Human Bite Infections of the Hand: Adjunct Treatment with Hyperbaric Oxygen

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Intermittent hyperbaric oxygen was prospectively studied in 16 of 43 patients with human bite wounds to the hand. Patients were hospitalized after culture, exploration, debridement, and cleansing of the wound. A portable hyperbaric unit encompassing the forearm administered 100% oxygen at 50mmHg intermittently for 90 minutes twice daily. Patients were selected to receive the hyperbaric oxygen on an availability basis. Important risk factors included joint and tendon involvement, severity of infection, delay in treatment, and osteomyelitis. Hospital stay was shortened in the severely infected hyperbaric oxygen group ($P < 0.05$).

Key words: Bite wounds, human • Hyperbaric oxygen • Hand infections

The hand contains a compact but disturbingly unprotected array of neurovascular and poorly perfused tendinous structures. Infection is a common but devastating complication of hand trauma, as a multitude of fascial planes and interconnecting sheaths permit establishment and propagation of bacterial inocula.

Human bite wounds to the hand, sustained by a bare-fisted assailant upon impact against the teeth of a victim, represent a particularly dangerous pattern. Commonly, the bursa over the metacarpal head, the extensor paratenon, and the metacarpal-phalangeal joint capsule are violated, with infection spreading to the subaponeurotic and web spaces, or laterally between the collateral and accessory ligaments.[1] The injury may appear superficial if not explored thoroughly, as the skin and extensor hood of the relaxed hand obscure the more serious pathology beneath (Figs. 1,2). The polymicrobial aerobic and anaerobic inoculum is high (100 million organisms per milliliter of saliva) and often overwhelms immunologic defenses in a devitalized, poorly vascular environment.[2]

Delay in treatment and variable compliance often encountered in this temperamental patient group contribute to suboptimal therapy. Recognition and aggressive management have decreased the need for amputation to control infection and have reduced the incidence of permanent stiffness.[3] Nevertheless, such infections require hospitalization and prolonged treatment, accounting for almost 50% of inpatients on a city hospital hand service. This study was undertaken to deter-

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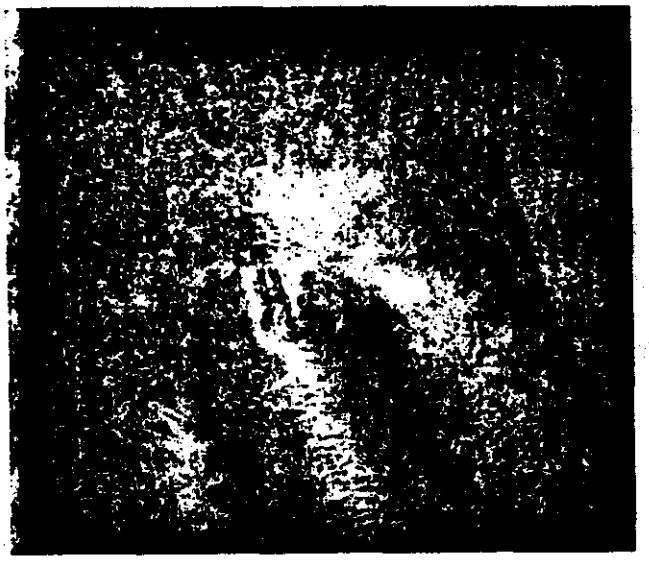

Figure 1. *Human bite wound in typical location at metacarpal-phalangeal joint. Wound might appear innocuous, but diffuse edema, induration, and necrotic debris suggest established infection.*

Figure 2. *Debridement reveals laceration of extensor mechanism, deep joint sepsis, and osteochondral fracture of metacarpal head, shown here after curettage.*

mine optimal treatment in order to shorten the hospital stay and to determine the effect of topical hyperbaric oxygen.

Methods

Patients admitted during a 6-month period to Denver General Hospital with human bite wounds were prospectively entered into the study. Initial evaluation was done in the emergency department. Wounds were explored, debrided, cultured aerobically and anaerobically, and cleansed with 2 liters of normal saline. Roentgenograms were obtained to exclude fracture or osteomyelitis. Whenever abscess, subfascial extension, or intraarticular or tendinous involvement were suspected, exploration, irrigation, and debridement were carried out under regional anesthesia in the operating room. All wounds were left open, and the patient was admitted.

Postoperatively, all patients were placed on penicillin G, 12 million units per day in 6 divided doses intravenously; and cefazolin (*Ancef, Kefzol*), 1g 3 times a day intravenously. Following culture results, the bactericidal antibiotic offering best coverage was substituted if necessary. Intravenous antibiotics were continued until discharge; an oral equivalent was continued until improvement was assured at follow-up. All patients were splinted with the involved hand elevated.

Range-of-motion exercises were started during or after twice-daily whirlpools. Saline-soaked fine-mesh wet-to-dry gauze bandages were then placed over the wound. In cases with exposed tendon, Bunnell's solution was substituted for saline. Patients were selected to receive hyperbaric oxygen treatments (prior to rebandage) on an availability basis to eliminate observer bias in the choice of treatment. If the chamber was in use by another patient upon admission, the new patient was randomized to the control group. If the chamber was vacant, the new patient was randomized to the hyperbaric group.

The chamber (Topox Corp., Jersey City, N.J.) is a portable lightweight Plexiglas humidified bedside unit (Fig. 3). A forearm can be placed into the unit, which is sealed with a latex sleeve. A pressure of 50mmHg 100% oxygen (via the wall outlet) is cycled every 30 seconds, so that the vascular supply is not impaired. Each of the twice-daily treatments (administered after whirlpool and before redressing the wound) lasts for 90 minutes. The unit is cleansed thoroughly between treatments with soap followed by isopropyl alcohol.

Wounds were classified upon entry as superficially infected (minimal cellulitis, no tendon or intraarticular involvement), moderately infected (cellulitis less than or equal to 2cm in diameter surrounding the wound), or severely infected (greater than 2cm cellulitis and/or lymphangitis). Risk factors such as delay in presentation, alcohol abuse, nutritional deficit, and diabetes mellitus were recorded. Wounds were evaluated twice daily and redebridement was performed as necessary.

Patients were discharged on twice-daily wet-to-dry dressing changes, with outpatient whirlpool and physical therapy, and visiting nurses when appropriate. Criteria for discharge were resolution of cellulitis, absence of pain about the wound, a granulating clean base, and improving range of motion. Return to functional status implied a clean, healing wound suitable for a small bandage, and dexterity permitting unimpeded daily activities. One orthopedic resident examined and treated all inpatients entered into the study. Several physicians examined patients in follow-up, which extended for

Table I
Wound Location

	Hyperbaric	No Hyperbaric
Thumb IP Joint		1
Index		
MCP joint	4	4
PIP joint		1
proximal phalanx		2
middle phalanx		1
Long		
MCP joint	4	5
PIP joint		1
distal phalanx		1
Ring		
MCP joint	2	4
proximal phalanx		1
Small		
MCP joint	2	1
PIP joint	1	1
proximal phalanx	3	
Small MCP and ring PIP		1
Dorsum left hand		2
Small PIP and ring MCP		1
Totals	16	27

Table II
Tendon and Joint Involvement

	# Patients*	Hyperbaric	Mean Days Hospitalized	*P* Value
Joint capsule penetration	10/14	+	5.0	*P* > 0.05 (N.S.)
	10/25	–	5.4	
Tendon and joint	5/14	+	7.2	*P* > 0.05 (N.S.)
	9/25	–	9.3	
Tendon alone	2/14	+	2.5	*P* > 0.05 (N.S.)
	2/25	–	4.0	

All but 1 patient moderately to severely infected.
*Represents only surgically proven cases.

Table III
Medical Risk Factors

	Superficial Infection	Moderate Infection	Severe Infection
Hyperbaric	—	4/9 EtOH*	6/7 EtOH
			1/7 Diabetes mellitus EtOH
Nonhyperbaric	1/7 hepatitis	7/15 EtOH	3/5 EtOH
	2/7 EtOH	1/15 ?AIDS†	

*Ethanol abuse
†Acquired immune deficiency syndrome

Table IV
Classification of Infection

	Superficial	Moderate	Severe
Hyperbaric (16 patients)	0	9	7
Nonhyperbaric (27 patients)	7	15	5

Table V
Days Hospitalized

	Superficial Infection	Moderate Infection	Severe Infection
Hyperbaric 4.4 (2–12)	—	4.1 (2–7)	4.7 (2–12)
Nonhyperbaric 5.2 (0–21)	2 (0–7)	4.2 (0–8)	11.2 (4–21)

6 to 9 months post discharge. Wound size and range of motion were recorded at each follow-up visit.

Analysis of treatment depended only on the initial assessment of wound severity (as previously defined) and its subsequent response to treatment (as judged by hospital stay). Wound categories were constructed to permit separate analysis by severity of infection and presence of tendon or joint involvement.

Results

Forty-nine patients with human bite wounds were treated in the emergency department at Denver General Hospital from July to December 1982. Three patients who were excluded from further analysis had superficial wounds or refused admission. Forty-six patients were admitted for further care; 27 received standard treatment, and 16 received, in addition, topical hyperbaric oxygen. The remaining 3 patients, who had osteomyelitis, were analyzed separately (see *Complications*).

The location of the wound on the hand varied (Table I). The metacarpalphalangeal joints of the long and index fingers were more commonly involved. The dominant hand was involved in 10 of 16 hyperbaric patients and 18 of 27 in the nonhyperbaric group. All but 4 patients were male. Only 2 patients described the mechanism of injury as an occlusional bite rather than a fist blow against a tooth.

Documentation of joint capsule penetration was available in 10 of 14 hyperbaric and 10 of 25 nonhyperbaric patients (Table II). Osteochondral fracture of the metacarpal head was present in 8 of these patients; this had no effect on hospital stay or eventual joint motion. Extensor tendon lacerations were found in a total of 18 patients, although the paratenon was violated in many more.

The most common medical risk factor identified was ethanol abuse, acute or chronic. The majority of patients had been drinking at the time of the incident. Chronic ethanol indulgence predominated among those with mod-

Table VI
Return to Functional Status

	Superficial Infection	Moderate Infection	Severe Infection
Hyperbaric	—	2.4 weeks	2.5 weeks
Nonhyperbaric	2 weeks	2.7 weeks	7.3 weeks

erate or severe infections (Table III).

Severity of infection. In an effort to quantify severity of infection, wounds were classified as superficial, moderate, or severe (Table IV). As expected, severity of infection correlated well with mean length of hospital stay (Table V).

Extensor tendon involvement alone did not contribute particularly to hospital stay, although both tendon and joint involvement markedly prolonged hospital stay. Topical hyperbaric oxygen did not statistically affect the rate of healing in this group (Table II). All but 1 of the wounds in these categories were moderately or severely infected. Of those patients with osteochondral fracture, 3 were severely and 4 were moderately infected.

Hyperbaric oxygen. The effectiveness of portable hyperbaric oxygen was assessed using 2 parameters: hospital stay and return to functional status. Average hospital stay (Table V) was shortened significantly, 4.7 versus 11.2 days, in the severely infected hyperbaric group only (Wilcoxon-Mann-Whitney ranked pair test, $P < 0.05$). This statistical analysis is specifically designed for small samplings (N = 12) and is independent of population distribution.[4]

Hyperbaric oxygen treatments were of no apparent value in the superficially or moderately infected groups. No significant differences in treatment delay, wound size, joint involvement, or risk factors were present in this comparison. Patients with osteomyelitis were analyzed separately, as they represent a unique subset (see *Complications*).

Table VII
Bacteriology

Patient	Aerobic Isolate	Anaerobic Isolate	Severity	Delay (days)
1	*S viridans, β-hemolytic Streptococcus*	Mixed anaerobes	S	5
2	Group D Streptococcus, enterococcus	Mixed anaerobes	S	6
3	*S viridans*, CDC group 2J		S*	2
4	Group D *Streptococcus, S aureus*	Mixed anaerobes, *B melaninogenicus*	S	5
5	Group A *β-hemolytic Streptococcus*		M	1
6	*S viridans*, group D *Streptococcus*	*Veillonella parvula*	M	1?
7	*S aureus*, group A *β-hemolytic Streptococcus, E cloacae*	Mixed anaerobes	S	7
8	Group A *β-hemolytic Streptococcus, S aureus*		S	5
9	Group A *β-hemolytic Streptococcus, S aureus*		S	12
10	*Streptococcus spp, S aureus*	Mixed anaerobes	S	3
11	Group A *β-hemolytic Streptococcus, S epidermidis*		S	7
12	Group A *β-hemolytic Streptococcus, S viridans*	Gram-negative rods, *Peptostreptococcus spp*	S	7
13	*S viridans, Neisseria spp*	*Veillonella alcalescens*	M	1
14	None	Gram-positive cocci/rods, gram-negative rods	S	28
15	*S pneumoniae*, group D *Streptococcus*		M	½
16	*S viridans, Hemophilus*		M	2
17	*S viridans, Neisseria, Staphylococcus spp*	*B saccharolyticus*	M	3
18	*S viridans*, Candida		M	1
19	*S viridans*, group D *Streptococcus*	Mixed anaerobes incl *B melaninogenicus*	M	1
20, 31	*S viridans, β-hemolytic Streptococcus*		M	4
21	Group A *β-hemolytic Streptococcus, S aureus*	Gram-positive rods	M	14
22	*S aureus*	Mixed anaerobes	M	6
23	Group A *β-hemolytic Streptococcus, S aureus*		M	3
24	*Streptococcus spp, β-hemolytic Streptococcus*	Mixed anaerobes	M	2
25	*S viridans, Pseudomonas stutzeri*	*Peptostreptococcus*, Kluyvera 6	M	1
26	Group A *β-hemolytic Streptococcus, S aureus*		M	5
27	*S pneumoniae*	Diphtheroids	M	1
28	*S viridans*	*Fusobacterium nucleatum, Peptococcus morbillorum*	M	1
29	*S viridans*	*B melaninogenicus*, spp interm, CDC group F_2	M	14
30	*S viridans, S epidermidis*		M	1?

*Superficial cultures not included.
Four anaerobic infections and 1 severe infection demonstrated no growth.

Return to functional status. Although return to functional status appeared to be shortened by hyperbaric oxygen treatment in the severely infected group (Table VI), this may not be a justifiable conclusion because of inconsistent patient follow-up.

Bacteriology. Bacteriology in hyperbaric and nonhyperbaric groups was examined (Table VII) for moderately and severely infected wounds. The polymicrobial nature and preponderance of strict and facultative anaerobes in human bite wound infections are striking. Mouth flora, as expected, were the predominant species. Overall, 15 wounds grew strict anaerobes, always (except in 1 case of osteomyelitis) in concert with other pathogens. Five of 6 patients in the severely infected hyperbaric group grew strict anaerobes, as did 3 of the 5 patients in the severely infected nonhyperbaric group. The delay in presentation was likely to be longer for those wounds growing strict anaerobes, averaging 4.7 days.

Complications. Osteomyelitis occurred in 3 patients. This complication occurred in conjunction with pyarthrosis, heavy ethanol use, and a prolonged delay in treatment of 1, 2, and 4 weeks. Hospitalization was equally prolonged, at 12 days (hyperbaric therapy), 21 days, and 15 days (nonhyperbaric therapy). Two of the 3 wounds grew mixed anaerobes, and all were severely infected; redebridement was required in all.

The outcome was poor in terms of joint motion, but thus far no amputation has been performed for stiffness. No extensor tendon ruptures were encountered in either group. Redebridement and rehospitalization was required in 1 patient treated with hyperbaric oxygen and in 2 patients not treated with hyperbaric oxygen.

In those patients without osteomyelitis, loss of joint motion was restricted to severely infected wounds, 1 in the hyperbaric and 2 in the nonhyperbaric group. Metacarpal-phalangeal motion was at least 60 degrees, presenting no functional deficit to this patient population. Follow-up and compliance with outpatient physical therapy was inconsistent.

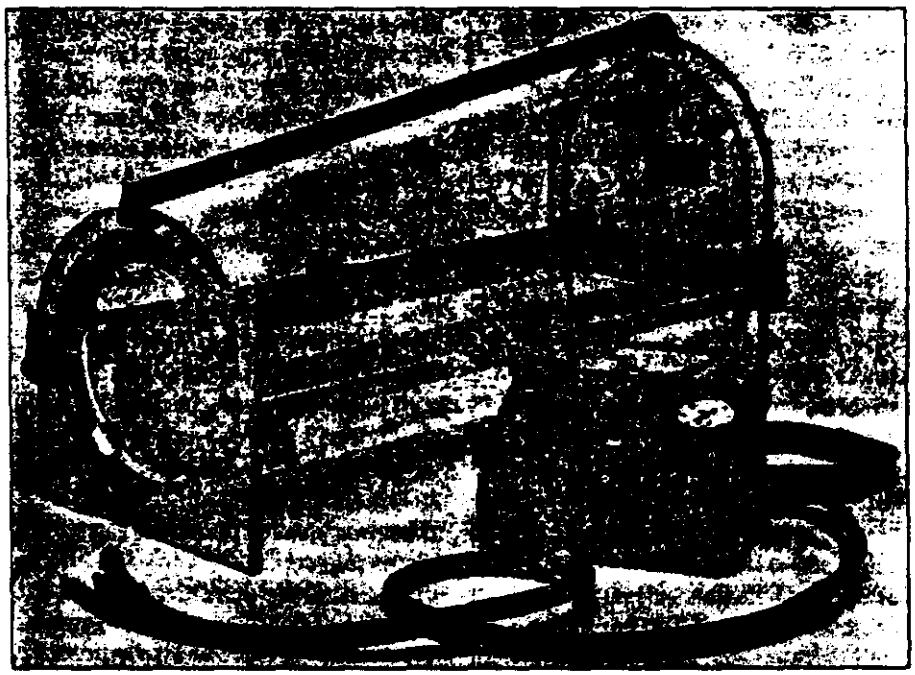

Figure 3. *Portable hyperbaric oxygen chamber.*

Discussion

The literature on human bite wounds is extensive and will not be reviewed in detail.[3-6] In this patient population of hand injuries, therapeutic prudence demands hospitalization, debridement, intravenous antibiotics, and observation for those presenting over 12 hours following injury. This management protocol is consistent with that of Peeples and colleagues[2] as well as Mann and associates[3] and conforms to basic surgical principles. This group of human bites was similar to those studied by Mann and Peeples in terms of demographics, delay in presentation (60% over 24 hours), and inconsistent follow-up. Nevertheless, average hospitalization was significantly less (4.4 and 5.2

Editorial Comment

The authors have outlined an approach to polymicrobial infections of the hand associated with a high risk of functional impairment and have evaluated hyperbaric oxygen therapy in a subset of patients. The finding that patients with severe infections who were treated with hyperbaric oxygen had shorter hospitalization than the nonhyperbaric oxygen group suggests that adjunctive therapy with hyperbaric oxygen may benefit such patients. Although the difference between groups was shown to be statistically significant, the statistical as well as the clinical significance of the findings is unclear. Patients were not assigned to treatment groups in a true randomized manner, nor were observers blinded with regard to treatment. These aspects, and the small number of patients in the groups, make it difficult to be certain of the conclusion drawn. A larger randomized, prospective, blinded series would be helpful.

The finding that 53% of positive cultures contained anaerobes confirms the polymicrobial nature of these infections and supports aggressive surgical and medical therapy of these injuries.

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days in this study, versus 7.5 days in Mann's group), which may be attributed to differences in microbial virulence as well as to the effect of hyperbaric oxygen on anaerobes and tissue healing response.[9,10]

Overall, return to functional status was more rapid in these patients than in those reported by Chuinard and coworkers,[5] possibly because of vigorous range-of-motion exercises begun at 24 hours rather than at 2 weeks. Also, in the authors' study early motion probably accounts for the lower incidence of permanent joint stiffness (compared to 50% of the hospitalized patients studied by Chuinard's team).

The microbiology of wounds in this study merits further attention. Only 33% of positive cultures grew *Staphylococcus aureus* (all penicillin-resistant, methicillin-sensitive), in contrast to 80% in other studies. The presence of *S. aureus* has been associated with a higher incidence of severe complications.[5,7] A higher number of strictly anaerobic isolates (53% of positive cultures) was seen in this study, suggesting improved anaerobic transport media, and perhaps better isolation techniques when a specific laboratory is designated to process such material.[11]

These data confirm the synergistic role of anaerobic and microaerophilic organisms in serious hand infections and emphasize the basic role of surgical intervention: to remove traumatically compromised tissue, to establish free drainage of violated deep spaces,[12] and to convert an anaerobic environment to an aerobic one. Specific antibiotics, physical therapy, and redebridement as necessary must not be ignored.

The antibiotic protocol used—penicillin and cefazolin—was based on previous reports documenting a high incidence of *S. aureus*, *Streptococcus* species, gram-negative organisms, and anaerobes cultured from these wounds. The results of this study suggest that cefoxitin (*Mefoxin*) is an appropriate single antibiotic for empiric coverage pending culture results. The effectiveness of this regimen, however, may be limited in severely infected, neglected wounds, in which anaerobes play a major role. *Eikenella corrodens* (not specifically identified in this series) would be variably suppressed.[13] Antibiotic selection should be adjusted according to sensitivity profiles when they become available.

Hyperbaric oxygen has been found effective in the management of certain anaerobic infections, particularly with clostridia species, presumably by elevation of redox potentials and resultant growth inhibition.[13] Hyperbaric oxygen also appears to be directly bacteriostatic on aerobes *in vitro*, especially *S. aureus*.[14] Open wounds appear to heal faster with exuberant granulation tissue when exposed to hyperbaric oxygen, an effect supported by tissue gas measurements.[9,15] Perrins[16] demonstrated improved survival (64% versus 17% complete coverage) of split-thickness skin grafts.

The advent of portable lightweight units generating intermittent pressures of up to 80mmHg 100% oxygen, which can be entirely isolated to an extremity, have circumvented problems of transport and cost. Complications of oxygen toxicity,[17] vertigo, embolus, and neurologic sequelae[18] have been eliminated. Pressures and conditions (particularly constant versus intermittent cycling) have never been subjected to a controlled trial, although case studies suggest the apparatus exerts a comparable effect, at least on leg ulcers and pressure sores.[9,15]

The beneficial effect of hyperbaric oxygen in the management of serious hand infections probably stems from the improved healing response of tissue[9,19] and bacterial inhibition. Serial quantitative tissue cultures could help clarify its effect. No response was seen in superficially or moderately infected groups, as standard debridement and antibiotics were capable of converting the wound to a healthy environment for recovery. In established, serious infections with severely traumatized tissues, however, topical hyperbaric oxygen may be an effective treatment modality. □

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