compression. Using native whole blood thromboelastography (a method for measuring coagulation dynamics), a technique has been developed for quantitating percent fibrinolysis. This technique has been applied in a clinical study where the percent fibrinolysis was monitored using native whole blood thromboelastography before and after 2 hours of external intermittent pneumatic compression applied to one arm of the patient.

The influence of fibrinolytic activity on thromboelastography is detected as a decrease in amplitude following the point of maximum amplitude. To quantitate fibrinolytic activity, one measures the maximum amplitude and then the amplitude at 10 mm, 20 mm, 30 mm, and 40 mm below the maximum amplitude. These values are placed in the following equation to obtain a value of percent fibrinolysis:

$$\%F = 1 - \left[\frac{Ma + 2a_1 + 2a_2 + 2a_3 + a_4}{8\,Ma}\right] \times 100$$

A series of 50 patients received external intermittent pneumatic compression applied to one arm for 2 hours. Of these 50 patients, 31 (62 percent) showed a quantitative increase in percent fibrinolysis following 2 hours compression. Precompression, percent fibrinolysis averaged 3.9 ± 4.0; postcompression, percent fibrinolysis averaged 6.2 ± 8.1. The average increase in percent fibrinolysis was 245 ± 286% with a range of increase of 8 percent to 1167 percent; no patient decreased.

Enhanced fibrinolytic activity secondary to external intermittent pneumatic compression was detected in the systemic circulation by blood drawn from the contralateral arm and analyzed by thomboelastography. It appears that the naturally occurring fibrinolytic activity is enhanced by external intermittent pneumatic compression. This activity, in addition to preventing stasis, is essential in its role in the prevention of postoperative deep venous thrombosis.

Evaluation of Electrical Techniques for Stimulation of Hard Tissue Growth

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We are pleased to note that Dwight A. Webster, M.D, has become part of the Orthopedic Research team at this station, as well as Chief of the Orthopedic Service. Dr. Webster will be working on both clinical and laboratory phases of our research program, notably electrical osteogenesis and silver bacteriostasis.

Use of Silver in Treatment of Chronic Osteomyelitis

The clinical research program for the silver mesh treatment of chronic osteomyelitis is progressing. To date 32 patients have been treated. Silver ions are electrically injected into a surgically debrided infected bone by daily application of anodically activated silver-coated conductive dressings, making use of the antibiotic effect of the silver to eliminate residual bacteria. An in-depth review of the first 25 patients treated with this method shows about 75 percent have an improvement in their clinical situation. Because of the indolent nature of osteomyelitis, only long term followup will indicate the real effect of this treatment. The application of the dressing is shown in Figure 1 and is described more fully in the literature (J. Bone Joint Surg. 60-A, pg. 871-881, 1978).

Electrical Osteogenesis—Clinical Trials

To date 30 patients have been treated for non-united fractures using the low-current silver cathode implant method. This technique continues to show approximately 75 percent success in patients with established non-union of 2 years median duration. We are now beginning a thorough analysis of the experience and data acquired thus far, in order to project the future course of this application. At the same time, new laboratory experiments are being designed to extend the electrical osteogenesis method to problems of large segmental loss of bone, an area for which there is no present adequate remedy. A particular advantage of the silver electrode is its ability to be rendered bacteriostatic by being operated anodically for a short period of time, prior to or during the 6-week cathodic osteogenic period.

Limb Regeneration Experiments

The pursuit of the limits of mammalian regenerative capacity has been carried one step further with the observation that surgically induced contact between peripheral nerve and the epidermis can lead to a regenerative response. An experiment has been completed using 80 Sprague-Dawley rats with unilateral amputations through the distal third of the femur. In half of the animals, the sciatic nerve was dissected free and its terminal branches fed through a hole in the epidermis directly over the cut femur and sutured to the skin. In the remaining animals (controls) the same hole in the epidermis was made, but the nerve was left in situ.

After 2 weeks the experimental group showed a blastemal-like cell mass and later active osteogenesis, myogenesis and epimorphic reconstruction of the lost structures. The maximum response (6 weeks) showed a bony outgrowth, an organized epiphyseal plate, capped by articular-like cartilage. In addition, 2 weeks after amputation, individual nerve fibres had grown out from the cut nerve and ramified throughout the wound epithelium. Healing in the control group was dominated by fibrous connective tissue proliferation and moderate amounts of chondrogenesis and, later, bone.

The results thus far indicate an important contribution of the neural-epidermal contact in triggering regeneration. They also confirm the

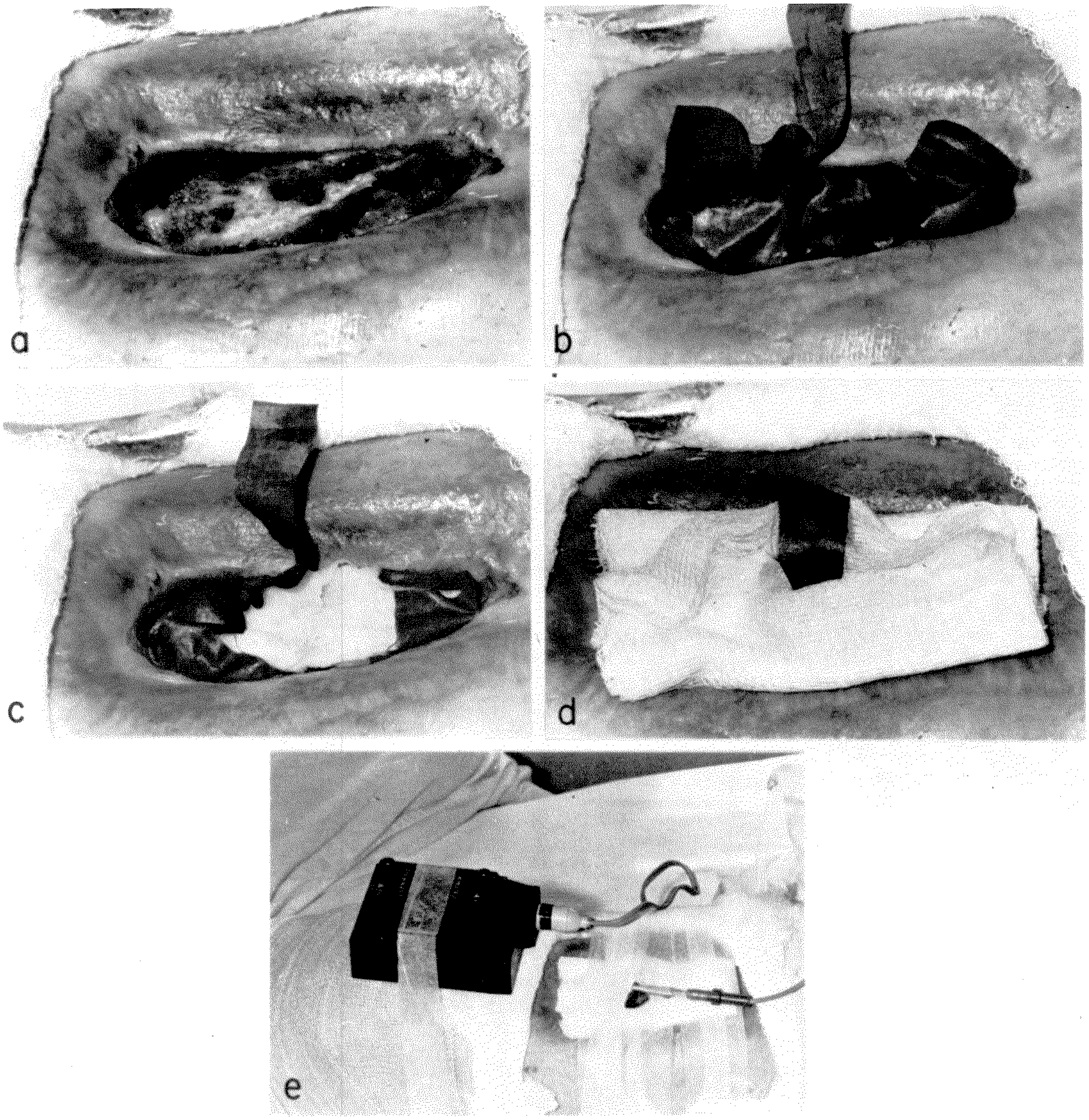

FIGURE 1.
Application of conductive silver-nylon anode material to saucerized, infected, tibial non-union: (a) the wound itself in cast window (case T.W.); (b) saline wetted silver-nylon placed in contact with all wound surfaces below skin level; (a "tail" is left out for electrical contact.); (c) a gauze stent moistened with normal saline packed over nylon; (d) dry sterile gauze placed over entire wound with "tail" protruding; (e) constant voltage source and positive lead connected to silver-nylon. Return electrode (not shown) is placed on intact skin with electrode paste and its position selected to enhance silver ion mobility into infected regions of the wound bed.

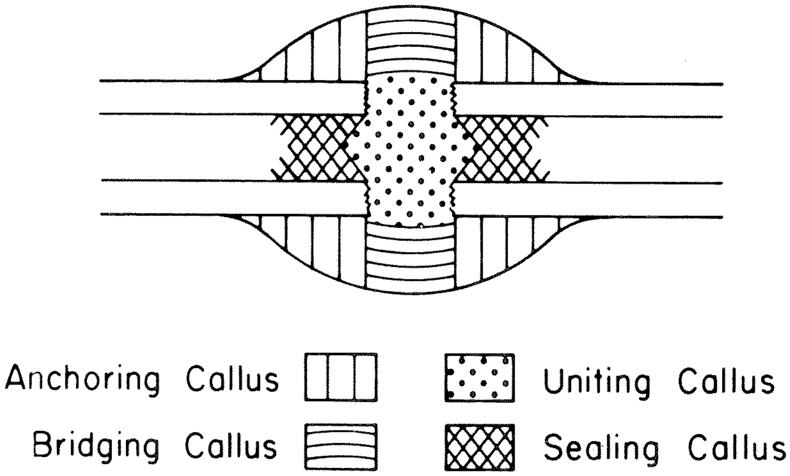

FIGURE 2.
Regional distinctions used in grading the status of fracture healing in the fibula of the rat. For each region the amount and quality of cartilage and bone was graded on a scale from 1-5. This data was combined with general characteristics (union, alignment, callus size) to obtain a final histological grading of the fracture (called the 'healing index'). (See: Marino AA, et al, Clin Orthop Rel Res 145, pg. 239, 1979.)

fact that mammals have more regenerative capacity than is generally believed. We will continue this work in an effort to learn why the neural-epidermal contact is so important, using (among other things) the electron microscope.

Influence of 60 Cycle Electric Fields on Fracture Healing

An experiment was performed to measure the influence of externally applied low-frequency electric fields on the rate of fracture healing in the rat fibula osteotomy model, a model often used in fracture healing studies. Osteotomies were performed on 75 rats, half of which were kept in special cages in which an alternating 60-Hz electric field of 5000 Volts/meter was applied vertically for the entire 14-day post-fracture period. The other half of the animals were kept in identical cages, with both plates grounded (i.e. no electric field). In all cases, the animals were completely insulated from contact with the field plates.

The fractures were graded histologically at 14 days by judging the growth in four regions (Fig. 2). The grading was done without knowledge of the time since fracture or whether the slide was from the control or treatment condition. The grading included determination of new bone, cartilage, alignment, fibrous connective tissue, etc., and formation of a "healing index" for each fracture. In the field-exposed animals, the new bone had thinner trabeculae and large blocks of cartilage in the uniting callus. They appeared at 14 days to be at the 10-day stage of healing for control animals. The overall healing index of exposed animals was significantly lower than controls ($p < 0.001$). This study suggests that low-frequency electric fields act as a systemic stress to the animal, thus retarding the metabolic efficiency of the bone healing process. It emphasizes the need for more knowledge of the results of environmental and therapeutic exposure of large areas of the body to such fields.

Foot Biomechanics: Force and Pressure Distribution in Health and Disease

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A modeling study of the stress distribution in the plantar aspect of the foot has been completed. This culminated in a Masters' thesis in engineering (Sachio Nakamura). This study included a representation, by finite element analysis, of the foot within a shoe. The finite element model included aspects of the bones of the foot, thick plantar-aspect skin, and shoe sole material. Numerical procedures permitted the prediction of the stress distribution throughout the foot-shoe structure during the activities of weightbearing. The objectives included an investigation of the effects that shoe sole elastic properties have upon the magnitudes of stresses developed within the thick skin of the foot. A systematic search of linearly elastic shoe sole properties revealed a significant dependence of the stress developed within the foot on the stiffness of shoe sole material. Relatively high stresses within the foot occurred when the foot was loaded through extremely soft or hard shoe soles. Shoe soles of intermediate stiffness generally lower the stresses within the foot. An optimum, linearly elastic, shoe sole material that minimizes stresses within the foot during weightbearing should be developed.

A study to measure experimentally the effects of pressure exerted upon the foot from shoes of different elastic properties is currently underway. This study involves the measurement of pressure upon the foot surface using thin pressure transducers within the environment of the shoe. The results of this study will comment upon the validity of the mathematical techniques used to predict stress distribution

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