CURRENT STATE OF THE EFFORT

Amputation Surgery and Prosthetics

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The basic program on Current State of the Effort in amputation surgery and prosthetics follows a logical trend. The primary goal is to avoid amputation, if possible, by means of better measurement and management of vascular problems. Discussion of rational selection of levels leads to amputation surgery and healing. The possibilities of skeletal attachment of a prosthesis lead into better methods for fitting and major areas of prosthetics, including both external and internal prosthetic joints and control of external power.

This section on amputation surgery and prosthetics starts with Dr. Bok Y. Lee, of Castle Point VA Hospital, on Hemodynamic Evaluation in Selection of Amputation Levels. His goal is to prevent amputation, if possible, or at least to conserve stump length and joints as much as feasible.

The next speaker on the same general topic of rational selection of the amputation site, Dr. Wesley S. Moore, devotes special attention to Skin Blood Flow and Healing. He emphasizes the role of skin as distinct from arterial blood flow. Dr. Moore is a general and vascular surgeon from the VA Hospital at San Francisco.

This apparent trend toward prevention of amputation, more distal amputation, and successful wound healing is perhaps more than just a suspicion. Even a limited number of situations raises obvious suspicion of cause and effect. (One may recall Gilbert Chesterton's famous comment: One giraffe with his long neck is laughable, but if you can see two or more giraffes, that series begins looking like more than a coincidence!) Dr. Burgess, who has already spoken this morning, has pioneered and improved the immediate postoperative fitting in this country and has a very long series of cases involving that technique. He also has started research in a number of related areas, most recently concentrating on problems of wound healing in controlled environ-

ments using transparent chambers developed at the British Biomechanical Research and Development Unit at Roehampton, a suburb of London.

The daring thing in the early days of immediate postoperative fitting was to attempt dressing in the absence of this kind of transparent "socket." It took courage for Dr. Burgess, and others, to apply a completely opaque rigid plaster dressing and leave it on the fresh surgical wound for days at a time. Most people were sympathetic with any surgeon's passionate curiosity to know what was going on under the opaque plaster dressing. As a matter of fact, one of the other early experimenters in the cooperative research program developed what he thought was stump hygiene; he deliberately took off the cast every day to examine the stump and then quickly reapplied a new dressing. As it turned out, that seemingly conscientious and conservative method did not work well because of rapid development of edema, even in the few moments while the stump was free from support. Based both on extraordinary experience with the rigid plaster dressing and on recent experiments, Dr. Burgess will discuss Wound Healing.

Unfortunately, Dr. Sarmiento has been plagued with problems. His associate who was supposed to have come to Chicago developed scarlet fever. Dr. Sarmiento said that he has not heard of the disease since he was a medical student himself and did not realize that anybody got scarlet fever anymore! Two other colleagues were unable to come because they are deeply involved in giving a course. Then Dr. Sarmiento, who was here this morning, was called back in an emergency. However, Dr. Edward Peizer, of VAPC, will replace Dr. Sarmiento to describe the work on complicated prosthetics fitting problems at University of Miami.

Mr. Leon Bennett, an engineer from New York University, has been involved with the artificial limb program since 1947, originally working with Mr. Renato Contini's group which was involved for many years in the evaluation of devices. Recently Mr. Bennett has been working part time with Dr. Fishman in the prosthetics education program and in the evaluation of devices for the Children's Bureau and the Maternal and Child Health program. He has also worked part time with VA support on mathematical, experimental, and model studies of stresses in flesh near a load. He is concerned particularly with the transfer of load from the socket of an artificial limb (or presumably the cushion of a wheelchair or the cuff of a brace) to the flesh. He has produced a number of interesting analyses of the distributions of compression and shear at and near a socket brim. Some of the results showing stresses in flesh *proximal* to the brim are not always self-evident to the layman.

This is an area of interesting interplay among theory, simple experiment, and clinical experiment, on a problem that has long been serious.

As is well known, above-knee amputees often have developed cysts in the adductor region. In the Barnes and Levy issue of Artificial Limbs, in 1956, such cysts were described as part of Dr. Levy's discussion of a variety of dermatological problems of amputees. (This paper is reproduced in the book *Selected Articles from Artificial Limbs.*) In the days before total-contact sockets, problems were typically just above the brim of the medial aspect of above-knee sockets, in the popliteal space above the brim of below-knee sockets, or at the end of the stump. The PTB below-knee and total contact above-knee sockets were later developed. Originally, when many amputees literally flinched at the thought of anything touching the end of the stump, one of the major goals of these sockets was to provide counterpressure to prevent terminal edema, thus helping to clear up problems at the end of the stump, shown clearly by studies performed at University of California. Thereby distal problems have been sufficiently solved for many years, but occasional skin problems above the brim still persist. In experimenting with current difficult cases, Mr. Bennett is receiving cooperation from the staff at Castle Point VA Hospital who are providing medical supervision and the recording of clinical problem cases; also, he will work with the VA Prosthetics Center. One may hope that ultimately some improvements will be possible in this second half of the dermatological problems, just as total-contact largely solved the edema problem.

Another way in which one might overcome problems in fitting of prostheses would be to "fit" to the patient, in the operating room at the time of amputation, a skeletal attachment protruding through the skin. In this way an external prosthesis could be attached through a quick disconnect. (Some sort of skeletal attachment to the patient might also be made at the time of the operation, initially buried but then, with a later procedure, exposed by coming through the skin.) This concept of skeletal attachment, of course, gets out of the frying pan of dermatological problems into the fire of much more serious biological problems. Surgeons and others with any biological training typically "know" that this intrusion through the integument will never work; it has been routinely condemned for many years. Nevertheless, there were experiments performed in Germany and in the United States during World War II and Dr. John O. Esslinger reported his animal experiments in this Bulletin (BPR 10-1 through 10-13). A few brave souls still retain an interest in the possibility of coming through the skin without supposed inevitable infection or inevitable biological rejection of the device. One such person is Dr. C. William Hall, a vascular surgeon, who originally was faced with the problem of trying to bring a power supply for an artificial heart through the chest wall. Later he perceived various concepts for use of such devices, including artificial limbs. He has a small VA-supported project at Southwest Research Institute.

At this point it should be noted that each participant has been given the opportunity to sign up for an appropriate workshop. Mr. Everett Cortright, Prosthetics Research Specialist from Dr. Newcomb's office in Washington, made the arrangements.

The next speaker, Mr. Hans A. Mauch, is a well known pioneer of the artificial limb program, who started working with Dr. Ulrich Henschke, and M.D. and a Ph.D. in physics, while both of them were still in Germany. We learned of their ideas when a team from the Army Surgeon General's Office visited Germany in spring 1946. Eventually they came to this country and worked with the Air Force for a number of years. Mr. Mauch initially worked on hydraulic knee joints, and then on ankles for artificial legs, as we shall hear today. Eventually he became involved as well with reading machines for the blind, as we shall hear from him and his associate, Mr. Smith, tomorrow. Mr. Mauch now has his own laboratory in Dayton, Ohio.

The next speaker is Professor Charles W. Radcliffe of the University of California. Another pioneer in the limb program, he became involved when he worked for Narmco, a subcontractor to the National Academy of Sciences, in 1946. Later he went to the University of California, which started to become active in the limb program in September of 1945. The University of California project illustrates the combination of fundamental studies in locomotion with subsequent design and development of specific devices reaching widespread clinical use. Long ago, Professor Radcliffe developed biomechanical principles for fitting and alignment of artificial legs at all levels, from the Syme to the hip disarticulation. He also developed a series of adjustable legs and copying jigs to facilitate application of these principles. He has been instrumental in development of the SACH foot, the PTB high-brim and TCS sockets, and multiple-bar linkages for knees.

Dr. Jacquelin Perry of Rancho Los Amigos is working on clinical gait analysis. She intends to develop a simple, inexpensive method using a hand-held calculator which does not require anything near the level of computer that Professor Radcliffe and Dr. Lamoreux worked with at University of California. Obviously there are great needs for quick, practical, but accurate analysis of gait of patients with any of a wide variety of clinical conditions. Objective measures of improvement after treatment would be very helpful.

There has been for the past year or so a VA project at Case Western Reserve University (CWRU) by Dr. Albert Burstein, a bioengineer. Working under him are Drs. Victor Frankel, an orthopedic surgeon, and Dr. E. Byron Marsolais, an orthopedic surgeon with a Ph.D. in engineering. There is close cooperation between CWRU, Highland View Hospital, and VA Hospital, Cleveland. The project deals with in-vivo telemetering of the stresses in surgically implanted artificial knee

prostheses. This is becoming increasingly popular as a method of replacing the arthritic or otherwise damaged knee, by analogy of the total hip operation which has been so successful in recent years. The problem is to measure the loads within the device itself and telemeter information out through the intact skin, recording the subject during gait and while performing various activities. The CWRU group made some preliminary experiments with the telemetering hip nail, which they already had developed in order to train their nurses and others involved. Tests with their aluminum mockup verified that the strain gages are able to measure loads in all three directions within the knee joint. Now they plan to build others, probably with surgical grade stainless steel, which they expect will transmit the radio waves. The entire outer shell of the stainless steel serves as the antenna for the telemetering of the strain-gage information from the gages inside the joint; in this way they will be able to measure vertical and shear loading on the knee joint as the patient moves.

Northwestern University in addition to serving as host for this Conference, has been involved for many years in a VA-supported interdisciplinary project on artificial limbs, particularly to aid geriatric and severely handicapped amputees. The project has been provided with ample clinical opportunities by physical location in the Rehabilitation Institute of Chicago, proximity to the VA Research Hospital, association with Dr. Thompson who conducts a VA clinic team, referrals from various other clinics, and for some years a close relationship with the Michigan Crippled Children's Commission program. Dr. Childress originally was especially interested in myoelectric control, but he and Mr. Billock then extended their efforts to develop a self-suspended, self-contained artificial arm for the below-elbow amputee. One might suggest that myoelectric control first fascinates many engineers but ultimately serves as bait to lure them into studying the *real* problems of fitting.

The next speaker, Dr. John Lyman of the University of California at Los Angeles, will discuss voluntary and adaptive control on upper-limb powered prostheses. Beginning in 1946, the UCLA project is one of the early pioneers in the prosthetics program. Dr. Lyman has been involved throughout most of its history, originally working with Dr. Craig Taylor in measuring arm and hand motions, much the same as the Berkeley group measured locomotion. Dr. Lyman has long been active in evaluating the various attempts to provide external power for artificial arms. He and his associates have studied the basic problems of control in an attempt to reduce the demands made upon the amputee.

Dr. Graupe, from Colorado State College at Fort Collins, Colorado, is particularly interested in the mathematical principles of signal recognition in separation of signals from noise. He is applying these concepts to

detection of myoelectric signals. He and his students have also built a toe-controlled arm with multiple motions which can be controlled through a logic system, substantially extending the Alderson toe-controlled arm.

Dr. Schmeisser, of Johns Hopkins Medical School, and Mr. Seamone, of the Johns Hopkins Applied Physics Laboratory, have been working together for some years on the development of a different approach to power-driven prostheses and orthoses. The basic approach involves a versatile winch-like drive for a Bowden cable, a quiet and relatively slow torque motor (rather than the usual high speed motor and large ratio reduction gear), and an assortment of controls, including myoelectric, small skin motion, and even clicking of teeth.