MULTIDISCIPLINARY CARE AND RESEARCH FOR BURN INJURY: 1976 PRESIDENTIAL ADDRESS, AMERICAN BURN ASSOCIATION MEETING

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Believing that history points the way to the future and that the only way to avoid making mistakes is to do nothing, I feel that review of the evolution of burn care confirms the effectiveness of multidisciplinary care and research and indicates ways that we can ensure that our errors will not be reinventions of the wheel. To provide perspective, and pay recognition to our Bicentennial, it is worth considering the burn treatment applied to the residents of Colonial America. In 1684, a Doctor Stafford of London gave Governor Winthrop of Plymouth Colony the following recipe "For Burning with Gunn Powder or Otherwise."

"Take ye Inner green rine of Elder, in latine Sambucus, Sempervive and Masoe that groweth in an old thacht howse top, of each alike; Boyle them in stale [lotium] and sallet oyle so much as may cover them four fingers. Let all the [lotium] Boyle cleane away and straine very well; putt new herbs and [lotium] as before, Boyle that likewise away and straine it as before. Then to that oyle add barrowes grease until it come to be an Oyntment with which anoynt a paper and lay it to ye burning anoynyt the place also with a feather" (26).

In the late eighteenth century, near the time of our revolution, experimental science was already making its presence felt in burn care, as indicated by the letter of Mr. John Vinall of Boston, dated 23 May 1790, which appeared in Volume II, Part 1, of the Memoirs of the American Academy of Arts and Sciences (32).

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"Sir: In making use of my large electrical machine which is constructed with both a positive and negative conductor, the air being humid and consequently unfavorable for electrical experiments, I made use of a small iron pan with some coals under the machine in order to qualify the surrounding atmosphere so as to answer my purpose. By accident I burned my thumb with the pan so much as to cause me great pain. Knowing that in some instances I had been relieved of slight burns by holding the part affected to a common fire I held my thumb a small distance from the negative conductor; put the machine in motion; and to my surprise found that in a few seconds of time the effects of the burn were destroyed, my thumb perfectly at ease, and no blister arose as would have been the case if I had not made use of electricity. I met with a similar instance not long after; I made use of the same remedy and received the same benefit."

Approximately one hundred years later, near the time of our country's Centennial, two burn care innovations were reported. The first in Volume 18 of the Medical and Surgical Report of Philadelphia, dated 1 February 1868, by Samuel W. Francis, M.D., was entitled, "Transparent Treatment: A New Invention for the Cure of Burns and Other Affections of the Extremities" (12). He wrote,

"As may be seen by the engraving, the scalded arm is placed at once in the glass globe, each finger finding its own division, which, though separate, is joined externally like a mitten to prevent breakage and water dressings, lime water, or Kreosote water, etc., allowed to flow in from the upper stop cock; an India rubber band or its equivalent preventing its exit."

Anticipating the present-day G-suit, the author further speculated,

". . . water or its equivalent could be forced in by a pump with sufficient power to produce pressure, which at times is very desirable."

The second innovation employed on the service of Dr. George Derby at the Boston City Hospi-
tal appeared in New Series Volume IV, of the Boston Medical and Surgical Journal, 1869, describing the care of a patient with an extensive but superficial burn covering the entire right foot, the left ankle, and the lower left leg to a distance of about four inches, caused by boiling water four days before (10). The house officer wrote,

"Dry earth finely powdered, was dusted from a dredging box over the entire burned surface; it was applied at frequent intervals whenever a moist spot showed itself. . . . This treatment was continued for three weeks at the end of which time the scab formed by the earth was washed off. A fine cicatrix beneath appeared. For three days more castor oil was applied, when the patient left the house with the ulcers nearly closed."

These latter two reports particularly well illustrate the aphorism that if you scratch a person with an open mind, you find one who is unfamiliar with the literature, for surely the transparent treatment is the ancestor of the Bunyan bag and the dry earth treatment the predecessor of Praetorian clay.

Since that time burn care has progressed in parallel with surgical and medical care in general. In fact, an effective spongiositis has resulted from this relationship and exerted a multiplier effect on advancement of burn care, as is well illustrated by developments in the areas of fluid resuscitation and wound treatment. In 1886, as reported by Dr. T. Watkins, in Volume III of the Philadelphia Medical Museum, resuscitation consisted of administration of laudanum, cautiously given oral fluids, and cathartics (34). This inattention to the at times prodigious fluid needs of the burn patient occurred 150 years following the demonstration by Christopher Wren, otherwise known for his architectural accomplishments, that medicines could be administered to animals by the intravenous route (1), and 140 years following Lower’s successful transfusion of homologous blood directly between animals (17). The clinical application of Lower’s work resulted in fatal transfusion reactions which led to legal proscriptions against blood transfusions, and it was not until Landsteiner discovered the isoagglutination phenomenon in 1900 (15), his identification of three major blood groups in 1902, and the discovery of the fourth major blood group by DeCastello and Sturli in 1902, that blood transfusions became a clinically useful means to treat hemorrhagic shock (9).

In a parallel development, saline infusions were used by Thomas Latta in 1831 (16), for the treatment in cholera patients of the volume deficit previously described by O’Shaughnessy (24). Buhl, in 1854, noted the similarity of volume losses in cholera patients and burn patients (5), but it was not until 1901 that Parascondolo, in Naples, recorded the good response of three burn patients to whom he administered intravenous saline solution (18). Shortly thereafter, Haldor Sneve, of St. Paul, Minnesota, reported eight cases of thermal injury, emphasizing the need for saline solutions (30). He administered normal saline orally, as chilled enemata, as transfusions, by hypodermoclysis, and as baths in which the patient was immersed.

Sneve’s recommendations, in what today we would call an anecdotal report, went largely unheeded until Frank P. Underhill, Professor of Pharmacology and Toxicology at Yale, studied 20 patients burned in the Rialto Theater fire of 1921 (31). He identified the severity of their postburn volume changes and his studies of blister fluid focused attention on plasma loss. Subsequent experimental studies by Alfred Bialock (4) and the clinical studies of Henry N. Harkins established plasma volume deficit as central to burn shock (14).

At a National Research Council conference, chaired by I. S. Ravdin in January 1942, Harkins calculated that patients with over 10% burns should be given 1,000 cc of plasma intravenously in the first 24 hours for each 10% of the surface burned. The consensus of the conference attendees was that salt solutions should also be given in a volume not to exceed the quantity of plasma administered. This formula, recommended by the National Research Council conference, was the first time that the extent of the burn was used to predict the fluid needs of burn patients (7). In 1947, Cope and Moore reported the results of studies on 19 burn patients, using modifications of the NRC formula based on their experience in the treatment of patients from the Cocoanut Grove fire, and advanced what has come to be known as the Burn Budget formula (8). Concomitant laboratory and clinical studies by Evans and his colleagues resulted in the publication in 1952 of their formula for fluid resuscitation, which again rec-
commended a volume of electrolyte solution equal to that of the plasma infused (11). In the introduction to that report Evans said, "Although there is a growing realization that adequate amounts of salt must be administered, the question remains: How much salt does the extensively burned patient need?" One of the references cited by Evans was the report of Carl A. Moyer at the Symposium on Burns held by the National Research Council in 1951, wherein Moyer emphasized the salt needs of the burn patient (21). In 1953 Reiss, Stirman, Artz, Davis, and Amsacher advanced the Brooke formula based on the fluids actually received by patients with greater than 20% burns who had survived (28). This formula for the first time placed emphasis on noncolloid fluids.

Moyer thereafter continued his studies relating salt loss to plasma volume deficit in a variety of surgical patients, including those with acute hemorrhagic losses. He applied the results of these studies to burn care and, in a report published in 1965, recommended lactated Ringer’s as the sole resuscitation fluid (22). Moyer’s studies were in turn corroborated and extended by Shires and Baxter to the treatment of patients with hemorrhagic shock and their work (29), plus that of others, has resulted in the widespread use of isotonic salt solutions for initial resuscitation of all injured patients and for preoperative and intraoperative volume support in surgical patients. As a result of this effective transport of ideas and investigative work between medicine and surgery in general, and burn care in particular, fluid resuscitation of burn patients today resembles that given to other surgical patients.

In recent years other formulae emphasizing both volume and salt dosage have been proposed and enthusiastically supported. Studies at our Institute have confirmed that fluids given according to Brooke formula estimate and altered according to the individual patient’s response permit an early blood volume deficit averaging 20% but defend against further loss with reconstitution of plasma volume by the third postburn day. Those studies have also shown that in the first 24 hours postburn, colloids are no more effective at volume restitution than an equal volume of electrolyte-containing solution and, in fact, appear to be merely expensive salt water (27).

The variety of resuscitation regimens proposed, all of which have been found clinically effective, reflects more the physiologic reserve of the average burn patient than any specificity of the formulae. In fact, the latitude of resuscitation fluid composition was examined in our laboratory by Moylan and Mason who developed a formula which, although not defining absolute limits, describes the range of salt and volume dose of early resuscitation fluids within which those fluids can be flexibly adjusted to restore cardiac output and meet the individual salt and fluid needs of the burn patient (23)*.

The controversy over resuscitation volume and composition has not been settled, as indicated by the two most recent formulae advanced, which emphasize respectively smaller volumes of hypertonic fluids and larger volumes of isotonic fluids (3, 19). In fact, this issue may never be resolved because of the well known fact that one can always find sufficient research to confirm one’s original belief. Perhaps all would agree that resuscitation should be effected by fluids in volume and composition sufficient to maintain vital organ function during the period of increased vascular permeability at least physiologic cost to the patient thereafter.

Our prior work and continued interest in burn resuscitation prompted our review of the resuscitation volumes actually received by ten recently treated young adult burn patients whose burns ranged from 47–83% total body surface, and averaged 64% of the total body surface. The patients received essentially only lactated Ringer’s solution in the first 24 hours and the volume of electrolyte fluid and total volume dosage received by each patient in the first 48 hours postburn were compared with Brooke formula estimates. An average of 2.88 ml/kg/% burn of electrolyte-containing fluid was infused in the first 24 hours with 48-hour volume and salt dosage exceeding but closely approximating Brooke formula estimates. The fact that clinically satisfactory resuscitation was achieved in all suggests that greater volumes of electrolyte-containing fluid in this age group are unnecessary and may only contribute to greater edema formation.

* $CO_2,CO_2 \times 100 = 50.125 + 3.44 (Na) + 0.26 (V)$ where $CO_2$ equals cardiac output 12 hr postburn, $CO_2$ equals cardiac output preburn, Na equals sodium in mEq per kilogram, administered in first 12 hr after burn, and V equals volume, in milliliters per kilogram, administered in first 12 hr after burn.
Following resuscitation, the burn patient characteristically has elevated levels of renin and aldosterone and a burn-size related increase in evaporative water loss, a situation favoring loss of water and retention of salt. Since clinical consequences of fluid overload are rare during the first 48 hours postburn but common later in the first postburn week, and since salt-free water is preferentially lost while sodium is avidly retained, a minimization of salt load by increasing the dose of fluid in which the salt dosage is administered would seem desirable. It appears to us, therefore, as if resuscitation regimens for the extensively burned patient should emphasize limitation of sodium dosage with the salt given in a fluid volume sufficient to maintain cardiac output and the perfusion of vital organs while maintaining the serum sodium concentration in the neighborhood of 130 mEq/L. We feel this can be achieved and unnecessary fluid or salt loading avoided by the administration of lactated Ringer’s solution calculated on the basis of 2 mg/kg/% burn, with full knowledge that the volume may need to be adjusted upward on the basis of the individual patient’s response.

The other area of burn care well illustrating the close relationship of progress in burn care with that in medicine in general is that of control of infection. In the first decade of the nineteenth century, two American physicians actually commented upon the occurrence of burn wound infection and noted the similarity of changes in the burn wound and other infections. T. Watkins, in his previously cited report of 1806 (34), noted that when the spirit of turpentine dressings which he had ordered for a 3-year-old child had been omitted for a 24-hour period, “... the whole wound has assumed a gangrenous appearance.” This turn of events was controlled by the instant application of bread and milk poultices of which he said, “The effect of these is almost inconceivable, for when I saw him at the same hour on the next day the wounds had recovered a healthy appearance.” Thomas Walmsley of Chambersburg, Pennsylvania, writing on, “Facts and Observations Relative to the External Employment of the Interior Bark of the Tilia Americana or American Lime Tree in Cases of Burns and Scalds,” speculated: “Neither can I say if it (the application of mucilaginous Tilia extracts) would be serviceable in erysipelas or other inflammations, but as there is some analogy between these and the inflammations from burns and scalds, the experiment would be worth making” (33).

In the early 1940’s, J. G. Allen in the United States as well as other groups in Canada and England noted the improvement in wound appearance and the lesser occurrence of life-threatening infection in burn patients to whose wounds sulfonamide creams were applied (2, 6, 13). The occurrence of what was called “sulfa toxicity” and the emergence of organisms resistant to Colebrook’s penicillin cream led to abandonment of topical therapy. The subsequent development of effective topical chemotherapy is well known and was described by John A. Moncrief in his Presidential Address to this Association in 1971 (20). The development of topical chemotherapy, as noted by Moncrief at that time, resulted from the collaborative laboratory and clinical efforts of a multidisciplinary group consisting of surgeons, pathologists, and microbiologists. The chronology of organisms causing life-threatening infections in the burn patient recapitulates the history of surgical infections as a whole and today, as was historically true with the earliest topical preparations, other opportunists such as Providencia stuartii, common in the Sulfaamylon-treated patients in 1969, and Enterobacter cloacae, common in patients treated with silver sulfadiazine over the past two years (Table I), and even nonbacterial organisms, have emerged to diminish the improvement in survival initially achieved with topical therapy (Table II).

This changing ecology of the burn patient has served to emphasize the vulnerability of the burn patient to organisms which are commonly no threat to unburned individuals. During the past decade, description and definition of the immunologic consequences of thermal injury have been initiated through the collaborative

<table>
<thead>
<tr>
<th>Organisms</th>
<th>No. of Isolates</th>
<th>1963</th>
<th>1969</th>
<th>1974</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pseudomonas aeruginosa</td>
<td>477</td>
<td>239</td>
<td>185</td>
<td></td>
</tr>
<tr>
<td>Providencia sp.</td>
<td>23</td>
<td>230</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>Klebsiella-Enterobacter sp.</td>
<td>300</td>
<td>223</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>(Enterobacter cloacae)*</td>
<td>(122)*</td>
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* The organism was so rarely encountered in prior years that it was not tabulated.
efforts of surgeons, internists, hematologists and immunologists. It is in this field that further multidisciplinary studies are needed to define new therapeutic approaches to the problem of sepsis in the extensively burned patient and bring about improved survival which cannot be vitiated by the adaptability of microorganisms.

Similar instances of interdisciplinary collaboration resulting in advances in diagnosis and care for the burn patient exist in the areas of metabolism, nutrition, endocrinology, and pulmonary and gastrointestinal consequences of thermal injury. These advances in turn have been applied with benefit to other patients, reflecting again the universality of the burn patient as a trauma model.

The majority of the work leading to these advances has been carried out at institutions possessing in-depth expertise in all disciplines represented in the burn care team and all disciplines needed for present-day clinical research. In addition to comprising a regionalized burn care system which is being used as a model for other systems of categorical health care these centers provide and also define what I regard as the conditions necessary for effective clinical research (Table III). First, a dependable and adequate patient density is assured by the regionalization of burn care for the estimated 16,000 out of 2,000,000 burn patients requiring burn center care each year in our country. Of equal importance, they provide the means whereby an experienced burn care team supported by a responsive clinical laboratory can identify problems of clinical significance. An indigenous nursing service cannot be overemphasized, since its members not only provide the intensive care necessary for optimum survival but assist in the identification of clinical problems deserving of study and resolution. In-depth clinical research also requires that dedicated clinical study areas be available so that the necessary special studies can be carried out without interfering with day-to-day patient care activities.

The research laboratory and clinical support capabilities provided by sophisticated basic scientists and members of the other biologic sciences have been important to progress in burn care, and provision must be made for the active involvement of microbiologists, physiologists, biochemists, bioengineers, mathematicians, and veterinarians. The talents and special skills of these individuals can be employed in meaningful fashion only by close association with the clinical staff and firsthand observation of the critically burned patient. In this way, the design of elegant studies in search of a problem is avoided and an environment is created where the efforts of a staff trained in a variety of disciplines can be directed towards problems of significance as they are defined in the patient.

The omnisystem effects of burn injury and the rapid doubling time of scientific knowledge

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**TABLE II**

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<td>0–14</td>
<td>30</td>
<td>56</td>
<td>40</td>
<td>46</td>
</tr>
<tr>
<td>15–40</td>
<td>(36–45)*</td>
<td>(52–62)*</td>
<td>(36–44)*</td>
<td>(40–54)*</td>
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<tr>
<td>&gt;40</td>
<td>52</td>
<td>62</td>
<td>52</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td>(49–55)*</td>
<td>(59–65)*</td>
<td>(50–54)*</td>
<td>(54–62)*</td>
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</tbody>
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* 95% confidence limits of LAso

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**TABLE III**

<table>
<thead>
<tr>
<th>Factors Essential for Burn Center Care and Research</th>
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<tbody>
<tr>
<td>1. Dependable and adequate patient density</td>
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<tr>
<td>2. Means to identify significant problems</td>
</tr>
<tr>
<td>a) Experienced physicians, nurses and allied</td>
</tr>
<tr>
<td>health care professionals</td>
</tr>
<tr>
<td>b) Sophisticated, responsive clinical laboratory</td>
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<tr>
<td>facilities</td>
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<tr>
<td>3. Dedicated clinical study areas</td>
</tr>
<tr>
<td>4. Research laboratory facilities</td>
</tr>
<tr>
<td>5. Active involvement of allied scientists</td>
</tr>
<tr>
<td>6. Multidisciplinary research team and teaching</td>
</tr>
<tr>
<td>program</td>
</tr>
<tr>
<td>7. Funding dependability and flexibility</td>
</tr>
<tr>
<td>8. Stability of senior staff</td>
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<tr>
<td>9. Effective review mechanism</td>
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</table>
demand multidisciplinary research teams of flexible composition for greatest research effectiveness. The desirability of such interdisciplinary research is well illustrated by the recent contributions of pulmonary physiologists, hematologists, immunologists, and gastroenterologists, to the study of those life-threatening complications of the burn patient which have been accentuated by the improved control of burn wound sepsis. Flexibility of funding is similarly essential to opportunistically explore promising leads which appear in the course of planned activities. A variety of sources provide such funds in the civilian community and at our Institute ILIR funds administered by Kendall Emerson provide us with this capability.

Stability of senior staff is also required for an orderly progression of planned research and has existed in our laboratory principally in the person of the civilian Chief of the Laboratory Division, A. D. Mason, who has provided the scientific continuity so important to our work during the past 19 years. All of the senior staff should be fully trained and, most importantly, experienced in their professional fields with a special interest in research and a strong record of productivity.

An active teaching program involving individuals at the undergraduate, graduate, and postgraduate levels maintains quality of burn care and facilitates timely dissemination of research findings. An effective review mechanism, both inhouse and external, is also essential for present-day clinical research—to appraise scientific merit and cost effectiveness, to prevent inhouse duplication, and to avoid needless repetition of the work of others.

Last, but perhaps most important at our Institute and I suspect at others as well, have been the contributions and selfless efforts of our junior staff. None of the studies and improvements in burn care at our Institute would have been possible without their enthusiastic participation.

This Association is holding its Eighth Annual Meeting at a time when medicine as a whole and surgery in particular are being assaulted from without and, at times, from within by what seem to be self-appointed experts. Burn care per se has come under scrutiny and at least two bills are pending in the Congress to establish more burn centers and nationwide programs of burn care. As an Association, we should perhaps view this with a mixture of concern and pride. Concern because an arbitrary proliferation of burn units may only be a modern example of H. L. Mencken's cynical dictum, "For every human problem, there is a neat, plain solution—and it is always wrong" (1). Ill conceived and poorly timed construction of burn facilities unrelated to documented need might well aggravate rather than answer what I view as the limiting factor in burn care today, namely, a shortage of trained, experienced burn team personnel for staffing of existing burn centers, let alone for new burn facilities. Conversely, we can regard government interest in burn care with pride, since the state of burn care and the accomplishments of burn research exemplify the benefits to be derived from the team approach in patient care activities and provide an outstanding example of the effectiveness of multidisciplinary, goal-directed research applied to a categorical disease. The facilities possessing in-depth expertise for burn care are the best examples extant of regionalized health care. Equally important, those facilities have established research environments which foster improvements in the care of the burn patient, relevant investigation, multi-level interdisciplinary educational programs, and a productive symbiosis between burn care and medicine at large.

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