Considerations in the Applications of Various Cooling Methods During Breast Thermography Stress Studies

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The concept of stress thermography in the area of breast cancer detection was introduced as a method to visualize the dynamic temperature response of the breasts to external cooling. Cooling of the breasts by either direct or indirect methods serves to lower their overall temperature such that a region of potentially pathological hyperthermia may become more apparent. Additionally, measurement of relative temperature changes and rates of cooling and re-warming could be taken to provide data which may be correlated with any suspected pathology. This paper seeks to compare and contrast the commonly used stressors with respect to the mechanism of action and potentially confounding variables introduced by each procedure.

Various methods of cooling have been utilized in stress thermography. Most commonly fast moving air streams directed at the breasts and hand or foot immersion in ice water were the methods of choice. Lesser used methods include alcohol or ether sprayed on the breasts or the dorsum of the hands, and application of ice directly on the mid thoracic region of the spine. When considering the use of a particular method of cooling, it is important to understand the mechanism by which the effect is produced as well as potential sources of error introduced by the procedure.

Physiological Mechanisms of Stress

Although most thermographers speak in terms of only one mechanism, generally speaking, the mechanisms of physiological stress fall into two categories. The first and most commonly spoken mechanism is a neurovascular challenge activated through the sympathetic division of the autonomic nervous system and is based upon the physiological characteristics of cancer induced neoangiogenesis. Since blood vessels produced by cancerous tissue are void of normal neural regulation, it has been reasoned that they would fail to constrict in response to a sympathetic stimulus. The difference in the blood flow through these vascular structures before and after sympathetic stress would translate into relative degrees of hyperthermia when visualized on a thermogram.(1)

The second category is that of a thermoconductive challenge in which a coolant is applied directly to the breasts. The initial rapid cooling of the entire surface of the breast produced by the stimulus causes the temperature of cooler regions to fall to a greater extent than the warmer regions. This produces a broader temperature range exhibited by the breasts allowing more subtle regions of hyperthermia to be visualized. In addition, the larger the thermal gradient between the superficial and deeper portions of the breasts increases heat transfer toward the surface. The regions of the breast which are more thermally active will re-warm the previously cooled surface faster than those which are less active.

Gauthier mentioned that a particular mechanism might be better suited to challenge certain thermal phenomenon as opposed to others(2). In one study he attempted to utilize both mechanisms for different purposes in his evaluation of stress thermography. In this paper, he stated that he preferred a local thermoconductive challenge (applied through the use of a hair dryer set on "cool") to delineate a diffuse hot spot whereas a neurovascular challenge (applied through hand immersion in ice water) appeared to provide more information regarding vascular hyperthermia.

This idea of utilizing different challenges for different thermal findings was most likely due to the previously held belief that a "hot spot" was caused by conduction of tumor heat to the surface of the skin rather than a function of neoangiogenesis(3). Currently, this belief is considered erroneous. Love, postulates through a series of mathematical equations that the internal temperature of a region can only rise slightly and sustain itself for a short period of time before the heat is transferred to an active blood supply and eventually dissipated. He then concluded that any heat produced by a tumor will have been dissipated by the blood supply long before it would have been conducted through the tissues directly to the skin(4). DeLarve et al observed in transplanted tumors, increased vascularization of the middle zone and periphery of the tumor(5). This information suggests that a local “hot spot” correlating with the location of a growing tumor could still be produced through an angiogenic mechanism. If this is the case, and the mechanism responsible for producing the thermal image is indeed neoangiogenesis, the need for a separate challenge to differentiate conducted heat would be unnecessary. A neurovascular challenge would be the stress of choice.

Methods of Stress Thermography

Ice water immersion is purely a neurovascular stimulus(1). Whether the hands or feet are immersed, after 45 seconds the intensity of the stimulus causes a global sympathetic reaction which lasts approximately 15 minutes. Measurements may be taken pre and post as well as during the cooling and the re-warming phase.

The use of cool or fast moving air streams (usually being produced by fans) has been used as both a thermoconductive and a neurovascular challenge throughout the literature. The air stream is directed at the breasts for a period of time and measurements can be taken pre and post as well as measuring the rate of re-warming. A small controversy exists between thermographers as to the exact mechanism of its effect. Clearly, an air stream blown directly at the breasts fits the classification of a thermoconductive challenge, however some thermographers will insist it is also sympathetic in nature.

Gauthier specifically identified fans as a local thermoconductive challenge whereas he chose to use hand immersion in ice water to challenge the vasculature(2). Hobbins, in a personal communication, clarified the reasoning behind this. He stated that although fans are potentially capable of producing a sympathetic reaction, they do not cause one to occur consistently. The response may be patient dependent rather than universal. The use of cool air streams also introduces several other potential problems of which the clinical thermographer must be aware. The area of the breasts most affected by an air stream will be that which is perpendicular to the stream. The speed and distance from the fans to the breasts must be uniform during the examination as well as consistent with prior examinations when performed for a follow-up. Additionally, the angle of the air stream relative to similar regions of each breast must be consistent as well. Care must be taken to insure the direction of the air flow is identical for each region of each breast. Asymmetries in the size, shape, and contour of the breasts may make this impossible to achieve or difficult at best. Failure to control the relationship between the breasts and the air stream in each of the above mentioned cases can result in the production of thermal artifacts which could potentially corrupt the thermal data. For these reasons, Hobbins believes that most thermographers moved away from fans.

Alcohol/ether spray has also been applied directly to the breast for the purpose of stress thermography although not as commonly as other methodology. As with fans, there is a small dispute as to whether it is capable of producing a consistent neurovascular response however it is generally considered to be thermoconductive in nature. In this test, the relatively fast evaporation rates of alcohol and ether causes rapid cooling of the surface of the breast creating a thermal gradient which draws heat from deeper structures and broadens the temperature range. As with fans, a pre and post measurement can be taken and the rate of re-warming can also be measured. The greatest difficulty in the application of this challenge is controlling the uniform and even distribution of coolant to both breasts. Even with the use of fine mist aerosol propellants, examiners encountered difficulties in achieving even and uniform coverage during the examination let alone reproducing coverage for follow-up studies(6). As with fans, uneven coverage can produce thermal artifacts which can potentially corrupt the thermal data. It would also seem that excessive quantity of coolant could potentially obliterate a more subtle thermal finding resulting in a false negative finding.

Conclusion

The appeal of indirect methods of breast cooling through neurovascular mechanisms is clear. Concerns over thermal artifacts are eliminated since no contact with the breasts is made. Since the vasoconstrictive response to a sympathetic stimulus is an all or none reaction, precise reproduction of the stress (i.e., water temperature) is not necessary as long as it is still cold enough to create a sympathetic response (approx. 5-10 deg. C). In addition, since the thermal response in a sympathetic challenge is purely neurovascular in nature, the test more directly evaluates thermal signs of possible neoangiogenesis. Direct thermoconductive cooling does, however, have the potential to accentuate the thermal contrast more so than indirect neurovascular. This is because indirect neurovascular cooling will be limited by the maximum degree of vasoconstriction achieved in the arterial supply whereas direct thermoconductive cooling is limited only by the level of thermal gradient produced between the environment and the breasts as well as the time of the application.

Still, direct thermoconductive cooling does have the potential to become excessive and could mask more subtle thermal signals in the process. With today's modern technology, the software of infrared cameras can be used to manipulate the thermal range exponentially allowing for enhancement of thermal contrast without actually altering the patients temperature. Thus, we can still achieve a comparable level of contrast to that of direct cooling artificially without introducing the variables associated with such methods.

Summary Points

- Stress Thermography has been used to enhance thermal contrast allowing more subtle regions of hyperthermia to become more apparent (thermoconductive challenge). However, the use of direct stress to the breast (i.e.. fans, spray, etc.) introduces numerous variables which may corrupt the integrity of the thermal data. This application can also be performed with most modern digital infrared imaging software when a subtle finding needs to be enhanced.

- More importantly, Stress Thermography has been used to aid in differentiating hyperthermia due to neoangiogenic blood vessel activity by activating the sympathetic nervous system (neurovascular challenge). This can be done by both indirect and direct stressors, however, indirect stress (at the magnitude of ice water submersion) applied to the hands or feet completely eliminates the confounding variables introduced by direct methods.

- It is critical when performing a neurovascular challenge that a stressor sufficient enough to elicit a sympathetic response is utilized. Stress at the magnitudel of ice water immersion seem to be best suited for this application

We hope that this information has been helpful. If you have any further questions, please feel free to contact us at info@iact-org.org.

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