

Technical Note

Infrared thermography brain mapping surveillance in vascular neurosurgery for anterior communicating artery aneurysm clipping

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Abstract

Background: Infrared thermography (IT) is a noninvasive, real-time diagnostic method that requires no contact with the patient and has a broad spectrum of potential applications in neurosurgery. It has been previously demonstrated the high sensitivity and specificity that IT has to detect brain blood flow changes.

Case Description: The case is based on a 64-year-old diabetic and hypertensive male, to whom an anterior communicating artery (ACoA) incidental aneurysm was discovered. We performed the basal infrared thermography mapping (ITM) and immediately after the transitory clip placement in both A1 segments of the anterior cerebral artery (A1-ACA), we performed a second ITM of the exposed brain cortex. After the definitive clip placement in the neck of the ACoA aneurysm, we removed the transitory clips of both A1-ACA and performed a third ITM of the cortical surface, without finding any cortical cooling or significant temperature differences (ΔT) compared to the basal ITM. The postoperative computed tomography (CT) and angio-CT did not show any ischemic damage and confirmed the accurate aneurysm clipping.

Conclusions: The ITM seems to be a real-time, safe, and useful brain mapping method to identify different temperature zones and temperature dispersion gradients in the human brain cortex. More studies are needed to evaluate the potential applications of IT mapping of the human brain and its use in neurosurgery and vascular neurosurgery.

Key Words: Aneurysm clipping, infrared thermography, infrared thermography mapping, real-time brain mapping, vascular neurosurgery

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INTRODUCTION

Intracranial aneurysms affect 3–5% of the adult population, with prevalence between the fourth and sixth decades of life. With the technological advances like the use of magnetic resonance imaging (MRI) and computed tomography (CT), the detection of nonruptured aneurysms has increased, allowing for early surgery or endovascular treatment.^[1] Noninvasive methods such as the incorporation of infrared thermography (IT) allow for procedures with a decrease in morbidity and mortality, complete resection, and minimally invasive approaches. IT also allows for real-time evaluation of cerebral blood flow in arteriovenous malformations or patency of bypass.^[4,8] Brain temperature has been studied as an independent variable for diagnostic and therapeutic objectives in different neuronal pathophysiological processes. One of the medical advances that has been developed for that purpose is the use of thermography using infrared cameras.^[7]

IT has become a new diagnostic method to assess thermal variations in tissues and blood. It is a remote method of imaging based on the detection of infrared radiation. This represents a part of the electromagnetic spectrum and its intensity is proportional to the surface temperature of the radiant object. In the past, this technique has been applied in coronary artery bypass surgery to measure the cooling effect during cardioplegia or to evaluate perfusion and permeability of grafts. Recent advances in infrared technology now make it possible to obtain images to evaluate the distribution of heat in the cerebral cortex.^[5] Thermographic cameras provide a sensitivity of less than 1 mK.^[3] The use of IT in neurosurgery has been investigated to differentiate between healthy and abnormal brain tissue. Image evaluation shows differences for both types of tissue, as neoplasms and normal tissue have different characteristics that produce and transfer heat. The two main factors that can contribute to hypothermia in the surface region of the brain corresponding to the epicenter of a tumor are (a) decreased metabolic rate of the tissues surrounding and superimposed by the perilesional edema and (b) low tumor microvessel density due to concomitant ischemia.^[6] It has been shown that glial tumors are hypothermic and brain metastases are hyperthermic in comparison with healthy brain tissue.^[2] Other studies have used IT in neurosurgery to monitor cerebral blood flow after resection of an arteriovenous malformation, observation of patency of bypass, temporary occlusion of arteries of the brain, among others.^[5,10] Intraoperative IT is becoming a promising new real-time diagnostic method: noninvasive, radiation-free, without exposure to drugs and without any known side effect. It can also improve the accuracy of tumor resections, as well as the assessment of cerebral blood flow in vascular neurosurgery,

to prevent the irreversible damage due to ischemia during surgery,^[3,6] among other potential indications.

We are publishing the first anterior circulation aneurysm clipping with infrared thermography mapping (ITM) surveillance during transitory and definitive clipping in vascular neurosurgery.

CASE DESCRIPTION

A 64-year-old diabetic and hypertensive male had a check-up that included a brain CT. An incidental, nonruptured, anterior communicating artery (ACoA) aneurysm was diagnosed [Figure 1].

DESCRIPTION OF THE PROCEDURE AND RESULTS

Under entropy-monitored general endovenous anesthesia, we performed a conventional frontotemporal right craniotomy. Immediately after the dura incision, we performed a basal ITM of the exposed brain surface using a handheld thermal imaging camera that combines the functions of surface temperature and real-time thermal imaging. We used a professional, precise, and efficient infrared imaging device. Our infrared thermal imager can turn a thermal image into a visible image. It quickly evaluates the different thermal gradients of the brain and it can also blend the visible and infrared images [resolution of infrared image/visible image: 3600 pixels/0.3 mega pixels; display: 2.4-inch full viewing angle high-resolution color screen; resolution: 60 × 60; resolution of visible image: 0.3 mega pixels; total pixel: 3600; FOV/shortest focal length: 20 × 20/0.5 m; thermal sensitivity: 0.5°C; measuring mode: thermopile; temperature range: −20°C to 300°C (−4°F to 572°F); measuring accuracy: ±2% or ±2°C (±4°F); wavelength range: 8–14 μm; emissivity: 0.1–1.0 (adjustable); image frequency: 6 HZ; focus mode: fixed; palette: iron red, rainbow, rainbow high contrast, gray scale (white glow), and gray scale (black glow); vision option: 5 kinds of full infrared to the full visual, mixing visible, and infrared; image storage: SD card (4G); file format: bmp; battery type: 4 × 1.5 V AA battery; authentication: CE; operating temperature: −5°C to 40°C (23°F to 104°F);

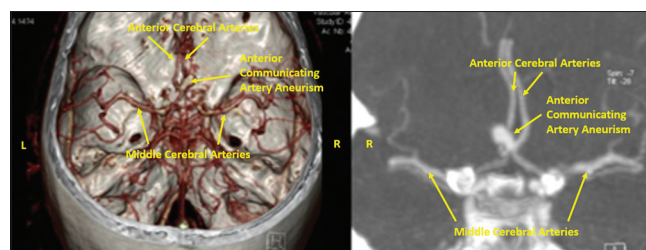


Figure 1: Unruptured incidental anterior communicating artery aneurysm of 8 × 5 mm

relative humidity: 10–80%] [Figure 2]. After Sylvian valley dissection and supraclinoid internal carotid artery, A1 segments of both anterior cerebral arteries (A1-ACA) and of the ACoA, we placed transitory clips in both A1-ACA. After the aneurysm neck dissection, we performed the second ITM [Figure 2]. After definitive clipping of the neck of the aneurysm, we removed the transitory clips after 12 minutes. Then we performed the last ITM without finding any descent of the cortical temperature (Δt) compared with the basal and second ITM [Figure 2]. Anesthetic profundity measured by entropy was RE46/SE46, inspired fraction of oxygen was 60%, oxygen saturation was 100%, and hemoglobin (13.4 g), hematocrit (39%), and CO₂ (32.3) by arterial blood gas obtained before the initial ITM. Corporal temperature was 34.5°C and the operating room temperature was 21°C, with a relative humidity of 60% in all ITMs. Cortical temperature went from 31.4°C to 31.8°C in the basal ITM, from 30.6°C to 31.8°C in the second ITM, and from 30.6°C to 31.7°C in the last ITM with the center of the record over the pars triangularis of the frontal lobe. We performed a CT, 12 hours after surgery [Figure 3] that showed the expected postoperative changes without ischemia. The patient developed transient hyponatremia that was corrected on the eighth day of hospital stay. He was discharged on the ninth day without neurological deficits.

DISCUSSION

The evaluation by intraoperative image of intravascular blood flow and cerebral cortical perfusion is essential during vascular neurosurgical procedures, both to guide surgical progress and as a diagnostic method to identify changes of cerebral perfusion in real time. Different methods have been developed to achieve this objective, for instance surgical arteriography, which shows postclipping stenosis in 20% of cases.^[10] Transoperative fluorescence angiography has demonstrated its

effectiveness for vascular imaging during procedures, but it has disadvantages such as the need for a specialized surgical microscope, exposure to drugs, and the lack of quantitative precision. This is due to factors such as its evanescence and interaction with blood products that affect the fluorescein. An ideal adjuvant must allow for real-time images to be obtained, be secure, and offer a high sensitivity and specificity to ensure vascular permeability and the prevention of possible cerebral ischemia.^[9]

Thermography-based blood flow imaging has been widely investigated in cardiovascular procedures, establishing a quantitative correlation between blood flow and temperature ($r = 0.96$). Watson *et al.* observed that changes in blood temperature are related to changes in brain blood flow, whereas cortical brain temperature is determined by cerebral blood flow–metabolism coupling and the infrared image could be sufficiently sensitive to detect ischemia.^[2,5] Arterial blood and core temperatures are higher than the exposed surface of the brain since they descend by evaporation and exposure to the environment. Therefore, local microvascular blood flow self-regulation of the brain can be used as a natural agent for monitoring thermal contrast with infrared imaging of the cerebral cortex during surgery. Gorbach *et al.* showed immediate and significant temperature decrease in the artery distal to the occlusion and the tissue perfused by it.^[2,3]

Based on the previously described evidence, which establishes the usefulness that IT has to detect even subtle blood flow changes, we describe an anterior circulation aneurysm clipping surveillance using ITM, getting images in real time with a noninvasive method and without the use of contrast media. Using IT, we monitored the cortical temperature in critical moments during surgery, where the cerebral circulation and metabolism could be affected by the placement of transient clips and the definitive clip. We did not find

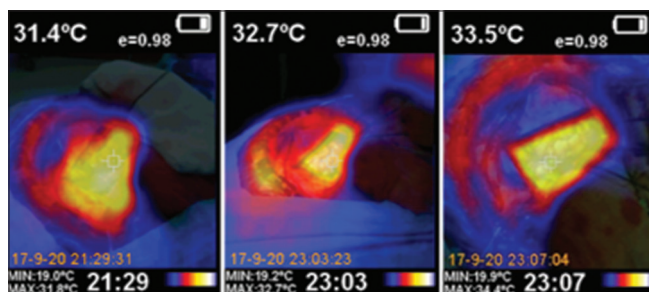


Figure 2: Image of the basal cortical metabolism measured by infrared thermography mapping (left). The temperature of the frontal lobe cortex is 31.4°C. Image of the second infrared thermography mapping during the transitory clipping of both A1-ACA (center). Image of the third infrared thermography mapping after definitive clipping of the neck of the anterior communicating artery aneurysm and removing of both transitory clips of both A1-ACA (right)

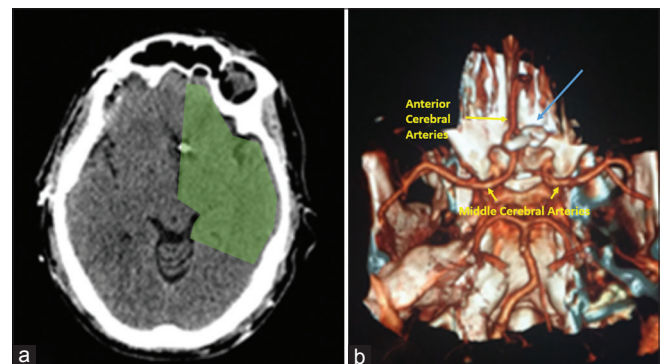


Figure 3: Postoperative computed tomography and angio-CT. No evidence of ischemia in the A1 or anterior communicating artery territory. Adequate clip placement in the neck of the aneurysm with total exclusion of arterial circulation and adequate filling of both A1-ACA

a significant descent of cortical temperature in any of the three records. We consider that the ITM can be an additional method for transoperative monitoring in both transient and final clipping of vascular structures as aneurysms. It can be used to register areas of different temperature gradients in real time, preventing secondary and permanent ischemic damage.

The use of IT in neurosurgery began in 2001 in patients with painful complex syndrome.^[7] New generations of infrared cameras are equipped with a system of high resolution to a minimum temperature difference. These images can show small changes in surface temperature related to both local and systemic physiological processes. Intraoperative surveillance using thermography in neurosurgery has been described in the resection of tumors and in monitoring of patency of bypass in arteriovenous malformations, in which it demonstrated adequate correlation compared with such conventional methods as postoperative CT, MRI, Doppler and angiography, among other methods.

The patient we describe stayed within stable physiological hemodynamic parameters during the surgical procedure to maintain cerebral self-regulation. With ITM, we found a cortical temperature increase of 1.3°C during the transient clipping for 12 minutes of both A1-ACA and a second increase of 0.8°C after placing the final aneurysm clip and removing transient clips. Based on the high sensitivity that IT has to detect blood flow related tissue temperature changes, it allows us to assume that there were no important changes in blood flow or in the cerebral metabolism during surgical manipulation and during transient clipping of both

A1-ACA that could have caused cerebral cortex cooling by hypoperfusion. Likewise, the ITM measurement after the placement of the final clip allowed us to establish an adequate cerebral perfusion by measuring an increase in cortical temperature in relation to the basal cortical temperature. We consider that ITM may be a promising adjuvant method for intraoperative monitoring in vascular neurosurgery. The main advantages and disadvantages of this initial experience are shown in Table 1.

CONCLUSION

Metabolic mapping by IT is a real-time noninvasive method that requires no manipulation of the tissues. Nor does not it require the use of contrasts or filters. It is safe, efficient, and low cost; hence it can be a promising adjuvant for intraoperative monitoring in neurosurgery and vascular neurosurgery. Based on the evidence that IT is effective to detect tissue temperature changes related to blood flow, we consider that ITM could be a useful method of avoiding damage by ischemia while using temporary and definitive vascular clips. More cases are required to determine the potential use of IT in neurosurgery for metabolic mapping.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names

Table 1: Main advantages and disadvantages of Infrared Thermography Mapping

Advantages	Disadvantages
Fast and accurate	Its use is not standardized yet
Noninvasive	It only measures the temperature of the exposed surface
Real-time imaging	As with any imaging study, it is subject to estimates that require analytical modeling done by the software included in the equipment's data processor
Safe	The reading can be affected by ambient temperature and environment humidity
Broad potential applications in neurosurgery for measurement of cerebral metabolism (tumors, vascular pathology, epilepsy, brain abscesses, among others)	
It allows for analysis of comparative physiology	
Potential applications for research	
It measures thermogenesis	
Useful for analyzing metabolic consumption	
Low cost	
Useful for analyzing cooling by evaporation and diffusion of heat	
Each case is its own control as there is a before and after in the placement of aneurysm clips as also there often is healthy brain exposed by craniotomy	

and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Etminan N, Rinkel GJ. Unruptured intracranial aneurysms: Development, rupture and preventive management. *Nat Rev Neurol* 2016;12:699-713.
2. Gorbach AM, Heiss J, Kufta C, Sato S, Fedio P, Kammerer WA, et al. Intraoperative infrared functional imaging of human brain. *Ann Neurol* 2003;54:297-309.
3. Hollmach J, Hoffmann N, Schnabel C, Kuchler S, Sobottka S, Kirsch M, et al. Highly sensitive time-resolved thermography and multivariate image analysis of the cerebral cortex for intrasurgical diagnostics. *Ther Diagn* 2013;8565:1605-7422.
4. Mery F. Technology and neurosurgery. *Rev Chil Neuropsiquiatr* 2010;48:173-4.
5. Nakagawa A, Fujimura M, Arafune T, Sakuma I, Tominaga T. Intraoperative infrared brain surface blood flow monitoring during superficial temporal artery-middle cerebral artery anastomosis in patients with childhood moyamoya disease. *Childs Nerv Syst* 2008;24:1299-305.
6. Naydenov E, Minkin K, Penkov M, Nachev S, Stummer W. Infrared thermography in surgery of newly diagnosed glioblastoma multiforme: A technical case report. *Case Rep Oncol* 2017;10:350-5.
7. Neves EB, Vilaça-Alves J, Rosa C, Reis VM. Thermography in neurologic practice. *Open Neurol J* 2015;9:24-7.
8. Raabe A, Nakaji P, Beck J, Kim LJ, Hsu FP, Kamerman JD, et al. Prospective evaluation of surgical microscope-integrated intraoperative near-infrared indocyanine green videoangiography during aneurysm surgery. *J Neurosurg* 2005;103:982-9.
9. Salles MS, da Silva SC, Salles FA, Roma LC Jr., El Faro L, Bustos Mac Lean PA, et al. Mapping the body surface temperature of cattle by infrared thermography. *J Therm Biol* 2016;62:63-9.
10. Watson JC, Gorbach AM, Pluta RM, Rak R, Heiss JD, Oldfield EH, et al. Real-time detection of vascular occlusion and reperfusion of the brain during surgery by using infrared imaging. *J Neurosurg* 2002;96:918-23.