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Fracture Blisters

Carl P. Giordano, MD; Kenneth J. Koval, MD**; Joseph D. Zuckerman, MD†; and Panna Desai, MD‡*

A clinical and histological study was performed on fracture blisters found in association with 13 surgically treated ankle fractures. The timing of surgery was dependent upon soft tissue swelling; the status of the blister did not affect this aspect of the decision making process. The average time from injury to surgery was 2.1 days (range, 1-3 days). At the time of surgery all blisters were intact. Skin biopsies were obtained from the edge of the incision in proximity to the blister, and from the bed of the blister when the incision was made through the blister. Clinically, 2 blister types were identified: (1) clear fluid filled, and (2) blood filled. Histologically, both blister types demonstrated a cleavage injury at the dermoepidermal junction. However, the dermis of the clear fluid filled blister retained occasional epithelial cells, while the dermis of blood filled blisters was completely devoid of epidermis. Minimal to no evidence of dermal injury was found in histologic sections from the blister beds or from the skin in close proximity to blisters. All incisions made through and around skin blisters went on to heal without evidence of infection or wound breakdown. Delayed wound healing occurred in 1 patient in whom an incision was placed through a blood filled blister. The blood filled blister appears to represent a slightly deeper injury than the clear fluid filled blister and had a higher risk of poor healing of surgical incisions.

The clinical significance of skin blisters in fracture management remains controversial. This is due in part to the lack of knowledge concerning the nature of these skin injuries. Although a large body of information exists on the biology and biomechanics of skin,[2,3,4,6,8,10,12,17,19,20] a relative paucity of scientific information exists on the etiology, significance, and optimal treatment of blisters associated with fractures. Fracture blisters have been referred to in a variety of ways including epidermal necrosis, epidermal separation, bullae, epidermolysis, and avascular necrosis of skin.[11] They have been felt to represent compromised viability of all or part of the epidermis, dermis, and subcutaneous tissue.[20] Unfortunately, there is little scientific investigation to support these concepts.

The purpose of this study was 3 fold: (1) to describe the histology of skin injury that occurs in association with fracture blisters; (2) to determine the extent of dermal viability compromised by the presence of fracture blisters; and (3) to correlate clinical out-

* From the Department of Orthopaedics, Hospital for Joint Diseases, New York, NY.

** Fracture Service, †Department of Orthopaedic Surgery, and ‡Department of Pathology, Hospital for Joint Diseases Orthopaedic Institute, New York, NY.

Reprint request to Kenneth J Koval, MD, Department of Orthopaedic Surgery, The Hospital For Joint Diseases Orthopaedic Institute, 301 E 17th St, New York, NY 10003.

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TABLE 1. Patient and Blister Characteristics

Case	Gender/ Age	Diagnosis	Lauge-Hansen/ Weber Class	No./ Location	Type	Size of Largest Blister (cm)	Incision
1	F/49	Bimalleolar	SE4/B	1 lateral	Clear	3 × 3	Around
2	M/21	Bimalleolar	SE4/C	2 lateral	Clear	3 × 4	Through
				2 medial	Blood		Around
3	M/51	Med mal fx	PA2	2 medial	Blood	2 × 2	Through
4	F/52	Fx disloc	SE4/B	3 medial	Blood	2 × 3	Around
5	M/47	Trimalleolar	SE4/B	4 lateral	Clear	3 × 3	Through
				2 medial	Clear		Around
6	F/27	Bimalleolar	SE4/B	2 lateral	Clear	1 × 1	Around
				1 medial	Clear		Around
7	F/59	Bimalleolar	SAD2/B	3 lateral	Blood	5 × 8	Through
				2 medial	Clear		Around
8	F/72	Fx disloc	SE4/B	2 lateral	Clear	3 × 3	Through
9	F/54	Bimalleolar	SE4/B	1 medial	Clear	3 × 4	Around
10	F/38	Trimalleolar	SE4/C	3 medial	Clear	1 × 2	Around
11	M/32	Trimalleolar	SE4/B	2 lateral	Blood	1.5 × 2	Around
12	F/36	Fx disloc	SE4/C	2 lateral	Clear	1 × 1	Around
13	M/44	Trimalleolar	SE4/B	3 lateral	Clear	2 × 3	Through

Med Mal Fx = Medial malleolar fracture; Fx disloc = fracture dislocation.

comes with these findings. The study group was limited to patients with fracture blisters around the ankle because of the clinical significance of fracture blisters in this area.

MATERIALS AND METHODS

From June 1988 to December 1991, 81 fractures of the ankle were treated at the authors' institution. Thirteen ankle fractures in 13 patients were complicated by the presence of overlying blisters. These 13 patients underwent open reduction and internal fixation in the presence of fracture blisters and comprise the study group.

The study group (Table 1) consisted of 5 male and 8 female patients with an average age of 44.8 years (range, 21–72 years). The Lauge-Hansen and Weber classifications were used to classify all ankle fractures.[14–16] The mechanism of injury was a fall in 10 cases and pedestrian versus motor vehicle accident in 3 cases. Eight patients were initially treated at another institution and transferred to the authors' institution after an average delay of 1.9 days (range, 1–3 days).

All 13 patients presented with blisters about the ankle. Blister location was primarily medial in 4 patients, primarily lateral in 5 patients, and both medial and lateral in 4 patients. Blister size ranged from 1 × 1 cm to 5 × 8 cm. The number of blisters ranged from 1 to 6 per patient. Eleven patients had more than 1 blister.

Preoperatively, all fractures were splinted and the extremities were elevated. The blisters were left intact and covered with a dry sterile gauze. This gauze was changed daily. The timing of surgery was dependent upon soft tissue swelling; the status of the blister did not affect this aspect of the decision making process. Normally the skin has its greatest excursion at right angles to langers lines. When langers lines were not visible, excessive soft tissue swelling was at a maximal limit, and the authors felt that difficulty might arise in skin closure. Extremities were deemed operable when langers lines were visible on the overlying skin of the injured extremity. The average time from injury to surgery was 2.1 days (range, 1 to 3 days). At the time of surgery all blisters were intact.

At the time of surgery the skin was prepped

with a Betadine soap solution and rinsed with sterile saline. The blister was unroofed and the roof skin was placed in 10% formalin. Betadine solution was then painted onto the extremity, including the base of the blister. The blister base was not scrubbed to avoid iatrogenic injury to the exposed tissue by either chemical irritation or physical abrasion. Incisions were placed in positions best suited for open reduction and internal fixation. Blisters did not alter incision placement.

Full thickness skin biopsies were taken immediately after the initial incision was made through the skin and into the subcutaneous tissue. The biopsies were taken along the edge of the incision by grasping the edge of the skin with a fine tooth forceps and incising 3–4 mm parallel to the initial incision for a length of 15 mm. This oval shaped full thickness skin biopsy placed within the surgical incision did not hamper wound closure. A 6.0 nylon suture was placed in the end of the specimen crushed by the tooth forceps to indicate specimen orientation and avoid histologic examination of this end of the specimen. Tissue specimens were then directly placed in formalin.

Biopsies were taken from 2 specific areas: the blister base and the skin around the blister. When an incision passed through a blister 2 biopsies were taken: 1 along the edge of the incision that was most centrally located within the blister, and another along the edge of the incision 1 cm outside of the blister. When an incision passed in proximity to a blister a skin biopsy was taken along the incision closest to the blister. Blisters that were not included within or adjacent to the surgical incision were not biopsied to avoid unnecessary morbidity.

Surgical incisions in 6 of the 13 cases passed through 6 blisters (2 blood and 4 clear), generating 12 full thickness skin biopsies. In 3 of these 6 cases a 2nd medial or lateral incision was made for fracture fixation. In these 3 cases this 2nd incision was in proximity to a blister, and a skin biopsy was taken along the incision closest to the blister. A total of 15 separate full thickness skin biopsies were taken from these 6 cases.

In 7 of the 13 cases no incision passed through a blister, however, 8 incisions passed around a blister and 8 biopsies were taken along the incision closest to the blister. In the 11 (8 + 3) biopsies of skin around, but not through, blisters the distance between the incision and the nearest portion of the blister averaged 10.2 mm (range, 1–29 mm). A total of 23 full thickness skin biopsies were taken from the 13 cases. Seventeen blister roofs (8 blood and 9 clear) were harvested and placed in 10% formalin. The total number of skin biopsies examined histologically was 40 (23 full thickness skin biopsies and 17 roofs). All specimens taken for histological studies were fixed, embedded in paraffin, sectioned, and stained with hematoxylin and eosin.

All ankle fractures were stabilized with plate and screw fixation. Tourniquets were not used and the incisions were closed with nylon sutures. Perioperative antibiotics were routinely administered for 48 hours after surgery.

Postoperatively, blisters were covered with Xeroform gauze in a manner similar to the care of the donor site of a split thickness skin graft. Dressings were allowed to become adherent, dry, and gradually fall off as the blister bed reepithelialized. Forty biopsy specimens were prepared for histologic evaluation in a standard manner using hematoxylin and eosin stains. Two of these were biopsy specimens of the blood filled blister bases. Four of these were biopsy specimens of clear fluid filled blister bases, and 17 of the specimens were of the skin around both blister types. There were 17 specimens of the blister roof. At least 5 histologic sections for each of the biopsy specimens were reviewed under 40×, 100×, and 400× magnification.

RESULTS

Preoperative clinical assessment identified 2 types of blisters: clear fluid filled, and blood filled (Fig 1). Eight patients had clear fluid filled blisters, 3 had blood filled blisters, and 2 had both types. Gross inspection of the unroofed clear fluid filled blister bed showed erythema, but no areas of punctate bleeding. The blood filled blisters showed either a markedly erythematous or pale white base with areas of punctate bleeding (Fig 2).

Histologically, clear fluid filled blisters showed minimal evidence of injury to the

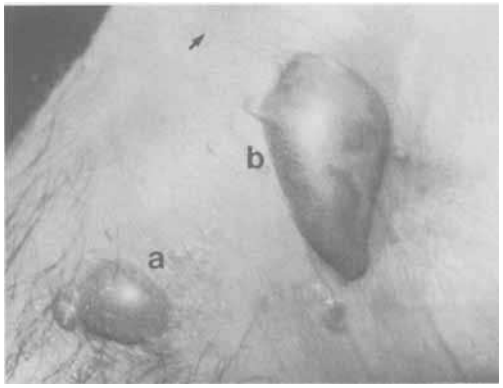

Fig 1A–B. Blister filled with transparent clear yellow fluid (A) and with opaque blood filled fluid (B). Note the creases visible on the skin (small arrow).

dermis as shown by the absence of edema, hemorrhage, vascular damage, inflammation, or cellular death (Fig 3). In some areas epidermal cells remained attached to the dermis (Fig 4). The blood filled blisters showed a similar pattern. However, the dermis was completely devoid of epidermal cells (Fig 5). The bases of both blisters retained the typical undulating pattern characteristic of normal dermis. The authors were unable to identify with the microscope any distinguishing histologic features between the patterns of blood filled blister beds that went on to heal or develop healing problems. The roofs of all the blisters were comprised entirely of epidermis, including the keratin layer (Fig 6). The biopsies of the uninvolved skin showed an intact dermoepidermal junction without significant injury to either the dermis or epidermis. However, the keratin layer in some specimens did show cleavage patterns (Fig 7).

The incisions and blister beds healed uneventfully in 12 of 13 cases. In these 12 cases the incision healed within 3 days, sealing off the deeper structures. Reepithelialization of the blister bed was considered clinically complete when 2 observers agreed that all evidence of a moist dermal layer or granulation type tissue was covered by an epithelial layer, and the blister bed was no longer sensitive to touch. Reepithelialization of the blister bed occurred several days after the dermal layer healed.

In the 1 case with a complicated course of healing, the incision was made through a blood filled blister. This patient had a supination adduction (SAD2) ankle fracture where the incision was through a 5 × 8 cm blood filled blister laterally, and a medial incision was made around a clear fluid filled blister. The medial incision healed without incident. The dermal edges of the lateral incision healed slowly and had a persistent serous drainage for 12 days. The incision did eventually heal with daily dressing changes after approximately 5 weeks. The blister bed required an extended period of time to epithelialize (26 days). There were no complications when incisions were made through clear fluid filled blisters or when incisions were made adjacent to either blister type. Based upon gross inspection, clear

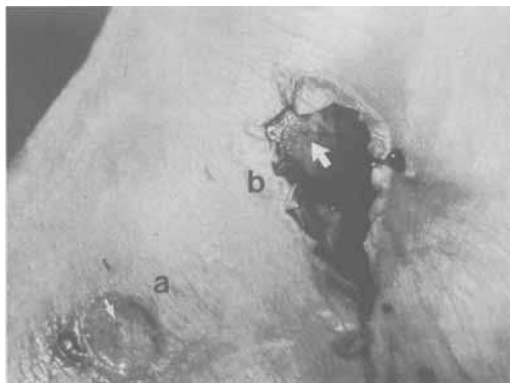

Fig 2. Clear fluid blister base after removal of the roof (A) revealing a homogeneous inflamed pinkish tissue with visible unruptured blood vessels coursing through the tissue (small arrow). Blood filled blister base after removal of the roof (B) revealing patches of pale white tissue (large arrow) as well as areas of punctate bleeding and ruptured arterioles.

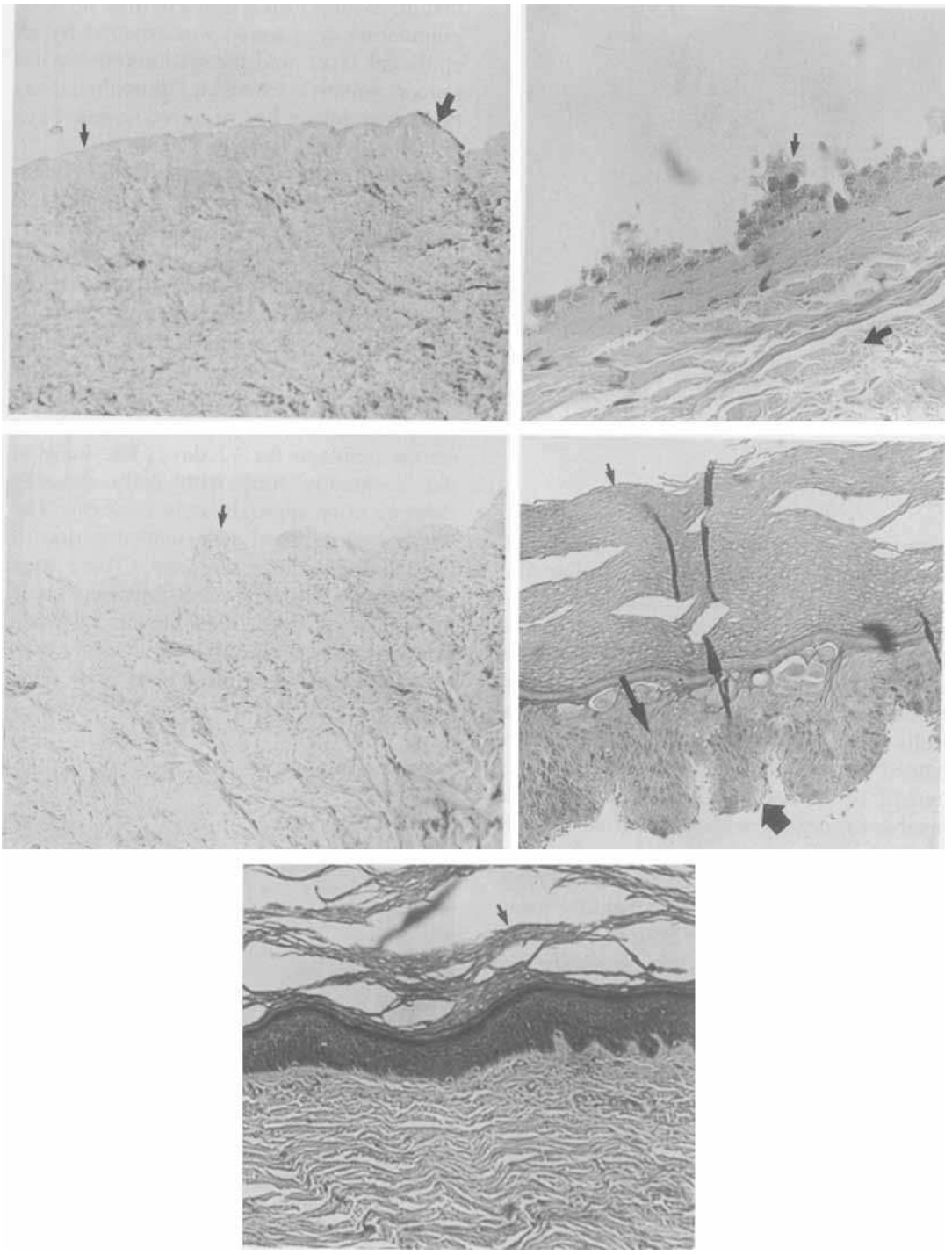

Fig 3. Top left. Biopsy of clear fluid filled blister dermis revealed no significant edema, hemorrhage, vascular damage, inflammation, or cellular death. The superficial layer of the dermis was stripped of epidermis (small arrow). Scattered areas of retained epithelial cells were present (large arrow). (Hematoxylin and eosin × 100.)

Fig 4. Top right. Clear fluid filled blister dermis with retained epithelial cells (small arrow) on the dermal layer (large arrow). (Hematoxylin and eosin × 400.)

Fig 5. Middle left. Blood filled blister dermis with no significant edema, hemorrhage, vascular damage, inflammation, or cellular death. There is no evidence of retained epithelial cells on the dermal layer (small arrow). (Hematoxylin and eosin × 100.)

Fig 6. Middle right. Blister roof showing keratin layer (small arrow) and epidermis (large arrow). Note the retention of normal undulations of the epidermis at the former dermal/epidermal layer (bold arrow). (Hematoxylin and eosin × 200.)

Fig 7. Bottom. Keratin cleavage injury (small arrows) of skin around blisters. (Hematoxylin and eosin × 100.)

fluid filled blisters reepithelialized in a mean of 12 days (range, 9–13 days); blood filled blisters reepithelialized in 16 days (range 11–19 days) excluding the case with a healing complication. Followup of all patients averaged 26.1 months (range, 18–40 months). No deep or late infections occurred.

DISCUSSION

Fracture blisters around the ankle represent problems of significant clinical importance that have been addressed only to a very limited extent in the orthopaedic literature. Correlation of the gross appearance, histology, and clinical outcomes of fracture blisters that develop in association with ankle fractures provides a much better understanding of the extent of skin injury.

The authors identified 2 types of blisters: clear fluid filled, and blood filled. Histologically, both blister types demonstrated a cleavage injury at the dermoepidermal junction. The dermis of the clear fluid filled blister showed scattered areas of retained epithelial cells that may have aided in faster reepithelialization of the blister bed and less morbidity. Blood filled blisters represented a more significant injury histologically and clinically. There were no areas of retained epithelium on the dermal biopsies of the blood filled blisters; this may have led to an increased time to reepithelialization. The authors suspect that the blood filled blisters were the result of injury to the papillary vasculature, allowing blood to escape into the blister (Fig 8). These factors may lead to greater morbidity when operating through these blisters. Minimal to no evidence of dermal injury was found in histologic sec-

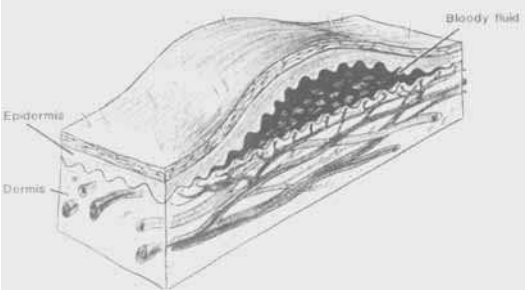

Fig 8 Drawing representing a blood filled blister showing blood separating the dermis from the epidermis.

tions from the blister beds or from the skin in close proximity to blisters; thus, dermal viability did not appear to be in jeopardy.

It appears that the mechanism of fracture blister formation is a mechanical separation of the epidermis from the dermis due to a stretch or torsional force. The biomechanical differences between these layers may make injury at this level more likely.[2,5,12] This injury creates a space which allows the potential influx of fluid resulting in blister formation. This mechanism is similar to that postulated for friction blisters,[1,3,7] although the level of injury is different. The level of skin injury in fracture blisters bears some similarity to a 2nd degree burn. Second degree burns represent epidermal and dermal injury with viable epithelial elements remaining. Donor sites from split thickness skin grafts are also similar to fracture blisters, although they represent a somewhat deeper level of involvement.

The skin around the ankle exhibits gross and histological differences from skin elsewhere, which may place this area at risk for blister formation. Grossly, there is an absence of well formed adipose or muscular layers which, when present elsewhere, usually function with the skin to share in the protection of deeper structures. Skin over the medial malleolus is usually 1.5 to 2.5 mm as opposed to 5 mm on the soles and palms.[9] Skin in this area can be as thin as 0.4 to 0.8 mm, as in collagen vascular disease.[9,13,17] Decreased skin thickness may be a predisposing factor to the development of wound complications following fractures in this area.

There is also a significant variation in the amount of pelage (hair). This may have important consequences in the reepithelialization of wounds since the hair follicle is a major source of epithelial cells.[18] Regional differences also exist for dermoepidermal composition and architecture. Histologically, the skin around the ankle differs from skin elsewhere by having extensive arborization of veins superficially in the dermis, flat epidermal papillae, and a relative sparsity of arterioles.[20] The authors do not feel that blisters represent compromised dermal viability as formation of the blister requires an intact circulation to provide the necessary fluid for blister formation.[3]

Blisters should remain intact up to the time of surgery to prevent bacterial colonization of the blister bed, which may compromise viability of the dermis. The type of blister—clear fluid versus blood filled—appears to be an important predictor of outcome. The size of the blister may be an important factor as well, however, the number of patients and blisters in this study was too small to make definitive conclusions. Work is presently ongoing in a larger clinical study to confirm the safety of operating through blood filled blisters.

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