

Staff Meeting Bulletin  
Hospitals of the » » »  
University of Minnesota

Infections  
of Extremities

STAFF MEETING BULLETIN  
HOSPITALS OF THE . . .  
UNIVERSITY OF MINNESOTA

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during the school year, October to May, inclusive.

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William A. O'Brien

I. LAST WEEK

Date: February 11, 1938  
Place: Recreation Room  
 Nurses' Hall  
Time: 12:15 to 1:15 P.M.  
Program: Movie: "What Do You Think"  
 Electrocardiograms  
 John Layne

Case Reports  
 Robert Hebbel

Discussion: First Case  
 George Kimmel  
 Robert Hebbel  
 Willis Thompson  
 Cecil J. Watson

Second Case  
 Edmund Flink  
 Robert Hebbel  
 Cecil J. Watson  
 Robert R. Tracht  
 Owen H. Wangensteen

Third Case  
 Blair Adams  
 Robert Hebbel  
 Wesley Spink  
 Cecil J. Watson

Present: 100

Gertrude Gunn,  
 Record Librarian

II. MOVIE

Title: "How to Start the Day"

Released by: M-G-M

III. ANNOUNCEMENT

The Department of Pediatrics has been interested the past few years in determining the underlying cause of allergy (asthma), and now investigations have gone far enough to warrant expansion of the work. Any member of the staff who knows of an intractable case of asthma, especially in a child between six and fifteen years of age, will please notify Drs. McQuarrie, Stoesser, or Cook. A trial study which may lead to improvement will be carried out in the hospital on the cases selected.

I. McQuarrie

IV. AUTHORS

Carroll J. Bellis, born in Shreveport, La., graduate of the University of Minnesota, B.S. '30, M.S. '32, Ph.D. in Physiol. '34, M.B. '36, M.D. '36, winner of Green prize in Physiology, Surgical Intern University of Minnesota Hospitals, '36-'37, Surgical Research Assistant '37 to date. Special Interest - Surgical Research from the Physiologic Standpoint.

Richard L. Varco, born in Fairview, Mont., graduate of the University of Minnesota, B.S. '34, M.B. '36, M.D. '37. Intern Minneapolis General Hospital '36-'37, Surgical Intern University of Minnesota Hospitals '37 to date. Special Interest - Clinical Surgery.

Owen H. Wangensteen, born in Lake Park, Minnesota, graduate of the University of Minnesota, A.B. '19, M.B. '21, M.D. '22, Ph.D. in Surgery '25, Professor of Surgery, Director of Department, Surgeon in Chief of the University of Minnesota Hospitals '31 to date. Winner of Samuel B. Gross prize in Surgery. Special Interest - Experimental and Clinical Surgery.

## V. INFECTIONS OF EXTREMITIES

C. J. Bellis  
R. L. Varco  
O. H. Wangensteen

### General Considerations in Wound Management

The problem of wound management is as old as surgery itself. Considerable advance has been made by the surgeon with aid of the chemist and the bacteriologist in the prevention of infections. Body cavities can be opened with impunity if aseptic methods and good surgical technique are used. The problem of dealing with established infection, however, is very much the same as it was before the days of Lister.

The surgeon has been essentially an empiricist in the management of infection. He has come to rely largely upon rest, application of heat, the use of immobilization and occasionally roentgenologic treatment. Although for a time employment of passive hyperemia (Bier, '09) had its vogue, it never found much favor in this country. On the European continent it is now largely used in the treatment of some chronic infections. However, when the method was in extensive use, it was applied in every kind of infection.

At the beginning of this century, medical men generally looked hopefully forward to an immunologic specific for every bacterial disease. Unfortunately, however, such specifics are still too few. A surgeon still has no reliable immunologic agents upon which he may lean with confidence in the treatment of suppuration of pyogenic origin. Pharmacologic specifics have also been brought forth from time to time but with exception of sulphanylamide, a relatively new agent, most of these specifics have not afforded the help or promise which their advocates held out for them. Sulphanylamide, however, promises to be a great boon to the surgeon in the treatment of Neisserian, streptococcal, and some other pyogenic infections.

In the treatment of localized infec-

tion, the surgeon evacuates pus by incision when suppuration is definitely present. He has learned through his own experience that it is a poor policy to incise areas of phlegmon and spreading infection. Although at one time he believed that if free incisions were made beyond the area of cellulitis he could stem its spread, he learned that by so doing he aided the infection and injured his patient. The surgeon, therefore, has become more withholding in the active management of spreading infection and has come to rely largely upon employment of rest and heat to aid natural defense mechanisms of the body in overcoming the infection. When the infection became localized, the surgeon could then evacuate exudate by incision.

Four years ago in this clinic a patient (Case 1) with severe sepsis in the left thigh and leg was treated by wide incisions and careful employment of the Carrel-Dakin technique which proved futile. As a matter of last recourse a windowed double plaster of Paris spica cast was applied extending from the toes to the nipples, immediately following which the relief of pain and general improvement were startling. A contemplated amputation was averted and her extremity was saved. This experience served to focus attention upon how little the surgeon could accomplish by active treatment of acute spreading infections. At first we employed immobilization as an after-thought or last measure before having recourse to radical or energetic surgical treatment. During the last two years, however, we have come to use immobilization and elevation of the infected extremity as the primary treatment in a number of acute infections, amongst which have been cases of infection of joints, bones, as well as soft tissue. The remote result in the treatment of the osteomyelitis cannot be definitely assayed. The impression has been gained that this method of treating joint infection when accompanied by proper incision to afford dependent drainage is superior to the Willems' method of active mobilization. In the main, the results attending its use in the infection of the soft tissues are super-

ior to that obtained by other means. We have not employed the method in tendon sheath infections. As a matter of fact, tendon sheath infections are seen late at this hospital.

### Historical

In the treatment of infections of the extremities, the keyword has been rest, heat, and elevation. Adjuvant measures in the surgeon's armamentarium have been the hyperemia of Bier, a procedure which one might well relegate to the category of unsound practice, and antiseptic solutions. With the discovery of Dakin's solution, hope was rekindled that wound infections could be overcome by antiseptics. During the World War Keen ('18) said, "Prevention and cure both are now ours." But, it seems that the chief merit of antiseptic solutions lies in hastening the clearing up of an infection which has already become localized. It appears to possess no virtue in localizing an infection. The patient must still fight out the conflict with bacteria with no specific help from chemical irrigating solutions and we must content ourselves to support the natural resistance of the patient in his combat with the invading bacteria. Hirschfelder has shown that no antiseptic agent will penetrate tissue effectively and preserve its antiseptic properties for more than a millimeter.

Hilton (1863) wrote a fascinating and informative treatise on rest and pain during the Civil War period in this country, in which he stressed the great importance of rest in the treatment of infections. Those skilled in the treatment of tuberculosis will attest to this fact. A short time later Dennis (1884) pointed out the great value of immobilization in plaster in the treatment of compound fractures, and Orr ('27), impressed with the futility of chemicals in localizing infection, adopted rigid immobilization in plaster as a constant sequel to sequestrectomy for chronic osteomyelitis, shortly thereafter employing closed plaster casts and massive vaseline pack together with extensive osteotomy in acute osteomyelitis.

### Our Method

In this clinic our essential treatment of acute infections of the extremities has been; immobilization of the entire extremity concerned in a plaster cast, including the body trunk, the affected member being positioned in the cast in such a manner as to most rapidly drain the fluid towards the heart by gravity. Table I presents the type and number of cases treated in this manner or by a modified procedure, from July 1st, 1937 to February 10th, 1938.

Table I

<u>Cases Treated by Immobilization and/or Elevation</u>	
<u>Diagnosis</u>	<u>No. of Cases</u>
A. Osteomyelitis (humerus, radius, ulna, femur, tibia, fibula, phalanges, pelvis)	29
B. Suppurative Arthritis	
1. Multiple Joints (shoulder, elbow, wrist)	1
2. Wrist	1
3. Hip	1
4. Knee	2
5. Ankle	1
	<u>(Total 6)</u>
C. Infected Compound Fractures	2
D. Soft Tissue Infections	
1. Shoulder	1
2. Elbow	1
3. Forearm	1
4. Wrist	1
5. Hand	9
6. Finger	2
7. Knee	2
8. Leg	1
9. Toe	1
	<u>(Total 19)</u>
E. Thrombophlebitis of Leg	3
	<u><u>TOTAL 59</u></u>

Appropriate windows are cut in the cast to permit of frequent observation of the infected area; when there is definite evidence of suppuration, not before, a small incision is made for evacuation of the exudate through the cast window; large incisions have no additional advantage, producing only more trauma to tax the patient's already burdened healing powers.

In acute osteomyelitis of the tibia, a body plaster is applied extending from the waist to the toes on the affected side and to the knee on the other side, a window being cut in the plaster directly over the tender area, permitting incision when evidence of abscess formation is present. The only type of case in which early incision is warranted is acute tenosynovitis. In such instances, the necessity of early opening of the tendon sheath to preserve the nutrition and identity of the tendon has been pointed out by Kanavel ('33).

#### Physiologic Effects of Immobilization in Plaster

The immobilization which can be secured by a body spica plaster is ever so much more efficient than that obtained by any other method. Sand bags, traction, voluntary rest, and other expedients do not begin to afford the relaxation and quiet rest to an injured or infected extremity that an adequate plaster cast will. We have had a patient with an infected knee joint treated with adequate traction cry with pain when the bed was touched. After the application of a cast, maintaining traction in the plaster, the patient could be turned over in bed without causing him the slightest discomfort.

Although it has been suggested that immobilization causes atrophy, the actual evidence of any great degree of atrophy is lacking. The work of Sherrington, reviewed by Cobb ('25), has adequately demonstrated the proprioceptive reflex nature of muscle tone, a phenomenon which can be initiated by such actions as passive changes in the position of the head (Marinesco and Kreindler, '35). Legg ('08) and Chlor and Dolkart ('36) have observed minimal atrophy in the

extremities of animals encased in plaster casts, but these observers and Thompson ('34), Schiff and Zak ('12), Davenport and Ranson ('30), and Lippman and Selig ('28) offer irrefutable evidence that such minimal atrophy is temporary and may be nearly entirely obviated by properly applied casts. Recent work (Hines and Knowlton ('34) suggests the profound effects of internal secretions on the maintenance of muscle tonus even in denervated muscles. It cannot be said, then, that normal muscles immobilized in plaster casts are in a state of inactivity; rather, muscle tone is preserved and normal voluntary motion, although partly isometric, begins with the disappearance of pain. Those who suspect immobilized muscles of diminished metabolism would do well to read Harding's enlightening paper ('26).

Since the lymphatic channels through which infection spreads lie in the fascias overlying the muscles, lessening of muscle movement which accompanies immobilization in plaster serves to obviate dissipation of the infection, and must be an important factor in aiding the natural defenses of the body in localizing the infection. Experimentally, Beecher ('37) and White et al ('33) have demonstrated the marked lymph flow attending muscular activity.

#### Effects of Posture

The role played by posture is equally as important as immobilization, for the reduction of swelling is an important item in the treatment of infection. In swellings of a chronic nature which accompany slowly uniting fractures and other conditions, common practice is to employ heat and massage in the reduction of the swelling.

Undoubtedly, elevation is effective, whereas these measures increase swelling. Landis and Gibbon ('33), Okuneff ('24), Bazett ('27), Drury and Jones ('27), and Landis ('30, '31) have shown that increasing the temperature of an extremity increases capillary filtration and produces greater

swelling.

The increase in limb volume which has been noted by others when venous return is impeded (Mende, '19, Eyster, '26, Beecher et al, '36, Hooker, '16, Carrier and Rehberg, '23, Runge, '24, and Villaret, '25) has been measured by a variety of methods. Mende estimated the volume from the circumference, but there have been refinements such as the plethysmograph of Johnson ('31, '32), and the photokymograph of Turner ('37). For the large volume changes with which we deal in infected extremities, the use of a water displacement method with the Pavaex boot (a similar chamber being employed for the upper extremity) was found to be satisfactory, the volume changes reported here being determined by this method.

That the swelling attending infection can be satisfactorily reduced by elevation of the affected part to the level of greatest hydrostatic pressure relative to the heart can be seen from the summaries of cases Nos. 3, 5, 6, 7 and 8. Fluid, tending to compress veins and cause more congestion of the infected area, is, thus, allowed to drain via lymphatics; with removal of this fluid, capillaries resume their normal tone, and congestion is relieved. It has been shown by Turner et al ('30), Bock et al ('30), and Harrop and Waterfield ('30) that posture affects not only the capillary tone but the lymphatic flow.

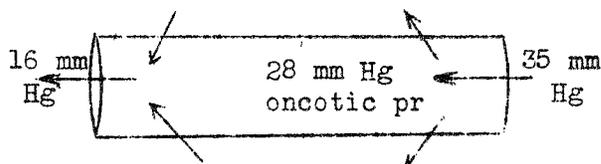
The profound effect of rigid immobilization and elevation, such as we employ, on the septic process is clearly evident on inspection of the patient's temperature record. The definite response to such physiologic treatment is illustrated in the temperature charts (Fig. 1) of the first three cases presented herewith.

It is doubtful whether one can consider heat as a therapeutic adjuvant in the treatment of infections of the extremities except for its virtue of assuaging pain. Gibbon and Landis ('32), Sheard et al ('38), Stewart ('11), Pickering ('31-'33), Müller ('05), Hewlett et al ('09, '10-'11), and Amitin (1897) have shown conclusively that heat applied directly to the skin of an

extremity or increasing the room temperature produces swelling and increased lymph production, and that cold has the opposite effect. It may probably be beneficial to keep a patient with such an infection in a slightly cooler environment than other patients.

#### Capillary Blood Pressure and Osmotic Pressure

On the various implications of the Starling hypothesis (1895-96) there are many contributions to the literature. He showed that the intracapillary blood pressure, tending towards ultrafiltration, operates in opposition to the colloid osmotic pressure of the blood, which holds water within the capillary. Landis ('34) has shown that the blood pressure at the arteriolar end of the capillary loop is 35 mm. Hg, that at the venous end is 16 mm. Hg, and the colloid osmotic pressure of the blood 28 mm. Hg. Thus, there is a tendency for ultrafiltration at the arterial end



of the loop and a tendency to reabsorption of fluid at the venous end. That this system operates only under "normal" conditions is well accepted (Youmans, '35, Field and Drinker, '31, Krogh, Landis, and Turner, '32), and that in conditions of inflammation or venous engorgement there is a tremendous outpouring of filtrate into the tissue spaces, a filtrate so rich in protein as to lower the colloid osmotic pressure of the blood has been shown by Moore and Van Slyke ('30), Schade and Claussen ('24), Smirk ('35-'36), v. Farkas ('26, '28), Thompson et al ('27-'28), Waterfield ('31), Rowe ('16), Darrow et al ('32), and the remarkable work of Muntwyler et al ('33).

### The Causative Factor of Vasodilation in Inflammations

Many suggestions have been offered as to the agent dilating the vessels in a local edematous area. Lewis ('30) has postulated an H-substance, which may be identical with Menkin's recently isolated factor ('38). Lewis and Grant ('25) have considered the intracapillary pressure to be largely responsible, but Landis ('28, '31) believes that impairment of tissue oxygenation is the important factor. Roy and Brown (1879-80) and Barcroft and Kato ('15-'16) favor the view that the local reaction is mediated through the concentration of certain metabolites. From the observations of Bayliss (1900-02) and Bayliss and Bradford (1894) one must admit a central nervous influence on the local vessels.

### Cause of Edema in Inflammations

The factors influencing the local formation of edema have been subjected to the most rigid investigations by competent observers. Field and Drinker ('30) and Landis and his co-workers ('26, '30-'37) conclude that the primary factors in the pathogenesis of such edemas are: 1) elevated capillary pressure, 2) lowered colloid osmotic pressure of the blood plasma, 3) damage to capillary wall, 4) lymphatic obstruction; contributory factors are: 5) low tissue pressure, 6) high salt intake, 7) high fluid intake, 8) warm environment, and 9) disturbed innervation. Krogh ('22) lays greatest stress on intracapillary pressure, while Schade ('27) and Schade and Menschel ('23) believe that the two most important balancing factors are the tissue tension (Gewebspannung) and the imbibition pressure of the interstitial colloids (extracelluläre wasser-durchtränkte Bindegewebskolloid).

The tissue fluid protein has been determined quantitatively, Drinker and Field ('31, '33) having observed .39% protein in edema fluid, a figure which may rise to 4.5% ('32), Iversen and Johansen ('29) about .6% protein in pleural fluid, (we have found pus to contain as high as 34% protein), Munk and

Rosenstein (1891) about 3.5% from a lymph fistula of the calf of the leg, and we have found blister fluid from experimentally produced burns to contain as high as 6% protein. Obviously, therefore, the tissue fluid, or lymph, in an infected area may contain a relatively enormous quantity of protein, and, as has been demonstrated by several investigators, raise the colloid osmotic pressure on the outside of the capillaries to such a level that reabsorption of fluid by the capillary through osmotic means may be greatly slowed or even impossible (Loewens et al ('31), Morawitz, ('06), Weech et al ('33, '34), Wells ('32), Landis et al ('32).

### Effect of Posture on Temperature of Extremities

The observations of Mulvihill and Harvey ('31), Lewis and Landis ('29-'31), and the brilliant essay of Thomas ('26) suggest that veins as well as arterioles are under sympathetic influence. This and the diminished arterial blood supply account for the depression of skin temperature of elevated extremities (Table II). The skin temperatures were determined with the assistance of Dr. Irwin Vigness. The findings of Turner et al ('36) concerning the pulse-volume relationship in the elevated arm are especially significant when it is observed (Table III) that there is an average difference (12 individuals) of 27 mm. Hg in systolic blood pressure between the elevated and horizontal position.

Table II

Effect of Elevation on Skin Temperatures  
of Extremities (C°)

	No.	Diagnosis	Extremity	Level	Elev.	Temp.Diff.
A. Normals (elevation 1 hour's duration)	1	.....	finger	29.3	25.5	3.8
	2	.....	"	30.0	26.0	4.0
	3	.....	"	27.4	24.0	3.4
	4	.....	"	30.4	24.2	6.2
	5	.....	"	32.5	27.6	4.9
						Avg.Diff.4.4°
B. Pathologic series	6	thrombophlebitis (leg)	toe	34.2	28.4	5.8
	7	infection of knee	toe	32.0	24.7	7.5
	8	osteomyelitis leg	toe	33.7	27.8	5.9
	9	cellulitis of forearm and elbow	finger	33.7	31.1	2.6
	10	post-traumatic hand	"	33.8	32.2	1.6
						Avg.Diff.4.7°

Table III

Effect on Systolic Blood Pressure (mm Hg)  
of Positioning Arm

No.	Arm	Horizontal (H)	Elevated (E)	Dependent (D)	Differences		
					E-H	H-D	E-D
1	R	96	80	130	16	34	50
2	R	106	90	120	16	20	36
3	L	120	92	132	28	12	40
4	L	106	94	116	12	10	22
5	R	108	90	114	18	6	24
6	R	120	98	132	22	12	34
7	R	110	76	116	34	6	40
8	L	88	68	110	20	22	42
9	R	108	66	116	42	8	50
10	L	124	80	150	44	26	70
11	L	120	76	148	44	28	72
12	L	110	76	128	34	18	52
				Average	27	17	44

## Tissue Tension

Landerer (1884) first wrote on the role of tissue elasticity or tension in counterbalancing intracapillary blood pressure, and he used a direct manometric system with a needle inserted into the tissues. Youmans et al ('34) have discussed the importance of the tissue tension during venous congestion, and have calculated ('35) the tensions that accrue, a method which Gildemeister and Hoffman ('22) used. The direct manometric method which we used for determining tissue tensions is a development of those of Meyer and Holland ('32),

Burch and Sodeman ('37), and Henderson et al ('08-'36), our device being simplified for more accurate and quicker measurements. Inspection of Table IV shows that normal intramuscular pressures as obtained on ambulatory individuals are greatly reduced after several days of bed rest. Contraction of a muscle elevates its internal pressure, the quadriceps femoris tension in one man being increased to 18-22 mm. Hg when weight was borne on that extremity. This finding is in corroboration of Noyons ('11), Springer ('14), Hill and McQueen ('21), and Gildemeister ('14).

Table IV

### Normal Intramuscular Pressures (mm Hg)

	Region	Tension	Range	No. Cases
A. Tensions after several days of bed rest	Biceps brach.	0	0-0	2
	Deltoid	0+	0-3	14
	Quadriceps fem.	0-1	0-4	10
B. Tensions on ambulatory patients	Deltoid	4-5	2-8	16
	Quadriceps fem.	3-4	1-6	10
	Ant. tibial	7	6-8	2

Table V shows the elevated tissue pressures (intramuscular or subcutaneous) that obtain in swollen areas. It is of particular interest to note the loss of pressure in fracture sites after immobilization and in treated edema of cardiac origin. The intramuscular and subcutaneous pressure is elevated in every site of inflammation. It might not be far afield to suggest, in the light of these

high tensions, the protein content of the fluid responsible for the tensions, and the work of many authors (Leiter, '28-'31), Fishberg, '31, Peters and Van Slyke '31, Barker and Kirk, '30, Shelburne and Egloff, '31, Lepore, '31, Weech and Ling, '31, Boyer, '37, and Fahr et al, '31, that the addition of a low salt, high protein diet may assist in diminishing the inflammatory edemas.

Table V  
Pathologic Tissue Pressures (mm Hg)

	<u>Before Immobilization</u>					<u>After Partial Immobilization</u>				
	Avg. Inj. Side	Range	Avg. Uninj. Side	Range	No. Cases	Avg. Inj. Side	Range	Avg. Uninj. Side	Range	No. Cases
A. Acute fractures										
1. Humerus										
a. intramusc.	15-16	6-28	5	0-12	7	5-6	2-12	2	0-6	3
b. subcutan.	13	3-36	1-2	0-4	6	0-1	0-3	0-1	0-3	5
2. Forearm										
a. subcutan.	16	16-16	6	4-8	2	2	0-4	2	2-2	2
3. Shaft femur										
a. intramusc.	14	14	6	6	1	2	2	2	2	1
4. Knee										
a. intramusc.	20	20	6	20	1	.....	.....	.....	.....	.....
b. subcutan.	16	10-22	5	0-10	2	.....	.....	.....	.....	.....
5. Leg										
a. intramusc.	18	12-26	8-9	8-10	3	.....	.....	.....	.....	.....
b. subcutan.	15	6-24	0	0-0	2	6	0-12	1	0-2	2
6. Ankle										
a. subcutan.	10	10	0	0	1	.....	.....	.....	.....	.....
7. Clavicle										
a. subcutan.	8	8	0	0	1	.....	.....	.....	.....	.....
B. Fractures after partial immobiliz. (all intramusc.)										
1. Humerus	.....	.....	.....	.....	.....	4	4	8	8	1
2. Forearm	.....	.....	.....	.....	.....	2	2	14	14	1
3. Femur	.....	.....	.....	.....	.....	1-2	0-4	7-8	6-12	4
4. Knee	.....	.....	.....	.....	.....	0	0-0	6	2-10	2
5. Leg	.....	.....	.....	.....	.....	0	0	6	6	1

Table V (Continued from Page 214)

	<u>Before Immobilization</u>					<u>After Partial Immobilization</u>				
	Avg. Inj.Side	Range	Avg. Uninj.Side	Range	No.Cases	Avg. Inj.Side	Range	Avg. Uninj.Side	Range	No.Cases
C. Arthrodeses of shoulder (all intramusc.)	.....	.....	.....	.....	.....	6	4-8	17	16-18	2
D. Acute shoulder dislocations (subcutan.)	4	4	0	0	1	.....	.....	.....	.....	.....
E. Infections of extremities										
1. Skin elbow (subcutan)	20	20	3	3	1	.....	.....	.....	.....	.....
2. Finger (subcutan)	16	16	4	4	1	.....	.....	.....	.....	.....
3. Knee (quadriceps)	.....	.....	.....	.....	.....	0	0	4	4	1
4. Osteomyelitis leg (intramusc.)	.....	.....	.....	.....	.....	0	0	5	5	1
F. Residual poliomyelitis (all intramusc.)										
1. Deltoid	.....	.....	.....	.....	.....	0	0-0	5	2-8	2
2. Quad. Fem.	.....	.....	.....	.....	.....	2	2	4	4	1
3. Ant. Tibial	.....	.....	.....	.....	.....	0	0	4	4	1
G. Cardiac decompensation										
1. Ant. Tibial										
a. intramusc.	21-22	14-30	(before medical treatment) 2			0	0	(after medical treatment) 1		
b. subcutan.	12-13	8-14	(" " " ) 3							

## Discussion

Whereas surgeons must still look hopefully forward to the time when bacteriologic and pharmacologic specifics will be available for the treatment of acute pyogenic infections, we must in the meanwhile employ those agencies which experience has shown will most favorably aid the natural defense mechanisms of the body. These are rigid immobilization and elevation, and when localized suppuration has occurred, incision and drainage.

Relief of pain attending employment of these conservative measures is frequently startling. In the main the use of the method in this clinic has been limited largely to what one might call major infections; that is, infections which have appeared threatening. A patient with a paronychia has not been encased in a body plaster with the finger, hand and arm in the elevated position; yet we have the impression from observations made in this clinic that many an early infection if so treated might be aborted. The extent of the surgery necessary (incision) in this conservative plan of management is certainly less than when hot packs are freely used with the extremity concerned in a dependent position, and rigid immobilization not being carefully observed.

Inasmuch as heat increases capillary filtration there is good reason to believe that surgeons should be more withholding in its employment than they have been accustomed to. Opinion is prevalent that the use of heat will accelerate localization of an infection. That it actually does so is still demanding of proof. In fact, Allen ('37) has recently shown that the harmfulness of tissue asphyxia is progressively increased as the temperature surrounding the extremity is elevated. The work of Adami ('11) and Bier ('09) had led surgeons to believe that increased swelling, such as attends the employment of heat or dependency, will help to fix an infection locally, and that such swelling aids in "smothering" infection. The clinical improvement attending reduction of swelling accompanying infection when the afflicted part is immobilized in an elevated position strongly suggests that swelling per se does not favorably influence the course of the infection.

It is obvious, of course, that the reduction of swelling does not depend alone on the grade of the elevation that can be obtained. In a large measure the nature of the capillary filtrate will determine the reduction in volume attending the use of elevation. It is perfectly obvious, however, that when an inflamed member is left in a dependent posture that the degree of swelling which will occur is limited only by the distensibility of the tissue. The development of a high tissue pressure restrains the escape of fluid from the capillaries and thus delimits the amount of swelling; at the same time, however, the development of a great tissue tension will threaten adequate oxygenation of the tissues. Another consideration which should not be lost sight of is that it is very likely that great tissue tensions favor the spread of bacteria in the tissues. The decreased lymph production which attends immobilization and the increased lymph flow which accompanies elevation undoubtedly are in part responsible for the improvement observed.

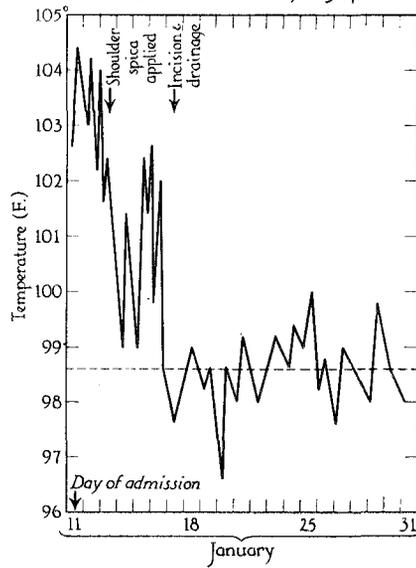
The same physiologic rest, therefore, which has been found to be advantageous in visceral disease (Wangensteen, '37, Schsner, '02, Bergh, '38) is of prime importance in treatment of infections of the extremities. The above review is intended to show how immobilization and elevation of such limbs have a physiologically sound basis; the method reduces the tension in the involved area, diminishes or obliterates pain, and converts the swollen and edematous infected area to a fresh field by drainage. Perhaps, by this method of treatment, the eventual sacrifice of extremities in vain attempts to stem sepsis, such as Lexer related ('22), may be terminated.

## Summary and Conclusions

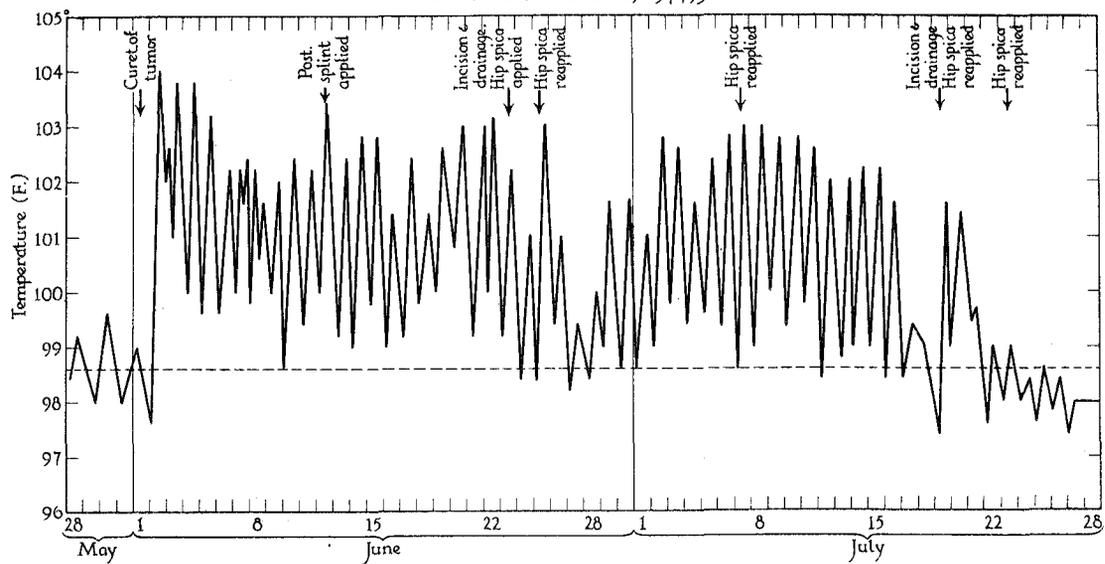
For a period of four years in this clinic rigid immobilization in plaster of Paris casts has been used as an important agency in the treatment of spreading infections of the extremities. For a period of two years it was em-

Fig. 1 TEMPERATURE RECORDS SHOWING EFFECTS OF IMMOBILIZATION FOR INFECTION

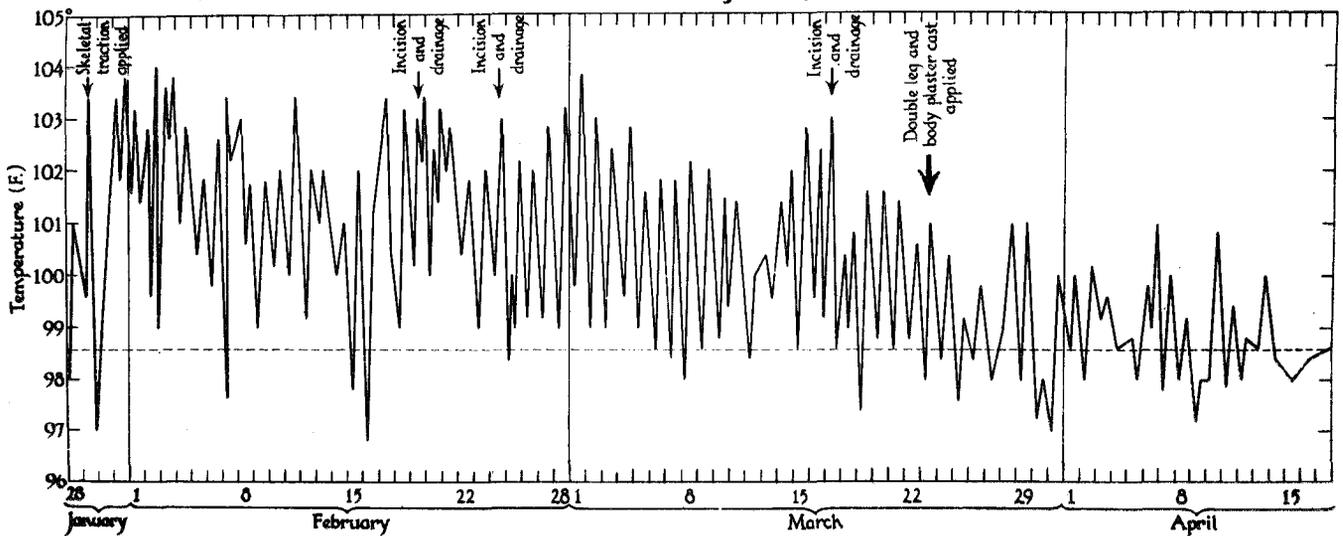
a. Case of Mrs. T.B., 665270



b. Case of Mr. B.H., 657493



c. Case of Miss J.S. 624349



ployed largely as a matter of last resort, but during the past two years it has been employed as the primary treatment, and at the same time it has become increasingly apparent that elevation of the inflamed member is equally important. It is important, particularly with reference to infections of the lower extremities, that careful thought be given to the matter of position of the patient in bed. It is apparent that Fowler's position is unphysiologic in the treatment of acute infections of the lower extremities; on the contrary, for infections of the head and neck the sitting posture may prove very useful. It would appear that the place of heat in the treatment of acute pyogenic infections has not yet been thoroughly established. That employment of heat actually accelerates localization of infection is not proved. It is apparent that inasmuch as heat increases capillary filtration, it should be employed sparingly or not at all in the treatment of acute infections of the extremities. In infections of the body trunk or of the body cavities, application of heat to the surface frequently allays pain, but whether it accomplishes something additional remains to be proved.

The chief role of the surgeon in the treatment of pyogenic infections of the extremities is the support of the natural defense mechanisms of the body in the conflict with infection. The surgeon can best do this by employment of rigid immobilization and elevation until localized suppuration has occurred, when incision is in order. With this conservative plan of treatment, earlier restoration of function will be obtained with less risk to life.

Exudates must be carefully studied bacteriologically so that patients having types of infections responsive to sulphanilamide will not be denied the use of this agent.

## Case Reports

### 1. Single Female

Age 23, admitted Jan. 28, 1934.  
The patient had sustained a compound fracture of the left femur on the day of

admission and presented a gas bacillus infection in the wound from which *B. welchii* were cultured. Following washing of the wound and application of skeletal traction by means of a pin through the os calcis, the patient was given polyvalent anaerobic antitoxin subcutaneously and intravenously. The anaerobic infection was quite well controlled -- the difficulty then being largely one of pyogenic infection -- but because of persisting high fever and elevated pulse rate, incision and drainage was performed 3 weeks after admission. Although hemolytic streptococci were isolated from the wound, blood cultures were consistently negative. Although operations for incision and drainage were performed on Feb. 24 and March 17, it was generally agreed that amputation of the extremity was necessary to stop the sepsis. Before resorting to such a radical procedure, it was felt that the patient should be encased in a plaster double hip spica, extending to the nipple line, including both lower extremities, with windows for dressings and inspection. The cast was applied on March 24, following which there was almost immediate diminution of pain and a gradual return of the temperature to normal within seventeen days (Fig. 1c), remaining normal after April 14 except for an occasional slight rise thereafter, and she was dismissed from the hospital on June 20. Except for sequelae due to prolapse of the sciatic nerve through one of the numerous incisions, the patient has made a satisfactory convalescence and has resumed her duties as a school teacher.

### 2. White Male

Age 33. This patient was first admitted to hospital on April 6, 1937, with a one year history of pain and gradual swelling of the right knee. Although roentgenograms suggested either a giant cell tumor or osteogenic sarcoma, tissue obtained by curettement on April 12 was reported as giant cell tumor. He was discharged on April 26, but was readmitted on May 24 because of extensive infection in the region of the previous biopsy. The tumor was thoroughly curetted on June 1 but the residual

cavity became the site of profuse suppuration, numerous cultures showing staphylococci and streptococci of the hemolytic and non-hemolytic type. The patient was given many transfusions because of general sepsis, and amputation of the extremity was seriously considered in order to terminate the septic process. It was decided, however, to try immobilization in a windowed spica cast extending from the costal margin to the right foot and the left knee, such a cast being applied on June 23. Several changes of the cast were necessary, but the fever gradually receded (Fig. 1b), the temperature returning to normal on July 22, following which there were only occasional elevations. He has been seen at intervals since that time, the radiographs suggesting bone deposition in the curetted cavity, the patient having no evidence of sepsis, being entirely free from pain, and gaining weight.

### 3. Female, Married

Age 50, admitted 1-11-38, with cellulitis of one week's duration involving left forearm and soft tissues about the elbow, following a furuncle. The temperature soon after admission rose to 104°F and continued to be elevated despite continued elevation of the arm at 90° on a Thomas splint and application of hot packs to the affected area. The following subcutaneous pressures in the area of maximum inflammation were obtained after 18 hours of such treatment:

<u>Right</u>	<u>Left</u>
0 mm Hg.	12 mm Hg

A preliminary volumetric determination was made, and a windowed shoulder spica cast was applied, holding the affected extremity at maximum elevation when the patient was at bed rest. The following morning her temperature had returned to nearly normal (Fig. 1a), pain had decreased remarkably, and her general condition was improved. Except for a brief rise in temperature, terminated by incision and drainage of an abscess through the window, the temperature remained normal except for minimal deviations. The infecting organism was staphylococcus albus. The cast was re-

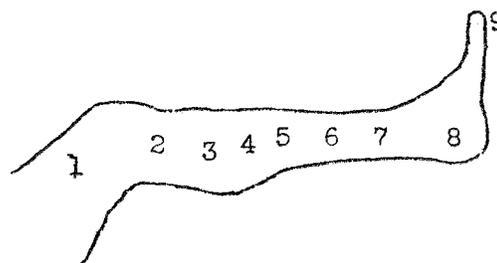
moved 15 days later, following which these subcutaneous pressures were obtained:

<u>Right</u>	<u>Left</u>
2 mm Hg	4 mm Hg

A second volumetric determination showed that there had been a loss of 447 grams of fluid from the mid-brachium to the finger tips during this period of immobilization and elevation in plaster. The patient was discharged with a slight drainage from the site of the previous incision and some residual stiffness of the elbow, but in otherwise good health.

### 4. White Male

Age 59, Admitted 11-8-37, giving a 2-3 week history suggestive of thrombophlebitis, and presenting with increased heat, redness, and swelling of the left leg below the knee and extending to the ankle. Subcutaneous pressures taken from the point of maximum tautness of the skin distally, in the involved area, were, respectively: 20, 12, and 6 mm Hg; corresponding areas on the normal leg registered, respectively, 4, 4 and 6 mm Hg. Retesting after elevation at 45° for 12 hours and at 180° for 6 hrs. gave the following respective values: 8, 6, and 2 mm Hg. for the left leg, and 0, 0, and 0 mm Hg for the right. The McClure-Aldrich test was performed at the time of admission, the wheals over the point of maximum involvement disappearing in 5 minutes, those on the more distal portion of the leg in 9 minutes, while the controls could still be palpated on the right leg after 30 minutes. Skin temperatures were obtained from the following points:



Position	11-8-37		11-10-37	
	Before elevation Left	Before elevation Right	After elevation Left	After elevation Right
1	35.9	34.9	35.9	33.9
2	37.2	36.3	34.9	34.8
3	36.6	35.4	33.2	34.5
4	37.0	35.2	30.3	34.2
5	37.2	35.7	39.3	34.5
6	36.9	35.2	29.1	34.8
7	37.2	35.3	28.3	35.0
8	35.3	35.3	28.1	35.3
9	.....	.....	27.5	34.9

	Left	Right
Middle finger	34.3	35.2
Wrist	34.5	35.6
Forearm	35.2	35.9
Elbow	35.1	35.1
Upper arm	34.3	35.3

A McClure-Aldrich test at the time of admission over the same area covered by the skin temperatures showed no wheals present after 9 minutes on the right arm, while control wheals were palpable for 25 minutes on the left. After about 40 hrs. of elevation at nearly 90° with the horizontal the total volume change of the extremity from the axilla to the finger tips was 415 grams of fluid.

5. Married Woman

Age 48: Thrombophlebitis of left leg, one week duration, with local increased heat, redness, and swelling. Subcutaneous tissue tensions on admission were:

<u>Right</u> 4 mm Hg	<u>Left</u> 40 mm Hg
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Circumferences 10 cm below tibial tubercle:

<u>Right</u> 33 cm	<u>Left</u> 36 cm
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After two weeks of continued bed rest and slight elevation at home, the subcutaneous tissue tensions were:

<u>Right</u> 0 mm Hg	<u>Left</u> 4 mm Hg
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Circumferences 10 cm below tibial tubercle:

<u>Right</u> 33 cm	<u>Left</u> 33.5 cm
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Total volume decrease from the mid thigh to the sole during this interval was 365 grams of fluid.

6. Married Woman

Age 61: Acute swelling of right arm secondary to radical mastectomy several months before. Skin temperatures at time of admission were:

7. White Male

Age 65. Thrombophlebitis of right leg of several weeks' duration. Tissue pressures at the time of admission were:

	<u>Right</u>	<u>Left</u>
subcutaneous	4 mm Hg	0 mm Hg
intramuscular	10 mm Hg	2 mm Hg

The affected extremity was elevated at 40° for 4 days when the following tissue pressures were obtained:

	<u>Right</u>	<u>Left</u>
subcutaneous	0 mm Hg	0 mm Hg
intramuscular	2 mm Hg	0 mm Hg

After 4 days at this elevation a volume decrease of 988 grams of fluid was found to have taken place. After allowing the extremity to remain horizontal for 16 hours a return of 255 grams of fluid was measured.

8. White Male

Admitted 1-10-38. The pertinent history dated back about 6 weeks when a furuncle over the right sacro-

iliac region was followed by local pain and a progressive paralysis of the same leg, associated with pain radiating inferiorly and posteriorly. Staphylococcus albus was cultured from a fluctuant mass over the sacrum, which was incised elsewhere on Dec. 7, 1937. The temperature continued to be of the intermittent type, however, and so a right inguinal mass was then opened, being found to contain only a small amount of pus and a large number of blood clots, the removal of which was followed by profuse hemorrhage. This cavity was then packed for hemostasis, the packs being removed on the ninth day with subsequent irrigations of normal saline and mild soap solution. Fever was still present despite administration of prontosil perorally, begun on Dec. 30. Examination on admission here revealed an emaciated, dehydrated, anemic white male with draining infected wounds over the sacrum and right inguinal regions. There was pronounced scrotal edema, a paralysis of the right leg except for the quadriceps femoris muscle, and a massive edema of this extremity. Elevation of the right lower extremity to an angle of 35° for 48 hrs. was followed by a volume decrease of 1225 grams of fluid, in the region from mid-thigh to toes. Raising the foot of the bed to about 20° and application of scrotal support were followed by disappearance of scrotal edema. To maintain elevation of the right leg a cast was applied extending from the toes to the groin on 1-13-38, a second volumetric decrease of 422 grams being noted on its removal two weeks later. The patient's temperature was of the septic type during the entire hospital period, altho repeated blood cultures were negative. Despite numerous supportive measures including several transfusions he expired on 2-4-38, 25 days after admission. Autopsy revealed purulent wounds of the right inguinal region and over the sacrum. Some pulmonary congestion was noted bilaterally, and a lung abscess containing 50 cc. of pus was found in the right lower lobe. There was an extensive degree of thrombosis with organization in the right common iliac and femoral veins, the same process existing to a less degree in the left, and veins in the right popliteal region presenting the same appearance.

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