 1989
37. Govindan, S. Thermography in narcolepsy. *Thermology* 1988. 3: 80-81.
38. Dalla Volta G, Anzola GP. Are there objective criteria to follow up migrainous patients? A prospective study with thermography and evoked potentials. *Headache.* 1988; 28(6):423-5
39. Swerdlow B, Dieter JN. Cold spot question heats up. *Headache.* 1989; 29(2):122-3. .
40. Swerdlow B, Dieter JN. The vascular "cold patch" is not a prognostic index for headache. *Headache.* 1989; 29(9):562-8.
41. Dalla Volta G, Anzola GP, Di Monda V. The disappearance of the "cold patch" in recovered migraine patients: thermographic findings. *Headache.* 1991; 31(5):305-9
42. Swerdlow B, Dieter JN. Cold Spots. *Headache* 1991, 31, 694
43. Drummond PD. Vascular Changes in Atypical Facial Pain. *Headache* 1988, 28, 121-123-42.
44. Mongini F, Caselli C, Macri V, Tetti C. Thermographic findings in cranio-facial pain. *Headache.* 1990; 30(8):497-504
45. Mongini F, Bona G, Garnerio M, Gioria A. Efficacy of meclizolam sodium versus placebo in headache and craniofacial pain. *Headache.* 1993; 33(1):22-8.
46. Paterna S, Parrinello G, Pinto A, Arrostuto A, Cottone C, Di Silvestre G, Maniscalchi T, Licata G. Effect of sumatriptan on facial temperature variations, blood pressure and electrocardiogram in healthy subjects and patients with migraine without aura. *Clin Ter.* 1995 Jun-Jul;146(6-7): 469-76.
47. Ford RG, Ford KT. Thermography in the diagnosis of headache. *Semin Neurol.* 1997;17(4):343-9.
48. Parrinello G, Paterna S, Di Pasquale P, Pinto A, Cardinale A, Maniscalchi T, Cottone C, Follone G, Tuttolomondo A, Bologna P, Colomba D, D'Angelo A, Ortoleva A, Garofalo L, Piovana G, Capodici E, Bova A, Giubilato A, Licata G. Effect of subcutaneous sumatriptan on head temperature in migraines. *Drugs Exp Clin Res.* 1998; 24(4):197-205..
49. University of South Alabama Headache Center. Images from headache: thermography redux. *Headache.* 2005;45(7):947.
50. Govindan S. Imaging the Effect of Betablocker in Migraine. *Thermol int* 2006, 16: 49-52
51. Govindan S. Imaging the effect of Sumatriptan in Migraine treatment. *Thermol int* 2006, 16:61-64
52. Wojaczynska-Stanek K, Marszal E. Thermographic examination in children with headache. *Thermol int* 2006, 16: 53-60

Address for correspondence

Prof Kurt Ammer MD, PhD
Institute for Physical Medicine and Rehabilitation
Hanuschkrankenhaus, Heinrich Collinstr 30
A-1140 Wien
Email: KAmmer1950@aol.com or lbfphys@a1.net