

The feasibility of infra-red skin temperature monitoring in the prevention of skin burn and nerve injury during HIFU ablation of fibroids and adenomyoma

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Abstract

High Intensity Focused Ultrasound ablation therapy for fibroids and adenomyoma has been increasingly applied in Gynecology. It is now considered a safe surgery with effectiveness compatible to open or laparoscopic myomectomy. However, to further minimize its potential risks of skin burn to the buttocks and nerve injury, this paper studied the skin temperature changes as monitored by infrared thermography in an attempt to identify the risks during HIFU treatment. Although the infrared imaging technology is safe and feasible to monitor the skin temperature changes during HIFU ablation, there isn't enough conclusive evidence to prove it can be used to avoid skin burn at the buttock or nerve injury.

Keywords: HIFU; fibroids; adenomyosis; Infrared monitoring; Skin burn; Nerve injury

Introduction

High Intensity Focused Ultrasound ablation therapy for fibroids and adenomyoma had been increasingly applied in Gynecology^{1,2}. Prior to the understanding of the risks of HIFU ablation therapy in the past, heat induced complications like skin burn to the abdomen (direct burn), the buttocks (indirect burn), and pelvic nerve injuries occurred. In two retrospective studies of 27,053 patients and 9,988 patients, skin burn was reported in less than 1% of patients (26/17,402) with uterine fibroids or adenomyosis after USgHIFU treatment^{3,4}. These skin burns were first and second degree skin burn especially in patients receiving ablation treatment under general anesthesia or heavy analgesic and sedation. After gaining increasing experience to avoid these complications, various approaches and treatment protocols have been adopted during the HIFU ablation treatment and had successfully reduced skin burn complications⁵. However, despite the awareness and improved treatment protocols, superficial buttock skin scald and short term nerve injury still occurs⁶, thus requiring a more sensitive and objective measure to reduce this complication.

Infrared thermography is around since the 1950s. This safe, noninvasive and nonradiation technology allows thermo-imaging to be useful in luxury cars, see through the smoke by firefighters and in medicine, it becomes a potential screening tool for breast cancer. However thermography was found far less sensitive than mammography at picking up cancer, thus the interest in the use of thermography in breast cancer detection had waned. In this study, the authors use the infrared thermography technology to monitor the skin temperature and demonstrate that it can sensitively reflect the skin temperature changes during HIFU ablation therapy. It is anticipated that it may be able to prevent skin burn and alert the doctor the possibility of nerve injury, reducing the potential heat related complications.

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1. Material and methods

During HIFU ablation treatment with a JC-200 model from Chongqing Medical Technology Co. Ltd, patient was treated lying prone with the ultrasound transducers sending focused ultrasound to target tumours in the pelvis (**Figure 1**). The targeted tumours, either fibroids or adenomyoma would be ablated at a temperature of 90-100 °C. Heat would radiate from the tumour to the neighboring tissues like nerves, large bowels and the skin of buttocks. A commercial infrared camera, model FLIR C3, manufactured by FLIR Systems, Inc., was used in this study. It collects images from the back and buttocks of patients receiving HIFU ablation treatments, and is able to capture temperature changes using infrared imaging technology. The monitoring camera was positioned on a metal frame at a height of 1 to 1.5 feet from the patient's body as shown in **Figure 2**. A nurse sat next to the patient and recorded all temperature changes and patient's complaints if any during HIFU treatment. If necessary, water spraying onto the buttock skin or alcohol swabbing are methods used to lower the skin temperature of the affected buttock. The computer linked up with the camera can display temperature patterns as a "heat" map as shown in **Figure 3**. In this study, up to 12 patients were monitored by infrared camera to measure skin temperature changes at the back and buttocks. For HIFU ablation of fibroids or adenomyoma, an ablation rate of 1sec ON /3sec OFF at a high power of 400 Watts was often used. The whole treatment process would take about 1.5 to 2.5 hours depending of the number, sizes and positions of fibroids or adenomyosis. The total HIFU ablation exposure time ranging from 500 seconds to 1500 seconds had been used. The temperature changes as detected by the camera were recorded, mapped and measured at different spots at the back and the buttocks.

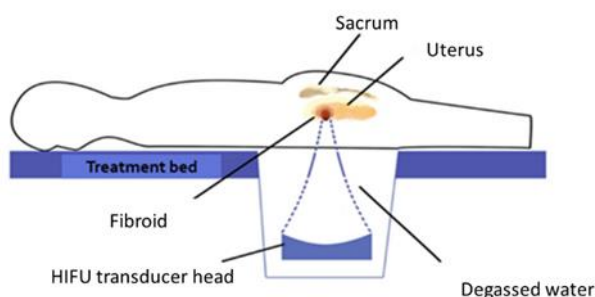


Figure 1 The position of patient receiving HIFU ablation of uterine fibroid

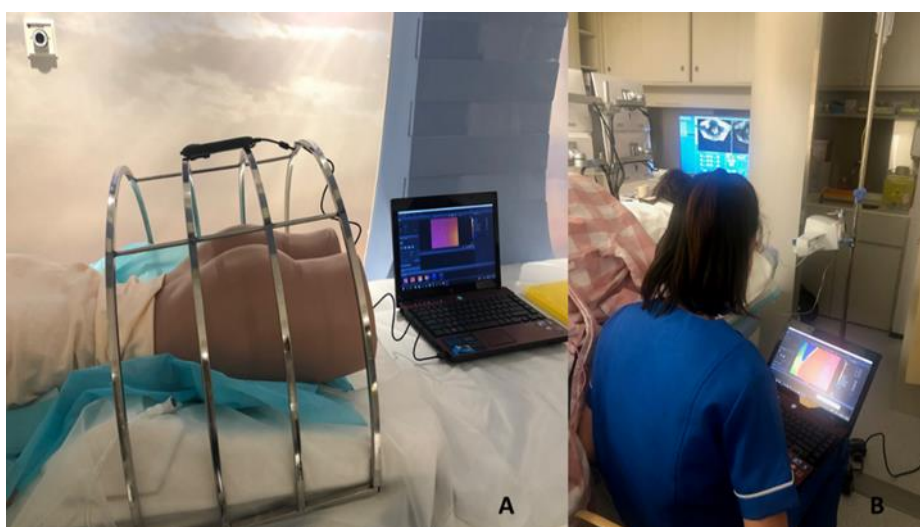


Figure 2 Set up of an infrared monitoring system during HIFU ablation operation.

As thermography can measure the heat that is given off at target areas in the pelvis and diffuses through intervening soft tissues to the skin at the buttocks, it can then be compared to another non-ablated area at the same time to reflect the temperature map during HIFU ablation.

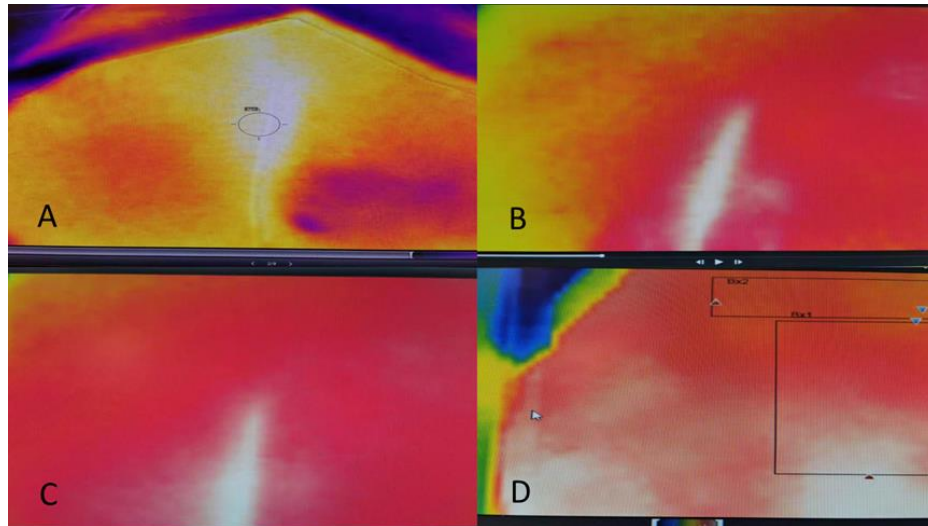


Figure 3 Skin temperature “map” as recorded; (A) at the beginning of treatment and; (B) during HIFU ablation of adenomyosis, the colour changes - in red was shown on the left buttock; (C) during HIFU ablation of fibroid, the colour changes in red on both buttocks; (D) A higher temperature – white colour, was recorded at the right buttock.

2. Results

Figure 4 showed the temperature changes in a patient with a large uterine fibroid of 10 cm, positioned within the whole pelvis. At the start of treatment, the midline groove of the buttocks showed a higher (white colour) temperature of 35 degrees centigrade (°C). It probably reflected the heat transmission was greater at the thinner muscle layers in the buttock groove compared to the thick gluteal muscles underneath the buttock skin. Before the HIFU ablation, the skin colour of the left buttock and the hip were shown in A. After the fibroid was ablated with up to 300 second ablation energy at 400 Watt, the skin colour changed to a temperature of 34-34.5 °C over the whole buttocks. There was an incidence when the patient complained of pain, the skin temperature was shown to rise to 35.3 °C (white colour). When the HIFU ablation stopped due to the pain, the temperature returned to normal from 35.3 to 34.5 to 33.5 °C.

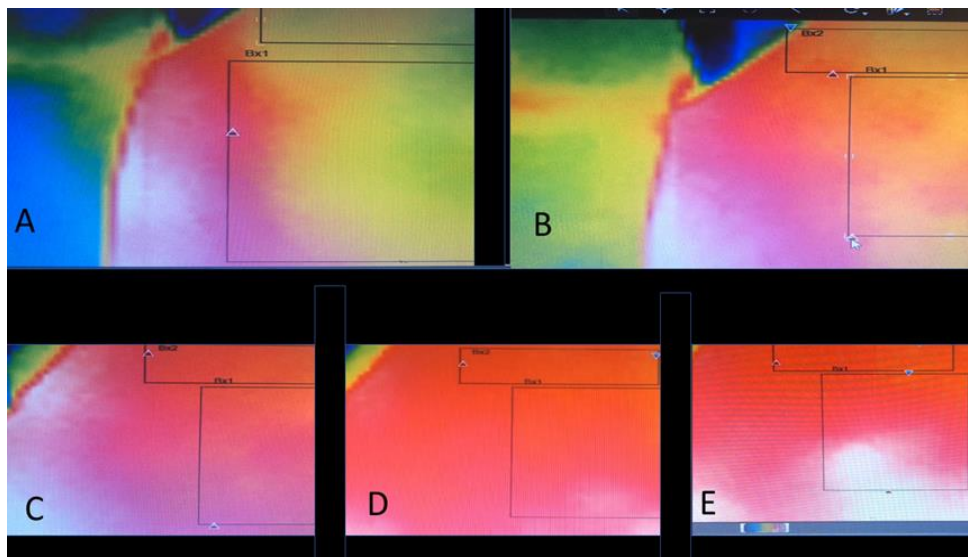


Figure 4 The temperature pattern changed during the HIFU treatment of a large uterine fibroid of 10 cm. (A) before HIFU ablation, the temperature was 33.2 °C; (B) at the beginning of HIFU ablation, areas of slightly raised temperature appeared 34 °C; (C, D) during HIFU ablation after ½, and 1 hour, the temperature rose to 34 -34.5 °C; (E) a peak of high temperature (35.3 °C) prior to pain experienced by a patient during treatment

From our observations, the temperature pattern of the buttock skin during HIFU ablation of adenomyosis appeared to differ from that of HIFU treatment of a large fibroid. Figure 5 showed the temperature changes in a patient with a large uterine adenomyoma of 8 cm, positioned over the pelvis's right side. Before HIFU treatment, the skin temperature was 33.2-33.5 °C. The temperature changes occurred at the right side of the buttock where the HIFU energy had targeted. When HIFU continued to ablate the adenomyosis, the skin temperature rose to 34 °C, rising to a high temperature of 34.5 °C over the right buttock. The patient did not complain of any pain at the buttock or any radiating nerve pain throughout the HIFU ablation treatment.

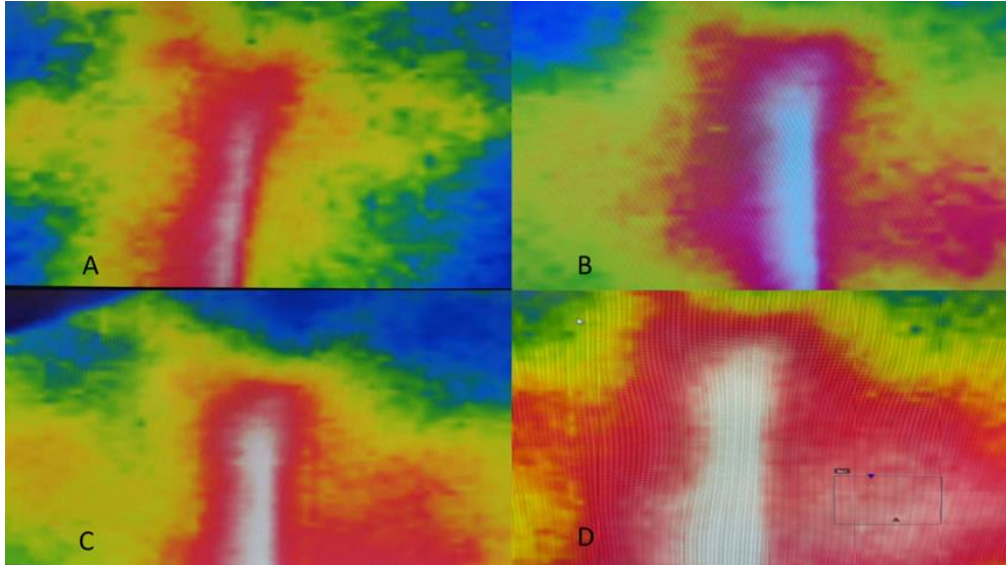


Figure 5 The temperature pattern during the treatment of uterine adenomyosis. (A) before HIFU ablation, the temperature was 33.2-33.5 °C; (B) at the beginning of HIFU ablation, small area of slightly raised temperature appeared 34 °C; (C, D) during HIFU ablation after ½, and 1 hour, the temperature rose to 34 to 34.5 °C.

Various measures had been recommended to lower the buttock skin temperature as monitored by the infrared camera system. The gradual cooling of the temperature by stopping HIFU ablation, by spraying the buttock with water, and the swabbing with alcohol had all produced a lower skin temperature recorded by the infrared camera, with the quickest changes associated with alcohol cooling.

3. Discussion

As skin burn over the buttocks had been reported in patients receiving HIFU treatment, various measures to prevent it have been recommended. They include 1) HIFU ablation is being done with patients being awakening and arousal under monitored anesthesia care (MAC); 2) open exposure of HIFU affected skin area, e.g., the buttocks, 3) frequent palpation of the buttocks to monitor the skin temperature, and 4) cooling of the buttock skin temperature regularly or as required when patients complain of heat. HIFU treatment protocols have also been improved, i.e., to ablate at a distance from the edge of the tumour and lower the ablation power to structure close to the nerves, stopping the ablation as soon as the patient complained of pain. All these successfully minimize the incidence of the indirect skin burn over the buttocks.

In this paper, we have illustrated skin temperature changes over the buttocks during HIFU treatment can be easily monitored and detected by infrared monitoring technology. In this observational study, we described the use of an infrared camera and a portable computer to detect, analyze, and produce a video recording of any temperature changes during HIFU treatment of uterine fibroids and adenomyosis. Wherever heat radiates, the image screening would show it in color shades with the degree of temperature recorded on any marked target area.

From our preliminary study of 12 patients, the infrared monitoring of HIFU ablation of uterine fibroids differed from that of uterine adenomyosis. To explain the differences, the ablation energy to uterine fibroid could probably have accumulated within the pseudocapsule of the fibroid. Thus the heat radiating to the skin would appear uniformly raised as recorded. Until the buttock skin temperature reached a critical higher level, it was 35.3 °C in a patient (in Figure 3E) who complained of pain at the buttock.

On the other hand, the skin temperature pattern showed HIFU treatment of adenomyosis induced skin temperature changes at the targeted area. There was no uniform skin temperature changes, as seen in the uterine fibroid. In our treatment of adenomyosis, the energy of HIFU treatment was also lower than that of fibroids, especially those we tried to conserve and protect the endometrial lining. Besides, we would not aim as high as an ablation rate of a uterine fibroid. Therefore the skin temperature changes may not be so marked.

We also noted that the relationship between high skin temperature and pain varied slightly in our group of patients. It might be related to the varying analgesic effect of MAC, the patient's tolerance to pain, the location of fibroids, the ablation frequency, energy and power of HIFU used during HIFU ablation treatment.

When the skin temperature at the monitored area was found to be higher than the surrounding area, various measures were taken, such as spraying the area with water, swabbing it with alcohol or stopping the treatment and moved it to other target area. The skin temperature changes vary due to these physical interventions were also recorded. In this study, all known preventive measures used as well as the present HIFU protocols are all useful to prevent skin burn at the buttock. Therefore after our study, we no longer adopt other measures to monitor the skin temperature of the buttocks such as palpating the buttock at the time of treatment.

However, the limitation of this study can be summarized as 1) it is only an observational study with a small number of patients; 2) no patients suffer from skin burn or scald which are uncommon today due to the well designed and safe treatment protocols; 3) the skin temperature only reflects the transmitted heat from the target tissue without measuring the actual heat temperature in the target organ; 4) it does not really assess the probability of nerve injury; 5) one last problem is that the infrared monitoring has trouble distinguishing the causes of increased heat within the pelvis. 6) Lastly the lack of an expensive but sensitive equipment is a disadvantage of this study. A commercialized equipment is being used in this study which needs careful interpretation and modification of the recording system to allow a better and accurate reflection of the heat developed inside the body.

Therefore, this study confirmed the safety of the present HIFU treatment protocols and effective preventive measures used today. It also suggested infrared monitoring of buttock skin temperature could be useful to record the skin temperature changes and prevent excessively higher temperature during HIFU ablation treatment, thus lower the risk of skin burn and provide evidence for medico-legal documentation if it did not ever happen. A defined high temperature prior to the patient's complaints of radiating nerve pain can only be obtained by a larger study group of patients requiring a multicenter clinical trial. Hopefully, it helps to alert doctors to the risks of nerve injury during HIFU treatment to fibroids and adenomyosis.

4. Conclusion

Infrared thermography can show areas of temperature changes as shown in this study, but there are some limitations in the study to make its preventative role in preventing skin burn or alerting doctors of potential nerve injury questionable. More clinical data should be collected to correlate the skin temperature changes prior to the complaint of nerve radiating pain and injury if any. Therefore more studies are needed to support its use in routine HIFU ablation. Yet its findings in this observation paper would hopefully encourage more studies to be done.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The author has no conflict of interest.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study

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