OPEN

PRS GLOBAL OPEN

CASE REPORT

Burns

High-frequency Power Doppler Ultrasonography in Predicting Burn Depth: A Preliminary Case Report

Yusaku Saijo, MD
Satoshi Akaishi, MD, PhD
Hiroaki Kuwahara, MD, PhD

Summary: Accurate burn depth assessment is essential to decide an appropriate surgical procedure. However, most cases of burn depth are diagnosed with subjective judgment by an experienced plastic surgeon. There is a need for a simple, noninvasive, and accurate diagnostic method. Here, the authors present two burn cases in which burn depth was predicted using high-frequency power Doppler ultrasonography. In case 1, the patient showed partial deep burn area prediagnosed by clinical inspection in dorsal area. However, pulsatile microcirculation was detected in the deep dermal layer using high-frequency power Doppler ultrasonography, and we rediagnosed it as deep dermal burn. Tangential excision was performed to debride necrotic tissue, preventing excessive removal of viable dermal tissue. In case 2, the patient showed anterior chest burn covered eschar. Pulsatile microcirculation was detected in the dermis using high-frequency power Doppler ultrasonography. The authors diagnosed the area as superficial dermal burn and opted for conservative treatment. Dermal microvascular damage is a more sensitive indicator of tissue injury. Hence, the burn depth can be assessed using dermal microcirculation. To the best of the authors' knowledge, there are no reports on the evaluation of blood flow in burn wounds using high-frequency power Doppler ultrasonography. In this case report, the authors introduce the possibility of using high-frequency ultrasonography to assess burn depth. *(Plast Reconstr Surg Glob Open 2024; 12:e5949; doi: 10.1097/GOX.0000000000005949; Published online 2 July 2024.)*

Accurate burn depth assessment is essential for early excision and skin grafting of deep dermal burns (DDBs) and deep burns (DBs), and tangential excision is often performed for DDB.[1,2] Tangential excision is performed in layers until pinpoint arteriolar bleeding is detected in viable tissue.[3] However, excessive viable tissue debridement might occur due to the difficulty in assessing the thickness of necrotic tissue before surgery.[3] Preoperative estimation of burn depth may lead to effective debridement. There are no reports on the evaluation of blood flow in burn wounds using high-frequency power Doppler ultrasonography. The authors introduce the possibility of using high-frequency ultrasonography to assess burn depth.

From the Department of Plastic Surgery, Nippon Medical School, Musashikosugi Hospital, Kawasaki, Japan.

Received for publication December 1, 2023; accepted May 1, 2024.

DOI: 10.1097/GOX.0000000000005949

CASES

In case 1, a 71-year-old man was injured after a fire burned his right back. Based on the physicians' clinical diagnosis, the wound was diagnosed as DDB to DB. Six days after the injury, the patient was taken to the operating room for debridement and skin grafting. Before the surgery, four representative areas were selected on the dorsal burn, which were diagnosed clinically as normal skin, superficial dermal burn (SDB), DDB, and DB (Fig. 1). These four areas were assessed using an LOGIQ e ultrasound device (GE Healthcare, Chicago, Ill.), using the L10-22-RS high-frequency linear array. The device was placed in contact with the skin in various regions and directions, with a depth of field set to 10mm. The burn wounds were observed under B-mode and power Doppler imaging. The pulsatile microcirculation in the dermis in the four areas was detected using power Doppler imaging (Fig. 2). The layer showing blood flow was determined to be viable tissue, and the thickness of the layer without blood flow in

Disclosure statements are at the end of this article, following the correspondence information.

Related Digital Media are available in the full-text version of the article on www.PRSGlobalOpen.com.

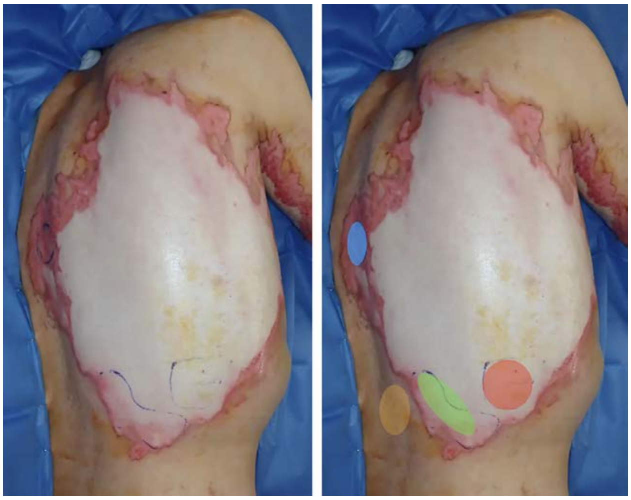

Fig. 1. A photograph of preoperation. Six days after the injury, tangential excision and split-thickness skin grafting were performed. The dorsal burn was divided into the following four areas based on the physician's clinical diagnosis: normal skin, superficial dermal burn, deep dermal burns, and deep burns.

the SDB-suspected, DDB-suspected, and DB-suspected wounds was approximately 2, 2, and 2.5 mm, respectively. The authors measured the burn thickness from the wound surface to the top of the microcirculation in the burn area, and tangential excision was performed. Good hemorrhage from the dermal layer was observed in the burned wound. (**See figure, Supplemental Digital Content 1,** which shows a photograph of initial finding. A 20-year-old man was injured after a flame burned his chest. His upper chest was covered with burn eschar. **http://links.lww.com/PRSGO/D334.**)

The wound was grafted with a split-thickness skin graft. Re-epithelialization occurred 16 days postoperatively. Six months after surgery, the dermal component remained, resulting in an epithelialization with good extensibility and quality. (**See figure, Supplemental Digital Content 2**, which displays a photograph of the patient 6 months after the operation. A partial hypertrophic scar is observed. However, good-quality epithelialization with extensibility was obtained due to residual dermal components. **http://links.lww.com/PRSGO/D335.**) In case 2, a 20-year-old man was injured after a flame burned his chest, which was covered with burn eschar (Fig. 3). The burn areas were assessed with high-frequency ultrasonography over chest burn eschar. The pulsatile microcirculation in the dermis was detected using power Doppler imaging (Fig. 4). The area was diagnosed as SDB and opted for conservative treatment. The partial wound could not achieve complete re-epithelization, so the patient underwent split-thickness skin graft 50 days after the injury. The patients provided their written informed consent to participate in this study. Written informed consent was obtained from the individuals for the publication of any potentially identifiable images or data included in this article.

DISCUSSION

Most cases of burn depth are diagnosed with subjectively by experienced plastic surgeons.[4] It was difficult to accurately predict burn depth over white necrotic tissue and eschar using subjective judgement. There is a need for a simple, noninvasive, and accurate diagnostic method.

The burn depth can be assessed using dermal microcirculation because dermal microvascular damage is a more sensitive indicator of tissue damage.[5] Skin microcirculation is composed of arterioles with diameters of 10–100 µm. Additionally, Berson et al[6] reported that high frequencies

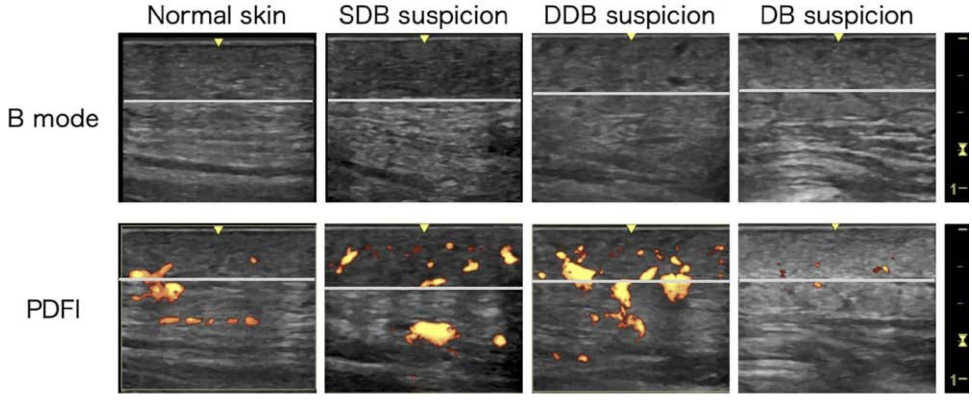

Fig. 2. A photograph of preoperative imaging findings. The number 1 in the scale represents 10 mm. High-frequency power Doppler ultrasonography (a GE Healthcare LOGIQ e ultrasound device with a high-frequency L10-22-RS linear array probe) detected dermal pulsatile vessels and tissue thickness without circulation in all four areas. The gray line in the image represents the border between dermis and subcutaneous fat. The authors measured the burn thickness from the wound surface to the top of the microcirculation. The thickness of the layer without blood flow in the SDB-suspected, DDB-suspected, and DB-suspected wounds was approximately 2, 2, and 2.5 mm, respectively. The area diagnosed with deep burns had a thicker tissue layer than in the superficial dermal burn and deep dermal burn areas, without circulation. PDFI, power Doppler flow imaging.

Fig. 3. A photograph of the operation. Necrotic tissue was removed using tangential excision. Good hemorrhage from the dermal layer was observed in the wound.

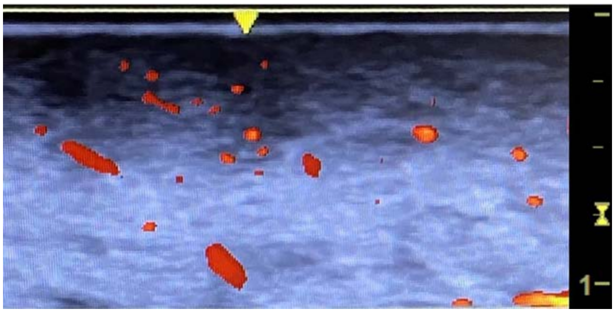

Fig. 4. A photograph of the initial examination finding. The device was attached over eschar. The number 1 in the scale represents 10 mm. High-frequency power Doppler ultrasonography detected dermal pulsatile vessels. This area was diagnosed as a superficial dermal burn.

are suitable to detect and measure blood flow in microcirculation, and velocities of less than 0.5 mm/s were measured in 100–300 μm diameter vessels using 20-MHz ultrasonography. The exact dimensions of the blood vessels in the dermis vary with skin site, body site, and age.[7] Blood vessels at burn site are dilated.[8] Furthermore, the detailed diameter of blood vessels detected by this method is unknown.

In case 1, blood vessels in normal skin could not be visualized but could be visualized by high-frequency ultrasonography when blood vessels were dilated by burn injury. Additionally, excessive viable tissue resection with fascial excision could be avoided because microcirculation was detected in the area where the authors suspected DB, and the area was rediagnosed as DDB. Therefore, this method has potential to discriminate between DDB and DB.

In case 2, the chest area was diagnosed as SDB over a region of eschar. However, the burn wound could not achieve complete re-epithelization with conservative treatment within three weeks. Therefore, distinguishing between SDB and DDB remains challenging using this method.

Clinical burn depth assessments by the subjective judgment has only 60%–70% accuracy.[9] Histological analysis is considered the gold standard of burn assessment. However, there are some disadvantages, including an infection risk, the requirement for an experienced pathologist, limited diagnosable areas, potential delays caused by waiting for pathological results before performing tangential excisions.[5] The second most accurate method for determining burn depth is laser Doppler imaging, which has 91% sensitivity and 96% specificity. However, the laser Doppler imaging apparatus is expensive, not widely available in all institutes, time-consuming for evaluations, and unable to assess dermal necrotic tissue thickness.[10] This method is suitable for bedside evaluation and can easily evaluate the depth of burned wounds noninvasively, quickly, and over time, in comparison to biopsy and laser Doppler imaging.

This method can predict the presence of intradermal blood flow, but it is difficult to conclude that there is no blood flow if the sonographic findings are negative. This is because there may be microvessels that are not detected by the device. Additionally, distinguishing between SDB and DDB remains challenging. Because distinguishing between SDB and DDB is not dependent on burn depth. In the future, this method should be scrutinized by evaluating the sonographic findings and pathology specimens. This report included only two cases and did not involve pathological assessment of the burn tissue; thus, further research is required.

CONCLUSIONS

Dermal microcirculation was detected over necrotic tissue and eschar using high-frequency power Doppler ultrasonography. Validation of this method could yield a simpler burn depth diagnostic method in the future.

Yusaku Saijo, MD
Department of Plastic Surgery
Nippon Medical School, Musashikosugi Hospital
1-383, Nakahara district, Kawasaki, Kanagawa, Japan
E-mail: y-saijo@nms.ac.jp

DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

REFERENCES

1. Hoeksema H, Van de Sijpe K, Tondu T, et al. Accuracy of early burn depth assessment by laser Doppler imaging on different days post burn. *Burns.* 2009;35:36–45.
2. Janzekovic Z. A new concept in the early excision and immediate grafting of burns. *J Trauma.* 1970;10:1103–1108.
3. Choi M, Panthaki ZJ. Tangential excision of burn wounds. *J Craniofac Surg.* 2008;19:1056–1060.
4. Li H, Bu Q, Shi X, et al. Non-invasive medical imaging technology for the diagnosis of burn depth. *Int Wound J.* 2024;21:e14681.
5. Jiang X, Li F, Chi Y, et al. Application of contrast-enhanced ultrasound in the diagnosis of burn depth. *Ann Transl Med.* 2021;9:1315.
6. Berson M, Grégoire JM, Gens F, et al. High frequency (20 MHz) ultrasonic devices: advantages and applications. *Eur J Ultrasound.* 1999;10:53–63.

7. Deegan AJ, Wang RK. Microvascular imaging of the skin. *Phys Med Biol*. 2019;64:07TR01–07TR01.
8. Ripszky Totan A, Greabu M, Stanescu-Spinu II, et al. The Yin and Yang dualistic features of autophagy in thermal burn wound healing. *Int J Immunopathol Pharmacol*. 2022;36:3946320221125090.
9. Mirdell R, Farnebo S, Sjöberg F, et al. Interobserver reliability of laser speckle contrast imaging in the assessment of burns. *Burns*. 2019;45:1325–1335.
10. Wang R, Zhao J, Zhang Z, et al. Diagnostic accuracy of laser doppler imaging for the assessment of burn depth: a meta-analysis and systematic review. *J Burn Care Res*. 2020;41:619–625.